



A Comparative Study of Water Quality Between Hot Spring and Borehole Waters of Mara, Shinyanga and Manyara Regions of Tanzania

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Abstract: This study conducted for the comparison of physico-chemical parameters between hot springs and borehole waters. Fourteen samples were collected at Mara, Shinyanga and Manyara in Tanzania. Multimeter used for the analysis of physical parameters pH, EC, TDS, salinity and turbidity. Titrimetric methods were used for the determination of Cl^- , total hardness, Ca^{2+} and Mg^{2+} . UV-Vis. Spectrophotometric method for NO_3^- , SO_4^{2-} , F^- , Fe^{2+} and Mn^{2+} and Flame Atomic Absorption Spectrometer for Cd^{2+} , Zn^{2+} , Ni^{2+} , Cu^{2+} and K^+ . The EC, TDS, salinity, turbidity, Cl^- , NO_3^- , SO_4^{2-} , F^- , Mn^{2+} and Cu^{2+} are higher (pH = 7.44-9.42, EC = 4251.33-15334 $\mu\text{S}/\text{cm}$, TDS = 2079-7526.7 mg/L, salinity = 2.2-8.67 ppt, Cl^- = 189.3-3577.6 mg/L, SO_4^{2-} = 11.83-1353.33 mg/L, F^- = 4.68-18 mg/L, Mn^{2+} = 1.03-2.0 mg/L, Cd^{2+} = 0.01-0.05 mg/L, Cu^{2+} = 0.37-0.93 mg/L and K^+ = 44-100 mg/L) in hot springs than borehole waters (pH = 6.36-6.58, EC = 270.0-2674.64 $\mu\text{S}/\text{cm}$, TDS = 123.67-1305 mg/L, salinity = 0.03-1.37 ppt, Cl^- = 6.25-659.93 mg/L, SO_4^{2-} = 28.92-493.33 mg/L, F^- = 0.89-3.0 mg/L, Mn^{2+} = 0.3-1.70 mg/L, Cd^{2+} = 0 mg/L, Cu^{2+} = 0.49-0.64 mg/L and K^+ = 16-52 mg/L). The t-test at the probability 0.05 showed that there is significant difference of the parameters pH and Ni^{2+} between hot spring and borehole waters. Some of the parameters are at higher levels than permissible values for both hot spring and borehole waters. Therefore, there is a need of treatment for these waters before using for domestic purpose.

Keywords: Hot Spring Water, Borehole Water, Physico-chemical Parameters, Titrimetry, Spectrophotometry, FAAS

1. Introduction

Water is a transparent and nearly colorless substance which is the main constituents of earth and fluids of most living organisms. Earth's surface water moves continuously through the water cycles. Okoro, et al., (2017) identified that the large amounts of water are chemically combined or adsorbed in hydrated minerals [1].

Groundwater is naturally recharged by rain water and snow melt or from water that leaks through the bottom of some lakes and rivers [2]. This water stored in the layers beneath the surface and helps protecting from contamination from its quality. However the temporal and spatial distribution of both surface and groundwater sources were not uniform and is controlled by climate and geology [3]. Therefore, water from underground contained 95% of the

ions such as Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl^- , SO_4^{2-} and F^- .

Water recharged and percolates deeply enough into the crust and heated as it comes into contact with hot rocks [4]. That influences the soluble mineral contents in hot waters and varies widely in their mineral composition of the local area. Kifua, (1958) identified more than 15 hot springs with above 40°C found over and near the active rift segments in Tanzania [5]. Locations of hot springs are usually depending on the East African rift valley that indicates geothermal activity [6]. The hot springs found in Mara, Shinyanga and Manyara are located at the swamp areas and bedrock surfaces. Borehole water is constructed by a narrow shaft bored in the ground vertically for the extraction of water [7]. Most of these boreholes support many people of urban, rural and remote areas around Tanzania.

The major source of groundwater in Mara and Shinyanga

regions are from the Lake Victoria basin, but in Manyara it is internal drainage basin. Water quality assessment in different water sources is very important in order to know the levels of natural and human induced contaminants for public and ecosystem health management interests. Therefore, hot springs being a part of water source in order to solve the water scarcity in the areas Majimoto, Uzogore, Masware and Lalaji, this study conducted to compare the physico-chemical parameters of hot spring water with that of borehole and permissible levels of drinking water from Tanzania Bureau of Standard (TBS) and World Health Organization (WHO). The parameters which help to define water quality includes: turbidity, EC, pH, TDS, total hardness and anions such as Cl^- , SO_4^{2-} , F^- , NO_3^- and others cations K^+ , Ca^{2+} and Mg^{2+} .

2. Materials and Methods

2.1. Study Area

The selected regions of this study comprised Mara, Shinyanga and Manyara as shown in Figure 1, Mara region ($1^{\circ}45'00''$ S and $34^{\circ}00'00''$ E) in which Serengeti district with one hot spring site called Majimoto. Shinyanga region ($3^{\circ}45'00''$ S and $33^{\circ}00'00''$ E) in which Shinyanga town contained one hot spring site known as Usangore/Uzogore. In Manyara region ($4^{\circ}45'00''$ S and $36^{\circ}40'00''$ E) there were two hot springs for the study that found in two districts Babati and Hanang'i namely Masware and Balangida, respectively. Borehole waters were found in the community with approximate distance of 0.5 km from hot spring sites.

2.2. Sample Collection and Storage

Before collection of the water samples a container of

volume 1 L was cleaned through washing with distilled water three to four times and rinsed with water sample in order to avoid contamination [8]. Two kinds of water samples, hot springs and borehole waters were collected. A total of 7 sites for water sample collected with two sets of water samples to each site. A total of fourteen samples were collected, whereby seven samples for physical and some chemical parameters and other seven used for FAAS analysis. Water samples from hot springs as well as borehole waters collected periodically for every 20 minutes for 1 hour with a volume of 900 mL from each sample.

After collection in each study site all samples were labeled as observed in Table 1 with specific descriptions mainly name and code of the sample then sealed to protect from atmospheric reactions. Water samples were transported by maintaining temperature at $4^{\circ}C$ with a thermos cool box. Water samples collected for the analysis of heavy metals were prepared separately by treating with 2 mL of HNO_3 for 1 L of water sample in order to prevent adsorption on the walls of the container. Water samples transported to Dodoma Urban Water Supply and Sewerage Authority (DUWASA), Mwanza Zonal Water Quality (MZWQ) and Geological Survey of Tanzania (GST) laboratories for further analysis.

Table 1. Coding and labeling of water samples collected in the study.

Water sampling sites	Code/Label
Hot spring sampling at Majimoto - Mara	HSW ₁
Hot spring sampling at Usangore - Shinyanga	HSW ₂
Hot spring sampling at Masware - Manyara	HSW ₃
Hot spring sampling at Lalaji (Balangida Lalu) - Manyara	HSW ₄
Borehole water sampling at Majimoto - Mara	BHW ₁
Borehole water sampling at Uzogore - Shinyanga	BHW ₂
Borehole water sampling at Masware - Manyara	BHW ₃



Figure 1. Tanzania map showing the selected hot spring sites and borehole waters with their respective regions.

2.3. Water Sample Analysis

Four methods were used to analyze nineteen physico-chemical parameters in each sample. Before analysis the instruments were calibrated with standard solutions prepared based on the respective ions or parameter analysed in order to get accuracy and precision of the respective instruments. All the chemicals used in this study were analytical grade from the manufacturer Sigma Aldrich, Germany. Buffer solutions for pH's 4, 7 and 10, EC standard solutions 1.5, 147 and 1413 $\mu\text{S}/\text{cm}$ used to calibrate pH meter and multimeter for analyzing pH, EC, TDS and salinity. Cl^- analyzed by titrating with AgNO_3 using K_2CrO_4 as an indicator. Buffer solution ($\text{NH}_4\text{Cl} + \text{NH}_4\text{OH}$) and NaOH solution used to raise the pH in the determination of total hardness and Ca^{2+} , respectively. Disodium salt of EDTA (0.01 M) was used to determine the total hardness and Ca^{2+} with EBT and Ammonium purpurate as indicators.

UV-Vis spectrophotometry was used to analyze some of the ions present in water samples using respective powder pillows. NitraVer 5 nitrate pillow was used for the analysis of NO_3^- at λ_{max} 500 nm. SulfaVer 4 sulphate pillows were used to analyse SO_4^{2-} at λ_{max} 450 nm. SPADNS reagent used to analyse F^- at λ_{max} 580 nm. FerroVer Iron pillows were used for the analysis of Fe^{2+} at λ_{max} 510 nm. Buffer powder citrate pillows with sodium periodate pillows were used to analyze Mn^{2+} at λ_{max} 525 nm.

FAAS and acetylene-air were used for the analysis of heavy metals with acidified water samples for the analysis of metals Cd^{2+} , Zn^{2+} , Ni^{2+} , Cu^{2+} and K^+ in water samples with respective wavelength 228.8 nm, 213.9 nm, 232 nm, 324.7 nm and 766.5 nm.

2.4. Data Analysis

Sample collection, handling, preservation and analyses were done by following standard procedures recommended by the American Public Health Association which ensure data quality and consistency. For every measurement, triplicate readings recorded and mean values presented with their standard deviations. Numerical data obtained from experimental work were analyzed by t-test and ANOVA using Microsoft Excel 2007. The numerical data of physico-chemical parameters obtained in this study were compared with the standard values of Tanzania Bureau of Tanzania (TBS) and WHO.

3. Results and Discussion

3.1. Temperatures of Hot Spring Water Samples

In Manyara region two hot springs were analyzed which are Balangida Lalu and Masware. Balangida Lalu hot spring water drained, gathered and formed as ponds at large swamp area. Its temperature ranged 33–36°C. Masware hot springs are divided into two faults associated with small swamps and its temperature ranged 41–48°C. One hot spring found in

each of Mara and Shinyanga regions with the site names Majimoto and Usangore, respectively contained high temperatures that range between 58 and 67°C. Animals and human use hot water directly from spring sources for drinking and bathing.

The significance of temperature is the identification of distances between rocks in the earth crust. Groundwater temperature increases with depth which in turn increase dissolved minerals and silicates with mud pot [9]. The measure of temperature helped to identify existence of hot springs in the study areas which distinguishes from borehole water.

3.2. pH, EC, TDS, Salinity and Turbidity

The ranges of pH, EC, TDS, salinity and turbidity are 6.36-9.34, 270-15334 $\mu\text{S}/\text{cm}$, 123.67-7526.7 mg/L, 0.03-8.67 ppt and 0.55-26.23 NTU, respectively (Table 2). Higher pH of 9.42 recorded in Balangida Lalu (HSW_4) hot spring water. Permissible levels of pH in drinking water are 6.5-9.2 and 6.5–8.5 according to the guidelines of TBS and WHO, respectively. Toure, *et al.*, (2017) identified higher pH values in hot spring compared with the borehole water due to the presence of the high levels of HCO_3^- or CO_3^{2-} and OH^- which causes the alkalinity in water [10]. The t-test shows that there are significant differences in pH values between hot spring and borehole water with p-value less than 0.05 (0.016 < 0.05).

The values of EC, TDS and salinity found higher in Balangida Lalu (HSW_4) hot spring with 15334 $\mu\text{S}/\text{cm}$, 7526.7 mg/L and 8.67 ppt, respectively. Lower values found in Masware hot spring (HSW_3) than other hot springs Majimoto (HSW_1) and Usangore (HSW_2). EC, TDS and salinity values were less in boreholes waters compared to that of hot springs. The increase in the values of EC leads to increase in the TDS and salinity values as it is reflected in the data (Table 2). The ions responsible for EC of water come from dissolved salts and inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds [11]. Dissolution of ions generally occurs in the groundwater by rapid ion-exchange between the soil and water. Instead of soil if there is a rock with insoluble minerals then that leads to low EC of water. The variation in the values of salinity caused by rock weathering that allows salt to be released as minerals break down over time as well as raise of water tables [12]. Permissible level of EC in drinking water is 2500 according to WHO. Permissible levels of TDS according to guideline of TBS ranges between 500-1200 mg/L and that of WHO is 1000 mg/L. All the hot spring water under study and one borehole water (Masware, BHW_3) have higher values of EC and TDS than permissible levels of drinking water. In the t-test, the obtained p-values were greater than 0.05, (p for EC = 0.06, p for TDS = 0.074 and p for salinity = 0.083) which is proving that there are no significant differences of EC, TDS and salinity between hot springs and borehole waters. Turbidity values ranged between 0.4 and 26.23 NTU. The permissible levels are ranged 5-25. All the water samples

having turbidity values with in the guideline values except Majimoto borehole water (BHW1).

Table 2. Physical parameters analysed by multimeters.

Samples	pH			EC			TDS			Salinity			Turbidity		
	Mean	SD (n=3)	% RSD	Mean ($\mu\text{S/cm}$)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (ppt)	SD (n=3)	% RSD	Mean (NTU)	SD (n=3)	% RSD
HSW ₁	9.07	0.06	0.71	9523.67	7.23	0.07	4233.7	9.07	0.21	4.57	0.15	3.35	0.4	0.04	9.01
HSW ₂	8.53	0.03	0.31	5740.33	1.53	0.03	2583.7	4.51	0.18	2.6	0.2	7.69	2.29	0.02	0.67
HSW ₃	7.44	0.04	0.49	4251.33	5.13	0.12	2079	9.85	0.47	2.2	0.2	9.09	4.11	0.02	0.49
HSW ₄	9.42	0.03	0.27	15334	30.3	0.2	7526.7	4.51	0.06	8.67	0.15	1.76	5.43	0.25	4.63
BHW ₁	6.44	0.1	1.53	270	3	1.11	123.67	2.08	1.68	0.03	0.06	173.2	26.23	0.31	1.17
BHW ₂	6.58	0.16	2.41	1194	4	0.34	540	3.61	0.67	0.3	0.1	33.33	0.64	0.06	9.11
BHW ₃	6.36	0.22	3.42	2674.67	4.51	0.17	1305	13.08	1	1.37	0.15	11.18	0.55	0.01	1.82
TBS	6.5-9.2			-			500-1200			-			5 to 25		
WHO	6.5-8.5			2500			1000			-			5 to 25		

3.3. Chlorides

The concentrations of Cl^- in hot spring ranges from 189.30 to 3577.6 mg/L while in borehole water it is from 6.25 to 659.93 mg/L (Table 3). Chloride ions leached from various rocks into both hot spring and borehole waters by weathering and transported to closed basin because of high mobility of chlorides [13]. Permissible levels of Cl^- in drinking water according to TBS and WHO drinking water guideline are 200 to 800 mg/L and 200 to 600 mg/L respectively. From the data obtained, it is observed that there are high levels of Cl^- in hot spring water compared to permissible levels as well as values of borehole waters. High levels of Cl^- in hot spring water give objectionable taste. There is no significant difference of chloride concentrations between hot spring and borehole waters from the t-test with p-values 0.35 which is greater than 0.05.

3.4. Total Hardness, Calcium and Magnesium

The values of total hardness, Ca^{2+} and Mg^{2+} in all the sites under this study are shown in Table 3. Total hardness increases the concentration of Ca^{2+} and Mg^{2+} and also Ca^{2+} is more abundant than Mg^{2+} . Total hardness ranges from 1.59-435.98 mg/L for hot spring and 22.08-430.4 mg/L for borehole waters. Ca^{2+} values ranges 0.26-103.9 mg/L in hot spring and 5.77-51.28 mg/L in borehole waters. It is observed that more concentrations in Ca^{2+} in borehole than hot spring water except for the site Masware (HSW₃). The concentration of Mg^{2+} ranges 0.24-42.92 mg/L in hot springs and 1.11-73.49 in borehole waters. Ca^{2+} and Mg^{2+} are responsible for hardness in water. Their presence is the result of dissolution of these salts when the flowing water comes in contact with rock of carbonate minerals such as calcite and dolomite [14]. Permissible levels of hardness are from 500-600 mg/L and 300 mg/L according to TBS and WHO respectively. Obtained values in this study are less than the maximum permissible level set by TBS where as both hot spring and borehole waters of Masware (HSW₃ and BHW₃) sites have higher values than the maximum permissible levels set by WHO. There is no significant difference in total hardness, Ca^{2+} and Mg^{2+} between hot springs and borehole waters from t-test with p-values of 0.50, 0.85 and 0.29, respectively. In all the

cases p-value obtained is greater than 0.05.

3.5. Nitrate, Sulphate and Flouride

Borehole waters have higher concentration of NO_3^- which ranges from 4.06-39.25 mg/L than hot spring waters (Table 4). This is due to anthropogenic activities conducted near water sources. All hot springs contains lower NO_3^- concentration. Commonly NO_3^- exists in the form of nitrogenous compound in natural processes of the nitrogen cycle. In addition to natural process anthropogenic sources have great influence on the nitrate concentration, particularly in groundwater [15]. The toxicity of nitrate to humans is mainly attributed to its reduction to nitrite. Major biological effect of nitrite in humans is in the oxidation of normal hemoglobin to methaemoglobin which is more susceptible to young infants [16]. The guideline values of nitrate according to TBS and WHO are 10-75 and 45-50 mg/L respectively. The nitrate concentration found in this study is within permissible levels. There is no significant difference in NO_3^- concentration between hot spring and borehole waters according to t-test ($p = 0.28 > 0.05$).

The concentrations of SO_4^{2-} ranged from 11.83-1353.3 mg/L for hot spring waters and 28.92-493.33 mg/L for borehole waters (Table 4). Lower concentrations of SO_4^{2-} found in Usangore hot spring (HSW₂) with a value of 11.83 mg/L and Majimoto borehole (BHW₁) with a value of 28.92 mg/L respectively. The presence of SO_4^{2-} in water mainly caused by groundwater temperature accompanied with nature of rocks from same geologic forces. Sulphates are a part of naturally occurring minerals in some soil and rock formations that contain groundwater [17]. Within the waters many other reactions occur and these typically involve sulphur and/or metal cations. Geothermal waters generally contain sulphur, initially in the form of hydrogen sulphide that may be oxidized, especially in the path of rising to the surface through rock fractures rather than faults [18]. The lowest taste threshold concentration for sulphate is approximately 200 to 400 mg/L from guideline of WHO and 200-600 mg/L from the guideline of TBS. All the values obtained in this study are less than the maximum permissible set by TBS except for the site Balangida Lalu (HSW₄). All the hot spring sites except Usangore (HSW₂) and one borehole site Masware (BHW₃) have higher concentrations of sulphate

than the maximum permissible level set by WHO. In t-test $p = 0.39 > 0.05$, it is interpreted that there is no significant difference between the SO_4^{2-} concentrations in hot springs and borehole waters.

Hot spring sources showed higher prevalence of F^- as compared to borehole waters (Table 4). Very high F^- concentrations of 18, 10.5, 9.3 mg/L was found in hot springs of Usangore (HSW₂), Majimoto (HSW₁) and Balangida Lalu (HSW₄), respectively. Among borehole waters maximum concentration of F^- (3 mg/L) found in Uzogore (BHW₂). High levels of F^- is due to solubilizing more fluoride salts because of the high temperature of hot spring waters compared to borehole water [19]. Fluorides are mainly found in groundwater resulting from the reaction of water with rocks and the soil of the earth crust as well as geothermal activity [20]. In most of the areas with hot spring sites, the water used for drinking purpose by cattle, goats and sheep and found affected with F^- concentration levels [21]. Some of the hot springs and all boreholes waters used for domestic purposes directly without any treatment. Usage of fluoride containing water leads to fluorosis to the people. There is an evidence of dental fluorosis for the people in Posht-e-kooh-e-Dashtesan area in southern Iranian communities that reported drinking spring water with more than 3 mg/L fluoride [22]. Therefore, from this study it is recommended to use these waters after treatment. A majority of the report's authoring committees also concluded that people who drink water containing 4 mg/L or more of fluoride over a lifetime are likely at increased risk for bone fractures [23]. The permissible guidelines values for fluoride in drinking water from TBS range 1.5 to 4 mg/L, but from WHO it is 1.5 mg/L. Most of the waters studied in this work have their fluoride contents more than the recommended values. The t-test revealed that there is no significant difference between F^- in hot springs and borehole waters in which p-value obtained is $0.06 > 0.05$.

3.6. Iron and Manganese

The maximum value of Fe^{2+} concentrations found at

Usangore (HSW₂) hot spring with 0.41 mg/L and Majimoto borehole with 1.22 mg/L (Table 4). Minimum concentrations of Fe^{2+} present in Majimoto (HSW₁) hot spring with 0.003 mg/L and Masware (BHW₃) borehole water with 0.02 mg/L. Permissible levels of Fe^{2+} in drinking water based on the guideline of TBS and WHO ranged 0.3-1.0 and 0.1-1.0 mg/L, respectively. Values obtained for both hot spring and borehole waters in this study are less than the guideline values except Majimoto borehole water (BHW₁) indicating that there is no harm in consuming this water with respect to Fe^{2+} .

The higher concentrations of Mn^{2+} found in Majimoto (HSW₁) hot spring with 2.00 mg/L (Table 4). Lowest Mn^{2+} concentration found at Balangida Lalu (HSW₄) hot spring water with 1.03 mg/L. Among the borehole waters Uzogore (BHW₂) and Masware (BHW₃) water having maximum concentrations of 1.7 and 1.5 mg/L respectively. Permissible levels of Mn^{2+} in drinking water according to the guidelines of TBS and WHO is 0.1-0.5 and 0.05-0.5 mg/L, respectively. The values obtained in this study are more than the permissible levels except for Majimoto borehole (BHW₁) water.

Groundwater tends to develop chemical characteristics that reflect the chemical composition of the water sources [23]. These are caused by water percolation through soil and rock and dissolve minerals containing Fe^{2+} and Mn^{2+} and hold them in solution. Fe^{2+} and Mn^{2+} in drinking water are not considered as hazardous to health. But high levels of Fe^{2+} in water can change the colour of water. High levels of Mn^{2+} can also turn water into black colour and it may cause people not to use it by expecting that the water is possibly contaminated. Fe^{2+} with the presence of Mn^{2+} in water may lead to the accumulation of microbial growth in the water distribution system [24]. The t-test ($p = 0.42 > 0.05$ for Fe^{2+} and $p = 0.59 > 0.05$ for Mn^{2+}) revealed that there is no significant difference of Fe^{2+} and Mn^{2+} between hot spring and borehole waters.

Table 3. Chemical parameters analysed by titrimetric methods.

Samples	Cl ⁻			Total Hardness			Ca ²⁺			Mg ²⁺		
	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD
HSW ₁	189.3	0.02	0.01	1.59	0.03	1.92	0.26	0.01	2.25	0.24	0.01	2.44
HSW ₂	674.26	0.05	0.01	7.2	0.1	1.39	1.9	0.02	1.05	0.58	0.02	3.45
HSW ₃	272.15	0.22	0.08	435.98	0.07	0.02	103.9	0.1	0.1	42.92	0.06	0.13
HSW ₄	3577.6	0.06	0	53.97	0.08	0.14	3.03	0.02	0.49	11.26	0.02	0.18
BHW ₁	6.25	0.01	0.16	22.08	0.02	0.07	7.01	0.02	0.22	1.11	0.03	2.7
BHW ₂	88.05	0.02	0.03	271.95	0.09	0.03	5.77	0.05	0.78	62.59	0.01	0.02
BHW ₃	659.93	0.42	0.063	430.4	0.2	0.05	51.28	0.03	0.06	73.49	0.02	0.02
TBS	200-800			500-600			50-100			50-100		
WHO	200-600			300			150-200			30-100		

Table 4. Chemical parameters analysed by UV-Vis spectrophotometric methods.

Samples	NO ₃ ⁻			SO ₄ ²⁻			F ⁻			Fe ²⁺			Mn ²⁺		
	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD
HSW ₁	0.02	0.02	125	447.59	1.09	0.24	10.50	0.50	4.76	0.003	0.01	173.20	2.00	0.10	5.00
HSW ₂	0.00	0.00	65.5	11.83	0.16	1.36	18.00	2.00	11.11	0.41	0.02	3.70	1.30	0.10	7.69

Samples	NO ₃ ⁻			SO ₄ ²⁻			F ⁻			Fe ²⁺			Mn ²⁺		
	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD
HSW ₃	2.81	0.25	8.94	571.00	30.05	5.26	4.68	0.02	0.43	0.02	0.02	65.47	1.50	0.10	6.67
HSW ₄	20.07	1.11	5.52	1353.30	94.52	6.98	9.30	0.13	1.35	0.07	0.01	14.29	1.03	0.15	14.78
BHW ₁	4.06	0.01	0.25	28.92	0.22	0.76	1.90	0.10	5.26	1.22	0.02	1.26	0.30	0.10	33.33
BHW ₂	18.57	0.25	1.36	367.54	0.55	0.15	3.00	0.10	3.33	0.28	0.02	7.52	1.70	0.10	5.88
BHW ₃	39.25	8.04	20.5	493.33	15.28	3.10	0.89	0.03	2.82	0.02	0.01	50.00	1.50	0.10	6.67
TBS	10-75			200-600			1.5-4.0			0.3-1.0			0.1-0.5		
WHO	45-50			200-400			1.5			0.1-1.0			0.05-0.5		

3.7. Cadmium and Zinc

Results showed that there are almost no or negligible concentrations of heavy metals Cd²⁺ and Zn²⁺ in both hot spring and borehole waters as observed in Table 5. It is observed that Cd²⁺ present only in hot spring waters. The concentration ranges from 0 to 0.05 mg/L with the highest value of 0.05 mg/L in Balangida Lalu hot springs (HSW₄), but the others contained the small concentrations of Cd²⁺ in hot springs and undetected levels of Cd²⁺ in borehole waters. Undetected levels are due to absence of any contamination with industrial or mining activities. The introduction of Cd²⁺ in water may originate from either geological formations or from other sources. The fact remains that the long term ingestion of water contaminated with cadmium may be hazardous to human health [25]. Higher concentrations of Cd²⁺ in hot springs indicate the presence of possible pollutant in water sources. Therefore, there is a need to educate society to maintain and established the habit of conserving hot spring as well as borehole waters. According to the TBS and WHO guidelines, the permissible levels of Cd²⁺ in drinking water are 0.05 and 0.003 mg/L, respectively. Concentrations of Cd²⁺ above permissible levels can cause adverse changes in arteries of human kidneys [26]. The levels of cadmium obtained in the present study are less than the permissible levels. Hence, there will not be any health problems associated with the consumption of this water with respect to cadmium. The t-test indicates that there is no significant difference in Cd²⁺ concentration between hot springs and borehole waters with p-value 0.06 > 0.05.

From Table 5, it is observed that there is no any concentration of Zn²⁺ in both hot spring and borehole waters except only two sites namely Masware (HSW₃) hot spring and Masware (BHW₃) borehole source with very low concentrations. The permissible levels of Zn²⁺ concentration in groundwater ranges from 0.01 to 0.05 mg/L according to WHO guidelines. The permissible levels according to guidelines of TBS range from 5 to 15 mg/L. In this study the concentration of Zn²⁺ in the waters of all the sites less than the permissible levels. This may due to lack of geological materials with Zn²⁺ concentrations [27]. The p-values (p = 0.44 > 0.05) of t-test shows that there is no significant difference of Zn²⁺ between hot springs and borehole waters.

3.8. Nickel

Concentration ranges of Ni²⁺ are 0.63–0.83 mg/L in hot springs and 1.18-1.31 mg/L in borehole waters (Table 5).

Nickel can be present in some groundwater's as a consequence of dissolution from nickel ore-bearing rocks [28]. It's effect in humans is mostly due to chronic skin contact with nickel but women are more commonly allergic to nickel exposure than men [29]. But, when ingested through water, in small amounts, it is harmless to humans and in fact necessary in our diet [30]. Permissible levels of drinking water are 0.5 mg/L by TBS and 0.07 mg/L by WHO. The results of this study show that the Ni²⁺ concentrations in all the samples are above permissible levels. All the hot spring waters under this study have lower Ni²⁺ concentration than that of borehole waters due to the existence of soil nature. Hence, there is a need to treat the water for Ni²⁺ before consumption. The p-value obtained is $2.46 \times 10^{-4} < 0.05$ from t-test which indicates that there is significant difference in nickel concentrations between hot springs and borehole waters.

3.9. Copper

From the Table 5 it is observed that the concentration of Cu²⁺ is highest in Balangida Lalu (HSW₄) and Masware (HSW₃) hot springs with concentrations 0.93 and 0.91 mg/L and these values are higher than that of any of borehole waters under the study. Intake of drinking water that contaminated with Cu²⁺ concentration greater than 3 mg/L in adult causes gastrointestinal effect and elicited nausea. The human body has a natural mechanism for maintaining the proper level of Cu²⁺ in it. Children below one year old have not yet developed this mechanism as a result these are more vulnerable to the toxic effects of copper [31]. Values of Cu²⁺ obtained in this study are below permissible levels set by TBS which ranges from 1 to 3 mg/L and for WHO 0.005 to 2 mg/L. Small amounts of Cu²⁺ are essential for good health but excess of Cu²⁺ can cause anemia and liver, kidney and brain damage. The p-value of t-test is 0.66 > 0.05 indicated that there is no significant difference of Cu²⁺ between hot springs and borehole waters.

3.10. Potassium

Highest concentration of K⁺ observed in Balangida Lalu (HSW₄) hot spring with 100 mg/L (Table 5). Among the borehole waters, the highest was present in Masware (BHW₃) borehole water with 52 mg/L as shown in Table 5. This is due to presence of K⁺ ions in groundwater which indicate the existence of many rocks in study sites with K⁺ salts. In general, the concentrations of K⁺ in hot springs greater than that of borehole waters. Lowest concentration of K⁺ is

present in Usangore (HSW₂) hot springs and Majimoto (BHW₁) borehole waters with their concentrations of 44 and 16 mg/L respectively. The sources of K⁺ is likely due to silicate minerals, orthoclase, microcline, hornblende, muscovite and biotite in igneous and metamorphic rocks [32]. Nature of rocks dictates K⁺ concentration in hot springs and borehole waters. Potassium is an essential element in humans and seldom found in drinking water. But at higher levels it will cause certain health problems to humans. The

permissible levels of drinking water not well stated by TBS and WHO but only shows its importance for the playing a critical role in many vital cell functions, such as metabolism, growth, repair and regulation, as well as in the electric properties of the cell. Therefore K⁺ works with sodium to maintain the body's water balance and is also involved in nerve function, muscle control and blood pressure. There is no significant difference of K⁺ between hot springs and borehole waters from t-test with a p-value of 0.08 > 0.05.

Table 5. Chemical parameters analysed by Flame Atomic Absorption Spectrometric methods.

Samples	Cd ²⁺			Zn ²⁺			Ni ²⁺			Cu ²⁺			K ⁺		
	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD	Mean (mg/L)	SD (n=3)	% RSD
HSW ₁	0.02	0.01	34.64	0.00	0.00	0.00	0.63	0.01	1.59	0.4	0.01	2.5	56.00	2.00	3.57
HSW ₂	0.02	0.01	24.74	0.00	0.00	0.00	0.71	0.01	1.41	0.37	0.01	2.7	44.00	1.00	2.27
HSW ₃	0.01	0.01	100.00	0.05	0.01	20.00	0.69	0.01	1.45	0.91	0.01	1.1	64.00	2.00	3.13
HSW ₄	0.05	0.01	20.00	0.00	0.00	0.00	0.83	0.01	1.21	0.93	0.02	2.15	100.00	1.00	1.00
BHW ₁	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.01	0.85	0.49	0.01	2.04	16.00	1.00	6.25
BHW ₂	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.01	0.77	0.59	0.01	1.7	20.00	1.00	5.00
BHW ₃	0.00	0.00	0.00	0.94	0.01	1.06	1.31	0.01	0.76	0.64	0.02	3.13	52.00	2.00	3.85
TBS	0.05			5-15			0.5			1 to 3			NLS		
WHO	0.003			0.01 - 0.05			0.07			0.005 - 2			NLS		

NLS* No Limit Specified.

4. Conclusion

In this study, water quality of hot springs and borehole waters tested and compared by collecting water samples from seven different locations selected in northern Tanzania. Selected physico-chemical parameters are pH, EC, TDS, salinity, turbidity, Cl⁻, total hardness, Ca²⁺, Mg²⁺, NO₃⁻, SO₄²⁻, F⁻, Fe²⁺, Mn²⁺, Cd²⁺, Zn²⁺, Ni²⁺, Cu²⁺ and K⁺ analyzed to predict the water quality status of hot spring and borehole waters of three regions (Mara, Shinyanga and Manyara) in Tanzania. The EC, TDS, salinity, turbidity, Cl⁻, NO₃⁻, SO₄²⁻, F⁻, Mn²⁺ and Cu²⁺ are higher (pH = 7.44-9.42, EC = 4251.33-15334 μS/cm, TDS = 2079-7526.7 mg/L, salinity = 2.2-8.67 ppt, Cl⁻ = 189.3-3577.6 mg/L, SO₄²⁻ = 11.83-1353.33 mg/L, F⁻ = 4.68-18 mg/L, Mn²⁺ = 1.03-2.0 mg/L, Cd²⁺ = 0.01-0.05 mg/L, Cu²⁺ = 0.37-0.93 mg/L and K⁺ = 44-100 mg/L) in hot springs than borehole waters (pH = 6.36-6.58, EC = 270.0-2674.64 μS/cm, TDS = 123.67-1305 mg/L, salinity = 0.03-1.37 ppt, Cl⁻ = 6.25-659.93 mg/L, SO₄²⁻ = 28.92-493.33 mg/L, F⁻ = 0.89-3.0 mg/L, Mn²⁺ = 0.3-1.70 mg/L, Cd²⁺ = 0 mg/L, Cu²⁺ = 0.49-0.64 mg/L and K⁺ = 16-52 mg/L). From the t-test on individual parameters, there is no significant difference between the quality of hot spring water and borehole waters except for pH and Ni²⁺. Based on this study it can be concluded that there is a need for treatment of both waters with reference to certain physico-chemical parameters before drinking. Moreover, additional measures must be taken by the Tanzania government and stake holders to improve the water quality of rural areas near hot spring sources in Tanzania in order to supply clean and safe water to the communities as well as to solve the water scarcity problems.

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