Study of some physicochemical properties of hot springs water in Shara'a and Kirsh, Lahj Governorate-Yemen

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Abstract

This research aims at determining some of the physicochemical properties of hot springs in the areas of (Shara'a and Kirsh) Lahj Governorate. 45 samples were collected for 15 sites. The following parameters were measured: acidity number (pH), total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), Calcium Hardness (TH.Ca), Magnesium Hardness (TH.Mg), Alkalinity, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Bicarbonate (HCO_3^{-}), Sulfate (SO_4^{2-}), Nitrate (NO_3^{-}), Fluoride (F^{-}), Chloride, and (Cl^{-}), Sodium Absorption Ratio (SAR). The results showed that the values of Total Dissolved Solids (TDS), Electrical Conductivity (EC), Alkalinity, Sodium, Potassium, Sulfate and Fluoride were higher than the maximum allowable limits of the World Health Organization (WHO) for drinking water by 100%, while the concentration of Chloride in Krish area and alkalinity in Shara'a area exceeded WHO limits by 100%. As for the rest of the parameters, they were less than the permissible limit according to the standard specifications. Also, the results showed that the water of Shara'a and Kirsh hot springs has temperatures (ºC) of 60 and 62.5 respectively. The waters from the hot springs in Shara'a and Krish are thus not fit for human consumption. The study recommends the use of hot spring water for recreational purposes should be closely monitored. It is thus important that the physical and chemical composition of hot springs should be monitored on a regular basis. Finally, the study recommends a comprehensive study of the chemical and therapeutic properties of hot springs water, as well as the geological characteristics of the study area.

Keywords: Physicochemical Properties, Hot Springs, Shara'a, Kirsh, Lahj, Yemen.

1. Introduction

Springs are drainage centers for groundwater that appear on the surface of the earth as a flow of water, as that has a higher temperature than normal groundwater is called thermal springs, and most of the springs are the result of long cracks in sedimentary rocks [25]. Thermal springs are classified as (-non-volcanic: heat and water supply are not directly related to volcanoes - medium: excess heat is caused by abnormally high ground temperature gradients resulting from volcanic activity, but the water is completely meteoritic - volcanic: characterized by excess heat, a lot of mineral content and part of the water from a volcanic source [35]. Since water is the most valuable resource in the long run with the high population growth and expansion of economic activities and the increasing use of groundwater for irrigation, bathing, local supply [3]. Thermal springs are natural resources, and if they are optimally developed, they can make a significant contribution at the local and economic levels [27]. From a health point of view, hot spring water should be suitable for the body and ideally comply with the standards required to maintain the health and well-being of those who use it, as archaeological evidence shows that thermal springs were used for religious/medicinal since before 2000 BC in India and for hundreds of years in Egypt, Japan, Turkey and others In addition to the countries of Europe and the Middle East, many thermal springs developed into centers of thriving religious culture and health, such as those in Bath in England, Vichy in France and Baden-Baden in Germany [11]. Hot spring water is increasingly being used in industrial and agricultural processing, bottled water, and the extraction of trace elements [27]. Although Yemen does not suffer from excessive water supply problems at present, but the very rapid population growth may increase the demand for water in the near future, and in light of the fact that most of the thermal waters have chemical properties that make them drinkable, so they are considered as long-term water resources [21].

The study aimed at determining the physicochemical properties of hot springs water in the areas of (Shara'a and Kirsh), Lahj Governorate-Yemen.

2. Materials and Methods

2.1. Study Area

The study areas were Shara'a (13°45'38.2"N 44°58'12.7"E) and Kirsh (13°23'02.4"N 44°28'17.4"E) Lahj Governorate /Yemen (Figure 1), in the first area (hot springs for Shara'a area) a hot spring and a plastic pipe extending from the spring directly to different sites to use it by the people of the area for different purposes and in the second area (hot springs for Kirsh area) there is a hot spring and a place that gathers water near the spring that the people of the area Neighboring takes water from this site to homes.

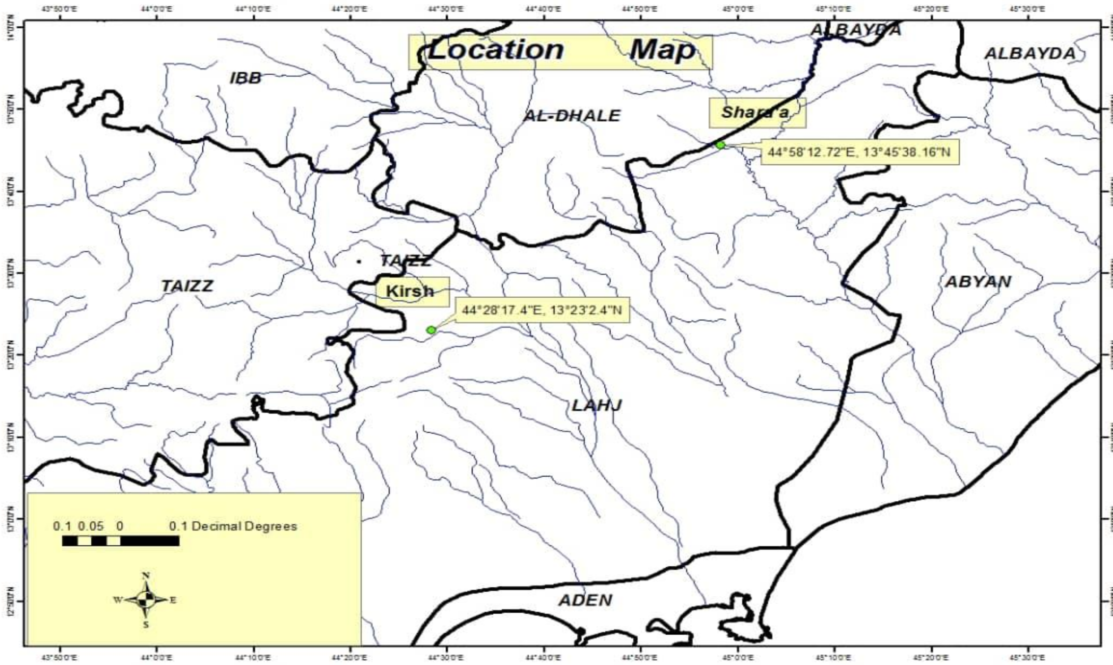

Figure 1: Map of study areas

2.2. Sample collection

Hot springs water samples were collected in March 2020 from the Shara,a and Krish areas in Lahj Governorate-Yemen, locations were determined by the Global Positioning System (GPS) (Table 1). Samples were collected in plastic containers a capacity of 750 ml pre-sterilized with 70% alcohol and then rinsed with distilled water.

The first area (**Shara'a area**): Samples were collected from **Eight Sites** (one site for the spring, two sites from of the plastic pipe, and five sites from homes). The second area (**Kirsh area**): Samples were collected from **Seven Sites** (two sites of the spring and the around the spring and five sites from homes). Three replicates for water samples were collected from 15 sites (Total 45 samples), but, when the results of the analysis were calculated, the average use three samples results.

Table 1: Latitude and longitude of sampling sites

Location	Sample No.	Name	Latitude	Longitude
Shara'a Area	1	Spring	13°76'06"	44°97'02"
	2	plastic pipe	13°76'058"	44°97'019"
	3	plastic pipe	13°76'034"	44°97'025"
	4	House	13°38'376"	44°47'21"
	5	House	13°38'273	44°47'335"
	6	House	13°38'274"	44°47'35"
	7	House	13°38'231"	44°47'427"
	8	House	13°38'217"	44°47'445"
Kirsh Area	9	Spring	13°38'40"	44°47'15"
	10	around the spring	13°38'397"	44°47'15"
	11	House	13°76'071"	44°97'005"
	12	House	13°76'026"	44°97'004"
	13	House	13°76'026"	44°97'032"
	14	House	13°76'003"	44°97'01"
	15	House	13°76'002"	44°97'037"

2.3. Instructions and Analytical Procedure

Temperature (T), pH, and Electrical conductivity (EC), were measured directly in situ using a mercury thermometer, pH-meter (HQ40d multi/HACH), and EC-meter (HQ40d multi /HACH) respectively). While other parameters were analyzed in the laboratory, where total alkalinity, hardness, calcium hardness, nitrate, sulfate, fluoride, and chloride were measured by UV-Spectrophotometer. Total Dissolved Solids (TDS), were measured by Digital TDS meter (HAANA-HI98192). Magnesium was measured by Calculation as from total hardness and calcium Hardness.

Water samples analyzed for chemical constituents such as sodium, potassium, calcium, magnesium, chloride, bicarbonate, sulphate, and nitrate analysis for using the standard methods as suggested by using the American Public Health Association (APHA) [4;5] and [9] for also Calcium and Magnesium.

Sodium Absorption Ratio (SAR): The sodium or alkali hazard in the use of water for irrigation is expressed in term of sodium adsorption ratio (SAR) which is very important parameter for determining the suitability of water for irrigation because it is a measure of alkali hazard to crops. It can be calculated using the formula [30;34]:

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

3. Results and Discussion

In the present study, physicochemical properties were determined such as acidity number (pH), total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), Calcium hardness (TH.Ca), Magnesium hardness (TH.Mg), Alkalinity, bicarbonate (HCO_3^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), fluoride (F^-), chloride (Cl^-), Sodium Absorption Ratio (SAR). where it was compared Concentrations of physicochemical properties of hot spring samples with the guideline values for drinking water as specified by the WHO [38] and YSSW [39] add to that the guideline values for irrigation water as specified by the FAO [6] are summarized in (Tables 2 and 3) and the use of this water for therapeutic purposes.

3.1. Temperature

The mean value of temperature (ºC) of Shara'a and Kirsh springs is 60 and 62, respectively. The temperature in this study was higher than the study of Hamazah et.al, [15] in all sites, except for the Longat site, which stated that the temperature was 67.9 °C [15]. According to Subtavewung et.al, [34], there are four types of hot springs, and are classified according to temperature as follows:

Cold spring < 20 ºC ; 20ºC ≤ hypothermal spring < 30ºC ; 30ºC ≤ thermal spring < 50º ; 50ºC ≤ **hyperthermal spring**

Based on this classification, the hot springs of **Shara'a and Kirsh are hyperthermal springs.**

3.2. pH

In this study, the results showed that the pH values of the study ranged from 7.43 to 7.67 units (Table 2). Most of hot springs in study area are weak alkaline. The values of the samples did not exceed the recommended limits of the WHO [38] and YSSW [39]. When comparing the results with the evidence developed by FAO [6] , the results showed that the pH value was within that the permissible limit by the Food Agriculture Organization. When comparing the results of this study in other studies, the results of this study are agrees with Minisalle et.al, in Yemen [21], as well as an Olivier et.al, in South Africa [27]. The natural pH range in fresh water ranges from about 4.5 for highly acidic waters to more than 10 in waters where there is intense photosynthesis activity by algae, however, the most common range is 6.5-8 [16].

3.3. Total dissolved solids (TDS)

In this study, the values of TDS ranged from the 1190.43 to 1866.67 mg/L (Table 3). The results showed that TDS values in all samples of a study areas were higher than maximum allowable limits by WHO (1000mg/L), and all samples of a Kirsh area higher than the maximum limit of YSSW, while the values of total dissolved solids in samples from Shara'a area within the recommended limits for YSSW and FAO, and also for Kirsh samples were according to FAO specifications (Table 3). When comparing the results of this study in other studies, the results showed that the TDS values in the Kirsh area is similar to the study of Minissale et.al, [21] and approached the results of a study of Bamesoud *et al.*, [7], which states that the hot springs in Hadhramaut, Assaiq and Senah showed that the values of TDS is 1958 and 2003 mg/L, respectively.

The increase in TDS values in some samples might be due to dissolved some small amounts of inorganic and organic matter present in solution in water, the presence of dissolved solids in water may affect its taste. The palatability of drinking-water has been rated by panels of tasters in relation to its TDS level, according to World Health Organization (WHO) [37], as follows: less than 300 mg/L, excellent; between 300 and 600 mg/L, good; between 600 and 900 mg/L, fair; **between 900 and 1200 mg/L, poor**; and **greater than 1200 mg/L, unacceptable**. **Based on this classification, Sharia water is poor, while Kirsh water is unacceptable**, according to the WHO [37]. Ground water containing mineral contents within the limit of drinking water standard i.e WHO, use as drinking water but if it contains mineral above these standards and temperature above 40 ^{o}C then it considers as mineral spring [17].

3.4. Electrical Conductivity

In this study, the values conductivity ranged from 2329.83 to 3254.67 µs/cm (Table 3). All samples taken from Kirsh area (3186-3254 µs/cm) exceeded the recommended limits of the WHO (1000µs/cm) and the YSSW (2500 µs/cm), while the samples taken from Shara'a area (2329.8-2371.67 µs/cm) were more then recommended limits of the WHO, and did not exceed the recommended limits of the YSSW. When comparing the conductivity of the study samples with FAO standards, the samples taken from Shara'a area were not exceed the permissible limits of 3000 µs/cm while the samples taken from the Kirsh area exceeded the limit value. This increase in conductivity values may be of the presence of iones and their total concentration, valency, relative concentration, and temperature of the water. Solutions of most inorganic acids, bases, and salts are relatively good conductors [14]. The increase in salinity can lead to a dry state and plants wither because the roots are unable to absorb water, Salinity is usually measured as TDS or Electrical Conductivity (EC) [32].

According to the American salinity classification mentioned by Richards [28], the samples in **this study were classified as high salinity C4, and not suitable for normal irrigation** (Table 2). It can be used in special circumstances. The soil must be permeable and irrigation water must be used extensively to provide greater filtration and crops that are highly salt tolerant must be selected [28].

Table 2: The classification of irrigation waters according Wilcox [36]

Index method	Range	Classification	Percentage of sample
EC	< 250	(C1)low salinity	
	250 - 750	(C2)medium salinity	
	> 750 - 2250	(C3)high salinity	
	>2250	**(C4)very high salinity**	100
SAR	< 10	(S1)low sodium	
	10 - 18	**(S2)medium sodium**	**100**
	> 18 – 26	(S3)high sodium	
	> 26	(S4)very high sodium	

Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR)

3.5. Total Hardness

Water hardness measures the amount of divalent cations present in the water especially calcium and magnesium that react with soap to form precipitates [30]. This study shows that the values of total hardness of the samples were ranged from 94.54 to 216 mg/L, the values of the samples did not exceed the recommended limits of the WHO and YSSW (Table 3). The current study (Kirsh area) surpassed of Naresh et.al, [25] study in India, which stated that the hardness mean value is 165.2 mg/L [25]. A study of Bamsaoud et.al, [7] mentioned that the amount of hardness for Assaiq and Senah is 1010 and 1100 mg/L, respectively, these values are higher than the current study. The classification of studied samples based on TH shows that they fall in moderately soft (Shara'a area) to hard category (Kirsh area) [30]. The total hardness in natural water varies according to the nature of the geological formation through which the water passes [8].

Calcium hardness: The average calcium hardness ranges from 65.17 to 186.67 mg/L (Table 3). All the hardness values for calcium in the study samples were lower than the recommended limits of the WHO and YSSW. The study of Bamsaoud et.al, in Hadramout mentioned that the calcium hardness of Assaiq and Senah was 710 and 930 mg/L, respectively [7], these values are higher than the current study.

Magnesium hardness: The average concentration of magnesium of the study area ranges from 27.67 to 34.67 mg/L (Table 3). All results of the samples were higher than allowable limits of the WHO (20 mg/L), but fall lower than the limits recommended by YSSW (150 mg/L) (Table 3). A study by Bamsaoud et al. mentioned that the amount of magnesium hardness for Assaiq and Senah was 300 and 170 mg/L [7], these values are higher than the current study.

3.6. Alkalinity

The results of alkalinity in the study area were between 219.33 to 262.68 mg/L. The results of the study area showed that the alkalinity in the study area was higher than the upper limit allowed by the Yemeni specifications (YSSW) (120 mg/L), as well as Shara'a samples that were higher than the maximum allowable limits by the WHO of 250 mg/L, when comparing the results of this study with other studies, The results of this study were higher than the study of Naresh et.al, (196 mg/L) from India [25], and less than the study of Bamasoud et.al, (280-310 mg/L) from Hadramout-Yemen [7]. The increases in alkalinity in the water may be due to dissolved of carbonates, bicarbonates, phosphates, and hydroxides, Limestone is a good source for the temporary storage of carbonates [14].

Sodium Absorption Ratio (SAR)

Sodium adsorption ratio (SAR) is an important parameter for determining the suitability of groundwater for irrigation because it is a measure of alkali/sodium hazard to crops [30 and 32]. The sodium absorption rate in this study ranged from 12 to 13.29 meq/L (Table 3). According to the American classification mentioned by Richards [28], classification of water based on the percentage of sodium, **the study samples fall within the category S2 of medium sodium water**. In this case, the danger lies on the soil with a high capacity for cation exchange, especially under conditions of low filtration. This type of water can be used for coarse soils with good permeability [28]. Irrigation water with high levels of SAR can lead to the accumulation of high levels of sodium in the soil over time which in turn can affect soil infiltration rates (due to soil dispersal). In addition, excess SAR levels can lead to soil crusting, poor seedling emergence and poor ventilation [20]. The sodium absorption rate in our study was higher than that the aim study of Bamasoud et.al, [7], its amount in Assaiq and Senah was 2.66 and 1.87 meq/L, respectively.

Table 3: Some of physicochemical properties in Hot Springs in Shara'a and Kirsh

Location	Sample NO.	Parameters							
		PH	TDS mg/l	EC μs/cm	T. H mg/l	T. Alk mg/l	Ca.H mg/l	Mg.H mg/l	SAR
Shara'a Area	1	7.5	**1197.33**	**2365.33**	95.70	**259.13**	67.03	**28.67**	13.21
	2	7.43	**1197.00**	**2329.83**	95.69	**260.82**	67.27	**28.42**	13.16
	3	7.53	**1198.17**	**2352.33**	95.67	**258.89**	67.03	**28.64**	13.00
	4	7.53	**1193.67**	**2366.33**	95.05	**258.73**	66.75	**28.30**	13.25
	5	7.43	**1197.33**	**2362.67**	95.22	**261.23**	66.45	**28.77**	13.23
	6	7.60	**1190.43**	**2366.33**	94.54	**262.03**	65.17	**29.37**	13.23
	7	7.53	**1196.67**	**2371.67**	95.24	**260.55**	66.25	**28.99**	13.21
	8	7.67	**1199.33**	**2343.00**	95.00	**262.68**	67.17	**27.83**	13.29
Krish Area	9	7.53	**1642.00**	**3193.33**	208.50	**221.20**	177.50	**31.00**	12.29
	10	7.57	**1645.67**	**3186.00**	210.83	**220.40**	178.33	**32.50**	12.00
	11	7.53	**1738.67**	**3230.33**	208.50	**220.33**	180.83	**27.67**	12.35
	12	7.63	**1866.67**	**3254.67**	211.50	**219.33**	179.17	**32.33**	12.10
	13	7.57	**1679.00**	**3190.33**	216.00	**229.67**	186.67	**29.33**	12.22
	14	7.57	**1679.67**	**3195.00**	211.67	**219.33**	179.17	**32.50**	12.40
	15	7.63	**1678.33**	**3194.00**	210.50	**219.67**	175.83	**34.67**	12.43
Standard	WHO[1]	6.5-9	**1000**	**1000**	500	250	75-300	**20**	…….
	YSSW[2]	9	**1500**	**2500**	500	**120**	200	150	……..
	FAO[3]	8.3	2000	3000	…….	……	…….	……	15

[1]Maximum allowable limits of the World Health Organization for drinking water (WHO, 2011) [38];
[2]Yemeni Standard Specifications for Water (YSSW, 1999) [39]; [3]Food and Agriculture Organization (FAO)[6]

3.7. The results of ions concentration in the water from hot springs in Shara'a and Kirsh

3.7.1. Bicarbonate

The values of bicarbonate for the samples under study ranged from 267.47 to 320.47 mg/L in Kirsh and Shara'a, respectively, all study samples were not exceeded the recommended limits of the WHO, FAO and YSSW (Table 4). There is a difference in the concentration of bicarbonate when comparing the results of our study with that of Minissale et.al, [21]. There is convergence in the results of our study for the site of Kirsh with the study of Bamasod et.al, [7] in Hadhramaut - Yemen that showed that the amount of bicarbonate for Assaiq and Senah was 378.20 and 341.60 mg/L, respectively. The present of bicarbonate in water because of interaction between water and rocks is the main source of bicarbonate, magnesium, and calcium ions in groundwater [18]. It may have been caused by the chemical reaction while thermal water flow through wall rocks which are limestone, dolometic-limestone and dolomite [34]. The high bicarbonate when compared to carbonate in the water is the result of the reactions of soil CO_2 with dissolution of silicate minerals [23 and 26]. The possible sources of bicarbonate include the presence of organic matter in the aquifer that is oxidized to produce carbon dioxide, which promotes dissolution of minerals. HCO_3^- may be resulted from the weathering of silicate minerals [23 and 29].

3.7.2. Calcium

Ca^{2+} level in the studied samples ranged from 26.07 to 74.67 mg/L in Shara'a and Kirsh, respectively, all samples were not exceeded the maximum permissible limits for WHO, FAO and YSSW (Table 4). The concentration of calcium in our study does not agree with the study of Minissale et.al, [21] and Ghilamicael [13], while converges with the results of Hamzah et.al, in Malaysia [15]. The study of Bamsaoud et.al, also showed that the amount of calcium for Assaiq and Senah was 284 and 372 mg/l, respectively, This values are higher than the results of our study. The calcium and magnesium ions present in groundwater may be derived from silicate leaching and form the magnesium and calcium-bearing rocks [15].

3.7.3. Magnesium

The values of magnesium in the study area ranged from 6.7 to 8.42 mg/L in Shara'a and Kirsh, respectively, all study samples were not exceeded the recommended limits of the WHO, FAO and YSSW (Table 4). When comparing the concentration of magnesium in this study with other studies, the difference is observed with the results of Ghilamicael et.al, [13] and Bamsaoud et.al, [7], but it is to some extent consistent with the results of Minissale et.al, [21].

3.7.4. Sodium

The values of sodium in the study area ranged from 296 to 415 mg /L in Shara'a and Kirsh, respectively, (Table 4), all samples were higher than the maximum permissible limits for WHO

(200 mg/L), whereas samples taken from the Kirsh area were exceeded the permissible imits of the YSSW (400 mg /L). The difference may be due to the earth quake happened in the location of Shara’a [21]. When comparing the results of this study with other studies, it shows that the results of the present study in the Kirsh area are in agreement with the study of Minissale et.al, [21], but the concentration of sodium in Shara'a and Kirsh were higher than the results of the study of Hamzah et.al, in Malaysia [14] and Bamsaoud et.al, In Hadhramout [7], while differ with study of Ghilamicaele et.al, [13] study also showed a difference with this study [13].The high sodium content is due to soil dissolution and rock weathering [22].

3.7.5. Potassium

The values of potassium in this study ranged from 16 to 25.3 mg / L for the Krish and Shara'a, respectively (Table 4). The difference may be due to an earth quake happened in the location of Shara’a [21]. The results of the study showed that the Potassium concentration in all samples were higher than the maximum permissible limit according to the specifications of the WHO and YSSW for drinking water. The results of our study in Kirsh area agree to some extent with the study of Minissale et.al, [21]. Bamsaoud et.al, which stated that the amount of potassium for Assaiq and Senah was 29 and 15 mg/l, respectively [7], where the concentration of potassium for the Assaiq region is somewhat consistent with the results of our study, but a difference was shown with Ghilamicael et.al, from Eritrea [13].

3.7.6. Sulfates

The values of sulfate in this study ranged from 283.13 to 461.33 mg/L for Shara'a and Kirsh, respectively (Table 4), the difference may be due to the earth quake happened in the location of Shara’a [21]. The samples taken from Shara’a found less than the permissible limit of YSSW, while samples taken from the Kirsh were higher than the maximum allowable limits for WHO and YSSW. When comparing the results of this study with the recommended limits of FAO, that the limit values were not exceeded. The results of our study in the Kirsh area are in agreement with the study of Minissale et.al,[21]. Bamsaoud et.al, studied the amount of sulfate for Assaiq and Senah were 1120 and 1320 mg/L, respectively [7], this is a higher value than the results of our study. The sulfates are found in water in different concentrations resulting from the cracking of sulfur-containing organic compounds also sulfates are formed from the oxidation of pyrene and some sulfur scattered in igneous and sedimentary rocks such as gypsum (anhydrides and calcium sulfate) [12]. The increase in sulfate concentration may be due to the that Sulfur is one of the main components in the volcanic zones being present in both liquid and vapor phases and either in the form of sulfur and/or sulfate, the origin of sulfur is attributed to the degasification of magma or leaching of rocks, influencing the chemistry of thermal fluids [2].

3.7.7. Nitrates

The values of nitrate of the study area ranged from 0.05 to 20.67 mg/L for Shara'a and Kirsh, respectively, all study samples were not exceeded the maximum permissible limit of the WHO and YSSW (Table 4). When comparing the concentration of nitrate between samples in the Kirsh area, the study shows that less concentrated for nitrates in the water of spring (the source of the hot spring water) (found less than 0.3 mg/L, NO_3^-) and this is a natural source, while the highest concentration was found in the consolidated water and housewater (ranges from 15 to 20.67 mg /L; NO_3^-), increasing the concentration of nitrates indicating that the human source (Man-made source). And also the concentration of nitrates in the water of the Shara'a area that the less concentration found in the hot springs water source (Natural source) and the highest concentration found in the housewater (Human source). When comparing the concentrations of nitrates in our study with the study of Minissale et.al, [21] the results showed a discrepancy in the values, which may be attributed to the lack of interest in private containers of water in homes. A small percentage of the nitrates found in natural waters are of mineral origin, most of which come from organic and inorganic sources. The first includes waste discharges and the other consists of synthetic fertilizers. However, bacterial oxidation and nitrogen fixation by plants both produce nitrates [37]. The possible sources of nitrates are poultry farms, animal wastages and septic tank leakages in the urban area. Nitrate leaching is enhanced by high infiltration of soil layer and low runoff potential [33]. The presence of high nitrate concentration in the drinking water increases the incidence of gastric cancer and other potential hazards to infants and pregnant women [25 and 33].

3.7.8. Fluoride

The values of fluoride ion in the studied samples ranged from 4.33 to 7.63 mg/L, for Shara'a and Kirsh, respectively, (Table 4), all the values of fluoride for the study samples were higher than the recommended limits of the WHO and YSSW (1.5 mg/L) (Table 4). The results of this study in the Kirsh region agree to some extent with the study of Minissale et.al, and but they differ with the results of Shara'a area [21]. A study by Bamsaoud et.al, showed that the amount of fluoride for Assaiq and Senah was 2.36 and 2.22 mg/L respectively [7], this is less than the results of our study. The current study somewhat agreed with the Ghilamicael et.al, which showed that the level of fluoride ranged from 6.48 - 8.20 mg/L, which is a value higher than the limits by WHO [13]. The increased concentration of fluoride may be attributed to rocks rich in alkali metals, and also obsidian, are as a class higher in fluoride where Fluoride often is associated with volcanic or fumarolic gases, and in some areas, these may be important sources of fluoride for natural water [16]. The reason for the rise of F^- is that the waters of the study area pass through sedimentary rocks containing fluorspar, which is one of the terrestrial minerals that is a source of fluorine, and this is consistent with what has been mentioned in literature [1 and 30].

3.7.9. Chloride

The values of chloride of the study area were ranged from 167.33 to 413.33 mg/L for Shara'a and Kirsh, respectively (Table 4). The results of the study showed that the water of Kirsh area contains high rates of chloride ion, which is higher than the maximum allowable limits by using WHO, but less than the specification limits of the FAO and YSSW. The results also showed that the chlorine concentrations in the samples of the Shara'a area were less than the standard limits of the WHO, YSSW and FAO. (Table 4). The chloride concentration of the study samples is somewhat consistent with a study of Minissale et.al, [21] and the samples of the Kirsh area with a study of Bamsaoud et.al, [7], while the results of this study (Shara'a and Kirsh) were higher than the Kumar and Sharma in India (11.72-13.49 mg/L) [19]. There are many sources of chloride from sedimentary rocks, fertilizers, sewage tanks, and industrial waste [18].

Table 4: The mean values of ions in the water from hot springs in Shara'a and Kirsh

Location	Sample NO.	Parameters								
		Ca^{++} mg/l	Mg^{++} mg/l	**Na^{+} mg/l**	**K^{+} mg/l**	**SO_4^{--} mg/l**	NO_3^{-} mg/l	**Cl^{-} mg/l**	HCO_3^{-} mg/l	**F^{-} mg/l**
Shara'a Area	**1.**	26.81	6.96	**297.07**	**24.67**	284.07	0.05	170.77	316.13	**5.04**
	2.	26.91	6.90	**296.00**	**24 00**	**283.17**	0.09	171.37	318.2	**5.10**
	3.	27.81	6.96	**296.33**	**24.67**	**283.40**	0.11	171.43	315.87	**4.99**
	4.	26.70	6.88	**297.17**	**25.00**	**283.13**	1.18	169.33	315.67	**4.87**
	5.	26.58	6.98	**297.10**	**24.50**	**283.93**	2.09	170.00	318.67	**4.95**
	6.	26.07	7.13	**296.00**	**24.00**	**283.17**	5.19	168.67	319.67	**4.77**
	7.	26.50	7.03	**296.47**	**25.00**	**283.87**	4.13	169.67	317.87	**4.57**
	8.	26.87	6.76	**297.93**	**25.30**	**283.87**	7.47	167.33	320.47	**4.33**
Kirsh Area	**9.**	71.00	7.50	**402.33**	**16.33**	**450.33**	0.24	**403.00**	269.86	**7.53**
	10.	71.33	7.90	**400.67**	**17.17**	**451.00**	0.26	**413.33**	268.80	**7.63**
	11.	72.33	6.70	**410.00**	**16.67**	**450.67**	15.00	**402.33**	268.53	**6.50**
	12.	71.67	7.86	**405.00**	**16.00**	**451.67**	15.67	**402.67**	267.47	**6.70**
	13.	74.67	7.13	**413.33**	**17.00**	**451.67**	18.33	**404.33**	280.20	**6.53**
	14.	71.67	7.90	**415.00**	**16.33**	**457.67**	19.67	**409.33**	267.60	**6.17**
	15.	70.33	8.42	**414.67**	**17.17**	**461.33**	20.67	**406.33**	267.67	**6.17**
Standard	**WHO[1]**	75-300	30	**200**	**12**	**250**	50	**250**	500	**1.5**
	YSSW[2]	200	150	**400**	**12**	**400**	50	600	500	**1.5**
	FAO[3]	400	60	…….	……	960	……	1065	610	……

[1]Maximum allowable limits of the World Health Organization for drinking water (WHO, 2011) [38]; [2]Yemeni Standard Specifications for Water (YSSW,1999) [39]; [3]Food and Agriculture Organization (FAO) [6].

Conclusions

This research studies the physical and chemical characteristics of two hot springs in Shara'a and Kirsh in Lahj Governorate, Yemen. It provides current information on some physical and Chemical properties of two hot springs located in Lahj Governorate, Yemen.

Waters from the hot springs investigated in the present study cannot generally be regarded as “pure”. There are unacceptably high levels of Sulfate, fluoride, TDS, and sodium in the Kirsh and Shara'a areas. Chloride levels in the Kirsh was also above the WHO limits set for human consumption. The waters from the hot springs in Shara'a and Kirsh are thus not fit for human consumption. In addition, the use of hot spring water for recreational purposes should be closely monitored. It is thus important that the physical and chemical composition of hot springs be monitored on a regular basis. Finally, the study recommends a comprehensive study of the chemical and therapeutic properties of hot springs water, as well as the geological characteristics of the study area.

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دراسة بعض الخصائص الكيميائية والفيزيائية للينابيع الحارة في حمام شرعة وكرش، محافظة لحج – اليمن

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الملخص

يهدف هذا البحث إلى تحديد بعض الخواص الكيميائية والفيزيائية في الينابيع الساخنة في حمامات شرعة وكرش محافظة لحج. تم جمع 45 عينة من 15 موقع. تم قياس المؤشرات التالية: رقم الحموضة (pH)، المواد الذائبة الكلية (TDS)، الموصلية الكهربائية (EC)، القساوة الكلية (TH)، القلوية، أيونات الكالسيوم، المغنيسيوم، الصوديوم، البوتاسيوم، البيكربونات، الكبريتات، النيترات، الفلورايد، الكلورايد، نسبة امتصاص الصوديوم (SAR). أظهرت النتائج أن تركيز المواد الصلبة الذائبة الكلية (TDS)، الموصلية الكهربائية (EC)، القلوية، أيونات المغنيسيوم، الصوديوم، البوتاسيوم، الكبريتات، والفلورايد تجاوزت حدود منظمة الصحة العالمية الخاصة بمياه الشرب بنسبة 100%، بينما تركيز االكلور في منطقة كرش والقلوية في منطقة شرعة تجاوزا حدود منظمة الصحة العالمية بنسبة 100٪. اما بقية المؤشرات كانت أقل من الحد المسموح به حسب المواصفات القياسية. كما اضهرت النتائج التقارب في درجات الحرارة حيث بلغت 60 و 62.5 درجة مئوية لكل من حمام شرعة وحمام كرش على التوالي، وبالتالي فإن مياه الينابيع الساخنة في شرعة وكرش غير صالحة للاستهلاك البشري.

توصي الدراسة بضرورة استخدام مياه الينابيع الساخنة للأغراض الترفيهية عن كثب، لذلك من المهم مرقية التركيب الفيزيائي والكيمائي للينابيع الساخنة بشكل منتظم، وأخيرا توصي الدراسة بإجراء دراسة شاملة للخواص الكيمائية العلاجية لمياه الينابيع الساخنة، وكدلك الخصائص الجيولوجية لمنطقة الدراسة.

الكلمات المفتاحية: الخصائص الفيزيائية والكيمائية، الينابيع الحارة، شرعة، كرش، لحج.