Physical and Chemical Characteristics of Assaiq and Senah Hot Springs Water in Hadhramout-Yemen and the Assessment of Water Quality for Drinking and Irrigation Purposes

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Abstract. AL-Diss Ashrqiya, known for its hot springs water. This study was performed to identify the physical and chemical characteristics of Assaiq and Senah springs water that located in AL-Diss Ashrqiya. The study was already done for the period (January 2017 - December 2018) to assess water quality for drinking and irrigation purposes. The results showed that the values of water temperature, the electrical conductivity, total dissolved solids, total hardness, calcium hardness, magnesium hardness, sulfate SO\textsubscript{4}^{2-}, fluoride F\textsuperscript{-}, manganese Mn\textsuperscript{2+}, calcium Ca\textsuperscript{2+}, potassium K\textsuperscript{+}, are not within the permissible levels of Yemeni and World Health Organization (WHO) standards. Therefore, the water of Assaiq and Senah can be classified as undrinkable water. In comparison with the Eaton classification, the water of Assaiq and Senah springs are not suitable for irrigation purposes due to the higher conductivity, as it is water with acute problems. Also, in comparison with the standards of the World Food and Agriculture Organization (FAO) results show that water of Assaiq and Senah can be used to irrigate crops that are more tolerant of salinity.

Keywords: Hot springs, water quality, sulfur water, drinking purposes, agricultural uses

1. Introduction
Thermal Springs, also referred to as Hot Springs, are determined by the excessive heat that their flowing water provides. The criteria for classifying a spring as a hot spring is the temperature of its water which reaches Earth's surface or whose water temperature exceeds the average temperature of the annual air temperature by at least 5°C [1]. Hot spring water is distinguished by different characteristics from the rest of the water. The heat of the water spring is probably generated from the high heat of the earth’s interior. That could be due to its proximity to volcanic activity sites, which can also be due to the high amount of radioactive elements found near its source [1]. The water of these
springs, sometimes, is called mineral and sulfur water which attributable to the increase in the quantities of dissolved salts and gases. The sources of the ionic components in these waters can be the atmosphere and the weathering of soil and rock [2].

Thermal springs are located in the natural environments of the Republic of Yemen, such as the seashore, narrow valleys, between mountains and/or areas of volcanic activity, and their waters flow from holes and gaps in contact areas between rocks. Although many visitors come from the surrounding communities to swim [3], these springs are considered to be attractive spots for all tourists looking for therapeutic tourism [4]. In their study of hot springs in the Republic of Yemen, Minissale and others indicated that there are more than 70 springs, of which 62 are hot water sources [5]. While Al-Faqih and Vali have reported that there are more than 100 hot springs in the Republic of Yemen [6]. Studying the thermal spring water in the Republic of Yemen will help in assessing the possibilities for resolving the worsening water problem in the area, by defining treatments needed to enable it to be a drinking and agricultural suitability. Studying thermal springs can also be the key to determining possible applications in tourism, medicinal research, and electricity generation.

The governorate of Hadhramout, the largest provincial governorate of the Republic of Yemen [7], has several springs from which mineral and sulfur water runs. These springs are called locally (Yanabie) and their singular is (Yanboa), and they are also called water fountains. The occurrence of such springs is also correlated with the development of faults parallel to the Red Sea (North-South) fault lines. In Hadhramout, the occurrence of mineral water flow is one of the distinctive phenomena [8]. The Minissale and other studies confirm the existence of six springs, including four hot springs accompanied by expelled gases, all of which are located east of the city of Mukalla (the governorate capital) in the area of AL-Diss Ashrqiya, which is about 110 km far from the city of Mukalla (Fig. 1)[5], at co-ordinates (14,910 ° N 49,992 E °). These springs were famous by their local names according to the area in which they are located, namely, Sweiber, Thuban, Senah, and Assaiq. Sweater and Thuban springs are two small villages west of the AL-Diss Alsharqiya city and the properties of these two springs have been studied in another research. There are two other springs in two locations in the AL-Diss Ashrqiya region, namely: water of Assaiq and Senah springs, located northeast of AL-Diss Ashrqiya, and these two springs are the focus of this study.

![Figure 1](image)

**Figure 1.** (a) Map of the Republic of Yemen and (b) Geological map for AL-Diss Ashrqiya region, showing the location of Assaiq and Senah springs.

This research aims to identify the hot spring sites in AL-Diss Ashrqiya, draw their maps to promote their accessibility. It is also planned to understand the physical and chemical properties of their water and assess spring water purity. To test the suitability for drinking and irrigation purposes,
laboratory water tests will be carried out. To the best of our knowledge, no recent studies have been carried out on the properties and suitability of the water of AL-Diss Ashiqiya springs for drinking and irrigation purposes.

2. Materials and working methods
A field survey was conducted of the flowing hot springs in the AL-Diss Ashriqiya area (Assaiq and Senah springs). These two springs are distinguished by their year-round water supply. Every spring’s coordinates have been taken by the (GPS) system to determine its geographical position. The processing and storage of samples were made possible by the sterile plastic bottles (1 liter). A series of tests and laboratory experiments were performed to examine the physical and chemical properties of hot spring water. Both chemical and physical studies were performed at the Local Water and Sanitation Corporation's central laboratory in Hadhramout Governorate, Yemen.

The research involved temperature estimation, the overall concentration of dissolved solids (TDS), electrical conductivity (E.C), and pH. Chloride (Cl), fluoride (F), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), and nitrate ion (NO₃⁻) percentages were also calculated. A spectrometer (Spectro Photometer DR / 2010) was used to determine the color and the percentage of sulfates, fluorides, nitrates, iron, and manganese. Hanna, pH Meter was used to measuring the pH, and to measure the electrical conductivity, a (Conductance Bridge, Griffin) device was used. Sodium and potassium were estimated using a (Flame Photometer). To evaluate the quality of water used for agricultural purposes and determine the degree of risk of sodium, calcium, and salinity in water sources, the following mathematical relationships were used.

Sodium Adsorption Ratio (SAR), calculated according to the following equation [9]:

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

The Residual Sodium Carbonate (RSC) was measured also with the following relationship:

\[
RSC = (CO_3^- + HCO_3^-) - (Ca^{++} + Mg^{++}) \tag{2}
\]

Total alkalinity, Total Hardness, Calcium Hardness, and Chloride were measured using the correction method or calibration. The amount of dissolved solids (TDS) was calculated using the following equation:

\[
TDS = E.C \times 0.64 \tag{3}
\]

To calculate the hardness of magnesium, the following equation was used [10]:

\[
\text{Total hardness} - \text{Calcium hardness} = \text{Magnesium hardness} \tag{4}
\]

3. Results and discussion
According to our humble knowledge, most of the previous studies, related to the hot springs and their locations in the Republic of Yemen, were concentrated on the north-western springs such as the springs of Dhamar Governorate and Damat Springs. Accurate descriptions of their positions, water content, geological structure, and potential causes of their water temperature were included in the research. There are no accessible reports in the literature to study the Hot Springs in Hadhramout Governorate except what Minissale et. al was mentioned in their studies [5]. Six springs were confirmed and investigated, but the localization coordinates were identified for only four springs, despite the existence of more than 20 springs in Hadhramout.
The geographic locations of the studied springs (Assaiq and Senah) were accurately determined using the Global Positioning System (GPS). Senah spring is located at the coordinates (E 49° 59' 56.065" and N 14° 55' 40.891"), and these coordinates are identical to the coordinates reported in Minissale et al research for AL-Diss Ashrqiya spring (Ad Diss est.)[5], while Assaiq spring is located at the coordinates (E 49° 59' 49.103'' and N 14° 55' 30.041'').

The flow rate of the two springs during the year was observed and it was noticed that the average flow of the Assaiq spring was comparable to the average flow of the Senah spring, where the average flow of the Assaiq spring and Senah springs was 4.2 and 3.91 liters per second, respectively. Figure 2 shows recent photos of (A) Assaiq & (B) Senah. Assaiq spring rises about 117 meters above sea level, while Senah spring is 93 meters above sea level.

Figure 2. Recent photos of (A) Assaiq spring & (B) Senah spring.

The temperature of the spring water varies depending on the location of the testing point (higher temperature near the source of the water and low on the top of the watershed) and the depth of the spring, as well as the period of measurement (morning, evening and seasonal). During Assaiq & Senah spring temperature observations, temperature observations revealed a difference in water temperature values. When the depth ranged between 20-30 meters, the water temperature of both springs ranged between 70-80°C. The average temperature of the water flowing out of the spring to the surface and collecting in the basin was (44°C) for the water of Assaiq spring and (49°C) for the water of Senah spring during the year. From the previous spring water temperature studies and If the (Dowgiallo) criterion is used to classify thermal springs, the spring of Assaiq & Senah can be assumed as a thermal spring [1].

The thermal springs and hydrothermal change areas are an important element to guide geologists to explore geothermal energy resources and to identify the hidden systems that cause the sources of this energy. Geothermal energy is one of the clean renewable energy sources that can be exploited in generating electric power. Power is generated when the groundwater absorbs the heat of the rocks and transforms the coming water into high-pressure steam that could rotate the turbine. About twenty-one countries in the world use water vapor from geothermal energy to generate electricity [6]. In the Republic of Yemen, more than 100 springs were identified, which deliver hot water with temperatures between 38°C and boiling degree according to the previous studies[1,5].
It is possible to reduce the costs of raising the temperature of hot spring water to the degree needed for the production of electrical energy. As the Yemeni regions in general and Hadhramout in particular, having broad brightening hours and high temperatures, spring-water temperatures could be increased using the solar baths [11].

4. Classification and evaluation of the quality of waters Assaiq & Senah springs for drinking purposes

Fresh and drinkable water specifications are often colorless, odorless, and tasteless [12]. No instrument could identify the gasses and the dissolved chemical on in the thermal water, therefore the validity of the water, as well as the strength and weakness of the hydrogen sulfide (H$_2$S) smell, were done based on human senses. Water containing hydrogen sulfide has a scent like rotting eggs, and swamp water has a particular marshy scent. When The water contains compositions like organic materials and microorganisms the water will have a particular smell. Also, when water contains a certain amount of highly concentrated inorganic compounds such as chlorides and sulfates, its taste changes to become salty, and it has a sweet taste if it contains large quantities of nitrogenous compounds of organic origin. The visitor of water Assaiq & Senah springs can distinguish the emitted odor, similar to the smell of rotten eggs, which is indicative of the emission of hydrogen sulfide gas, as this smell is approximately equal in concentration for both springs. And when the water from both sources is tested, it becomes clear that the water is bitter and less salty, and it can be drunk, and it certainly does not mean that it is suitable for use.

Table 1. Shows the results of the physical quality of hot spring water in the Al-Diss Ashrqiya region (Assaiq & Senah springs). The pH is an indicator of the concentration of hydrogen ion in the solution, meaning whether the solution is acidic or alkaline [13,14]. The pH mean levels of water springs from Assaiq and Senah are found to be between 6.45 and 6.53, which shows the water’s acidic nature of these two springs. The ability to scatter or consume light in water is assessed by the turbidity. The turbidity arises due to the fragments of cement, colloid compounds, and some microorganisms present in the water. The experimental findings revealed that the water of the two springs (Assaiq & Senah) was equivalent in the turbidity rate, and the turbidity rate was calculated to be (2.00 NTU). In comparison, by measuring the watercolor ratio, the Assaiq spring watercolor ratio was (15 units) and the Senah spring watercolor ratio (14 units).

Table 1. The physical properties of water Assaiq & Senah water springs in the Al-Diss Ashrqiya area.

| Parameter Description | Assaiq springs | Senah springs | Specifications Limits (Yemen) [15] | Specifications Limits (WHO) [16] |
|-----------------------|----------------|---------------|-----------------------------------|----------------------------------|
| Flow rate (l/sec)     | 4.20           | 3.91          | -                                 | -                                |
| Temperature (˚C)      | 44             | 49            | 8 – 25                            | 0 – 25                           |
| Watercolor (Unit)     | 15             | 14            | 8 – 25                            | 0 – 25                           |
| Turbidity (NTU)       | 2.00           | 2.00          | 5                                 | -                                |
| pH                    | 6.53           | 6.45          | 6.5 – 9.0                         | 6.5 – 9.0                        |
| Conductivity @ 25°C (µmhos/cm) | 3060   | 3130          | 2500                              | 1000 -2500                      |
| Total Dissolved Solid (mg/l) | 1958    | 2003          | 1500                              | 500 – 1500                      |
The ability of an aqueous solution to conduct electrical current is known as electrical conductivity (E.C.), and its value increases by increasing the percentage of free ions conducting electric current in the solution, which is often a result of dissolved salts in addition to the presence of the hydrogen ion (H⁺) and (OH⁻). An increase in the proportion of the presence of the hydrogen ion in the solution means that the (pH) value ranges between (1-6), which indicates the acidity of the solution. Acids are a good conductor of electric current due to the high presence of hydrogen ion (H⁺). The electrical conductivity of a solution is an indicator of the percentage of the presence of the hydrogen ion and the hydroxide group (OH⁻), as well as the ions present as a result of the dissolution of dissolved salts in the solution. (14, 17) The degree of electrical conductivity is useful in estimating the total degree of salinity in the water. (18) Chemically pure water has an electrical conductivity. Weak and considered a good insulator, and its conductivity value reaches lower limits (250 µmhos/cm), while the water is suspicious or unusable within the limits of (2000 µmhos/cm) or more. (19) Assaïq water spring has an electrical conductivity of (3060 µmhos/cm), while Senah water spring recorded (3130 µmhos/cm), as these two values are considered to be much greater than the permissible value according to the Yemeni and WHO standards. The connection of aqueous solutions to the electric current is considered a guide for measuring the amount of dissolved salts in it, as there is a direct relationship between the electrical conductivity and the ratio of dissolved solids in drinking water. The dissolved solids or group of total dissolved solids (TDS) consist of a group of inorganic salts such as the salts of elements (calcium, magnesium, potassium, sodium, bicarbonate, chlorides, and sulfates) as well as small amounts of dissolved organic materials in water. (TDS) in water varies greatly in different geological areas due to the difference in the degrees of dissolution of minerals and the formation of their salts. Total dissolved solids (TDS) (2003 mg/l). If the maximum value of the total dissolved salt of fresh water is (1500 mg/l), then the water of water Assaïq and Senah springs can be described as brackish water. (20)

### Table 2.

The rate of presence of some ions of the elements and chemical compounds in the water of water Assaïq and Senah springs, and its comparison with the Yemeni standard specifications and the standards of the World Health Organization (WHO) for the validity of water for drinking purposes.

| Parameter Description (mg/l) | Assaïq Spring | Senah Spring | Specifications Limits (Yemen) [15] | Specifications Limits (WHO) [16] |
|-----------------------------|----------------|--------------|----------------------------------|----------------------------------|
| Total alkaline              | 310            | 280          | 120                              | 120 – 350                        |
| Total Hardness as CaCO₃     | 1010           | 1100         | 500                              | 100 -500                         |
| Calcium Hardness as CaCO₃   | 710            | 930          | 200                              | 75 – 200                         |
| Magnesium Hardness          | 300            | 170          | 150                              | 30 – 150                         |
| Chloride (Cl⁻)              | 300            | 350          | 600                              | 200 – 600                        |
| Fluoride (F)                | 2.36           | 2.22         | 1.5                              | 1 – 1.5                          |
| Iron (Fe)                   | 0.01           | 0.03         | 1.0                              | 0.3 – 1                          |
| Manganese (Mn)              | 0.5            | 0.3          | 0.2                              |                                  |
| Calcium (Ca⁺⁺)              | 284            | 372          | 200                              | 75-200                           |
| Magnesium (Mg⁺⁺)            | 72             | 40.80        | 150                              | 10 -100                          |
| Potassium (K)               | 29             | 15           | 12                               |                                  |
| Sodium (Na⁺)                | 156            | 142          | 400                              | 0 – 220                          |
it is necessary to study the total hardness of the water of these two springs because the increase in total hardness (TH) in drinking water leads to an increase in cardiovascular disease and high blood pressure, followed by the deposition of salts in the body and atherosclerosis [21]. The measure of total hardness is a measure of calcium and magnesium salts, iron, tin, and aluminum salts[22]. As these salts form deposits during their contact with soap (with palmitate and calcium oleites), these sediments prevent the foam needed for cleaning and can be characterized as the inability of water to form soap foam [14]. The most important sources of natural water hardness are calcium and magnesium salts since they are among the main components of human cells, bones, and teeth[23]. The average hardness value of the Assaiq water spring is (1010 mg / l), while the water spring of the Senah is having a higher average hardness value (1100 mg / l) [14].

The presence ratio of ions such as chloride, calcium, magnesium, fluoride, sodium, potassium, manganese, and iron is seen in Table 2., and these the values are compared with the applicable ratios according to the Yemeni standards and the standards of the World Health Organization. The spike in the amount of chloride influences the activity of the kidneys, which contributes to kidney failure [21]. In Assaiq and ed Senah springs water, the chloride ion detected was less than the normal local and globally accepted amount. Calcium is an essential component of the body since it is essential for the stages of fetal growth, breastfeeding and lactation. For the formation of bones and teeth, blood clotting and the functioning of the nervous system, calcium is also important. The calcium ratio in the water of the two springs is around four times higher than the maximum permitted amount. Like calcium, one of the most common positive fundamental ions in groundwater is the magnesium ion [17,20]. In the studied water springs of Assaiq and Senah, the magnesium ion is present at a rate compatible with the permissible ratios of the Yemeni and WHO standard measures.

Fluoride ions are considered to be one of the most common ions in nature and are present in limited concentrations in groundwater [17,24]. If the level of fluoride reaches the normal range (0.7-1.2 ppm), it causes staining and degradation of the teeth, especially in children, and it could cause rickets. By looking at the presence of the fluoride ion of both springs, it could be noticed that the Assaiq and Senah water springs contained a higher level of the fluoride comparing to the standard levels(see Table 2.). In terms of the presence of minerals in the water, sodium is ranked sixth among minerals. Sodium ions are present in some natural waters and can be contained in salted and hard water at high concentrations, where sodium chloride solution is used for the treatment of these waters [26]. Nitrates (NO3), sulfates (SO4), carbonates (CO3), and bicarbonate (HCO3) are among the chemical compounds whose presence is of paramount significance in water. If these compounds are found in water beyond the quantities approved, the risks to users of this water for drinking or agricultural purposes will increase. Experimental tests have shown that the percentage of sulfate (SO4) in the waters of Assaiq and Senah springs is above the permitted value in compliance with the specifications of the Yemeni and WHO measurements and, for this reason, the waters of Assaiq and Senah springs may be called sulphuric water.

|          |       |       |       |       |
|----------|-------|-------|-------|-------|
| Carbonates (CO3⁻) | 0 | 0 | 120 | - |
| Bicarbonates (HCO3⁻) | 378.20 | 341.60 | 500 | 150 – 500 |
| Sulfate (SO4²⁻) | 1120 | 1320 | 400 | 200 – 400 |
| Nitrates (NO3) | 1.6 | 3.3 | 50 | |
Through investigating the presence of elemental ion and chemical compound concentrations in the water of the studied springs, it was found that the present levels of most of the chemicals ions in Assaiq and Senah springs do not match to Yemeni norms and WHO norms. The study also showed the occurrence of the free chlorine ion, iron, magnesium, and sodium ion within the limits of the permissible rates according to the Yemeni standards and international health standards. Moreover, the study showed that the carbonate, bicarbonate, and nitrate ion levels are within the permissible limits. The percentage of sulfate ion presence in the water of water Assaiq and Senah springs increases at a rate of three times the maximum acceptable limits limit locally and internationally.

Table 3. shows the classification of water according to the electrical conductivity (EC) value, the total dissolved salts (TDS), and the ratio of sodium absorption (SAR) according to the American Salinity Laboratory[27,28].

| Description         | Total Dissolved Salts (TDS) mg/l | Electrical Conductivity (EC) µmhos/cm | Section |
|---------------------|---------------------------------|-------------------------------------|---------|
| Low Salinity        | 160-0                           | 0-250                                | C1      |
| Medium Salinity     | 480-160                         | 250-750                              | C2      |
| Hard Salinity       | 1440-480                        | 750-2250                             | C3      |
| Very Hard Salinity  | 3200-1440                       | 2250-5000                            | C4      |

| Damage caused by alkalinity | Sodium Absorption (SAR) % | Section |
|-----------------------------|---------------------------|---------|
| Low                         | 10–0                      | S1      |
| Medium                      | 18–10                     | S2      |
| Hard                        | 26–18                     | S3      |
| Very Hard                   | 30 – 26                   | S4      |

5. Classification and evaluation of water for agricultural uses
International classifications, such as the American Salinity Scale, which focuses on salinity and the ratio of sodium adsorption, were used to determine the validity of Assaiq and Senah spring water for irrigation and agricultural purposes. This classification is known to be one of the most commonly used systems for the evaluation of water quality for agricultural purposes. The previous electricity conductivity studies of Assaiq's spring water (3060 µmhos / cm) and Senah's spring water (3130 µmhos / cm) reveal that they have electric conductivity higher than that of the American salinity scale (2250 µmhos / cm). Therefore, Assaiq's and Sena h's spring water could be classified as water of extremely tough salinity. The use of this form of water to irrigate less salt-tolerant crops is also predicted to pose a serious problem. The water can be used to irrigate crops that are more salt-tolerant, such as palm trees. This water should be used only in well-permeable lands, provided that the water is used in excess quantities that are sufficient to remove the salts accumulated in the soil from the previous irrigation[29]. The results in Table 4., also indicated that the value of sodium adsorption (SAR) for study water ranged from (1.86 2.14%) that is, it is located between (0-10), which includes the section (C4 - S1). This represents the low alkalinity influence. Therefore, we expect the damage from alkalinity to be lower. According to the classification of the American Salinity Laboratory, this type of water should be used only on medium and coarse lands with good drainage and used with crops with high salt tolerance [30]. One of the measures that were used in this study is the Eaton
division [27], which is based on the relationship between the degree of electrical conductivity in (µmhos/cm) and the residual sodium carbonate (RSC) value in (milliequivalent/liter). When comparing the results of Assaiq and Senah spring water (Table 4.) with the Etonon classification and measuring sodium carbonate, it was observed that Assaiq and Senah spring water were not appropriate for irrigation because of the electrical conductivity value was greater than (2250 µmhos/cm). The results also showed that the residual sodium carbonate (RSC) value for all the waters of the study area ranged from (-13.91) to (-19.02) (milliequivalent/liter), meaning that it is less than (1.25) and therefore falls within the water suitable for irrigation.

According to the evidence developed by the Food & Agriculture Organization (FAO), the values of the acidity function (pH) of the two springs water and its manufacture fall within the appropriate range for the irrigation water [31]. It was also found that the electrical conductivity (EC) of the two springs' water exceeded the maximum permissible values (µmhos/cm 3000), and thus it is expected a problem resulting from the severe salinity from the use of this water [32]. The results showed that the percentage of total dissolved solids (TDS) for the water of the Senah spring made slightly exceeded. Permissible limit. The results of the analysis of sulfate, sodium, and potassium ion for the studied water gave the presence of these ions in a percentage exceeding the permissible limit. The results also showed that the concentration of bicarbonate, carbonate, chlorine, calcium, and magnesium ions in the water of Assaiq and Senah springs falls within the permissible limits, therefore we do not expect a problem resulting from the presence of these ions in the water of the two sources. It was observed from the sodium adsorption rate (SAR) analysis for the water of the two springs that the percentage is less than (3%). Therefore, it is expected that there will be a permeability problem resulting from the adsorption of sodium in the soil [33].

Table 4. Chemical and physical analyzes of water Assaiq and Senah springs produced and compared with the standards of the Food and Agriculture Organization (FAO) for the use of water for irrigation purposes.

| Parameter Description | Assaiq Spring | Senah Spring | SPECIFICATIONS LIMITS (FAO)(31) |
|-----------------------|---------------|--------------|---------------------------------|
| pH                    | 6.53          | 6.45         | 6.0 – 8.3                       |
| Conductivity @ 25°C (µmhos/cm) | 3060          | 3130         | 700 -3000                       |
| Total Dissolved Solids (mg/l) | 1958          | 2003         | 450 – 2000                      |
| Bicarbonates (HCO₃⁻) (mg/l) | 378.20        | 341.60       | 0 – 610                         |
| Carbonates (CO₃⁻) (mg/l) | 0             | 0            | 0 – 120                         |
| Chloride (Cl⁻) (mg/l) | 300           | 350          | 0 – 1065                        |
| Sulfate (SO₄²⁻) (mg/l) | 1120          | 1320         | 0 – 960                         |
| Calcium (Ca+++) (mg/l) | 284           | 372          | 0-400                           |
| Magnesium (Mg+++) (mg/l) | 72            | 41           | 0-60                            |
| Sodium (Na⁺) + Potassium (K) (mg/l) | 185           | 157          | 0 – 47                          |
| Sodium Absorption (SAR) % | 2.66          | 1.87         | 0 -15                           |
6. Conclusions
Through our study of the spring water in the AL-Diss Ashrqiya region, it was found that the water of Assaïq and Senah springs flowed throughout the year and that the average water temperature of these two springs' ranges between (44 to 49 degrees Celsius), and the temperature of this water increases as the depth increases. Hot spring water contains calcium, magnesium, and sodium ions. This indicates that the chemical properties of the subsurface water are affected by the quality of the rocks, and therefore the water of these two springs can be used for the purpose of healing from the skin and rheumatic diseases. Hot spring water, Assaïq, and Senah in the AL-Diss Ashrqiya region are not suitable for drinking because many of its chemical and physical properties are higher than the permissible limits according to the Yemeni and the World Health Organization (WHO) standards specifications for drinking water. The water of Assaïq and Senah Springs was classified and evaluated according to the scale of the American salinity laboratory as water of very hard salinity and poor in sodium adsorption (SAR) (C4-S1). Hot spring water (Assaïq and Senah) can be used to irrigate salt-tolerant crops, such as palm trees, according to the requirements of the Food & Agriculture Organisation (FAO). Water should be used in well-permeable fields, assuming that the water is used in excess amounts necessary to extract salts from prior irrigation activities deposited in the soil.

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