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Investigation of the Physical and Chemical and Characteristics With Analysis of a Few Groundwater Wells and the Level of Contamination in the Rada'a Albaydha City, Yemen.

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Abstract: This investigation focuses on assessing the levels of positive and negative ion contamination in groundwater and its potential health impacts on residents in the Rada'a Albaydha city area. This locale is known for its extensive number of wells, estimated at around 20, which have been excavated randomly in recent times. For this study, (8) wells were specifically chosen to analyze their suitability for both irrigation and drinking purposes. Through conducting physical and chemical assessments, including the measurement of positive ions (Ba 2+ , Mg 2+ , Ca2+ , Li+, K+, Na+) utilizing an Inductively Coupled Plasma (ICP) instrument, variability in ion concentrations was observed across the samples, reflecting their various origins. The analysis revealed that the levels of well water contaminants fall within the safety limits set by Yemeni and international standards, except for potassium ions, which exceeded these thresholds. Similarly, sodium ion levels were detected within acceptable limits in some wells, while other wells recorded levels surpassing the safety benchmarks established by Yemeni and international authorities. Additionally, negative ions (CO3---, HCO3-, F-, CL-) were quantified using a Spectrophotometer (2800). For these eight wells, the concentrations of all tested water samples complied with Yemeni and international permissible levels, with the exception of two wells where chloride and fluoride ions were found in excess of the allowable limits. Moreover, parameters such as normal acidity (pH), electrical conductivity (EC), and total dissolved solids (TDS) were evaluated, revealing that the pH levels ranged from 6.5 to 6.8, categorizing the well water as slightly acidic. The EC and TDS measurements varied significantly, with values ranging from 492 to 3999 micro-siemens/cm , correlating with the concentration of dissolved salts. Notably, the water from all but one well was deemed suitable for consumption and agricultural use based on the TDS content meeting Yemeni and international guidelines. However, one well was identified with TDS levels beyond acceptable limits, rendering it unsuitable for drinking or irrigation purposes.

Keywords: Groundwater, Physicochemical Parameters, Chemical analysis.

1. Introduction

Water resources hold pivotal importance for global agriculture, particularly in the context of the scarcity of these resources. This situation necessitates appropriate attention towards the analysis, study, and research of all issues and aspects that could contribute to the development and preservation of these resources, aiming to achieve the highest possible levels of quality and efficiency in their utilization [1].

The rising population growth rate has led to increased water consumption, with numerous warnings being voiced about the insufficiency of fresh water due to the declining global reserves [2]. This urgency has driven the use of alternatives to fresh water, such as wastewater, sewage, and industrial water, deeming such measures essential for achieving agricultural development [3]. Studies and research conducted globally and in the Arab region have confirmed the possibility of using saline water in agriculture, whether it

originates from wells or drainage. However, proper water and soil management is crucial, including the use of leaching requirements ranging from 10-40%, mixing, alternating irrigation, or supplementary irrigation. Unplanned use could lead to salt accumulation [4].

Rada'a city faces a substantial water deficit for agricultural purposes and significant groundwater consumption, as the city's water basin is threatened with depletion due to arbitrary irrigation practices. In this context, the aim of this research is to analyze the water from some groundwater wells in Rada'a city, assess its suitability for irrigation and drinking based on international and Yemeni standards, and explore appropriate methods to reduce the salinity of this water for its utilization in irrigation and drinking purposes [5].

1.1 Study area:

Rada'a Albaydha is one of the cities of Yemen located in the southeast of the capital, Sana'a, at a distance of (150 km) and about (2100 meters) above sea level. It is geographically affiliated to Albaydha Governorate ,Yemen. .

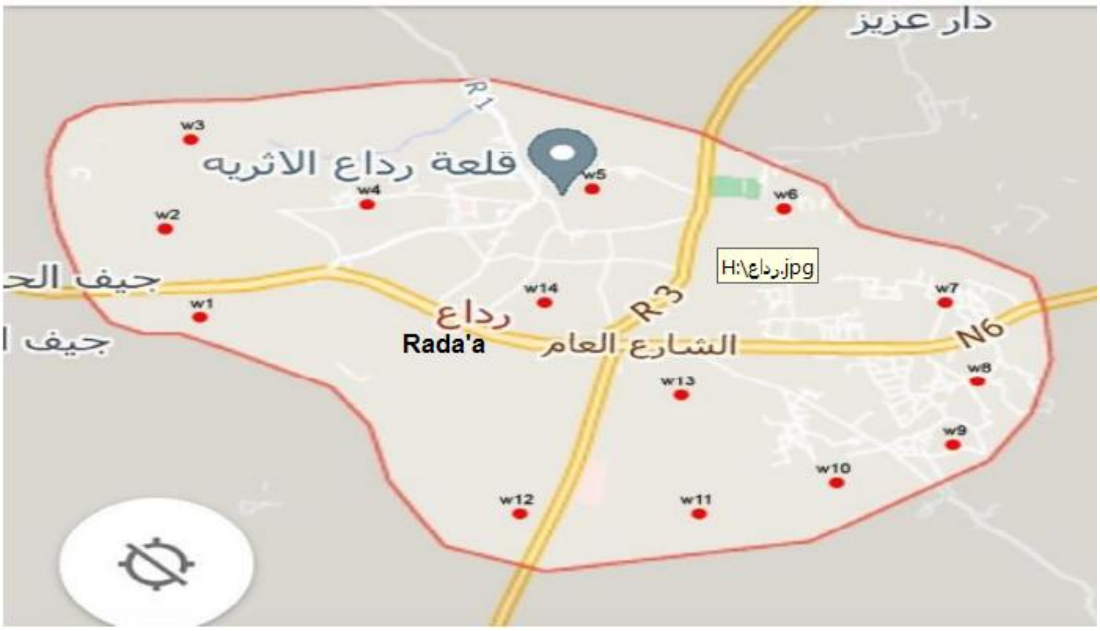

Fig. 1. Rada'a Albaydha, Yemen Located

2. Materials and Methods

Samples were (8) collected from groundwater wells distributed in the Rada'a region at different depths from the surface of the earth, which are widely used for irrigation purposes for different crops due to the lack of rain water in the winter due to the remoteness of the villages of the study area from surface water. The sampling process including after operating the pump for a period of time. Ten minutes for the purpose of getting rid of stagnant water in the well. For this purpose, plastic containers of (one liter) capacity were used, washed with distilled water, and then filled with sample water, then concentrated nitric acid was added at an amount of 1 ml to each sample immediately after taking it, in order to prevent the elements to be measured from sticking the walls of the containers [6], and kept the samples in a cool place (4°C) that is not exposed to sunlight, due to the positive and negative ions being affected by sunlight.[7] Therefore, the samples were taken in two stages, the first stage was on Sunday 1/3/2023 and the second stage was on Saturday 3/27/2023 . Physical analyzes were performed And the chemical of the water of these wells, which are written and as follows. Positive ions (Ba^{2+}, Mg^{2+} Ca^{2+} , Li^{+}, K^{+}, Na^{+}) were measured in the laboratory using the ICP plasma device from the VISTA-MPX company located in the laboratories of the Yemeni water for specifications, standards and quality control, Sana'a. Negative ions (CO_3^{--}, HCO_3^{-}, F^{-}, CL^{-}) were measured using a spectrophotometer of 2800 in the laboratory of the Local Corporation for Water and Sanitation, Dhamar. Also, the acid function (pH), electrical conductivity (EC), and total dissolved salts (TDS) were measured using a pH meter and a Conductivity meter in the laboratory of the Department of Chemistry, College of Education and Science, Rada'a , Al-Baydha University. And find the Sodium Adsorption Ratio (SAR) and the total hardness (TH), which are written as follows [8].

1- Acidity function (pH) and electrical conductivity (EC).

2- And the (pH meter) device (Conductivity meter), respectively, according to the method mentioned in the source [9].

3- Positive ions, as the estimate was made according to the work steps attached to the device (given by the specialist in the laboratory) and specified by the manufacturer of the device.

4- Chlorides were estimated according to what was mentioned in the source as for carbonates and bicarbonates, they were estimated according to what was stated in the source [10,15].

$$SAR = \frac{[Na^{+}]}{\frac{[Ca^{2+}]+[Mg^{2+}]^{\frac{1}{2}}}{2}}$$

The sodium adsorption rate (SAR) was found a according to the following relationship:

$T.H=2.497Ca^{2+}+4.116Mg^{2+}$

Total hardship: (TH) was found according to the following relationship

3. Results and Discussion

Some physical and chemical measurements of the well models showed, in general, that the water of the wells of this city differs from each other in values, as shown in Table No. (1). Therefore, an evaluation of the water of the study wells was carried out to determine its suitability for human consumption and agricultural use, as follows: Physical and chemical analyzes of water[9-10]

3.1 pH :

pH is considered function of well water ranged between (6.5-6.8), and this criterion has an important role in determining the acidity and basicity of the reaction medium for water, as when viewing the results shown in Table No. (1) on the classification approved by [10], we find that it determined the range between (6.5- 8.5) for agricultural use and that there is no problem in the field of irrigation, either in terms of comparing the water for drinking and irrigation and within the limits for permissible water. Within the Yemeni and international specifications.

3.2 Electrical Conductivity (EC) and Total Dissolved Salts (TDS)

It is noted that the highest electrical conductivity of the used well water is in well No. (2) and the lowest electrical conductivity of the used well water is in well No. (1), which ranged from the highest to the lowest value between (358-3999) microsiemens.cm. These values are proportional to the amount of salts Total dissolved salts, as when comparing the results shown in Table No. (1), it is also noted that this water is suitable as drinking and irrigation water because the amount of total dissolved salts (TDS) is within the permissible limits according to international and Yemeni specifications, except for one of the wells in which the percentage of total dissolved salts increased due to the layers the rock formation of this well is considered non-potable water[8,11]

3.3 Total hardship

It is the total salts of carbonates, bicarbonates, sulfates, chlorides and nitrates of calcium and magnesium. As for the water of the study wells, the total hardness ranged between (786.13-148.77) mg/L^{-1}, and thus some wells exceeded the permissible limits as a maximum of (500) mg/L, while others did not exceed the permissible limits. According to the Yemeni and international specifications for drinking water [12-14] to determine the suitability of water for drinking, and this increase may have occurred in some wells as a result of the dissolution of some soil components in the water [13] or as a result of the interaction of carbon dioxide gas with limestone to form bicarbonates in this water, where the compounds and affect It is plays a major role in the growth of algae and the protection of the aquatic environment, as magnesium and calcium ions are non-reducing substances due to the toxic effect of some heavy elements, as well as The increase in the basicity does not significantly affect the health of humans or animals water in freshwater systems because it regulates the acidity function (pH), which is usually affected by plant activity as a result of its excretion of carbon dioxide gas through the process of respiration and decomposition Aerobic for organic matter [15-27]. It is noted that the water of these wells is according to the specifications for the validity of drinking water for irrigation, that it did not exceed the maximum permissible limits

3.4 Chloride

The most important sources of chloride ion present in natural waters are rains, where he indicated that 55% of the concentrations of this ion are the result of rock erosion, and that 45% is the re-transition cycles of rain. Studies also showed that the presence of high concentrations of this ion in groundwater is an indication of the presence of salts of this ion in sedimentary basins as a result of sedimentary cycles of marine origin, and the highest concentration in natural waters was found in seas and oceans [12-14]. and chloride is found in most water sources under natural conditions. As a result of the dissolution of sedimentary and igneous rocks in water [23]. The highest results of chloride (370) mg per 1 liter of water from the wells of this region were in well No. (7) and the lowest results were in well No. (1), (34) mg/L. According to the approved specifications, it is noted that the water of the study wells did not exceed the maximum permissible limits. For irrigation and drinking water, except for one of the wells, it appeared that the proportion of the amount of chloride exceeded the permissible limits according to the Yemeni standards and specifications and international organizations. This well is considered unfit for drinking and irrigation .

3.5 Fluoride

Fluoride can have benefits and harms, depending on the amount of consumption. If consumption is in accordance with international standards, it contributes in the prevention of dental caries [13]. The highest results of fluoride (2.5) mg per 1 liter of the water of the wells of this region were in well No. (7) and the lowest results were in well No. (1)) (0.5) mg/L. According to the It also has the same effect on the physical and chemical properties of the soil in this study. Calcareous soil is rich in its content of calcium, and its content may reach between 10-20% of the sedimentary rocks were found to be poor in their content of magnesium for kidneys, and they also noticed that the dissolved and exchanged magnesium in the soil increases with the increase in the ratio of clay or (mud + salt). It is also noted that the highest concentration of magnesium in well No. (5) is (228. 4) mg/L, and the lowest concentration of magnesium was in well No. (8), which is (44.915) mg/L. These concentrations for the elements calcium and magnesium and for all well water are within the permissible limits according to the specifications.

3.6 Potassium, sodium and magnesium

As for the elements potassium and sodium, they are found in feldspar minerals and in alkali minerals, the presence of potassium is normal in fresh water, much less than the concentration of calcium and sodium and magnesium. As for sodium, measuring the concentration of sodium is one of the most important factors used in determining water quality and its suitability for life

purposes, especially if it is Concentrations are high. Most fresh water contains appreciable concentrations of sodium, while sea water contains [11-14]. At high concentrations up to (1000) mg/L.

Sodium, like other positive ions, when it enters the soil through irrigation water, it is precipitated by mutual interactions with the natural minerals present in the soil, causing This creates undesirable physical conditions, especially if the sodium ion is the dominant ion in the water [9]. It is noted from Table No. (1) that the water of the study wells ranged between the highest concentration of sodium, which was in well No. (3) which was (276.285) mg/L, while the lowest sodium concentration in well No. (1) was (138.655) mg/L. It is noted from Table No. (1) that the potassium concentration in all water samples ranged between (49.859 - 62.513) mg/L This means that potassium concentrations in the water of the study wells exceeded the permissible limits according to international and Yemen.

Study meaning that they are not suitable for drink agricultural purpose [10-12]. As for measuring the concentration of sodium is most important factors used in determine .

Table No1. Physical and Chemical Analyzes of Well Water in the Study Area.

Well no	pH	T.L(HCO3-CO3-2)mg/L	EC MS/cm	TDS mg/L	TH mg/L	Positive ions mg/L						Negative ions mg/L				ASR
						Ca+2	Mg+2	K+1	Na+1	Li+1	Ba+1	HCO3-	CO3-2	Cl-	F-	
1	6.5	216	841	475	406.5	101.1	37.5	55.9	138.7	0.06	0.1	263	0	34	0.5	16.7
2	6.8		3999	2000	836.6	150.68	77.84	61.91	276.28	0.35	0.5	0	0	0	1.2	13.3
3	6.7	172	1078	521	696.4	46.44	12.74	59.44	168	0.06	0.09	209	0	92	1.5	25.9
4	6.5	236	1105	525	646.7	193.13	73.83	62.51	246.21	0.09	0.03	287	0	154	0.6	22.4
5	6.7	312	2134	1042	168.4	228.4	64.69	53.71	160.40	0.11	0.06	380	0	364	0.7	30.9
6	6.6	192	1679	823	519.5	163.66	57.82	55.71	235.6	0.21	0.05	234	0	220	0.9	24.1
7	6.8	296	2066	1074	786.13	164.40	26.5	58.1	234.70	0.12	0.07	361	0	370	2.5	21.31
8	6.5	208	870	451	148.8	44.9	8.9	49.9	160.54	0.1	0.11	253	0	88	0.6	31

Appendix No 2. International, Iraqi and American Specifications for Determining the Validity of Drinking Water

Environmental Protection Specifications Agency,1975(USEPA) mg/L	Standard Specifications Amalgam. 1996 (IQS, Iraqi) mg/L	Standard Specification 2008,Jordan mg/L	Parameter
500	1000	1000	TDS
-	-	-	TL
-	-	-	EC
-	6.5 -6.8	6.5-8.5	pH
500			EC
500	500	500	TH
200	150	200	Ca^{+2}
125	50	50	Mg^{+2}
-	-	1	Ba^{+2}
20	-	-	K^{+}
200	200	200	Na^{+}
-	-	-	Li^{+}
250	-	-	HCO_3^{-}
-	-	-	CO_3^{2-}
250	250	500	Cl^{-}
-	-	1.5	F^{-}

4. Conclusion

The findings of this study highlight the importance of monitoring and analyzing groundwater quality, particularly in regions with extensive well networks like Rada'a Albaydha city. While most wells met safety criteria, the presence of elevated potassium levels and excess TDS in one well underscore the need for continued monitoring and potential remediation efforts to ensure the safety and usability of groundwater for residents' consumption and agricultural needs. Further research and interventions may be required to address specific ion contamination issues and uphold water quality standards in the Rada'a , Albaydha city in Yemen.

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دراسة الخصائص الفيزيائية والكيميائية مع تحليل بعض آبار المياه الجوفية ومستوى التلوث في مدينة رداع البيضاء، اليمن.

الملخص: تركز هذه الدراسة على تقييم مستويات التلوث بالأيونات الموجبة والسلبية في المياه الجوفية وتأثيراتها الصحية المحتملة في سكان مدينة رداع. وتشتهر هذه المنطقة بوجود عدد كبير من الآبار، تقدر بحوالي 20 بئرا، تم حفرها بشكل عشوائي في الآونة الأخيرة. وتم اختيار (8) آبار بشكل خاص لتحليل مدى ملاءمتها للاستخدام في الري والشرب ، من خلال إجراء تقييمات فيزيائية وكيميائية، بما في ذلك قياس الأيونات الموجبة (+Ba2، +Mg2، +Ca2، +Li، +K، Na) + باستخدام جهاز البلازما المقترن الحثي (ICP)، ولوحظ التباين في تراكيز الأيونات عبر العينات، مما يعكس منشأها المختلف. وأظهر التحليل أن مستويات تلوث مياه الآبار تقع في ضمن الحدود الآمنة المحددة من قبل المعايير اليمنية والدولية، باستثناء أيون البوتاسيوم الذي تجاوز هذه الحدود. بالإضافة، إلى الكشف عن مستويات أيونات الصوديوم داخل الحدود المقبولة في بعض آبار المدينة، بينما سجلت الآبار الأخرى مستويات تتجاوز المقاييس الآمنة المحددة من قبل السلطات اليمنية والدولية. بالإضافة إلى ذلك، تم تقدير تركيز الأيونات السلبية (- HCO3 , - CO3، - F، CL)- باستخدام جهاز الطيف (2800)، بالنسبة لهذه الآبار الثمانية، وكانت تراكيز جميع عينات المياه المختبرة تتوافق مع المستويات المسموح بها من قبل السلطات اليمنية والدولية، باستثناء بئرين حيث تم العثور على تراكيز زائدة من أيونات الكلورايد والفلوريد.

علاوة على ذلك، تم تقييم معلمات، مثل: الحموضة (pH)، والتوصيلية الكهربائية (EC)، والمواد العالقة الكلية (TDS)، مما أظهر أن قيم الpH تتراوح بين 6.5 إلى 6.8، مصنفة لمياه الآبار كحمضية طفيفة. كما كانت قياسات التوصيلية الكهربائية والمواد العالقة الكلية تختلف بشكل كبير، حيث تتراوح القيم بين 492 إلى 3999 ميكروسيمنز/سم−1، متناسبة مع تركيز الملح المذاب.

ومن الجدير بالذكر أن مياه الآبار من جميع آبار المدينة باستثناء واحدة وجدت أنها مناسبة للاستهلاك والاستخدام الزراعي استناداً إلى اجتياز محتوى TDSلها للمعايير اليمنية والدولية. ومع ذلك، تم التعرف على بئر واحدة بمستويات TDS تتجاوز الحدود المسموح بها، مما يجعلها غير مناسبة للشرب أو أغراض الري.