# Evaluation of some Physical-Chemical and Biological Properties of Wells Water and its Suitability for Drinking in Al-Muthanna Governorate/Iraq

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## Abstract

The current study was conducted in Al-Muthanna Governorate, five wells were selected and some physical, chemical and bacteriological properties were measured, starting from the first well in the Wadi Kharaz region and ending with the fifth well in the Al-Rehab region to determine the water quality of these wells and their suitability for use and to monitor the differences in months and locations during the study period from (January to June) 2021. The study included the measurement of some physical factors, including Water temperature, Turbidity and some chemical factors, including pH,Total hardness (TH), Phosphate (PO4), Nitrite (NO2), Nitrate (NO3) and bacterial contamination, which includes calculating the total number for coliforms bacteria (TC) Fecal Coliform Bacteria (FC) and Fecal Streptococci bacteria (FS). By conducting tests on this water, it was revealed that some of the physicochemical values were not within the acceptable value of the Iraqi drink and WHO as mentioned in (Table, 2), such as the value of the total hardness, which ranged between (1600-3600) mg /l. The results showed that the water temperatures ranged between ( 23-27 degrees Celsius. The turbidity values in all studied wells were low and within the standard specifications, ranging between (0.10-3.70) NTU, and the pH values in low basal wells water ranged between (-7.3). 8.4). The concentration of phosphate was (0.001-0.004) mg/l, while the level of Nitrite ranged (0.001-0.006) mg/l and Nitrate (0.131-0.302) mg/l, as for the microbial examination, the total coliform bacteria ranged between (4200-86000) CFU/ml,Fecal coliform (3900-69000) CFU /ml and Fecal Streptococci (1230-120000/) CFU/ml. The study showed that the sources of bacterial contamination were among human and animal sources for the water of all wells during all months, depending on the ratio of FC / FS as mentioned in (Table,3).

Keywords: Wells, physical-chemical properties,Total coliform bacteria.

## 1. Introduction

Water is a major natural resource that is always present by the grace of God Almighty, and is necessary for all forms of life. Water is an essential part of the human body and acts as a universal solvent and mediator for all chemical reactions of living organisms [1], It is extremely important in a variety of professions such as agriculture, industrial activities, fisheries, and other activities [2].

Groundwater is an important source of drinking water for humans and animals all around the world, used for the drinking, agriculture and manufacturing sectors it is also a very valuable source of water. Water reservoirs, which constitute a major part of the hydrological cycle, rely on precipitation and refill methods. The physical, chemical and biological features of groundwater are the foundation of consistency of groundwater [3].

Wells are holes in the ground that converge the water table as water-bearing rocks streaming as springs [4]. The major sources of groundwater contamination in recent decades have been the farming, manufacturing, residential, trade and native growth. Water quality is determined by the chemical, physical parameters of water. It is a measure of the state of the water with respect to the necessities of human needs or purposes [5].

Microbiological risks remain associated with several aspects such as water use for domestic tasks and recreational water contacts. The quality of water is classically monitored by searching for and quantifying bacterial indicators of contamination because their presence indicates that contamination may have occurred.Three indicators most commonly used today by both volunteer and professional monitors—total coliforms, fecal coliforms, and fecal streptococci —are bacteria that are normally prevalent in the intestines and feces of warm-blooded animals, including wildlife, farm animals, pets, and humans. The indicator bacteria themselves are not usually pathogenic.

Study problem: The phenomenon of groundwater pollution is a problem that the various study areas suffer from. The growth in the size of the population, the increase in their urbanization and the expansion of the diversity of their activities, led to a growing demand for water, and its consumption in domestic, service and industrial fields, all of this increased the quantities of Wastewater and sewage that were not treated, and leaked out.Through cracks and faults to the aquifers and raise the levels of water pollution, especially near population centers and its liquid and solid waste. Also, the expansion of the agricultural area and the excessive use of fertilizers, pesticides and irrigation water led to contamination of wells water in various study areas. What added to this problem is that most of the water sources are notit is protected, and it is not checked periodically so that the qualitative evaluation of the most important water sources is a priority for the general environmental

doi.org/10.31838/hiv22.02.237 Received: 08.05.22, Revised: 09.06.22, Accepted: 21.08.22

health of the population and their different uses of water. The aim of present study was assessment physical - chemical and biological properties of wells water in Al-Muthanna governorate, Iraq.

# 2. Materials and Methods

## Description of the study area

The study area is located in the outskirts of Al-Muthanna Governorate southern Iraq, which lies between latitudes 30º 51'26.19" to 31º13'24" north and longitudes 44º 51'27'31 " to 45º02'27" east. The studied wells were classified as medium-depth and closed wells that were drilled by mechanical excavators.The depths of the wells range between 40-75 m and the duration of use is between one to 15 years. The first well this well is located in the Wadi Kharz, scond well in Al-Mamlha,Third well this well is located in the Al-Ghadari, The fourth well this well is located in the Al-Ameed, The tifth well this well is located in the Al-Rehab as mentioned in (Fig: 1) The wells of the current study were selected from different areas of the governorate due to their proximity to agricultural lands and because of their use by a number of residents of these areas.These wells are linked to non-point sources of pollution, that these wells are close to agricultural areas and there are population centers near them, and that the increase in human activities, as well as the presence of a number of animals and the leakage of water from these agricultural lands and pesticides, as well as the nature of these wells led to physical, chemical and biological pollution.

## 1-The First well

This well is located in Wadi Kharaz, northwest of Al-Muthanna Governorate. The well is of a closed type and mechanically drilled, with a depth of 45 meters, a lifespan of one year, a tube diameter of 4 inches, and a period of use for one year. One of the most important uses of the well is for drinking after desalination, irrigation and other uses. This area is about 43 km away from the city center.

## 2-The second well

This well is located in the Al-Mamlha area in the northwestern of AL-Muthanna Governorate. The well is of a closed type and mechanically drilled, with a depth of 40 meters, the diameter of the intake pipe is 4 inch, and the duration of use is fife year. The most important uses of the well are for drinking after desalination, irrigation and other uses. It is approximately 22.18 km away from the first well.

## 3 -The Third well

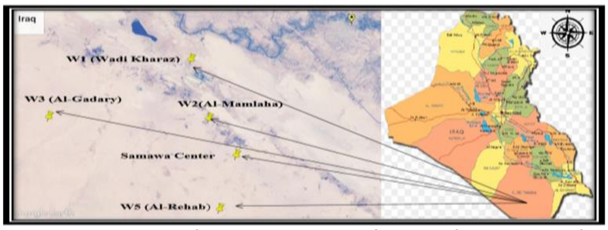
This well is located in the Al-Ghadari area west of Muthanna. The well is of a closed type and mechanically drilled, with a depth of 45 meters, the diameter of the intake pipe is 4 inch, and the duration of use is one year. The most important uses of the well are for drinking after desalination, for irrigation and domestic uses, and it is about 5 km away from the second well.

## 4 -The Fourth well

This well is located in the Al-Ameed area west of Muthanna. The well is of a closed type and mechanically drilled, with a depth of 75 meters, the diameter of the intake pipe is 4 ang, and the duration of use is 15 years. The most important uses of the well are for irrigation, uses and watering animals, and it is about 10 km away from the third well.

## 5 -The Fifth well

This well is located in the Al-Rehab area, west of Muthanna. The well is of a closed type and is mechanically drilled with a width of 70 meters, the diameter of the intake pipe is 4 inch, and the duration of use is five years. The most important uses of the well are for irrigation, domestic uses, and watering animals. It is about 53.12 km away from the fourth well.




*Figur (1): Map showing sites in the Study sites in Al-Muthanna Governorate during the study period*

## Sample collection

The samples were collected from five wells.Use a sterilized plastic bottle 5 liter (for physiochemical parameters) and a sterilize tube10 ml for (bacteriological tests).Samples were collected from the wells after pumping water and waiting for five minutes until the dust or bacteria stuck in the pumping tube is removed. The plastic bottle washed with the sample water three times to ensure that the bottle contains only sample water and then it is closed. Put the bottles for the bacterial examination in a cold box until they reach the laboratory, as well as the bottle for the physicochemical tests away from sunlight to preserve the sample from any changes [6].

Sampling procedurers

1-Physiochemical Parameters

* Water temperature (°C) was measured by thermometer.

* pH were measured by using a portable Multimeter (SM801).

* Turbidity (NTU) were measured by using Turbidity meter.

*Total hardness (TH) were measured by using a titrimetric method mentioned in Patnaik [7].

*Nitrate (NO3), and Nitrite (NO2) measured according to Tr et al. [8].

* Phosphate (PO4) measured according to [7].

* Total Coliform bacteria (TC) count and dignosis according to (Ang and Tham, 2020 ).

* Fecal Coliform bacteria (FC) count and dignosis according to (Ang and Tham, 2020)

*Fecal Streptococci bacteria (FS) count and dignosis according to (Ang and Tham, 2020 )

# 3. Results and Discussion

## Physical- chemical Parameters

### Water temperature

Temperature plays an important role in influencing the quality of proper water bonds; It affects the chemical reactions that occur in water and affects the pH values and the solubility of salts and gases, especially oxygen and carbon dioxide, and has a prominent role in influencing the effectiveness and activity of microorganisms and affecting the biological analysis processes of organic matter and oxidation and reduction processes.High water temperature (20-30°C) can also increase the growth of microorganisms and may lead to problems with taste, odor, color and corrosion. The most desirable temperatures for drinking water are between 4°C and 10°C. Temperatures above 25 °C are usually objectionable [9].

The results in Figure (2) showed that the temperatures in the study area ranged between [1, 4, 10, 11] degrees Celsius, and the highest value was in well 2 [1] degrees Celsius in June, while the lowest value was in well 3 with the same temperature. Temperature [10] degrees Celsius in January and February. The water of the study wells is classified as warm water according to the classification of water according to its temperature [12]. The temperature of groundwater depends largely on different geological conditions, the source of nutrition, and the diversity of the depth of the aquifers, and well water is not affected by air temperature during seasons or months due to groundwater temperatures. The rocks in the wells that contain water are at a certain temperature, so the temperature of the water in these wells remains constant, and if some changes occur, they will be slight. The results of the current study were close to the results obtained [13].

The results of the statistical analysis (P≤ 0.05) showed that there were statistically significant differences between all months.

**Table (1): Classification of water according to its temperature [12].**

| Item | Thermal range (°C ) |
|---|---|
| Cold | < 20 |
| Warm | 20-37 |
| Hot | 37- 42 |
| Very hot | >42 |

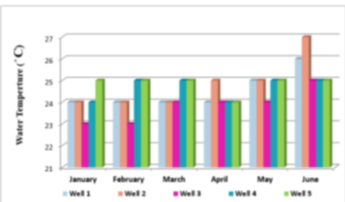


**Figure (2): Monthly variations for Water temperature mean value in study sites**

### pH

pH is defined as the negative logarithm of hydrogen ion concentration [7]. The pH is a very important factor affecting the development of aquaculture that determines the suitability of water for different purposes [14].

The results have been noted that the pH of the wells ranged from (7.30 to 8.40), which is within the Iraqi standard limits, (6.5 to 8.5) according to the standard specifications for Iraqi drinking IQS [15] and [16] as shown in (Table, 2). However, during all months the pH was neutral only the pH value in well 4 was [14] as shown in Figure 3. This slight increase in pH may be due to the possibility of contamination from people living around this area or The reason may be due to the regulatory capacity of the water containing bicarbonate and carbonate compounds, as well as the water entering the body of these compounds from the surrounding soil, given that the Iraqi soil is rich in these compounds that work on the acid equation when entering the water, as well as the fact that most of the wells studied Far from direct atmospheric changes, which cause them to dissolve carbon dioxide in water, as well as the hardness and alkaline rich in bicarbonate, which resist the change in pH, [17]. Samawah city, Muthanna Governorate, where the pH values ranged between [7, 18, 19]. The results of the statistical analysis (P≤ 0.05) showed that there were statistically significant differences between all wells and all months.

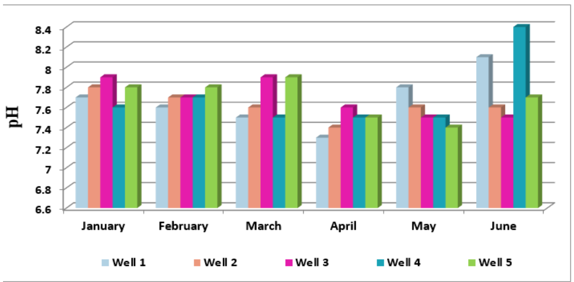



*Figure (3):Monthly variations for pH mean value in study sites*

### Turbidity

Turbidity is an expression of some light scattering and light absorption properties of a water sample resulting from the presence of clay, silt, suspended matter, colloidal particles, plankton and other microorganisms present in the water [11].

The results in Figure (4) showed that the turbidity in the studied wells ranged between (0.10-3.70) NTU and the highest value was in well 2 (3.70) NTU, followed by well 1 with turbidity [17, 20] NTU in April, and the lowest value was in wells 4 in January and in well 3 in June (0.10)NTU. The reason for the decrease in turbidity values in most of the studied well water during the months of the study is due to the relative stagnation of well water. The turbidity values in all wells in the study areas are identical to the Iraqi standard specifications for drinking [15] and [16] as shown in (Table,2), which are 5 NTU. The turbidity results of this study are dis agree with results of Alasedi [18] which conducted on groundwater in Najaf city / Iraq. The results of the statistical analysis (P≤ 0.05) showed the presence of statistically significant differences between wells as in wells 2 and 3, and the presence of significant differences as in the month of April.

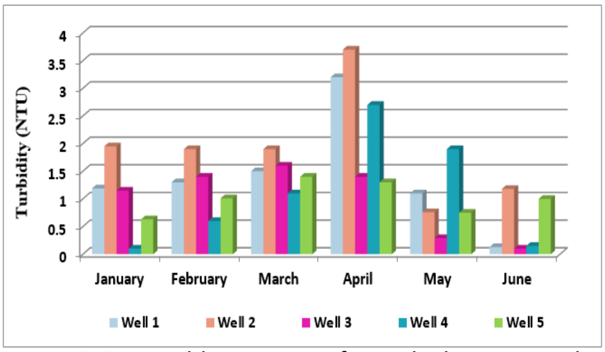



*Figure ( 4): Monthly variations for Turbidity mean value in study sites*

## Total hardness (TH)

TH is defined as the total sum of dissolved calcium and magnesium. The current study. The concentration of TH (1600-3600) mg.CaCO3./l, as in Figure (5) was higher than the limited range of the Iraqi drinking water standard specifications for the Fao [2] and [16] (500 mg/l) in all Wells in different months as shown in (Table, 2). The hardness of the water varies with the source of the water, as the surface water is usually less hard than the ground water and this follows the geological nature of the land. However, the highest value of the total hardness is in January. It is attributed to the characteristics of the nature of the Iraqi lands, as it is characterized by being of a calcified nature in addition to the high concentrations of dissolved and basic solids and sulfates in the water that increase the hardness values . However, the results showed an increase during January. This attribution of precipitation was making the access of pollutants, organic and inorganic materials and agricultural residues from adjacent lands from the surface to the groundwater helped to increase the hardness rates of the groundwater [21]. The results of the total hardness of the current study agree with the results of the study for well water in Karbala governorate, which ranges between (1160 - 2545) mg /l. The results of the statistical analysis (P≤ 0.05) showed that there were significant spatial differences between all wells and all months.

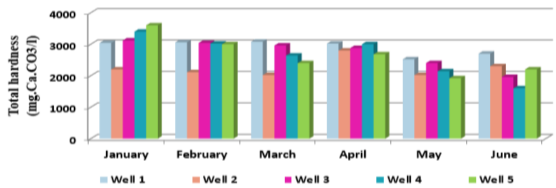



*Figure (5): Monthly variations for Total hardness mean value in study sites*

## Nitrite (NO2)

Nitrite (NO2) is an intermediate compound formed by reducing nitrate to nitrite or by oxidizing ammonia. The presence of nitrite in water is an indicator of water contamination with wastewater.

The results of Nitrite in the present study ranged between (0.001-0.006) mg/l. The height value of nitrite in June at well 3 and lowest values in June in well 4. The concentration of nitrite was low in all wells and all months, where the values were within the acceptable limits of Iraqi water for nitrite [17] mg /l as shown in (table, 2). Both nitrate and nitrite occur naturally in the environment, and are produced by the oxidation of nitrogen by microorganisms. The nitrite values in the current study were disagree with the results of the study [22], which was in Basra Governorate, whose nitrite value was [9] mg /l. The results of the statistical analysis (P≤ 0.05) showed significant differences between all wells and all months.

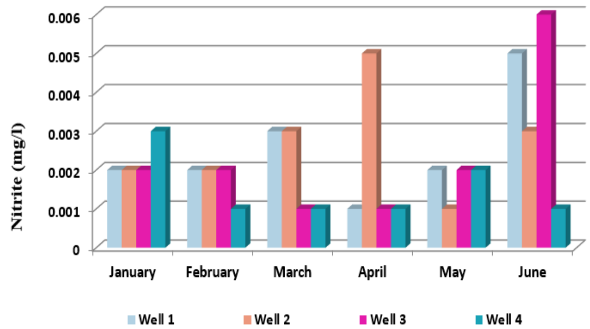



*Figure: (6) Monthly variations for Nitrite mean value in study sites*

## Nitrate (NO3)

Nitrate (NO3) is an essential nutrient and is found naturally in unpolluted water bodies due to the process of animal and plant growth and putrefaction. However, excess nitrate causes a significant increase in plant growth and negatively affects the health of aquatic animals and humans [7].

The mean value of nitrate in the present study ranged between (0.131-0.302 mg/l ) The height value of nitrate in April at well 1 and The lowest values of nitrate in May in well 5.The nitrate values were Within the acceptable values for Iraqi water (50 mg /l) as shown in the Figure (7). The values of nitrate in the wells of the current study are located within the Iraqi standards specifications 2009 which amounted to (50) mg/l and less than the specifications [16] which amounted to (10-45) mg/l as shown in table (1). The results of the study were disagree with results obtained by Umer et al. [23]. The results of the statistical analysis using the analysis of variance at the level of significance (P≤ 0.05) showed the presence significant differences between all months and all wells.

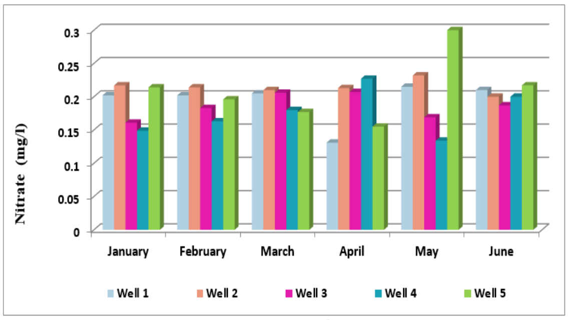



*Figure (7): Monthly variations for Nitrate mean value in study site*

## Phosphate (PO4)

Phosphorous is found in natural waters and effluents only in the form of phosphates. They are classified as condensed phosphates, organically bound phosphates, and orthophosphates. Phosphate used on agricultural land as fertilizer is transported to groundwater by storm runoff [7].

Phosphate values in the current study ranged between (0.001-0.004) mg/L, where the highest value of phosphate was in well 2 in the month of May and the lowest value was in well 5 in April as in the Figure (8). Phosphate concentration was low in all wells in the different months.As in the Figure (8), it was within the acceptable limits for Iraqi [15] (0.5 mg / l) and the international specifications of the [18] mg /l as shown in table(1). The results of the statistical analysis (P≤ 0.05) showed clear temporal significant differences between months and all wells.

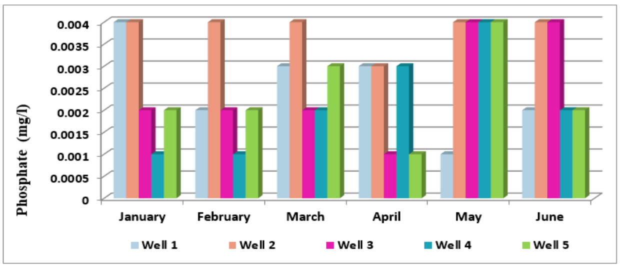



*Figure: (8) Monthly variations for Phosphate mean value in study sites*

## Bacteriological test

### Total coliform bacteria (TC)

One of the most common bacterial indicators of fecal contamination in water was the coliform group.

The results in Figure (9) showed that the total number of coliform bacteria in the studied wells ranged between (4200-86000) Cfu/ml and the highest value was in well 5 (86000) Cfu/ml in January, while the lowest value was in well 1 (4200) Cfu/ml in April. The reason for the relative increase in the number of bacteria in the wells of the current study is due to rainfall, rising water levels and the entry of organic matter into them as a result of water dredging and washing agricultural lands that often use animal fertilizers, and it is a major source of bacteria and microorganisms access to groundwater. The results of the statistical analysis using the analysis of variance at the level of significance (P≤ 0.05) showed that there were clear time significant differences, as in January, with clear spatial differences, as in well 5 and showed significant correlation between the total coliform bacteria with each of the following factors. pH (r = 0.109), TH (r = 0.567).

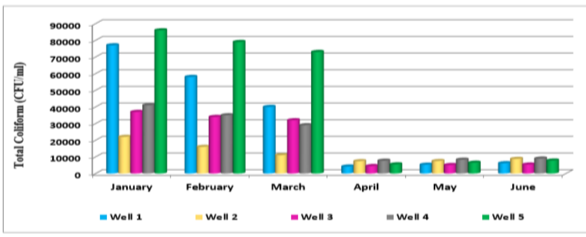



*Figure (9): Monthly variations for total coliform bacteria mean value in study sites*

### Fecal Coliform bacteria (FC)

One group that is used as indicators worldwide of water pollution are faecal coliforms [16].

The results in (Figure,10) showed that the numbers of fecal coliform bacteria in the studied wells ranged between (3900 - 69000) CFU/ml. The numbers of pectic cells differed from the wells of the current study, but were highest in January, February and March. The reason for the presence of these bacteria is due to the contact of the wells with air contaminated with bacteria from animal excrement or proximity to sewage water. In addition to what is characterized by fecal coliform bacteria in their longer survival outside the human or animal body, which distinguishes them from the rest of the pathogenic intestinal bacteria, and this is what facilitated their detection during the investigation of fecal contamination of the studied wells Water.

.he results were higher than the Iraqi drinking water standards [24] and international specifications which amounted to 1-2 CFU/100 ml, therefore these wells are not suitable for humans.

The results of the statistical analysis (P≤ 0.05) showed statistically significant differences between all months and all wells, and showed a significant positive relationship between fecal coliform bacteria with each of the following factors TH, K, respectively (r1 = 0.53, r2 = 0.54).

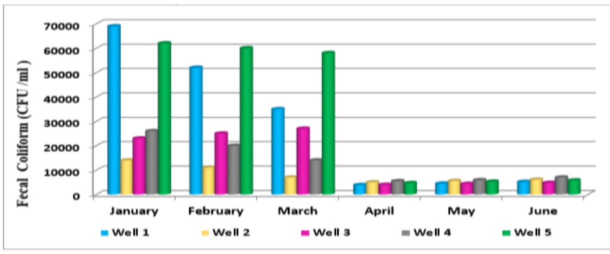



*Figure (10 ): Monthly variations for Fecal coliform bacteria mean value in study sites*

### Fecal Streptococci (FS)

One of the important bacterial groups that are used as indicators worldwide of water pollution is faecal streptococcus.

The results in (Figure,11) showed that the number of fecal streptococcus bacteria in the studied wells ranged between (1230-120000) CFU/ml. The high proportion of bacteria in these wells in January, February and March is due to several reasons, including the fact that the used study wells are close to the surface of the earth, which increases the chances of exposure to biological pollution from several sources such as human activities, which leads to the leakage of pollutants into the wells from wastewater. healthy. Purification of plants and animal breeding places and the resulting fecal pollution, as well as pollution as a result of the interaction between groundwater and sewage water.

The water that passes on the surface of the soil as a result of rainfall contains many pollutants, as well as the waste of residential areas that end in rivers, streams and groundwater where pollutants reach water wells, or the cause of pollution may be poor construction.. From the well or the presence of gaps in it, or the contamination may also be from landfills. Or due to the decomposition of organic matter, or because rainwater falls directly on it, and this waste water permeates and becomes saturated with microorganisms and other pollutants in the soil, which seeps into the groundwater.

The results were higher than the standards for Iraqi drinking Varol et al. [25] and the global standard which amounted to 1 - 2 CFU/100 ml, thus these wells are not suitable for human use.

The results of the statistical analysis ($P \leq 0.05$) showed that there were statistically significant differences between all months and between all wells, and there was no positive correlation between faecal streptococcus bacteria with each of the factors.

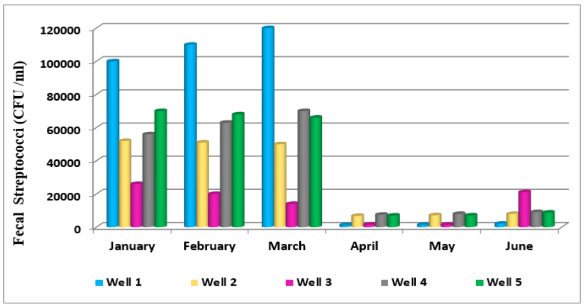



*Figure (11 ): Monthly variations for Fecal Streptococci bacteria mean value in study sites*

## Determination Fecal coliform(FC) /Fecal streptococci(FS)

Determining the FC / FS ratio because Streptococci. spp is an indicator of human and animal feces contamination in water, so the presence of Streptococci. spp in wells water was an indicator of fecal contamination [26], and the results showed that the ratio of FC / FS in The wells that were studied during six months, some of them are less than 0.4, and this indicates that the source of pollution is animal, and some are more than 0.4, and this indicates that the source of pollution is humans, as shown in (Table,3).

**Table (2): Iraqi (2009) and WHO Drinking Water standards (2011) for physical & chemical parameters and bacterial indicators**

| Parameters | Iraqi standards (2009) | WHO standards (2011) |
|---|---|---|
| Temperature (C°) | --- | --- |
| pH | 6.5–8.5 | 6.5–8.5 |
| Turbidity (NTU) | 5 | 5 |
| Total hardness (mg.Ca.Co3/l) | 500 | 500 |
| Phosphate (mg/L) | .50 | 5 |
| Nitrite (mg/l) | 3 | --- |
| Nitrate (mg/l) | 50 | 10-45 |
| Total Coliform bacteria (CFU/ml) | --- | ---- |
| Fecal coliform bacteria(CFU/ml) | --- | ---- |
| Fecal streptococci bacteria(CFU/ml) | --- | ---- |

**Table (3) The ranges in bacterial counts and FC /FS ratio for the six months in study sites**

| Month | Wells | FC (CFU/ml) | FS(CFU/ml) | FC/FS ratio | Contamination Source |
|---|---|---|---|---|---|
| Janoury | W1 | 69000 | 100000 | 0.9 | Human fecal contamination |
| | W2 | 14000 | 52000 | 0.2 | Animal fecal contamination |
| | W3 | 23000 | 26000 | 0.8 | Human fecal contamination |
| | W4 | 26000 | 56000 | 0.4 | Human fecal contamination |
| | W5 | 62000 | 70000 | 0.8 | Human fecal contamination |
| February | W1 | 52000 | 110000 | 0.2 | Animal fecal contamination |
| | W2 | 11000 | 51000 | 0.2 | Animal fecal contamination |
| | W3 | 25000 | 20000 | 1.2 | Human fecal contamination |
| | W4 | 20000 | 63000 | 0.3 | Animal fecal contamination |
| | W5 | 60000 | 68000 | 0.8 | Human fecal contamination |
| March | W1 | 35000 | 120000 | 0.2 | Animal fecal contamination |
| | W2 | 7000 | 50000 | 0.1 | Animal fecal contamination |
| | W3 | 27000 | 14000 | 1.9 | Human fecal contamination |
| | W4 | 1 4000 | 70000 | 0.2 | Animal fecal contamination |
| | W5 | 58000 | 66000 | 0.8 | Human fecal contamination |
| April | W1 | 3900 | 1230 | 3.1 | Human fecal contamination |
| | W2 | 5000 | 6800 | 0.7 | Human fecal contamination |
| | W3 | 4000 | 1600 | 2.5 | Human fecal contamination |
| | W4 | 5500 | 7500 | 0.7 | Human fecal contamination |
| | W5 | 4700 | 7000 | 0.6 | Human fecal contamination |
| May | W1 | 4500 | 1400 | 3.2 | Human fecal contamination |
| | W2 | 5600 | 7200 | 0.7 | Human fecal contamination |
| | W3 | 4300 | 1500 | 2.8 | Human fecal contamination |
| | W4 | 5900 | 8000 | 0.7 | Human fecal contamination |
| | W5 | 5300 | 7100 | 0.7 | Human fecal contamination |
| June | W1 | 5200 | 2100 | 2.4 | Human fecal contamination |
| | W2 | 6100 | 8000 | 0.7 | Human fecal contamination |
| | W3 | 4800 | 21100 | 0.2 | Animal fecal contamination |
| | W4 | 7000 | 9100 | 0.7 | Human fecal contamination |
| | W5 | 5800 | 8800 | 0.6 | Human fecal contamination |

## 4. Conclusion

Depending on the sources of contamination obtainedThe water of the current study wells was contaminated from both human and animal sources during all months based on FC/FS ratio. The physical and chemical properties of the water wells of the current study, most of which are higher thanthe standard value of Iraqi drinking water and the World Health Organization, such as total hardness, as the water of all wells is very hard, by comparing it with the standard values of drinking water. The pollution is also due to the geological nature of these wells, which helps to pollute these wells and the leakage of water resulting from washing agricultural lands and bacteria to make this water unfit for drinking and it needs treatment in order to benefit from it.

## 5. References


.1 Rosborg I, Kozisek F, Ferrante M. Health effects of de-mineralization of drinking water. In: Drinking Water Minerals and Mineral Balance. Springer, 2019. p. 149-60. https://doi.org/10.1007/978-3-030-18034-8_7

.2 Fao F. Agriculture organization of the United Nations. 2012. FAO statistical yearbook. 2012 .

.3 Kulkarni NH. A New Numerical Model Coupling Modified Method of Characteristics and Galerkin Finite Element Method for Simulation of Solute Transport in Groundwater Flow System. Aquademia. 2018;2 .04:(2) https://doi.org/10.20897/awet/90719

.4 Olabode A. Assessment of waste generation and sanitation strategies for sustainable environmental management in Akungba-Akoko, Nigeria. Journal of Waste Management and Disposal. 2018;1(1):102 .

.5 Abbasi T, Abbasi S. Water quality indices. Elsevier. London, UK. 2012 .

.6 Maiti S. Handbook of methods in environmental studies. ABD publishers Jaipur, 2003 .

.7 Patnaik P. Handbook of environmental analysis: chemical pollutants in air, water, soil, and solid wastes . Crc Press, 2017. https://doi.org/10.1201/9781315151946

.8 Tr P, Maita Y, Lalli C. A manual of chemical and biological methods for seawater analysis. Pergamon Press, OxfordPassow U, Alldredge AL, Logan BE (1994) The role of particulate carbohydrate exudates in the flocculation of diatom blooms Deep-Sea Res. 1984;41:335357Ratkova .

.9 Fowlie P. CALA Guide to Current Sampling Practices. 2014. Available from: https://cala.ca/wp-content/uploads/2019/07/CALA_guide_to_current_sampling_practices.pdf

.10 Nazar ZO ,Al-Musawi NO, editors. Using Ultraviolet Technique for Well Water Disinfection. IOP Conference Series: Earth and Environmental Science; 2021: IOP Publishing. https://iopscience.iop.org/article/10.1088/1755-1315/856/1/012037/meta

.11 Pederson A, Rootman I .From health care to the promotion of health: Establishing the conditions for healthy communities in Canada. In: Healthy Cities. Springer, 2017. p. 43-61. https://doi.org/10.1007/978-1-4939-6694-3_3

.12 Kanna T, Lakshmanan M, Dinda PT, Akhmediev N. Soliton collisions with shape change by intensity redistribution in mixed coupled nonlinear Schrödinger equations. Physical Review E. 2006;73(2):026604. Available from: https://journals.aps.org/pre/abstract/10.1103/PhysRevE.73.026604

.13 Al-Maksousi ABD, Al Mousawi AFZ. Diseases rampant in the Kut district during the royal era 1921-1958 (historical study). Available from: https://philosophicalreadings.org/wp-content/uploads/2022/01/Philosophical-Readings-XIII.4-2022-pp.-3316-3325.pdf

.14 Ahipathy M, Puttaiah E. Ecological characteristics of vrishabhavathy River in Bangalore (India). Environmental geology. 2006;49(8):1217-22. https://doi.org/10.1007/s00254-005-0166-0

.15 IQS IS. Iraqi standard of drinking water No. 417. Second modification. 2009 .

.16 Organization WH, WHO. Guidelines for Drinking-water Quality. IWA Publishing, 2004. Available from: https://books.google.com.pk/books?id=SJ76COTm-nQC

.17 Abed SM, Alaraji KHY, Essa RH. Assessment of the biological and physiochemical properties of groundwater in Al-Muthanna Province, Iraq. EurAsian Journal of BioSciences. 2020;14(2). Available from: https://www.researchgate.net/publication/353794137

.18 Alasedi KK. Ground Water Quality Assessment of Najaf City, Iraq. Int J Sci Eng Res. 2014;5(3):490. Available from: https://www.researchgate.net/publication/307601076

.19 Ross JS, Tse T, Zarin DA, Xu H, Zhou L, Krumholz HM. Publication of NIH funded trials registered in ClinicalTrials. gov: cross sectional analysis. Bmj. 2012;344. https://doi.org/10.1136/bmj.d7292

.20 Rasmussen PE. Health Canada Healthy Environments and Consumer Safety Branch 50 Colombine Driveway Ottawa, ON, Canada, K1A 0K9 pat_rasmussen@ hc-sc. gc. ca HD Gardner Department of Earth Sciences University of Ottawa, Marion Hall, Room 121 Ottawa, ON, Canada, K1N 6N5. Available from: https://journals.lib.unb.ca/index.php/GC/article/download/11085/11742?inline=1

.21 Salih NY, Al-Azzawi M. The assessment of some physical and chemical parameters of drinking water quality in Al-Wahda and Al-Qadisiyah treatment plants at Baghdad, Iraq. Iraqi Journal of Science. 2016:286-95 .

.22 Mohammed MH, Ala'a AM, Al-Ba'aj AK. Determination of nitrate, nitrite and chloride in ground water of some wells/Basrah, south of Iraq. Journal of Basrah Researches (Sciences). 201036;(1B). Available from: https://www.iasj.net/iasj/article/56151

.23 Umer MI, Abduljabar PA, Hamid NA, editors. Assessment of Ground Water Pollution by Heavy Metals and Anions in Kwashe Industrial Area, Duhok City, Kurdistan Region. Iraq. IOP Conference Series: Materials Science and Engineering; 2018: IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/454/1/012004/meta

.24 Tsutsui WM. W. Edwards Deming and the origins of quality control in Japan. Journal of Japanese Studies. 1996;22(2):29 .325-5https://doi.org/10.2307/132975

.25 Varol M, Gökot B, Bekleyen A, Şen B. Water quality assessment and apportionment of pollution sources of Tigris River (Turkey) using multivariate statistical techniques—a case study. River research and applications .38-1428:(9)28;2012 . https://doi.org/10.1002/rra.1533

.26 Chik AH, Emelko MB, Anderson WB, O'Sullivan KE, Savio D, Farnleitner AH, Blaschke AP, Schijven JF. Evaluation of groundwater bacterial community composition to inform waterborne pathogen vulnerability assessments. Science of the Total Environment. 2020;743:140472. https://doi.org/10.1016/j.scitotenv.2020.140472