ORIGINAL ARTICLE

Assessment of physicochemical and bacteriological analysis of the hot water spring, Al Aridhah, Jazan Province, Saudi Arabia

Mohammad Firoz Alam[1]*, Sivakumar Sivagurunathan Moni[2], Elaf Makki Mohammed Kinani[2,3], Khan Tabbasum Tanweer[4]

[1]Department of Pharmacology and Toxicology, College of Pharmacy, Jazan University, Jazan, Saudi Arabia, [2]Department of Pharmaceutics, College of Pharmacy, Jazan University, Jazan, Saudi Arabia, [3]Department of Pharmacy, Al Thagar Hospital, Jeddah, Saudi Arabia, [4]Department of Physiology, Faculty of Medicine, Department of Jazan University, Saudi Arabia

Abstract

Introduction: Balneotherapy is the medicinal use of thermal water from a natural spring. Saudi Arabia has blessed with many hot water springs (HWSs) across the country. One among them is Al Aridhah, situated in Jazan Province. The present work is focused on analyzing physicochemical and bacteriological load in HWS samples. **Materials and Methods:** The physicochemical parameters of HWS were determined by performing dissolved oxygen (DO), total dissolved solids (TDS), pH, oxidative reduction potential (ORP), zeta potential (ZP), PDI, and % PDI before and after open-air exposure of HWS for 2 weeks. The bacteriological load of HWS was analyzed by determining colony-forming unit on the agar plates before and after open-air exposure. **Results:** The level of DO, pH, TDS, conductivity, ORP, ZP, PDI, % PDI, and the bacteriological load was increased after exposure to open air for 2 weeks. The present study suggested that physicochemical parameters were suitable except TDS level. The HWS showed a higher TDS level that exceeds the World Health Organization standard limitation values, indicating that the water is not suitable for drinking purposes. However, HWS can be used for medicinal purposes externally. **Conclusion:** Fresh hot water spring of Al Aridhah showed excellent physicochemical characterization except TDS and it was found to contain insignificant bacterial contamination.

Key words: Balneotherapy, hot water spring, physicochemical characterization, bacteriological load

INTRODUCTION

The quality of water highly influences human health. Interestingly, the quality of the water is greatly influenced by topography, geological structure, and climatic condition.[1] Spring is the opening of the natural discharge of water at the earth's surface from underground resources. Balneotherapy is the use of natural thermal water from spring to heal many diseases.[2] Hot springs are also termed geothermal springs.[3] Worldwide, the hot water springs (HWSs) are the notable miracle of nature blessing and reported as medicinal significance, such as reducing stress, soreness, and skin diseases. Conventionally, in Saudi Arabia, many HWSs have been identified due to their geological structure.[4] Saudi Commission for Tourism and National Heritage in 2018 has encouraged business people to invest in developing medical tourism in the Kingdom.[5] Al Aridhah of Jazan Province is situated in the Southwestern part of Saudi Arabia and has been known and famous for HWSs. However, the local public has had access to the HWS for medicinal use for a long time, but the pharmaceutical significance of the HWS of Al Aridhah, which is not explored yet. Based on this reason, the work had been designed to analyze the physicochemical and microbiological characterization of HWS. The outcomes of the finding will serve to establish the pharmaceutical importance.

Address for correspondence:
Dr. Mohammad Firoz Alam, Department of Pharmacology and Toxicology, College of Pharmacy, Jazan University, Saudi Arabia.
E-mail: firozalam309@gmail.com

Received: 10-08-2021
Revised: 10-12-2021
Accepted: 22-12-2021

MATERIALS AND METHODS

Study Area and Collection of Water

Al Aridhah of Jazan Province in the Southwest part of Saudi Arabia are situated in the Red sea's coastal region. Its geographical area coordinates 17° 9' 0" North and 42° 30' 0" East [Figure 1]. The hot water stream is flowing unidirectionally and properly channelized. The water stream is surrounded by palm trees and shrubs, which looks like beautiful greenery [Figure 2]. The water sample was collected in 1 L sterile glass bottle by holding the glass bottle in a flat position at the running water stream until filling. The bottle was closed immediately after filling with hot water from the spring and transported immediately to the laboratory for further analysis.

Chemicals and Media

All analytical grade chemicals with high purity were purchase from the Sigma-Aldrich, USA. Agar and media used for antibacterial analysis were purchased from HiMedia, Laboratories GmbH, Germany.

Physicochemical Analysis of HWS

The various parameter studies for the analysis of hot spring water were performed immediately after collecting samples and after 2 weeks exposing the water samples in the open air by placing 30 ml of water sample in a Petri dish and half-opened. The physicochemical characterization of the hot water sample was analyzed for dissolved oxygen (DO), pH, conductivity, total dissolved solids (TDS), electric potential, zeta potential (ZP), polydispersity index (PDI), and zeta size analysis. In brief, DO was determined using a DO meter, Lutron DO-5509, Taiwan, and the value of DO is expressed in milligrams per liter (mg/L). The TDSs measure the dissolved inorganic salts and organic matters in drinking water, and the value was expressed in parts-per-million (ppm). Both pH and oxidative reduction potential (ORP) were measured by Oakton pH 700, a benchtop meter, Oakton meter, USA. The redox potential is expressed in the millivolt (mV).

ZP is the electrical charge that develops at the interface between a solid surface and its liquid medium. It monitors the water clarification capabilities by measuring the repulsive interaction between the dissolved particles, which migrates toward the electrode of opposite electric charge at a specific velocity. ZP is expressed as mV. The electric conductivity was also measured and described in millisiemens per centimeter (mS/cm). The PDI is the breadth of the molecular weight distribution and measures the deviation from dispersion uniformity. Particle size analysis is the measure to understand the size of the particle's composition of water. ZP, PDI, and zeta size analysis were performed using Zetasizer Nano S, Malvern Instruments, U.K.

Bacteriological Load Analysis of HWS

The bacterial growth quality was assessed by determining the colony-forming unit (CFU) on agar plates. Before and after exposure to open air, 100 µl of HWS was placed on Mueller-Hinton agar plates, and then, the HWS was spread thoroughly throughout the agar surface. Then, the plates were incubated at 37°C in a bacteriological incubator for 24 h. The growth of the bacterial colony was expressed as a colony.

RESULTS AND DISCUSSION

The physicochemical and bacteriological parameters such as DO, pH, conductivity, TDS, electric potential, ZP, and PDI were carried out of HWS. Table 1 depicts the physical characterization of the Al Aridhah HWS. DO is one of the

Figure 1: The map shows Al Ardha of Jizan Province in the southwest part of Saudi Arabia which is situated in the coastal region of Red sea. Its geographical area coordinates 17° 9' 0" North and 42° 30' 0" East

most critical parameters that determine the quality of water. The DO of HWS, Al Aridhah, was found to be 6.6 mg/L before open-air exposure. An earlier report suggested that the DO concentration of the spring-fed pond and spring water gushing from the river bed (St. C) was 6.88 mg/L.[6] ZainiHamzah *et al*., 2013, reported the physicochemical characters of various hot springs and stated that the level of DO was 1.97–5.27 mg/L varied with geological location.[7]

Interestingly, the concentration of DO was decreased when the water samples were exposed to open air for 2 weeks. It might be due to bacterial contamination reflected in bacterial load studies performed in this study. Thus, decreased DO indicate the bacterial contamination of water since bacteria can consume oxygen of water for survival.

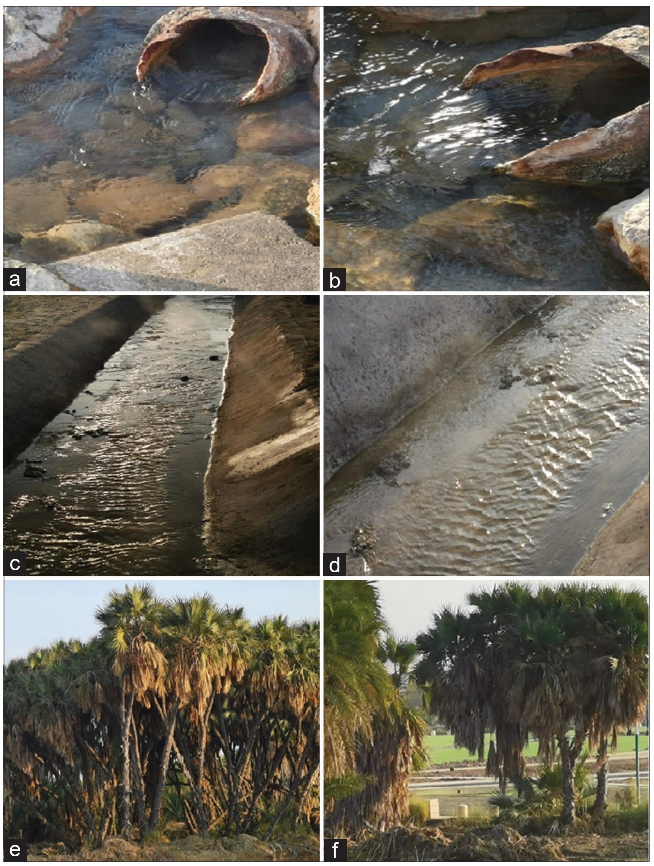

Figure 2: The location of study area, hot water spring, Al Aridhah. (a) The ventral view of the water flow from the hole opening of a rock. (b) Dorsal view of the opening of the water flow from the hole opening of a rock. (c) The longitudinal view of a channel through hot water flow unidirectionally. (d) Zoomed view of hot water flow unidirectionally. (e and f) Natural beauty around the hot water spring habitat with palm trees with shrubs

PH is an essential factor influencing water quality by regulating the solubility of chemical constituents such as phosphorus, nitrogen, carbon, and heavy metals. The present study showed that the pH of HWS was 7.39 before open-air exposure and 8.08 after open-air exposure. The quality of soil and rocks influences the alkalinity of water from natural resources through the water flows since they contain various salts and minerals.[8] Notably, the pH of the water sample was increased slightly after exposure to the open air. The study on pH indicates that HWS, Al Aridhah has drinking water quality as other commercially available bottled drinking water.

TDS indicates the presence of inorganic salts and organic matters in water. In this study, HWS showed a very high TDS value of 1915 ppm before exposure to open air. However, after exposure to open air, the TDS value was increased above 2000 ppm. In 2013, Fawaz Al-Badai *et al*. reported that the TDS value of Semenyih River, Selangor, Malaysia, was ranged from 17.66 to 80 mg/L during the rainy season.[9] An earlier report showed that the TDS value was observed between 130 and 18,570 mg/L in 86 thermal water samples.[10] According to the World Health Organization TDS report (WHO, 1996) on water quality, if water showed that <300 ppm is an excellent grade of water.[11] In this study, the TDS value was very high, so the water is not suitable for drinking water through the pH was ideal. Interestingly, the TDS was further increased when the HWS was further exposed to open air, probably due to dust accumulation.

The geological area highly influences the electric conduction of water through the water flows. Studies suggested that naturally, the water sample has less conductivity. The lesser conductivity is due to the water passage through granite bedrock since it contains inert materials.[12] However, when the natural perennial stream passes through the clay, the soils show higher conductivity due to ionizing materials.[13] The present study showed that the electrical conductivity of HWS Al Aridhah was 4.10 millisiemens which is equivalent to 4100 microsiemens indicating the minerals rich water. An earlier report showed that the electrical conductivity of natural water varied from 30 to 70,000 microsiemens.[14] However, the conductivity increased further when the water sample was exposed to open air due to bacterial contamination.

Table 1: Physical characterization of various water before and after exposure to open air

Sample analysis	DO (mg/L)	pH	TDS ppm	Conductivity (mS/cm)	ORP (mV)	Zeta potential (mV)	PDI	% PDI	Bacterial load CFU/ML
Phase 1	6.6	7.39	1915	4.10	−17.5	−6.88	0.785	88.6	2×10^{-3}
Phase 2	4.8	8.08	Above 2000	4.78	−66.9	-	1	32.4	8×10^{-3}

DO: Dissolved oxygen, pH: Scale used to specify how acidic or basic, EC: Electrical conductivity, TDS: Total dissolved solid, ORP: Redox potential, PDI: Polydispersity index. Phase 1: Water sample was analyzed immediately after sampling. Phase 2: Water sample was analyzed by exposing to open air and incubated at room temperature for 2 weeks

ORP is otherwise called redox potential, which measures electric potential energy per unit of charge. ORP is an important parameter to analyze the quality of drinking water.[15] In the present study, the ORP value of HWS Al Aridhah was −17.5 mV before open-air exposure. Still, the ORP value was increased to −66.9 mV after open-air exposure indicated bacterial contamination. A recent research report showed that the ORP value of groundwater ranged from −165 to −59 mV.[16] The study suggested that the ORP value was highly influenced by geochemical modeling.

ZP is a magnitude to monitor the water clarification capabilities by measuring the repulsive interaction between the dissolved particles that migrate toward an opposite electric charge electrode at a specific velocity.[17,18] In this study, the ZP of HWS was −6.88 mV. ZP varied and could not detect when the water was exposed in the open air, indicating water contamination. PDI of HWS before open-air exposure was 0.785, and the percentage PDI was observed at 88%. The PDI was increased to the maximum level and reached one after open exposure to air. Interestingly, the % PDI was decreased tremendously indicated that the water has sediments after exposure to open air.

The quality of HWS was directly linked with microbial contamination. This study observed the bacterial load as 2×10^{-3} CFU/mL before open-air exposure. However, the bacterial load was increased 4 times to 8×10^{-3} CFU/mL after open-air exposure. ORP values can easily access water contamination since the oxidative, reductive reaction depends on the biodegradation process. In this study, the ORP values were increased after open exposure to air which can be linked to the bacterial load of the water sample. Thus, open exposure to air led to bacterial contamination in the HWS, Al Aridhah.

CONCLUSION

The present study suggested that HWS, Al Aridhah showed excellent physicochemical characterization except for TDS. The study indicated that bacterial contamination was observed after open exposure to air *in vitro*. Further study should be conducted to analyze heavy metals and the suitability of medicinal use of HWS, Al Aridhah, to confirm the beneficial properties for human health.

REFERENCES

1. Balasubramanian N, Sivasubramanian P, Soundranayagam J, Chandrasekar N, Gowtham B. Groundwater classification and its suitability in Kadaladi, Ramanathapuram, India using GIS techniques. Environ Earth Sci 2015;7:1-23.
2. Sergio D, Franco B, Marco B, Giovanni S. Thermal waters and hermetic effects of hydrogen sulfide on inflammatory arthritis and wound healing. The Science of Hormesis in Health and Longevity. Ch. 10. United States: Academic Press; 2019. p. 121-6.
3. Darwin AT, Carlos Daniel AM, Elisabeth RP. Geothermal and mineralogic analysis of hot springs in the puracé-la mina sector in Cauca, Colombia. Geofluids 2019;2019:3191454.
4. Alsaleh MA. Natural springs in Northwest Saudi Arabia. Arab J Geosci 2017;10:335.
5. Al-Kinani M. Saudi Commission for Tourism and National Heritage Uses hot Springs to Boost Investment in Medical Tourism. India: Arab News; 2018.
6. Asaeda T. The effect of spring water on the growth of a submerged macrophyte *Egeria densa*. Landsc Ecol Eng 2014;10:99-107.
7. Hamzah Z, Rani NL, Ahmad S, Khalik WA. Determination of hot springs physico-chemical water quality potentially use for balneotherapy. Malaysian J Anal Sci 2013;17:436-44.
8. Deborah C. Water Quality Assessments-a Guide to Use of Biota, Sediments and Water in Environmental Monitoring. 2nd ed. Geneva: World Health Organization; 1996.
9. Al-Badaii F, Shuhaimi-Othman M, Gasim MB. Water quality assessment of the Semenyihriver, Slangor. Malaysian J Chem 2013;2013:871056.
10. Subtavewung P, Manop R, Jarin T. The Characteristic and Classification of Hot Springs in Thailand. Antalya, Turkey: Proceedings World Geothermal Congress; 2005.
11. World Health Organization. Total Dissolved Solids in Drinking-water, Guidelines for Drinking-water Quality, Health Criteria and other Supporting Information. 2nd ed., Vol. 2. Geneva: World Health Organization; 1996.
12. Rachna B, Disha J. Water quality assessment of lake water: A review, sustain. Water Resour Manage 2016;2:161-73.
13. Gupta T, Paul M. The seasonal variation in ionic composition of pond water of lumding, Assam, India. Curr World Environ 2013;8:1.
14. Mccleskey RB, Nordstrom DK, Ryan JN. Electrical conductivity method for natural waters. J Appl Geochem 2011;26:227-9.
15. Matsayesva O. Influence of redox potential of different water quality on the human Blood. Environ Technol 2017;33:34-8.
16. Wątor K, Dobrzyński D, Sugimori K, Kmiecik E. Redox potential research in the field of balneochemistry: Case study on equilibrium approach to bioactive elements in therapeutic waters. Int J Biometeorol 2020;64:815-26.
17. Nobbmann U, Morfesis A, Billica J, Gertig K. The role of zeta potential in the optimization of water treatment. Nanotech 2010;3:605-7.
18. Mroczko D, Zimoch I. The use of zeta potential measurement as a control tool of surface water coagulation. J Ecol Eng 2020;3:237-42.

Source of Support: Nil. **Conflicts of Interest:** None declared.