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Assessment of groundwater quality and health risks resulting from nitrate pollution in Daquq District and Taza Subdistrict, Kirkuk Governorate, Iraq

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Abstract:

This study aims to assess the quality of groundwater in different areas of Daquq District and Taza Sub-district in Kirkuk Governorate by analysing physical, chemical and bacteriological variables, with a focus on the health risks posed by nitrate concentrations HQ and CDI to humans. The results of the physical and chemical property tests were as follows: electrical conductivity ranged from 742 to 3440 µS/cm, total alkalinity ranged from 143 to 280 mg/L, total hardness ranged from 312 to 922 mg/L, calcium hardness ranged from 70 to 220 mg/L, magnesium hardness ranged from 237 to 703 mg/L, sodium ions ranged from 22 to 69 mg/L, potassium ions ranged from 2 to 4.8 mg/L, chloride ions ranged from 39 to 97 mg/L, and sulfate ions ranged from 165 to 684 mg/L. Bacteriological tests showed that the total bacterial count ranged from 4 to 83 CFU/ml, and the total coliform count ranged from 0 to 16 cells/100 ml. Regarding the risks of nitrates to human health, the Hazard Index (HQ) values resulting from nitrate concentrations in well water ranged from 0.85 to 10.85, all above the safe limit (HQ > 1), indicating a potentially high health risk. Chronic Daily Intake (CDI) values ranged from 1.8 to 17.36 mg/kg/day, which are within critical levels that could negatively impact the health of consumers of all ages. These high values are attributed to the high nitrate concentrations in the studied samples, reflecting the urgent need for immediate preventive measures. Taken together, these results indicate the need for periodic monitoring of groundwater quality and the development of treatment and awareness programs aimed at reducing nitrate and bacterial contamination to ensure the safety of this water for human, animal, and environmental uses in the study areas.

Keywords. groundwater, water quality, nitrate, water pollution, health risks .

تقييم جودة المياه الجوفية وتقدير المخاطر الصحية الناتجة عن تلوث النترات في قضاء داقوق وناحية تازة، محافظة كركوك، العراق

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مستخلص:

تهدف هذه الدراسة إلى تقييم جودة المياه الجوفية في مناطق مختلفة من قضاء داقوق وناحية تازة في محافظة كركوك من خلال تحليل المتغيرات الفيزيائية والكيميائية والبكتريولوجية، مع التركيز على المخاطر الصحية التي تشكلها تركيزات النترات (HQ و CDI) على البشر. كانت نتائج اختبارات الخصائص الفيزيائية والكيميائية كما يلي: تراوحت قيم التوصيل الكهربائي بين (742– 3440) ميكروسيمنز/ سم، وتراوحت القلوية الكلية بين (143–280) ملغ/ لتر، وتراوحت الصلابة الكلية بين 312و 922 ملغ/ لتر، وتراوحت صلابة الكالسيوم بين 220 و70 ملغ/ لتر، وتراوحت صلابة المغنيسيوم بين 237و 703 ملغ/ لتر، وتراوحت أيونات الصوديوم بين (69–22) ملغ/ لتر، وتراوحت أيونات البوتاسيوم بين (2– 4.8) ملغ/ لتر، وتراوحت الكلوريد بين (97–39) ملغ/ لتر، وتراوحت الكبريتات بين (165_684) ملغ/ لتر. أظهرت الاختبارات البكتريولوجية أن العدد الإجمالي للبكتيريا تراوح بين (4–83) CFU /ml والعدد الإجمالي للبكتيريا القولونية بين (0_16) خلية/ 100 مل. أما بالنسبة لمخاطر النترات على صحة الإنسان، فقد تراوحت قيم معامل الخطر (HQ) الناتجة عن تركيزات النترات في مياه الآبار بين0.85و 10.85، وجميعها فوق الحد الآمن (HQ > 1)، مما يشير إلى خطر صحي محتمل مرتفع. تراوحت قيم الاستهلاك اليومي المزمن (CDI) بين 1.8و 17.36 ملغ/ كغ/ يوم، وهي ضمن مستويات حرجة قد تؤثر سلبًا على صحة المستهلكين من جميع الفئات العمرية. تُعزى هذه القيم العالية إلى تركيزات النترات العالية في العينات المدروسة، مما يعكس الحاجة الملحة لاتخاذ تدابير وقائية فورية. مجتمعة، تشير هذه النتائج إلى الحاجة إلى مراقبة جودة المياه الجوفية بشكل دوري وتطوير برامج معالجة وتوعية تهدف إلى تقليل التلوث بالنترات والبكتيريا لضمان سلامة هذه المياه للاستخدامات البشرية والحيوانية والبيئية في مناطق الدراسة.

الكلمات المفتاحية: المياه الجوفية، جودة المياه، النترات، تلوث المياه، المخاطر الصحية .

1.Introduction

The importance of water for humans and living organisms has been known since ancient times, as human survival is linked to the survival and purity of water. As a result of increased agricultural and industrial activities near water sources, water has become susceptible to pollution and a source of disease and epidemics [1]. Water constitutes 75-95% of the protoplasmic mass of each cell, and none of the processes of digestion, absorption and metabolism can take place except in an aqueous medium [2]. Groundwater is a vital natural resource and a major source of water supply in urban and semi-urban areas around the world, where it is heavily relied upon for domestic and agricultural purposes due to the low quantity and quality of surface water. Groundwater is the main source of irrigation and drinking water in Iraq, especially in rural areas of the western desert. Groundwater is one of the most important water resources in Iraq, especially in areas far from surface water resources. It plays a key role in people's livelihoods by providing water for drinking, irrigation, industrial purposes and others [3]. Groundwater is the second most important source of water after rivers, and this water reaches the surface through the digging of wells, where people can use it for drinking and other purposes [4]. Groundwater also contributes to the stability of ecosystems by feeding rivers and springs during periods of drought. It is less susceptible to pollution and evaporation than surface water, making it a more sustainable source. In addition, groundwater is a strategic reserve that can be relied upon in emergencies or when surface water resources are scarce [5]. Physical, chemical and bacteriological characteristics are key factors in assessing the quality of well water, as they reflect the extent to which the water is affected by environmental factors and surrounding sources. Studying these characteristics also helps to determine the suitability of the water for different uses and to detect any signs of contamination that may affect human health or the environment [6]. These characteristics provide important information about changes in water quality resulting from human use or natural factors, and help to identify potential sources of pollution and assess the associated health risks. Therefore, the analysis of physical, chemical and bacteriological characteristics is an essential step in water resource management and ensuring its sustainability [7]. The level of nitrate in water has increased significantly worldwide due to the widespread use of inorganic nitrogen fertilisers and animal manure. Due to the high solubility of nitrate in water, humans are exposed to it. primarily through various means, including water, food, etc. [8]. Among the chemical pollutants that pose a direct threat to human and animal health is nitrate (NO_3^-), which is often transferred to groundwater through the leakage of nitrogen fertilisers and animal waste [9]. Increased use of synthetic fertilisers, waste disposal, especially from animal husbandry, and changes in land use have contributed significantly to the gradual increase in nitrate levels in groundwater supplies [10]. Since water does not contain antioxidants, nitrate intake from drinking water may be more harmful than intake from food, which may contain antioxidants. Other proposed mechanisms for the potential effects of nitrate on reproductive health include the formation of N-nitroso compounds and thyroid and endocrine disorders [11]. The current World Health Organisation (WHO) guideline value for nitrate in drinking water is 50 mg/L as nitrate (NO 3 −) or 11.3 mg/L as nitrate-nitrogen (NO 3 -N) (NO 3 − mg/L × 12). Several epidemiological studies conducted on humans have indicated a relationship between prenatal exposure to nitrate and adverse reproductive outcomes, including birth defects, premature birth, low birth weight, and small size for gestational age [13].

This study aims to assess the quality of groundwater wells in different areas of Daquq district in Kirkuk province by analysing their physical, chemical and bacteriological characteristics and determining their suitability for livestock watering using a water quality index. It also seeks to assess the health risks resulting from high nitrate concentrations by calculating the hazard coefficient and chronic daily intake, with the aim of classifying water quality and providing recommendations to reduce its negative effects on human and animal health .

2. Materials and Methods

2.1. Study Area

The study area is located south of Kirkuk, specifically in the Daquq district and Taza subdistrict. Daquq is about 30 kilometres from the city centre, while Taza is 7 kilometres away. All areas are characterised by urban and agricultural development and livestock farming. Six wells were randomly selected, three for each area. The wells ranged in depth from 150 metres to 60 metres and were classified as deep wells with closed mouths. The locations of the wells were determined using the Google Earth GPS application, as shown in the figure. (1). The wells were selected in the study area to assess water quality, which is characterised by a lack of studies on groundwater quality, in addition to the dependence of the inhabitants of the two areas on well water for drinking and various civil uses.

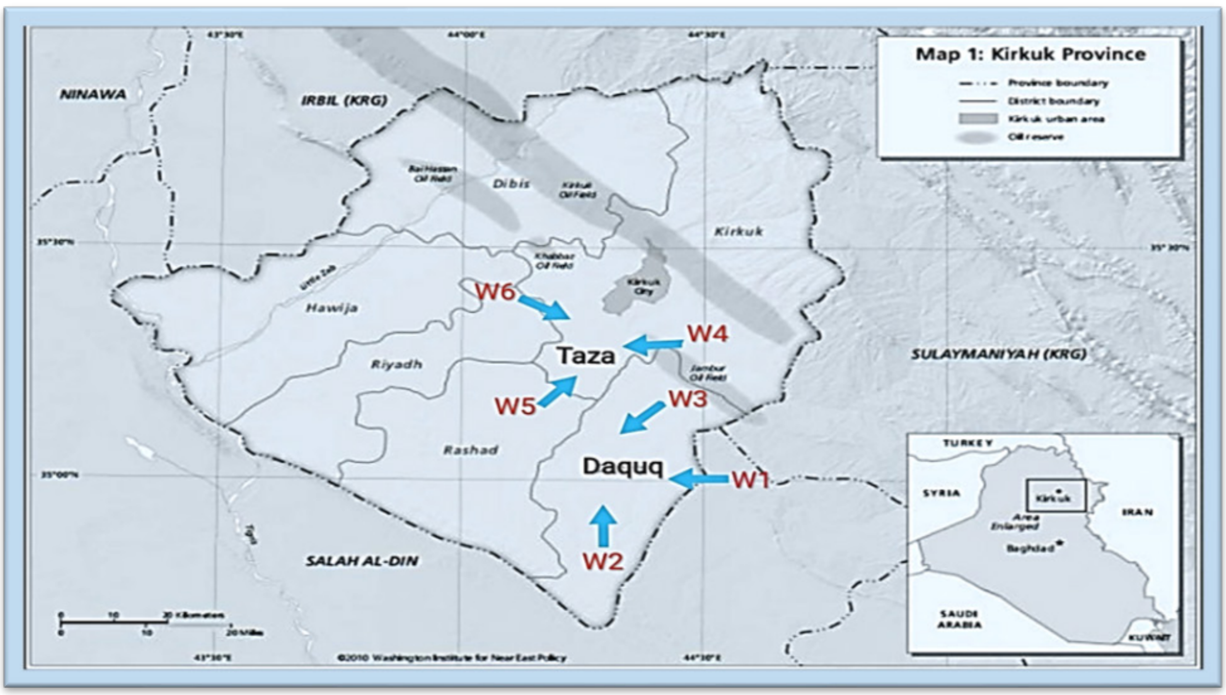

Figure 1: shows the locations of the wells in the study areas.

2.2. Sample Collection

Water samples were collected monthly from six wells in Daquq and Taza from October 2023 to March 2024, using clean, pre-washed polyethylene bottles. The well pumps were operated for more than 10 minutes before sampling to maintain the accuracy of the physical and chemical properties. For bacteriological tests, sterile glass bottles were used, and the samples were transported in refrigerated containers to the laboratories. All analyses were carried out in the laboratories of Hawija and the Kirkuk Water and Sewerage Departments.

2.3 Physicochemical Analyses

The following properties were analysed using standard methods in accordance with the American Standard Methods for the Examination of Water and Wastewater [14]. Electrical conductivity (EC): The electrical conductivity of well water was measured using an EC meter in microsiemens/cm, after calibrating it with distilled water and adjusting the temperature to 25 °C using the equation:

$$EC25 = EC / (1 + 0.0191) \times (T - 25)$$

Three readings were taken for each sample and the values were recorded after stabilisation[15].

Total alkalinity: Total alkalinity was calculated according to the method described by (15) by taking 100 ml of well water, adding 3 drops of orange methyl indicator, and then titrating with sulphuric acid (0.02N) until the colour turned pink, according to the equation [16]:

$$T.Alk\ (mg/l) = (V \times N \times eq.wt \times 1000) / sample\ volume$$

Total Hardness: Total hardness was estimated by taking 50 ml of the sample, adjusting the pH to 10, then adding Erichron Black indicator and titrating it with Na_2EDTA (0.01N) until the colour turned blue, according to the equation:

$$T.H\ (mg/l\ as\ CaCO_3) = (V \times N \times .eq.wt \times 1000) / sample\ volume$$

Calcium Hardness: Calcium hardness was measured by taking 50 ml of the sample, adjusting the pH to 12 by adding NaOH, then adding merocase dye and titrating it with Na_2EDTA (0.02N) until the colour turned violet, and calculated according to the equation:

$$Ca.H\ (mg/l\ as\ CaCO_3) = (V \times N \times eq.wt \times 1000) / sample\ volume.$$

Magnesium Hardness: Magnesium hardness was calculated using method [15] mathematically by subtracting calcium hardness from total hardness:

Mg.H (mg/L) = T.H – Ca.H.

Sodium ions : Sodium ions were measured using a flame photometer after calibration, by diluting 5 ml of the sample with 50 ml of distilled water, multiplying the reading by the dilution factor, and expressing the result in mg/L.

Potassium (Na^{+}, K^{+}): Potassium ions were measured using a flame photometer after calibration, by diluting 5 ml of the sample to 50 ml, multiplying the reading by the dilution factor, and expressing the result in mg/L. [14].

Chloride (Cl^{-}): Chloride ions were measured using the Mohr method by taking 50 ml of the sample, adding potassium chromate, and then titrating with silver nitrate (0.0141N) until the colour turned brick red, according to the equation [15]

Cl^{-} (mg/L) = (V × N × 35.5 × 1000) / sample volume.

Sulphate (SO_4^{2-}): The sulphate concentration was measured by the turbidimetric method using a spectrophotometer at 420 nm after treatment with a conditioned reagent and barium chloride [14].

2.3. Bacteriological Analyses

Total Bacterial Count: To calculate the total number of aerobic bacteria, the plate pour method was used according to [17] using decimal dilutions up to 10^{-3}. One millilitre of the last two dilutions was placed in Petri dishes, then poured into sterilised and cooled nutrient agar medium and mixed with a figure-eight motion to homogenise it. After solidification, the plates were incubated upside down at 37°C for 24–48 hours. The colonies were then counted using a counting device, and the total number of aerobic bacteria (TPC) was calculated using the equation:

Number of colonies × Inverse dilution = TPC (CFU/100mL).

Total Coliforms: To estimate the total number of coliform bacteria in groundwater, the most probable number (MPN) method was used according to [16], where three groups were inoculated, each comprising three 25 mL test tubes containing 10 mL of Macconkey broth and Durham tubes to detect the resulting gas.

3-5 *Calculating the potential risk to human health from nitrate ions (HHR)*

Calculating the potential risk to human health (HHR) from nitrate ions is one of the widely used indicators for assessing health risks to humans, developed by the US Environmental Protection Agency (USEPA) [18]. The human body absorbs contaminants directly and primarily from water intended for civil use [19]. Therefore, nitrate ion concentrations No3 were selected to assess the potential risks to human health (HHR) in current studies, where the chronic daily intake (C. D. I) and the hazard index resulting from nitrate ions (HI nitrate or HQ) Hazardous Quotient were calculated using the following equations [20]:

$$CDI = Cw \times IR \times ER \times ED / BW \times AT$$

HI nitrate = HQ = CDI / RFD

Where:

CDI: represents the chronic daily intake value in milligrams per kilogram per day.

Cw: represents the concentration of nitrate ions in drinking water (milligrams per litre).

IR: represents the average amount of water consumed per day for different ages in litres.

ED: represents the duration of exposure of an individual over several years within the study area.

EF: Represents the frequency of exposure per year, which is 365 days.

Bw: Represents the average body weight in kilograms.

AT: Represents the average time values in days.

RED: Represents the reference dose of nitrate (1.6 mg/kg/day).

If the value of either HI or HQ exceeds the permissible standards, it poses a risk to consumer health. When their values are equal to or less than 1), the water is considered safe for human consumption [21]. This data is obtained from health risk system information [22].

Statistical analysis:

Significant differences were extracted using one-way analysis of variance (ANOVA). These differences were confirmed by standard error. Differences were also determined using Duncan's multiple range test at a significance level ($P<0.01$).

3. Results and Discussion

3.1. Electrical conductivity:

The results of the current study indicated varying values during the months of the study, as shown in Table (1), ranging between (3440 – 742) microSiemens/centimetre, with the lowest electrical conductivity values (742) microSiemens/centimetre recorded in well No. (1) in December 2023 and the highest value (3440) microSiemens/centimetre in well No. (6) in February 2024. The results of the variance analysis and Duncan's test confirmed significant spatial differences in the average conductivity values at a significance level ($P \leq 0.05$) between the stations under study. The results of our study were higher than those of [23], which ranged from 900 to 278 micro-Siemens/cm when assessing the quality of groundwater in the Qush basin in the city of Mosul, and lower than the results of study [24] to assess the water quality of a number of wells, which ranged between 7900 and 400 microSiemens/centimetres. The variation and difference in the results of the current study is due to friction, i.e. the time it takes for water to pass through the rock layers of the geological region and reach the groundwater formed from gypsum and anhydrite rocks, as well as the nature of the geological formation of the region [25].

3.2. Total alkalinity:

The results of the current study of well water samples, shown in Table (1), indicate that total alkalinity values ranged between 280 and 143 mg/L1. The results of the current study of total alkalinity values were lower than the results [26] in his study evaluating the water of some wells in the Yaji district of Kirkuk province and determining its quality using mathematical models, which ranged from (365-155) mg/litre1 and were similar to the results of the study [27] for his study evaluating the water of wells in the Daquq district, south of Kirkuk, which ranged between (214-144) mg/litre1 . The total alkalinity of all well water samples in the current study is of the bicarbonate type because the pH values of all well water samples are below 8.3, as indicated by [28] . The reason for the high total alkalinity values in the studied well water is attributed to the decomposition of organic matter dissolved in water by bacteria, causing an increase in carbon dioxide concentrations, which converts carbonates to bicarbonates [29]. The results of the analysis of variance and Duncan's test of the well water samples at a significant level (P≤0.05) showed significant spatial differences in the means of total alkalinity values.

3.3. Total hardness:

The results of the current study in assessing the quality of well water, shown in Table (1), indicate that total hardness (T.H) values vary in most months and locations, ranging between (922–312) mg/ litre. The results of our study on the total hardness values of well water were higher than the results [27] in his study on the physical, chemical and biological characteristics of well water in Kirkuk Governorate, which ranged between (562-260) mg/l. The rise and fall in total hardness values from one well to another in the study area is likely due to the depth and age of the well, as well as the pumping and withdrawal of groundwater for various uses, in addition to the nature of the subsoil composition of calcareous and limestone rocks that are susceptible to decomposition and dissolution through the passage of acidic water through them [30]. The results of the analysis of variance and Duncan's test for total hardness values showed clear spatial differences relative to the averages of the sampling locations at a significance level (P≤0.05).

3.4. Calcium hardness:

The results of the current study, shown in Table (1), indicate that the calcium hardness values (Ca.H) vary relatively among the selected well water samples, ranging between 220 and 70 mg/L. The results of our study of calcium hardness values are lower than the results [31] in his study to assess the suitability of well water in the north and east of Kirkuk province, which ranged between (750-115) mg/L, while the results of our study were higher than the results [32], which ranged between (122-34) mg/litre-1 in her study of the physical, chemical and biological characteristics within Kirkuk province. The reason for the increase and decrease in calcium concentration levels in well water samples is due to the geological composition of the studied area of sedimentary rocks, limestone and dolomite containing these waters, or when they flow through these rocks during their natural continuous movement or are fed by rainwater seepage, where calcium [33] The results of the analysis of variance of the calcium hardness values of the studied samples documented no significant temporal differences in the average months of sample collection at a significant level (P≤0.05), while the results showed significant spatial differences during the study period according to the statistical analysis.

Magnesium hardness: The results of the current study of well water samples shown in Table (1) indicate that magnesium hardness values ranged between (703-237) mg/litre-1. The reason for the variation in magnesium hardness values for well water samples is likely due to the geological composition of the area and the presence of different rocks such as limestone and dolomite in the earth's layers, as well as the washing of neighbouring lands with rainwater, which leads to its leakage through cracks and pores into groundwater [33] . The results of the variance analysis and Duncan's test showed significant differences in the sampling locations at a significance level (P≤0.05).

Sodium ion: Table (1) Sodium ion values ranged between (69–22) mg/L. The results of the current study for sodium ion values are higher than the results [31] in his study evaluating the suitability of well water in the north and east of Kirkuk, which ranged between (61–8) mg/litre, and lower than the results [26] in his study evaluating the quality of well water in the Yaji district of Kirkuk city using mathematical models, which ranged from ranged from 179 to 51 mg/l. The reason for the high concentration of sodium ions is due to the geological nature of the area, which contains salt rocks and clay stones rich in bicarbonates that decompose and dissolve when water reaches them, forming sodium ions [34]. The results of the statistical analysis and Duncan's test confirmed that there were no significant temporal differences in the average sodium ion values relative to the months of sample collection at a significant level (P≤0.01) and that there were clear significant spatial differences between the sample collection sites.

3.5. Potassium ions:

The potassium ion concentration values for the current study results, shown in Table (1), ranged between (4.8–2) mg/L. The variation in potassium ion concentration values and the increase in its concentration are due to the geological composition of the area, rock weathering, and the process of washing salts from rock formations and soil in the area when heavy rains fall, as well as the frequent use of agricultural fertilisers and pesticides, which led to high potassium values in the water [35]. The results of the analysis of variance and Duncan's test of the mean values of potassium ions for well water samples showed significant and spatial differences at a significance level (P≤0.05).

Chloride ions :The results of the current study, shown in Table (1), indicate that the chloride ion concentration values for well water samples ranged between (97–39) mg/L. The results of the current study were lower than the results of study Lower than the results of the study by[36] when evaluating the quality of well water in Kirkuk City, which ranged between 56–112 mg/L. The reason for the low chloride ion values in the studied wells is that the soil surrounding the wells has a low concentration of chloride ions, and the depth of the wells and their distance from surface water and well water led to a decrease and low concentration of chloride ions during groundwater recharge and a decrease their percentage. [37] The results of the analysis of variance confirmed by Duncan's test documented the existence of significant spatial differences in the mean values of chloride ions for well water samples at a significant level (P≤0.05).

3.6. Sulphate ions:

The results of the current study, shown in Table (1), indicate that the sulphate ion values for the well water samples ranged between (684–165) mg/l. The results of the current study were higher than those of [38] in her study estimating the quality of well water and its suitability for various uses in the city of Kirkuk, which ranged from 480 to 19 mg/l, and lower than the results of [26] in his study to evaluate the water of some wells in the Yaji district of Kirkuk and determine its quality using a number of mathematical models, which ranged from 1080-320 mg/l. The variation in the values of sulphate ions in well water is attributed to the oxidation and reduction processes of sulphur phases, as well as the diversity in the geological composition of the area through which the groundwater passes and comes into contact with in the study area [32]. The results of statistical analysis using analysis of variance and Duncan's test for the mean values of sulphate ions at the level ($P \leq 0.05$) indicated significant spatial differences in well water samples in the study area.

3.7. Total number of bacteria:

Table (1) The total bacterial count (T.P.C) values for well water samples in the study area ranged between CFU/ml (83-4). The results of the statistical analysis confirmed by Duncan's test showed that the total bacterial counts were at a significant level ($P \leq .05$). Significant differences in the averages of the sites were attributed to the high total bacterial counts due to the drift of organic matter into the groundwater as a result of rainfall and the washing of agricultural land rich in organic animal fertilisers, which are a major source of bacterial and microscopic organisms in groundwater, and the possibility of leaks from the sanitary drainage system into groundwater, especially wells close to sources of bacterial contaminants [39]. The reason for the decrease in the number of bacteria in well water samples is that most wells are deep, have closed mouths, and are far from sources of pollution. The decrease in the number of bacteria during certain periods is due to high water temperatures, which reduce the amount of dissolved oxygen, thereby reducing the growth rate of bacteria in the water, as well as an increase in the activity of protozoa in the water with high temperatures, which are considered predators of bacterial species [32].

3.8. Colon bacteria:

The results of the current study, shown in Table (1), indicate that colon bacteria counts ranged between (16 – 0) cells/100 ml, where the results of the analysis of variance and Duncan's test for colon bacteria counts showed a significant level ($P \leq 0.05$) that there were significant spatial differences in the well water samples. The reason for the low number of coliform bacteria is attributed to the great depth of the wells and their closed mouths, which are far from pollutants such as air laden with waste and dust, in addition to their distance from sewage pollutants, or due to the filtration process of water as it passes through geological layers, preventing coliform species from reaching the well water, or due to the sedimentation process B [40]. The high levels in well water samples are attributed to the proximity of these wells to sewage leaks, wastewater, animal waste, and their depth close to the ground surface, which does not exceed 40 metres, and their open mouths [41].

Table 1. the highest and lowest values for the factors studied and the average rates for the locations.

Factors	first site	Second site	Third site	Fourth site	Fifth site	Six site
EC	(742-812) 783a	(976-3230) 1979b	(2530-3150) 2800c	(3114-3430) 3312c	(2550-3230) 2895c	(3214-3440) 3357c
TA	(143-148) 144a	(162-188) 180b	(206-228) 217c	(212-228) 221c	(204-219) 211c	(200-280) 223c
TH	(312-328) 320.6a	(322-364) 345.1a	(556-668) 611.6b	(762-922) 852.0d	(674-862) 732.8c	(689-892) 762.5c
CaH P	(70-78) 75.0a	(74-80) 78.3a	(156-196) 168.6b	(196-219) 204.8c	(180-220) 195.1c	(176-220) 196.1c
Mg H	(248-696) 494.6a	(246-703) 487.6a	(237-680) 414.0b	(244-664) 437.1d	(241-574) 421.3b	(246-566) 416.1b
Na	(22-25) 23.1a	(32-36) 33.5b	(60-69) 65.3d	(32-40) 35.8b	(35-44) 39c	(40-42) 40.8c
K	(2.2-2.6) 2.3a	(2.5-3.1) 2.7b	(2-4.5) 2.6b	(2.8-4.8) 3.4c	(3-4.5) 3.5c	(3.1-4.1) 3.6c
Cl	(39-44) 41.6a	(40-50) 47.6b	(86-97) 92.5c	(42-52) 46b	(44-58) 48.8b	(48-54) 50.6b
SO4	(165-174) 168.5a	(181-196) 187.5a	(460-684) 547c	(484-512) 503.6c	(386-496) 424.5b	(442-510) 473.3b
TPC	(4-15) 9.6a	(10-85) 40.8b	(32-82) 59.8c	(12-83) 46.1c	(16-40) 33a	(16-50) 32.1a
MPN	(0-4) 1.8a	(3-6) 4.5b	(9-15) 11.3c	(12-16) 13.6d	(0-3) 1.0a	(9-14) 11.6c

Assessment of Human Health Risk of nitrate via drinking water (HHR)

The potential health risks posed by nitrate ions in the studied well water were calculated and assessed based on human health risk (HHR) using chronic daily intake (CDI) values for all age groups. The results of the current study, shown in Table 2, indicate that the nitrate ion values in the drinking water of the studied well water samples ranged from 184 to 40. and that the nitrate ion risk quotient (HQ-HI nitrate) values ranged from 10.85 to 0.85, according to the classification [21]. If the HI-HQ values exceed one, they are considered a health hazard to consumers, as they may cause cancerous and non-cancerous diseases. Therefore, all wells are considered a health hazard to consumers and all groups, except for the third well, which is safe for age groups between 18 and 16 years of age can overcome the toxic effects of nitrate ions. The chronic daily intake (CDI) values for the studied well water samples ranged between 17.36 and 1. 8). Therefore, the water from all wells is considered to be potentially dangerous to all age groups. The reasons for the high values are due to the high concentration of nitrate ions, which is reflected in the chronic daily intake (CDI).

Table (2). CDI, HQ,and HI values taken from samples of the wells studied

Aage years	6-12 Years	6-11 Years	11-16 Years	16-18 Years	18-21 Years	21-65 Years	65 Years	Wells
CDI	17.36	7.11	6.36	4.16	5.46	5.89	5.39	W1
HI=HQ	10.85	4.44	3.97	2.60	3.41	3.68	3.36	W1
CDI	7.25	2.97	2.65	1.73	2.28	2.46	2.25	W2
HI=HQ	4.53	1.85	1.66	1.08	1.42	1.53	1.40	W2
CDI	5.71	2.34	2.09	1.36	1.8	1.94	1.77	W3
HI=HQ	3.57	1.46	1.30	0.85	1.12	1.21	1.10	W3
CDI	15.6	6.39	5.71	3.73	4.91	5.29	4.84	W4
HI=HQ	9.75	3.99	3.57	2.33	3.07	3.31	3.02	W4
CDI	12.08	4.95	4.42	2.89	3.80	4.104	3.755	W5
HI=HQ	7.555	3.09	2.76	1.81	2.37	2.56	2.34	W5
CDI	13.95	5.72	5.11	3.34	4.39	4.73	4.33	W6
HI=HQ	8.72	3.57	3.19	2.09	2.74	2.96	2.70	W6

When comparing the results of the current study with those of previous studies, it appears that the values were high when compared with the results of his study [31] to assess the suitability of water from some wells in the north and east of Kirkuk in terms of its risks to consumer health from high nitrate ion concentrations (HHR), with HI-HQ values ranging between (1.94-0.11) and CDI values ranged between (3.13-0.18). One of the reasons for the lower values in his study is the lower nitrate ion concentrations, which is reflected in the chronic daily intake (CDI) values. The results of the current study showed higher values than those of study [37], in which HI-HQ values ranged between (4.21-0.11) and CDI values ranged between (6.74-0.18).

4. Conclusions

The results of the study indicate that the quality of groundwater in the districts of Daquq and Taza suffers from clear exceedances in some physical and chemical characteristics and the presence of bacterial contamination in a number of samples, in addition to nitrate concentrations exceeding safe limits, posing potential health risks to consumers. This is attributed to the combined effects of intensive agricultural activities and excessive use of nitrogen fertilisers, as well as the possibility of pollutants leaking from various sources, which calls for urgent preventive measures and periodic monitoring to ensure water safety.

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