SEBHA UNIVERSITY CONFERENCE PROCEEDINGS, VOL.03 NO. 2 2024
DOI: 10.51984/SUCP.V3I2.3343

وقائع مؤتمرات جامعة سبها
Sebha University Conference Proceedings

Confrence Proceeeding homepage: http://www.sebhau.edu.ly/journal/CAS

Study of Physical and Chemical Parameters to Evaluate the Quality of Drinking Water for Some Groundwater Wells in the City of Al-Bayda, Libya

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Keywords:
Groundwater
Physicochemical parameters
Drinking water quality
International and local standards
Al-Bayda City.

ABSTRACT

The purpose of this work was to investigate the physicochemical characteristics to find the quality of groundwater and whether it is suitable for drinking purposes or not. Ten sites were selected in the Al-Bayda city and three replicates were taken from each well site. The current study's results show that there are differences between stations. In contrast, the pH values varied between (7.63 - 7.92), TDS values ranged between (285 - 493.33 mg/L), EC values were ranged (593.33 - 864.67 µS/cm), The values of alkalinity (measured as HCO_3^-) varied from (262.6 - 341.6 mg/L), The range of total hardness values was from (253.54 - 308.25 mg/L), The range of Ca^{++} levels was (88.18 - 122.38 mg/L), Mg^{++} (52.8 - 73.92 mg/L), Cl^- (44.90 - 89.81 mg/L), Na^+ (26.41- 53.99 mg/L), K^+ (0.48 - 5.81 mg/L), and NO_3^- (0.27 - 4.46mg/L). The findings showed that the values of pH, EC, TH, TDS, Cl^-, Ca^{++}, Na^+, K^+ and NO_3^- were found to be within the permissible limit values. On the other hand, the values of Alkalinity, and Mg^{++} exceeded the acceptable limit. All parameters vary depending on the nature of the terrain, geological structure, and soil. Based on the aforementioned findings, the local government should establish more water filtration plants and conduct routine water quality monitoring to provide safe drinking water.

دراسة المعايير الفيزوكيميائية لتقييم جودة مياه الشرب لبعض آبار المياه الجوفية في مدينة البيضاء، ليبيا

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الملخص

كان الهدف من هذا العمل هو دراسة الخصائص الفيزيائية والكيميائية لمعرفة نوعية المياه الجوفية وهل هي مناسبة لأغراض الشرب أم لا. تم اختيار عشرة مواقع في مدينة البيضاء وتم أخذ ثلاث مكررات من كل موقع بئر. وأشارت نتائج الدراسة الحالية إلى وجود اختلافات بين المحطات. في المقابل، كانت قيم الأس الهيدروجيني بين (7.63 - 7.92)، وكانت قيم المواد الصلبة الذائبة بين (285 - 493.33 ملغم/لتر)، كما بلغت قيم التوصيلية الكهربائية (593.33 - 864.67 ميكرو سيميز/سم)، كما بلغت قيم القلوية (المقاسة بـ HCO_3^-) من (262.6 - 341.6 ملغم / لتر)، وكان نطاق قيم الصلابة الكلية من (253.54 - 308.25 ملغم / لتر)، وكان نطاق مستويات الكالسيوم (88.18 - 122.38 ملغم / لتر) المغنيسيوم (52.8 - 73.92 ملغم / لتر)، الكلوريد (44.90 - 89.81 ملغم / لتر)، الصوديوم (26.41 - 53.99 ملغم / لتر)، البوتاسيوم (0.48 - 5.81 ملغم / لتر)، و النترات (0.27 - 4.46 ملغم / لتر). أظهرت النتائج أن قيم الأس الهيدروجيني والمواد الصلبة الذائبة والتوصيلة الكهربائية والصلابة الكلية والكالسيوم والكلوريد والصوديوم والبوتاسيوم والنترات كانت ضمن القيم الحدية المسموح بها. من ناحية أخرى، تجاوزت قيم القلوية والماغنسيوم الحد المقبول. تختلف جميع المعلمات حسب طبيعة التضاريس والبنية الجيولوجية والتربة. بناءً على النتائج المذكورة أعلاه، يتعين على الحكومة المحلية إنشاء المزيد من محطات تنقية المياه وإجراء مراقبة روتينية لجودة المياه من أجل توفير مياه الشرب الآمنة.

الكلمات المفتاحية:
المياه الجوفية
المعلمات الفيزيائية والكيميائية
نوعية مياه الشرب
المعايير الدولية والمحلية
مدينة البيضاء

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Article History : Received 16 June 2024 - Received in revised form 23 August 2024 - Accepted 06 October 2024

1. Introduction

Water is necessary for all living things to live. Surface water and groundwater are the two primary sources of water [1]. Roughly one-third of the world's population gets their drinking water from groundwater [2]. Groundwater is a great natural water resource that is readily available and appropriate for residential use [3]. In dry and semiarid locations, groundwater has traditionally been the favored source of drinking water [4]. Libya has four water sources: desalinated seawater, wastewater recycling, surface water, which includes rainwater and dam building, and groundwater, which provides approximately 95% of the country's needs [5]. The primary source of drinking and irrigation water on the African continent is groundwater. Groundwater is vital to Al-Bayda City people's household, agricultural, livestock, and drinking needs [6]. Therefore, the global food production and public health sectors have turned their attention to the quality and sustainability of groundwater due to the rising demand for it. One of the biggest problems with groundwater in both developed and developing nations is water contamination [7]. Therefore, to identify suitable and sanitary groundwater sources, the estimate of groundwater quality is essential. Many areas of the world's population struggle with the supply and contamination of water, and African nations struggle to provide their citizens with satisfactory sanitation. and safe drinking water [8]. Particularly severe groundwater contamination occurs in semiarid or arid countries with limited water supplies. Libya's groundwater quality is a serious problem that poses a risk to public health because of the high concentration of certain chemical and physical parameters [9]. Water quality and approval for drinking and other local purposes are determined by its physicochemical and microbiological properties [10]. According to statistics, the contaminated state of drinking water is a direct cause of 80% of illnesses in underdeveloped countries. Furthermore, unclean and contaminated drinking water is linked to the contamination of groundwater and can result in diseases like cholera, diarrhea, dysentery, and hepatitis. Over 842,000 people worldwide pass away from diarrhea every year [11]. Therefore the main objective of this work is to evaluate the quality of 10 groundwater wells within the study region of groundwater by studying the physicochemical and chemical parameters.

2. Material and Methods

2.1 Description of the Study Area

The study was conducted in the city of Bayda in Libya. The city is located in northeastern Libya on the eastern coast of the Mediterranean Sea. It is approximately 11,429 km^2 in total. With coordinates of 32° 45′ 59″ N, 21° 44′ 30″ E, Bayda is located at Jebel Akhdar's western side, on the level of Cyrenaica. As of early 2012, the estimated population of Bayda was 380,000 [12]. Because of its proximity to the Green Mountain, agricultural activities (both irrigated and non-irrigated), animal wealth, and economic activity, the research region is regarded to be among Libya's most important locations. GPS MAP was used in the field to pinpoint the exact positions of the groundwater well sampling stations. The Mediterranean environment, with its hot, dry summers and moderate, rainy winters, has an impact on the studied region. The research area has a semi-desert-like environment with little rainfall, significant rates of evaporation, and a distinct aridity that permeates the whole region [13]. To ascertain the level of water quality, an evaluation of ten groundwater wells within the study region was carried out, as illustrated in Figure (1). The groundwater wells under investigation are described and their coordinates are displayed in Table (1).

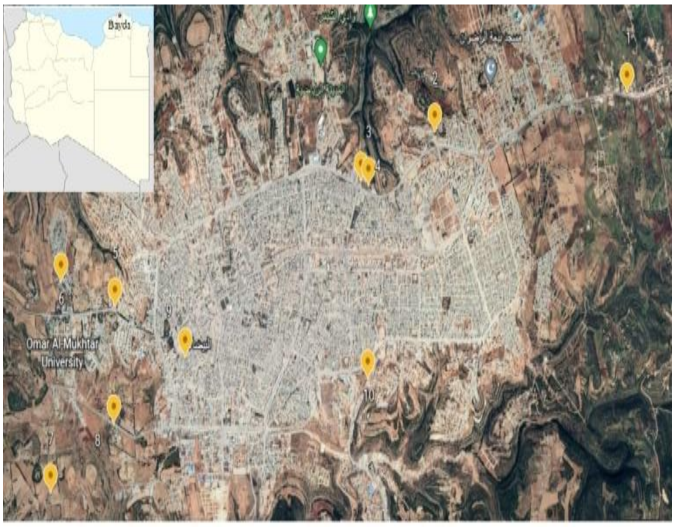

Fig. 1: Lunar map displaying the research region of Al-Bayda City, where the study sites are located [13].

Table 1: Groundwater Well Description

No	Wells Name	Coordinates		H (meter)
S1	Wardama well	32°46'50"E	21°48'58"N	677
S2	Sultan well	32°46'37"E	21°46'55"N	622
S3	Jawher well	32°46'18"E	21°46'08"N	593
S4	Gharbawia well	32°46'19"E	21°48'02"N	604
S5	Boughandor well	32°45'35"E	21°43'19"N	609
S6	Zawia well	32°45'44"E	21°42'44"N	631
S7	Belgra well	32°44'30"E	21°42'37"N	598
S8	Dream Land well	32°45'18"E	21°43'19"N	607
S9	Alsouq well	32°45'10"E	21°46'06"N	622
S10	Algarik well	32°45'10"E	21°46'07"N	591

2.2 Sampling

After approximately thirty minutes of pumping three times the capacity of the casing pipes, the samples were collected (triplicate) using plastic bottles with a 100 ml capacity made of polyethene. The materials that were subsequently moved should be preserved in the lab until preparation and analysis when they were kept in a bag containing crushed ice at 4°C [14]. In January 2022, a total of thirty (3 x 10) samples were collected.

2.3 Samples Analysis

A digital pH meter with a composite electrode was used to monitor the pH. An electric conductivity meter was used to measure EC. The Total Dissolved Salt meter was used to measure TDS by the device (Model Metrohm, pH.EC, and TDS Lab 827). By titrating with 0.02 N sulfuric acid and employing methyl orange indicator for bicarbonates and phenolphthalein indicator for carbonates, total alkalinity was determined. Using the EDTA titration method, total hardness, calcium, and magnesium were assessed [15]. Chloride was measured by titrating a solution of 0.01 N silver nitrate ($AgNO_3$) with 5% potassium chromate (K_2CrO_4). This titration is repeated until the endpoint is reached [16]. The turbidity spectrophotometric method, which operates at a wavelength of 410 nm, was used to estimate the nitrate concentration [17]. A Flame photometer type (Jenway – PFP7) England (UK) was used to test the ions of potassium and sodium [18].

2.4 Statistical Analysis

Descriptive statistics like average, standard deviation, max-min, and par charts were computed using statistical analysis via the program's Excel package.

3. Results and Discussion

3.1 pH

The carbon dioxide-bicarbonate-carbonate equilibrium system regulates the pH of water, which is a measure of the acid-base equilibrium in the majority of natural waters. pH will rise in response to a decrease in carbon dioxide concentration and fall in response to an increase. The pH of well water is influenced by the catchment area's geology. Limestone and carbonate minerals are two substances that can buffer pH variations in water. pH can be neutralized by combining calcium carbonate ($CaCO_3$) and other bicarbonates with hydrogen or hydroxyl ions [19]. Figure (2) and Table (2) indicate that the pH of the water from the springs under study varied from 7.63 (S1) to 7.92 (S10). The results showed that the water had a minor alkaline quality, which could have been caused by dissolved salts. The pH values of every water sample examined fall between the safe range of 6.5 to 8.5, as established by the LNCSM and WHO [20, 21].

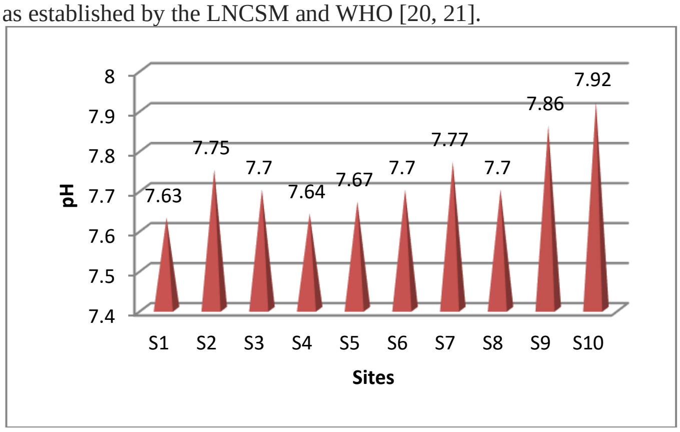

Fig. 2: The average pH concentration at various sites.

3.2 Total dissolved solids (TDS)

An aggregate measurement of the minerals in water is called total dissolved solids, or TDS. Dissolved organic matter is another component of TDS, but it is far less significant than inorganic minerals. The primary factors that determine flavor in drinking water are the kind and quantity of minerals present [22]. It has been discovered that the concentrations of TDS in natural sources differ greatly. In addition to being a significant determinant of one's preference for drinking water, TDS levels are also crucial for the capacity to distinguish between various waters [23]. TDS concentrations varied from 285 mg/l (S1) to 493 mg/L (S4) across all sampling sites, as shown in Figure (3) and Table (2). These values were within the standard limits of drinking water quality of 1000 mg/L set by both WHO and LNCSM [20,21]. As a result, well waters with low TDS concentrations are suitable for drinking and other household uses.

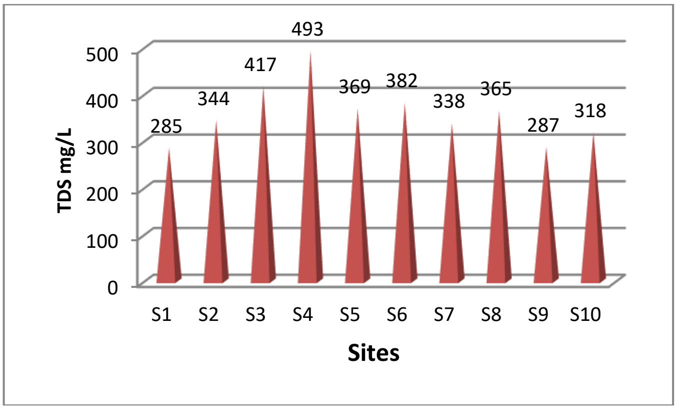

Fig. 3: The average TDS concentration (mg/L) at various sites.

3.3 Electrical Conductivity(EC)

The ability of an aqueous to carry an electrical current is measured by its electrical conductivity (EC) which is dependent upon the temperature, the mobility and valence of the ions, and their presence and total concentration. [24]. High dissolved solids are the cause of high EC values in groundwater. The conductivity values in all sampling points in the current study varied from 593 (S1) to 865 (S3) µS/cm as shown in Figure (4) and Table (2). The conductivity values reported at all sampling sites fell between the WHO and LNCSM standard norms of 2000 µS/cm [20,21]. The sort of rocks and minerals that water runs through in subterranean water systems, as well as their geology, can be responsible for variations in conductivity. For instance, because carbonate minerals dissolve in limestone, conductivity increases. Conductivity may also be impacted by the flow rate, the flow path, and the duration of water-rock contact.

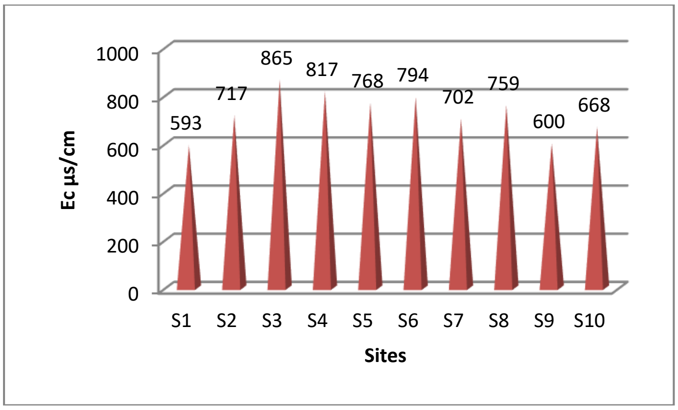

Fig. 4: The average EC concentration (µs/cm) at various sites.

3.4 Alkalinity as HCO_3^-

All natural fluids contain the ion bicarbonate, (HCO_3^-), as bicarbonates are all soluble in water. Carbonate hardness is created when bicarbonate combines with calcium and magnesium. Bicarbonate concentrations in regions of non-carbonate rocks are over 400 mg/L and natural water is less than 25 mg/L. A high concentration of bicarbonates in drinking water is deviated by weathering of calcium-bearing rocks. The dissolved carbon dioxide derived from rain is the primary source of bicarbonate ions in wells water. As it enters the soil and rocks, it dissolves more carbon dioxide in water. Carbonates such as limestone, dolomite, and calcite dissolve to form bicarbonates by the action of CO_2 on these basic materials [25]. Bicarbonate ion concentrations in the water of the wells were between 262.3 (S5) and 341.6 (S10) mg/L as shown in Figure (5) and Table (2).In general, the values of Alkalinity recorded in this study exceed permissible limits for international standards of drinking water for both WHO and LNCSM [20,21] of 200 mg/L.

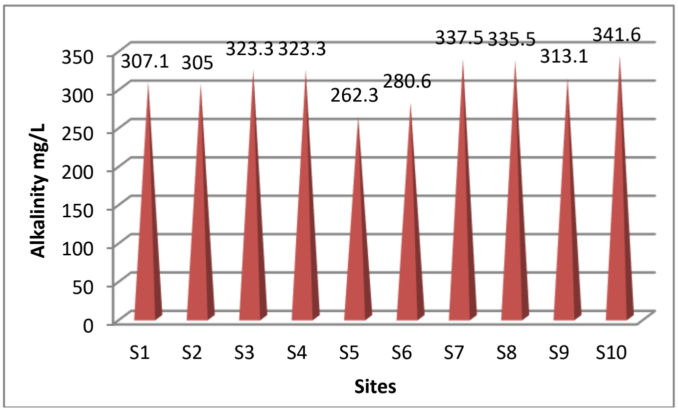

Fig. 5: The average Alkalinity concentration (mg/L) at various sites.

3.5 Total Hardness

Total hardness is the property of water which prevents the lather formation with soap and increases the boiling points of water. Hardness, which occurs naturally in water, is an aggregate parameter that is the sum of aqueous divalent cations. Calcium and magnesium are the major divalent cations in natural fresh waters, and hence the major ions in hardness. Both calcium and magnesium are essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences. Occasionally, ferrous ions or manganese ions can contribute to hardness, but these metals are minor. Hardness varies substantially with the presence of limestone and dolomite in the local geology [26]. Total hardness values for the ten wells studied show no major difference from one well to the other. They vary between 220.2 and 308.3 mg/l respectively recorded at wells S9 and S3 as shown in Figure (6) and Table (2). The water quality analysis showed the hardness values of the well water samples were within permissible limits for international standards of drinking water for each of both WHO and LNCSM [20,21] of 500mg/L. and are safe for drinking and other domestic uses.

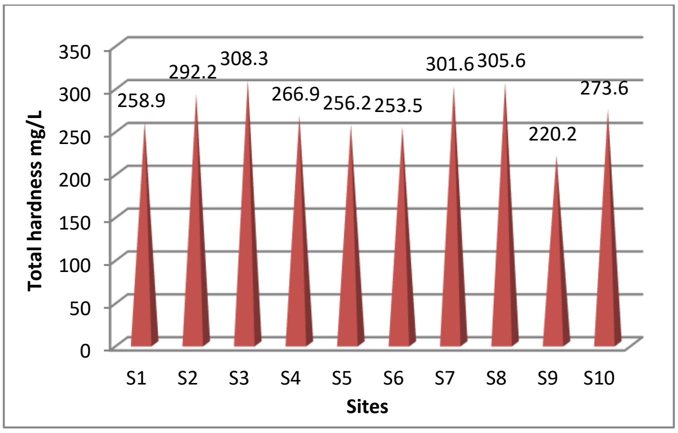

Fig. 6: The average Total hardness concentration (µs/cm) at various sites.

3.6 Calcium Ca^{++}

This is the most important and plentiful element in the human body, and healthy growth and development depend on getting enough of it. The maximum amount needed each day, which is mostly found in dairy products, is between one and two grams. There is some evidence that places supplied by a public water supply with a high degree of hardness, the principal constituent of which is calcium, have a lower incidence of heart disease, implying that the element's presence in a water supply is advantageous to health [27]. Calcium (Ca^{++}) is dissolved easily out of almost all rocks and is, consequently, detected in most waters. The permissible limit of calcium in drinking water is 200 mg/L as given by both WHO and LNCSM [20,21]. In the present study, the results of calcium in all sampling sites ranged from 88.2 mg/L (S9) to 123.5 mg/L (S3) as shown in Figure (7) and Table (2). The calcium level recorded in the entire sampling points of the well water was lower than the permissible limits of the standard values.

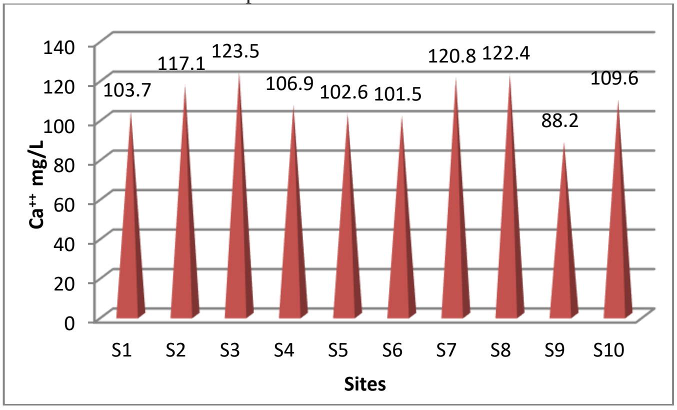

Fig. 7: The average Ca^{++} concentration (mg/L) at various sites.

3.7 Magnesium (Mg^{++})

This is a common ingredient of natural water because it is very abundant in the earth's crust in the form of salts with a high solubility in water. It is the second most important component of hardness [28]. The permissible limit of Magnesium in drinking water is 50 and 150 mg/L as given by both WHO and LNCSM [20,21]. In the present study, the results of Magnesium in all sampling sites ranged from 52.8 mg/L (S9) to 73.9 mg/L (S3 as shown in Figure (8) and Table (2). The Magnesium level recorded in the entire sampling points of the well water was lower than the permissible limits of the standard values.

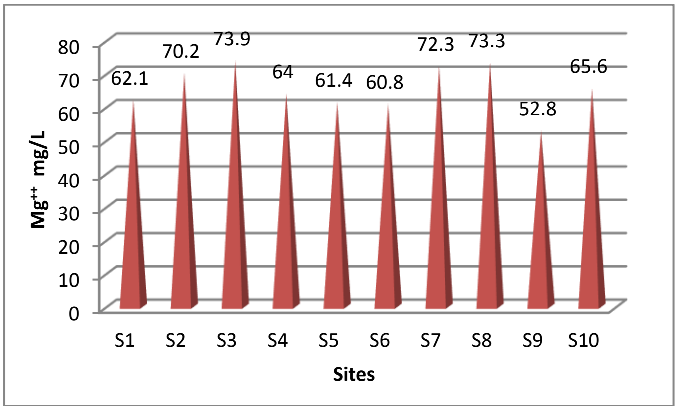

Fig. 8: The average Mg^{++} concentration (mg/L) at various sites.

3.8 Chloride (Cl$^-$)

Chloride, (Cl$^-$) occurs naturally in fresh, estuarine or salt water from the dissolution of rocks and minerals. In freshwater, its concentration is commonly less than 10 mg/L [29]. Chloride is normally the most dominant anion in water and it imparts a salty taste to the water. The permissible limit of chloride in drinking water is 250 mg/L as given by both WHO and LNCSM [20,21]. In the present study, the results of chlorides in all sampling sites ranged from 44.9 mg/L (S1) to 89.8 mg/L (S3) as shown in Figure (9) and Table (2). The chloride level recorded in the entire sampling points of the well water was lower than the permissible limits of the standard values.

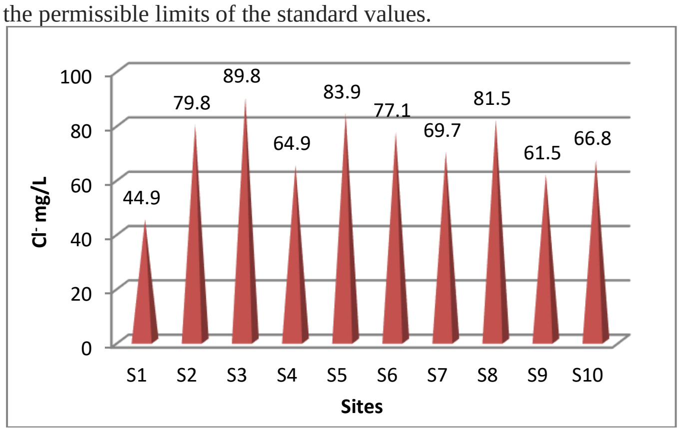

Fig. 9: The average Cl- concentration (mg/L) at various sites.

3.9 Sodium (Na$^+$)

Sodium (Na$^+$) is a common element that is found in most natural waters. It is the sixth most prevalent element. Sodium can be found in a variety of minerals, the most common of which is rock salt (sodium chloride). In many parts of the world, increased pollution of surface and groundwater has resulted in a significant increase in the Na content of drinking water over the last decade [30]. Proper quantity of sodium in the human body prevents many fatal diseases like kidney damage, hypertension, headache etc. The permissible limit of sodium in drinking water is 200 mg/L as given by both WHO and LNCSM [20,21]. In the present study, the results of Sodium in all sampling sites ranged from 26.4 mg/L (S1) to 53.9 mg/L (S3) as shown in Figure (10) and Table (2). The sodium level recorded in the entire sampling points of the well water was lower than the permissible limits of the standard values.

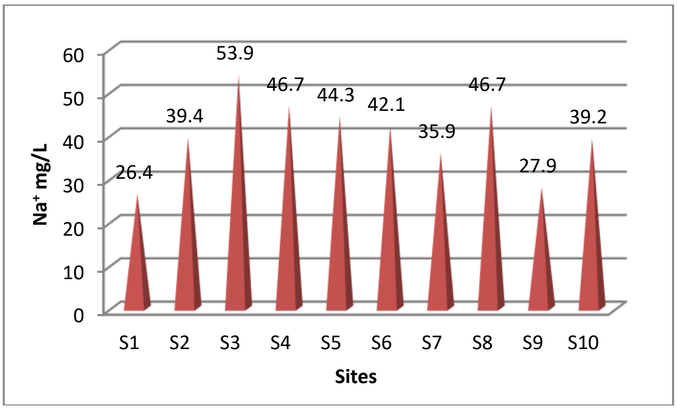

Fig. 10: The average Na^+ concentration (mg/L) at various sites.

3.10 Potassium (K^+)

Potassium is found in all human and animal tissues, notably in plant cells, because it is required for the proper functioning of living organisms [31]. Although potassium (K^+) is a plentiful element, it rarely exceeds 20 mg/L in natural freshwater [32]. The permissible limit of potassium in drinking water is 20 and 40 mg/L as given by both WHO and LNCSM [20,21]. In the present study, the results of Potassium in all sampling sites ranged from 0.2 mg/L (S9) to 5.8 mg/L (S5) as shown in Figure (11) and Table (2). The potassium level recorded in the entire sampling points of the well water was lower than the permissible limits of the standard values.

Thus it is safe and can be rendered as potable and also will not pose any serious health hazard.

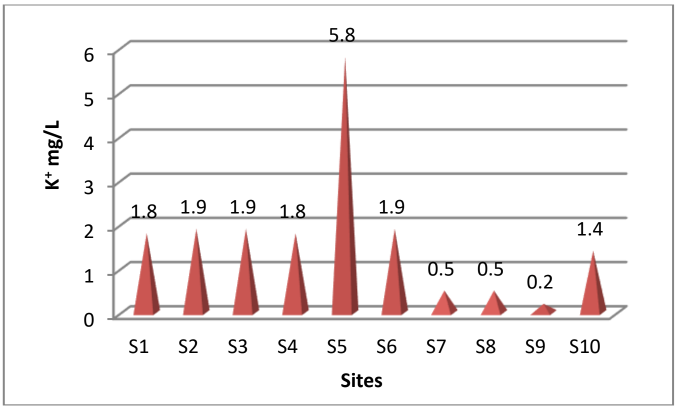

Fig. 11: The average K^+ concentration (mg/l) at various sites.

3.11 Nitrates NO_3^-

Nitrates are found in nature. Nitrate-nitrogen is present in all groundwater aquifers and rainfall. [33]. Surface and groundwater normally contain minimal amounts of nitrogen (in the form of nitrate). On the other hand, human-caused high nitrate is water pollution. There are numerous ways that nitrate gets into groundwater or well water. These include fertilizer, septic system drainage, wild animal waste, and nitrogen-rich geologic formations. Drinking water with high nitrate content can cause the "blue baby" condition, which is dangerous for young children (methemoglobinemia). The nitrate levels in all of the sampling sites for this investigation range from 0.3 (S7) to 4.5 (S3) mg/L as shown in Figure (12) and Table (2). All of these values are also far lower than the suggested allowable limit established by both WHO and LNCSM [20,21] of 50-45 mg/L respectively. Reduced nitrate values show that human activity had little effect on the well waters.

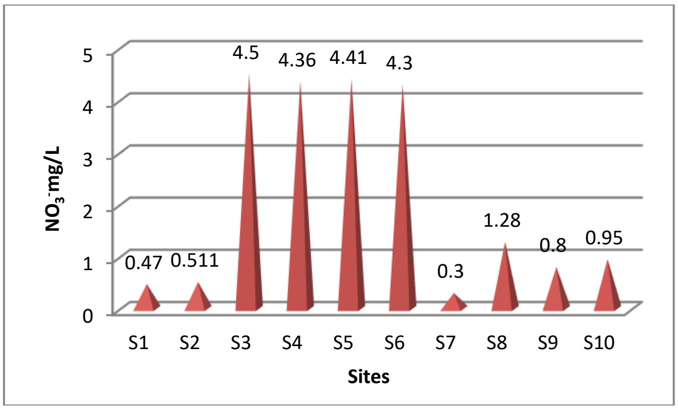

Fig. 12: The average $NO3^-$ concentration (mg/L) at various sites.

Table 2: The water samples that were collected and their physical and chemical parameters.

Parameter	Unit	Min	Max	Mean±SD	LNCSM permissible limit	WHO permissible limit
pH	-	7.63	7.92	7.74±0.09	6.5-8.5	6.5-8.5
Total dissolved solids (TDS)	mg/ L	285	493	359.8±62.36	1000	1000
Electric Conductivity (EC)	µs/cm	593	865	728.3±89.76	2000	2000
Total alkalinity (HCO_3^-)	mg/ L	262.3	341.6	312.93±25.51	200	200
Total hardness(TH)	mg/ L	220.2	308.3	273.69±29.83	500	500
Calcium (Ca^{++})	mg/ L	88.2	123.5	109.61±11.31	200	200
Magnesium(Mg^{++})	mg/ L	52.8	73.9	65.63±6.77	150	50
Chloride(Cl^-)	mg/ L	44.9	89.8	71.96±13.21	250	250
Sodium (Na^+)	mg/ L	26.4	53.9	40.18±8.46	200	200
Potassium (K^+)	mg/ L	0.2	5.8	1.63±1.59	40	20
Nitrate (NO_3^-)	mg/ L	0.3	4.5	2.18±1.91	45	50

4. Conclusion

The water samples from several groundwater well systems that were analyzed showed that nearly all of the physical and chemical parameters were in good condition, indicating that they were suitable for drinking. Significant issues with the alkalinity parameter are present in all sites, and this is because the water at these locations is directly drawn from groundwater, which has a high concentration of dissolved salts, raising the overall alkalinity. Also, there is a slightly higher magnesium parameter compared to Libyan standards (LNCSM 50 mg/L) in all sites. The likely cause of the excessive concentration in these parameters is either the geological makeup of the water supply or poor maintenance. Competent authorities should keep a careful eye on the quality of drinking water supplied to consumers to protect public health.

5. Recommendations

- Interest in conducting periodic analyzes of groundwater well samples used for drinking water, noting the changes that occur to them.
- Take appropriate preventive and remedial measures that ensure the improvement of the quality of groundwater and follow all scientific and practical means that ensure the sustainability of this source
- Providing financial support for the analysis of groundwater wells and mineral samples by providing laboratories and specialized

experts in this field to analyze water samples periodically.

6. References

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