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Physico-Chemical Analysis for Potential Health Benefits of Hot Springs Around Gahtelay Area of Eastern Eritrea

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ABSTRACT
This study investigated the physical and chemical characteristics of three hot springs situated on Eritrea's eastern escarpment. These parameters were measured by using various instruments such as digital pH meter, conductivity meter, turbid meter, flame photometer and spectrophotometer. Eight (8) water samples were collected from the hot springs. The cations and anions as well as some of the heavy metals were analyzed and compared with WHO guidelines. The temperatures of the hot springs water at source were varied from 36.6°C to 60.4°C while pH levels were ranged from 6.30 to 7.52. The compositions of the spring water were analyzed and some of the therapeutic minerals include Na^+, $SO4^{2-}$, K^+, Mg^{2+} and Ca^{2+} and the results for these minerals were (198.03-412.26 mg/L), (32.66-126.33 mg/L), (13.33-14.43 mg/L), (0.96-4.80 mg/L) and (12.00-35.20 mg/L) respectively. The F^- was found (5.20-5.83 mg/L) which was above the WHO limit in all the samples. Turbidity of the collected samples was found within the WHO standard limit except for ASHD-07A (11.28 NTU). In the present study, the hot springs water cannot generally be regarded as "pure" since some of the samples contain higher temperature, turbidity, total alkalinity, the Na^+, K^+ and F^- ions when compared with the WHO limit.
Total of 22 questionnaires were distributed among individuals from different places who have visited to these thermal waters. The feedback from the questionnaire suggested that muscle, joint problem and skin diseases were the most common and it was observed changes (above 50%) after bathing in these hot springs. It is very important that to carry out additional studies on the physical and chemical analysis together with the health professionals on hot springs in different seasons as well as monitoring the sites on a regular basis.

Keywords: **Physicochemical parameters, hot springs, Akwar, Maiwooi and Feshash**

1. INTRODUCTION

Water, as vital as air, is fundamental to all plant and animal life. It's essential for drinking, irrigation, industry, transportation, recreation, fishing, and maintaining biodiversity[1]. It also plays an important role in climate regulation cycle. Hot water issuing from the earth's surface has been a subject of awe since the dawning of humankind. The ancient civilizations valued thermal springs because they were believed to have supernatural and healing powers[2]. Evidence from archaeology demonstrates that bathing in thermal springs was practiced in diverse ancient centers, including Mohenjo-Daro (India, pre-2000 BC), the royal complex at Knossos (Crete, 1700-1400 BC), and the Egyptian royal city of Tall al-'Amarinah (c. 1350 BC) [3]. Thermal spring water's applications have expanded beyond traditional uses to include industrial processing, agriculture, aquaculture, the bottled water market, and rare element extraction [4]. Hot spring waters are suitable for medical purposes especially for skin therapy owing to the presence of sulfur and sulphate ions [5]. Sulfur-rich hot springs treat skin issues like rashes and eczema, and may also help with dry scalp, arthritis pain, menopausal symptoms, and digestive problems. The mineralogy of the thermal waters corresponds to the geological formations present at the site and potentially indicates the depth of their source [6]. While people have bathed in geothermal and mineral waters for therapeutic and relaxation purposes for millennia, some sources are dangerously hot, causing scalding or even death [7]. The therapeutic use of natural mineral water to treat and cure disease, known as balneology, has a long history. Thermal springs are natural resources with the potential for significant economic contribution locally and regionally when optimally developed. However, the presence of toxic elements (such as arsenic and mercury), radioactive elements, and pathogens like meningitis-causing Naegleria fowleri and Legionella pneumophila in geothermal water necessitates careful decision-making regarding their use [9-11]. Eritrea is found in the Saharan and sub-Saharan region in the horn of Africa which lacks enough rainfall, classified with those which suffer from drought. There are three main drainage systems in Eritrea, which can be distinguished as the:

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- The Mereb-Gash and Tekeze-Setit rivers, flowing westward into the Nile River.
- The eastern escarpment is accompanied by the Barka-Anseba rivers, which flow eastward into the Red Sea.
- Along the southeastern border with Ethiopia, rivers drain into the closed Danakil Basin [12].

Along Eritrea's eastern escarpment, hot springs are located at various sites: Akwar and Maiwooi near Gahtelai; Garbanabra and Gelti near Irafayle, bordering the Gulf of Zula; and Elegedi in the Alid volcanic center. At their source, water temperatures range from 49.5°C to 100°C, with pH levels between 6.97 and 7.54.

Natural springs, rich sources of essential minerals, provide around 80 nutrients vital for over 7000 enzymatic processes in the human body. Balneologists recommend these mineral waters for therapeutic use, as common elements found in them have healing properties. The therapeutic effect occurs primarily through osmosis, where minerals are absorbed through the skin and into the bloodstream [13]. The composition of the hot spring water must be monitored regularly. This is because if the concentrations of some common elements are in a high concentration, for example, hydrogen sulfide exerts toxic and potentially fatal effects through the inhibition of cellular respiratory enzymes, resulting in cell anoxia and subsequent cellular damage.

The main suspected problems for the study were in depth studies were not carried out regarding to health benefits of the water collected from Akwar, Maiwooi, and Feshash and conducting research about the safety of these water source for drinking purpose.

In Northern Red Sea region, hot springs known with the name of Maiwooi, Akwar and Feshash are located near Gahtelay. Many people nationwide visit these places, particularly Maiwooi, to bathe in and drink the spring water for therapeutic relief from skin conditions, allergies, and other diseases. Observed significant benefits have created a growing demand, prompting the need for scientific analysis of the water's mineral properties.

The main objectives of the studies were to evaluate the chemistry of the hot-spring water sources by conducting the analysis of physiochemical and trace metals comparing to domestic use and expand the knowledge on the chemistry of the selected hot spring water sources in relation to the therapeutic use by leaving a window for further studies.

Water is considered as the origin of life and plays a vital role in different activities of life. Crucially, it facilitates functions such as digestion, absorption, thermoregulation, and waste elimination [14]. Water quality (its physical, chemical, and biological characteristics) is a principal factor governing health and disease in living organisms [15]. Globally, the physicochemical properties of hot spring waters are frequently analyzed and reported. Indian research encompasses springs such as Atri in Khurda District [16]. Recently, a significant 'Return to nature' trend has emerged, favoring natural treatment methods like therapeutic spring water use [17].

Thermal water, a type of hot mineral water with healing properties, is utilized in thermal establishments due to its health-promoting mineral salts, gases, and sediments. To be classified as mineral water under French law, it must originate from a defined spring and maintain identical composition and purity at both source and point of use [18].

The curative power of spring water stems from its diverse mineral content, which differs significantly between springs and regions. Hot springs, rich in approximately 80 essential nutrients, contribute to thousands of bodily enzymatic reactions. Therapeutic minerals including sodium, potassium, calcium, and magnesium, as well as trace elements such as iron, copper, manganese, and chromium, are absorbed through the skin by osmosis. An example is Aab-e-Shifa, naturally heated to 34°C, whose specific mineral profile makes it effective against skin diseases and other ailments [20]. Sulfate (SO_4^{2-}) enters water naturally as gypsum and other common minerals undergo leaching. The presence of a high concentration of SO_4^{2-} can be mainly due to rocks, in those areas the geology consists of a sedimentary rock, gypsum ($CaSO_4$) [21].

As a measure of hydrogen ion concentration, pH is linked to the surrounding terrain in natural waters. Crucially, it is the most important factor determining water's corrosive nature, where lower pH values typically indicate greater corrosiveness [22].

Minerals transfer to the skin through osmosis from mineral water and the bloodstream, contributing to healthy skin. During treatment, increased temperature promotes skin dilation, facilitating oxygen flow to the tissues [23]. The therapeutic potential of Aabe-Shifa water for skin diseases (e.g., scabies, acne, ringworm, arthritis[20]) and other conditions is attributed to key minerals (Na^+, K^+, Ca^{2+}, Mg^{2+}, Zn^{2+}) and its temperature (34°C). During bathing, water movement into or out of the body is governed by the osmolality of the bathwater and the bather's hydration, potentially resulting in mineral absorption or loss. Importantly, direct mineral absorption through the skin from thermal springs is limited and depends on the water's mineral concentration and chemical form. Instead, the curative skin effects appear to arise from local interactions between the mineral water and the skin [24]. Medical balneotherapists report that remarkably small amounts of therapeutic minerals, adsorbed through the skin, yield significant curative effects [19]. No

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research had been carried out before on the composition and health benefits of Maiwooi, Akwar and Feshash spring water. The aim of the study is to assess the physical and chemical parameters, the composition of water content and associate with the health benefits of these hot springs.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study area is located in the eastern escarpment of Eritrea at the Asmara-Massawa highway, near Gahtelay town. The thermal springs along the Asmara-Massawa highway are on a section of the middle to lower levels of the western escarpment of the Red Sea. The hot springs; Maiwooi (511850 E 1718952 N), Akwar (510345 E 1720218 N) and Feshash (514457 E 1714762 are located near Gahtelay at elevations of 330.1 344.5 and 325 m respectively. We performed physical and chemical analyses at the Maiwooi, Akwar, and Feshash spring water areas. These areas contain low-energy hydrothermal features, specifically warm and hot springs, defined relative to a temperature of 50 °C. Their near-neutral, chemically dilute waters flow quietly, with no observable steam separation or gas evolution.

2.2. Sample Collection

Sample collection is an important and integral part of research studies and it should be representative. A representative sample meets two key criteria: (1) the relative proportions of all pertinent components match those in the material being sampled, and (2) the sample's composition undergoes no significant alteration prior to testing. The water samples were collected in May from the selected study areas (FS-01, FS-02A, ARS-03A, ASE-04A, ASH-05A, ASER-06A, ASHD-07A, GFS-08A) as given in Table 1. The samples were collected in 500 mL and 1-liter polyethylene bottles which were thoroughly washed with detergent, dilute HNO_3 and deionized distilled water before use. In the field, the sampling bottles and their respective caps were rinsed three times with the water before sampling.

Two samples were collected from each four locations or sources and one sample each from the other four locations. The samples were taken for the physical and chemical analysis to be done in the water resource department (WRD) in Asmara. During the sampling time almost all the field parameters were measured at the time of sample collection.

Table 1: Location of Hot Spring Water Sources

Sample Code	Source Name	Samples	Location
FS-01	Felhit Spring 1	2	Mai wooi
FS-02	Felhit Spring 2	2	Mai wooi
ARS-03	Akwar Spring 3	2	Akwar
ASE-04	Akwar Spring 4 for eye	1	Akwar
ASH-05	Akwar Spring 5 for heart	1	Akwar
ASER-06	Akwar Spring 6 for ear	1	Akwar
ASHD-07	Akwar Spring 7 for head	1	Akwar
GFS-08	Gahtelay (Feshash) Spring 8	2	Gahtelay

3. EXPERIMENTAL

3.1 Chemicals and Materials Used

Sample pH was measured using a digital pH meter (Model HI 9828, HANNA instruments, Woonsocket, Rhode Island, USA). The electrical conductivity, temperatures and salinity of the samples was measured using a conductivity meter (Model WTW-Multi 197i 98, WTW, London, UK) and turbidity of the water samples was measured by a turbidimeter (Model HI88703, HANNA instruments, Woonsocket, Rhode Island, USA). Dissolved oxygen was measured by oxygenmeter (Model HQ30d HACH Instrument). A flame photometer (Model BMW XP PLUS, BWB TECHNOLOGIES, and Newbury, UK) was used for the determination of Na^+ and K^+ ions. Titrimetric was used for determining the total alkalinity of the samples. The analysis of trace metals was accomplished using HM3000 Metalyser instrument. The spectrophotometric determination of total iron, manganese, sulphate, nitrate, nitrite, fluoride, phosphate, Copper, Chlorine, Chromium, was done by a spectrophotometer (Model DR 2800, HACH, Loveland, CO, USA). The chemicals used in this study were HNO_3, H_2SO_4, PhosVer 3, 5ml SPANDS reagent, SulfaVer 4, FerroVer, NitraVer 5, NitriVer 3, citrate type buffer, diphenylearbrozon reagent, mercuric nitrate, Bromocresol green pillow powder, methyl red pillow reagent, ManVer 2 reagent, and CalVer 2 reagent, Cuver-1, DPD Free Chlorine, ChromaVer-3 and EDTA. All the chemicals used were of analytical grade.

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3.2 Sample Pretreatment

Samples were collected after the measurement of in situ. Prior to analysis, the samples were filtered to remove dust particles which could make some errors during the experimental procedures. In the process of filtration, 0.45 µm filter paper of a cellulose-acetate membrane was used. After doing the filtration process the eight prepared samples were directly analyzed for physicochemical analysis process. During the sample collection the samples for heavy metal analysis were acidified by adding 5 mL of HNO_3 (10%) to concentrate and protect from microorganism contamination of the samples.

3.3 Physicochemical Analysis

A total of eight samples were analyzed from eight sources. The field parameters like Temperature, pH, EC, salinity and DO were determined during the sample collection time. All preparation and analysis utilized chemicals, standards, and water of the highest analytical grade purity, including de-ionized water where required. Total alkalinity was determined by titration using H_2SO_4 and Bromcresol green-methyl red pillow powder as an indicator. Cl^- concentration in a similar manner was established by titrating using Mercuric nitrate and diphenyl cabazon reagent as an indicator. The determination of total hardness was also performed using standard EDTA titration with ManVer 2 reagent pillow powder. *t*-test was employed in order to make comparison of the ions that have therapeutic effects with that of WHO limits and error bars were utilized to present the level of ions for the sample sources.

3.4 Spectrophotometric Analysis

With the use of the reagents: FerroVer, SulfaVer 4, NitraVer 5, NitriVer 3, SPANDS, Molybdate, PhosVer 3 and sulfide 1 and 2, the concentration of total Fe^{2+}, SO_4^{2-}, NO_3^{3-}, NO_2^-, F^- and $PO_4^{3-}$was analyzed using a spectrophotometer (model DR-2800, HACH, Loveland, CO, USA) respectively.

3.5 Flame Photometer Analysis

A flame photometer (Model BMW XP PLUS, BWB TECHNOLOGIES, and Newbury, UK) was used to determine Na^+ and K^+. For Calibration, 300 mg/L standard, solution was prepared by taking 12 mL of 10,000 mg/L from the standard solution and adding 400 mL of deionized water.

3. RESULTS

4.1 Physicochemical Characteristics of Hot Springs

The efficacy of thermal water therapy is largely determined by physical parameters (pH, temperature, mineralization, conductivity) through their impact on chemical dissolution and reaction kinetics. Hypothermal waters promote decreased local metabolism, muscle spasm, edema, and nerve conduction, plus increased anesthesia. Hyperthermal waters, used for brief thermal stress, cause significant opioid peptide release from the skin, modulating pain thresholds. Variation in physicochemical properties of Maiwooi, Akwar and Feshash hot springs were summarized in Table 2. The results of the ions (Na^+, K^+, SO_4^{2-}, Ca^{2+} and Mg^{2+}) that have high therapeutic effect were shown respectively in Figures 1(a-e).

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Table 2: Physicochemical characteristics of water of Maiwooi, Akwar and Feshash Hot Springs along with WHO standards.

Parameters	WHO standard	Felhit FS-O1	Felhit FS-02A	Akhwar ARS-03A	Akhwar ASE-04A	Akhwar ASH – 05A	Akhwar ASER – 06A	Akhwar ASHD – 07A	Gahtelay GFS– 08A
pH	6.5 – 8.5	6.75±0.00	7.52±0.00	6.42±0.00	6.35±0.00	6.3±0.00	6.31±0.00	6.3±0.00	7.14±0.00
EC (µs/cm)	2000	942.00±0.00	958.00±0.00	1785.00±0.00	1950.00±0.00	1942.00±0.00	1936.00±0.00	1982.00±0.00	1079.00±1.00
Temperature (^{0}C)	25	60.40±0.00	47.20±0.00	50.70±0.00	38.20±0.00	39.30±0.00	43.00±0.00	36.60±0.00	42.20±0.00
TDS (mg/L)	1500	631.10±0.00	641.90±0.00	1196.00±0.00	1306.50±0.00	1301.10±0.00	1297.10±0.00	1327.90±0.00	722.93±0.65
Turbidity (NTU)	<5	0.28±0.00	1.19±0.01	4.78±0.01	0.08±0.01	1.61±0.02	0.24±0.02	11.28±0.06	2.69±0.01
TA (mg/L)	300	316.00±0.00	332.00±0.00	600.00±0.00	604.00±0.00	620.00±0.00	624.00±0.00	620.00±0.00	345±1.00
TH (mg/L)	500	40.00±0.00	42.00±0.00	80.00±0.00	64.00±0.00	76.00±0.00	78.00±0.00	80.00±0.00	76.00±0.00
Salinity (%)	<3%	0.30±0.00	0.30±0.00	0.80±0.00	0.80±0.00	0.80±0.00	0.80±0.00	0.90±0.00	0.30±0.00
DO	6.5-8	3.89±0.02	4.09±0.02	1.52±0.04	1.99±0.10	3.7±0.02	1.88±0.01	1.89±0.01	3.18±0.02
Na^+	200	198.03±0.15	208.36±0.32	401.36±1.06	404.06±5.03	406.03±3.43	407.70±2.05	412.26±0.74	211.03±4.73
K^+	12	14.13±0.31	14.43±0.30	23.03±0.21	26.30±0.46	26.30±0.56	25.90±0.30	26.66±0.42	13.33±0.23
Fe^{2+}	0.3	0.05±0.01	0.04±0.00	0.23±0.01	0.41±0.01	0.39±0.00	0.40±0.00	0.41±0.01	0.04±0.00
SO_4^{2-}	400	33.66±0.58	32.66±0.57	110.33±0.57	121.33±1.15	120.00±1.00	123.33±3.06	126.33±1.53	85.00±2.65
Cl^-	600	87.00±1.00	84.66±0.57	152.66±1.53	155.33±0.58	153.33±1.52	156.33±0.58	157.00±1.00	62.60±0.58
Mn^{2+}	0.5	0.06±0.00	0.05±0.00	0.40±0.00	0.40±0.00	0.40±0.00	0.45±0.00	0.40±0.00	0.10±0.00
F^-	1.5	5.77±0.05	5.78±0.01	5.53±0.04	5.20±0.02	5.62±0.06	5.44±0.17	5.83±0.04	3.83±0.07
Cu^{2+}	2	0.03±0.00	0.03±0.00	0.09±0.01	0.05±0.01	0.08±0.01	0.07±0.01	0.07±0.01	0.03±0.00
Cr^{3+}	0.05	0.06±0.00	0.06±0.00	0.07±0.00	0.06±0.00	0.06±0.00	0.06±0.00	0.06±0.00	0.06±0.00
PO_4^{3-}	1	0.09±0.01	0.08±0.01	0.33±0.01	0.14±0.01	0.31±0.01	0.30±0.01	0.30±0.01	0.15±0.01
Ca^{2+}	200	12.80±0.00	12.00±0.00	28.80±0.00	17.60±0.00	28.80±0.00	28.80±0.00	29.60±0.00	35.20±0.00
Mg^{2+}	150	1.92±0.00	2.88±0.00	1.92±0.00	4.80±0.00	0.96±0.00	1.44±0.00	1.44±0.00	1.92±0.00
HCO_3^-	50	385.50±0.00	405.00±0.00	732.00±0.00	736.90±0.00	756.40±0.00	761.30±0.00	756.40±0.00	420.90±1.20
NO_3^-	50	6.33±0.23	6.33±0.23	6.46±0.23	6.20±0.00	6.46±0.23	6.76±0.29	7.10±0.00	6.76±0.29
NO_2^-	3	0.23±0.00	0.02±0.00	0.02±0.00	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00	0.01±0.00

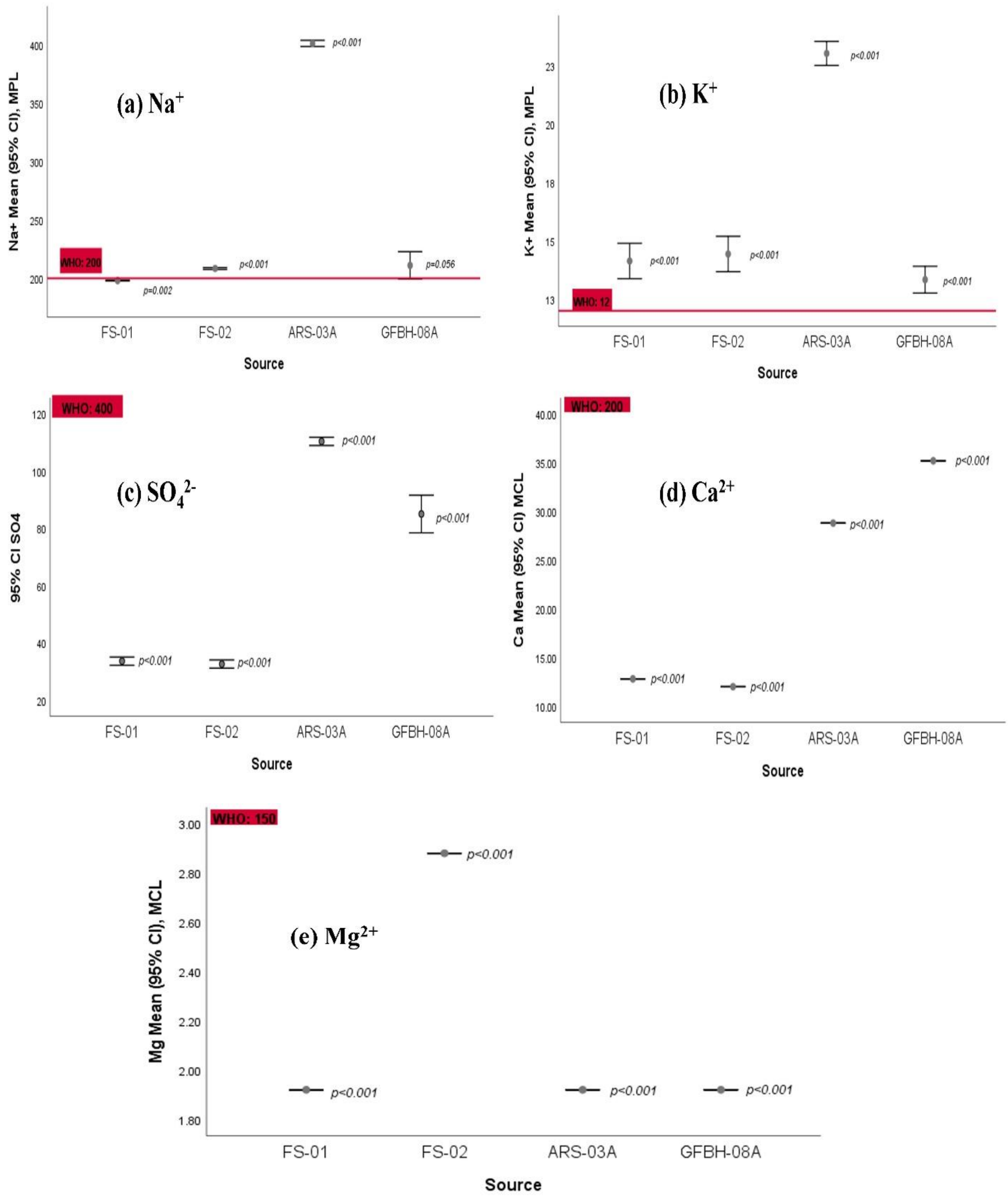

Figure 1: The comparison of Na^{+}, K^{+}, SO_4^{2-}, Ca^{2+} and Mg^{2+} ions with WHO limits in the samples.

The high abundance of SO_4^{2-} is clearly observed in the studies areas especially in Akwar. During the assessment made, SO_4^{2-} concentration in all the samples was agreed with the recommended guide line of WHO (32.66-126.33 mg/L). The high abundance of S^{2-} is an indication of the presence of SO_4^{2-} concentration in Akwar.

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4.2 Discussion

The pH varied from slightly acidic to slightly basic (6.3-7.52) in which the values for the samples from FS-01, FS-02A, and GFBH-01A were within the recommended guideline of WHO for drinking water (6.5-8.5) but for samples from ARS-03A, ASE-04A, ASH-05A, ASER-06A, ASHD-07A it was found to be 6.3-6.42. According to WHO standards the temperature of water used for drinking purpose should be maximum 25 ^{o}C. But in hot springs it always above 25^{0}c and in this study the temperature was found to be in the range from (36.6-60.4 ^{o}C). EC was found to be in the range from (942-1982) µs/cm which is within the permissible limit of WHO standard. The high electric conductivity in Akwar springs are due to the more salts that are dissolved in the water, as a result more current flows through it, that is it has high EC. High EC of the water increased its corrosive nature. Turbidity of the collected samples was found within the WHO standard limit which is (0.076-4.78 NTU) except for ASHD – 07A (11.28 NTU) this high levels of turbidity are associated with disease causing bacteria, this hinders straight-line transmission of light through the sample by causing scattering or absorption. Based on the WHO standards the total hardness of the drinking water should be less than or equal to 500 mg/l. In this study TH was found to be in the range from (40-80) which is within the soft water quality classification. Total alkalinity is due to dissolved CO_2 and it acts as a stabilizer for pH. It is measured using titration methods. The experimental alkalinity values (316-624 mg/L) exceeded the WHO permissible limit of 300 mg/L. This could be due to high dissociation of CO_2 as result the concentration of CO_3^{2-} (carbonate), HCO_3^- (bicarbonate) and lime stone which are the main constituent of alkalinity will be increased. According to WHO standards maximum TDS should be 1500 mg/L. TDS was found in the range of 631-1328 mg/L, which were within the permissible limit of WHO standard. The experiment was done in May and DO was found in the range of 1.52-4.09 mg/L.

4.3 Minerals (Chemicals) Quality Parameters

Surface water generally acquires inorganic minerals through stormwater runoff or from geological sources within the earth's crust. Water bodies gets polluted with trace metals from variety of sources such as chemical weathering of rocks and soil, decomposing vegetation, animal matter and human activities. The major cations, anions and trace elements analyzed in this study are discussed in the following sections and the result s were tabulated in Table 2.

Ca^{2+} provides hardness for water. It is low toxic compared to other metals. It is determined using titration methods. Based on the WHO standards amount of calcium should be <200 mg/L. The measured calcium (Ca^{2+}) concentration in the samples ranged from 12 to 35.2 mg/L, conforming to the permissible limit set by the WHO. Sodium (Na), another essential electrolyte, plays a critical role in enzyme activity, nerve and muscle function, and may help alleviate arthritic symptoms while stimulating the body's lymphatic system. Based on the WHO standards amount of Na^+ should be <200 mg/L. All of the samples that were analyzed were above the permissible limit (208.36-412.26 mg/L) except for the sample from FS-01 which has 198.033 mg/L which indicated that Na^+ is a dominant mineral in the chemistry of the water sources. More than 300 enzymes of our body require Mg^{2+} for their action. It metabolizes blood sugar into energy while enhancing skin health and radiance. According to WHO standards the amount of Mg^{2+} in a potable water required to be <150 mg/L. Based on the analysis made, the Mg^{2+} concentration of all samples was within the recommended guide line of WHO (0.96-4.8 mg/L). K^+ is useful for nerve transmission in all living organisms and is vital for heart and kidney health. It has measured using flame photometer. According to WHO standards the amount of K^+ in potable water is recommended to be < 12 mg/L. Five of the samples have K^+ above the WHO limit (23.03-26.66 mg/L) which makes the other three samples within the WHO limit (13.33-14.43 mg/L). According to WHO standards the amount of Mn^{2+} in a potable water has recommended to be <0.5 mg/L. The assessment made has indicated that Mn^{2+} concentration in all the samples was found to be within the WHO standard (0.05-0.45 mg/L). It acts as a cofactor for many enzymes. According to WHO standards the amount of Fe^{2+} in a potable water should be <0.3 mg/L. Four of the samples were having Fe^{2+} in concentrations within the allowable limit (0.04-0.23 mg/L) and the remaining samples were above the standard limit (0.39-0.413 mg/L). Bicarbonate (HCO_3^-) promotes the dilation of peripheral blood vessels, enhancing blood circulation. HCO_3^- concentration was very high and the range of HCO_3^- in the analyzed samples was found to be 385.5-761.3 mg/L. Cl^- acts as an essential electrolyte and maintains homeostasis, and transmits action potential in neurons. According to WHO standards the amount of Cl^- in a potable water has required to be <600 mg/L. All the examined samples were having Cl^- concentrations in the required WHO limit (62.6-157 mg/L). NO_3^- and NO_2^- ions comply with the WHO the permissible limit. Many ionic SO_4^{2-} are known and many of those are highly soluble in water and are used in water purification such as aluminum sulfate. Used as a coagulant for removing turbid materials from the water. Pain relief is another benefit, alongside its essential role in maintaining healthy skin, hair, and nails. And according to the WHO standards sulfate in drinking water would be required if it is < 400 mg/L. According to WHO standards the amount of F^- in a potable water should be <1.5 mg/L. The F^-concentration was found to be above the WHO standard limit (5.20-5.83 mg/L). This concentration is elevated and may adversely affect human health, increasing the risk of dental cavities, skeletal fluorosis, and bone fractures if consistently supplied as drinking water.

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CONCLUSION

The current study adds to our understanding of the physical and chemical properties as well as the health advantages of the three hot springs in Eritrea—Akwar, Maiwooi, and Feshash. It offers some initial details about the chemical and physical properties of these hot springs in Eritrea's Eastern escarpment. Generally, waters from the hot springs investigated in the present study cannot be considered as "pure" since all the samples contain higher turbidity which is above the WHO limit as well as the high levels of F^- were present in the samples. Based on the assessment made and comparing to the analyzed parameters with the given standard, the three Eritrean hot springs waters sources are not appropriate for human consumption. Although further studies together with the health professionals are required, the practice of using thermal spring water for therapeutic purposes should be continued, since these thermal waters contain high levels of dissolved minerals which can be absorbed by the skin and contribute to the health benefits of humans. In this study the analyzed therapeutic mineral includes Na^+, SO_4^{2-}, K^+, Mg^{2+}, Ca^{2+}, and the obtained results for these minerals are (208.36-412.26 mg/L), (32.66-126.33 mg/L), (13.33 - 14.43 mg/L), (0.96-4.8 mg/L) respectively. The high amount of SO_4^{2-} and Na^+ ions shows that the health benefits of the spring water for the skin relief, enzyme operations, nerve and muscle function, and alleviating arthritic symptoms and stimulates body's lymphatic system. In conclusion, the presence or absence of the microbial species of the hot spring water is seasonal. The previous report of WRD show that there is a positive test of microbial during the rainy season. However, the microbial test is zero in the absence of rain as the temperature in this particular period is very high reaching at 66 ºC although some bacteria which are resistant to very high temperature could exist at a particular season. Total of 22 questionnaires were distributed among individuals from different places who have visited to these thermal waters. The feedback from the questionnaire suggested that muscle, joint problem and skin diseases were the most common and it was observed changes (above 50%) after bathing in these hot springs. It is very important that to carry out additional studies on the physical and chemical analysis together with the health professionals on hot springs in different seasons as well as monitoring the sites on a regular basis.

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Conflict of Interest

The author(s) do not have any conflict of interest.

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Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Author Contributions

AH, and ET: Supervision and review

AH: Conceptualization, supervision, review, and editing.

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KS: Review, and editing

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

Not applicable

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