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RESEARCH ARTICLE

A COMPARATIVE STUDY OF WATER QUALITY BETWEEN HOT SPRING AND BOREHOLE WATERS OF SINGIDA AND DODOMA REGIONS OF TANZANIA

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ABSTRACT

This study aims to compare physico-chemical parameters of the water quality between hot springs and borehole waters. Twenty samples were collected from two regions Singida and Dodoma of Tanzania. Multimeter used for the analysis of physical parameters pH, EC, TDS, salinity and turbidimeter used to analyseturbidity. Titrimetric methods were used for chemical parametersCl^-, total hardness, Ca^{2+} and Mg^{2+}. UV-Visible spectrophotometric methods used for the analysis of NO_3^-, SO_4^{2-},F^-, $Fe^{2+}$and Mn^{2+} and Flame Atomic Absorption methods for Cd^{2+}, Zn^{2+}, Ni^{2+}, Cu^{2+} and K^+. The parameters EC, TDS, salinity, turbidity,Cl^-, NO_3^- , SO_4^{2-}, $F^-$and $Mn^{2+}$are higher (EC = 508.33-4790 μS/cm, TDS = 249.33-2349.30 mg/L, salinity = 0.27-2.53 ppt, turbidity = 0.81-513.73 NTU,Cl^-= 54.32-900.52 mg/L, NO_3^-= 0.1-63.30 mg/L, SO_4^{2-}=38.33-343.33 mg/L, F^-=0.47-9.5 mg/L and Mn^{2+}= 0.6-1.9 mg/L) in hot springs than borehole waters (EC = 844.0-1821.67 μS/cm, TDS = 414.67-891.33 mg/L, salinity = 0.4-0.87 ppt, turbidity = 3.8-147.9 NTU,Cl^- = 119.68-356.50 mg/L, NO_3^- = 0.93-16.78 mg/L, SO_4^{2-} = 42.0-128 mg/L, F^-= 0.18-1.38 mg/L and Mn^{2+} = 1.5-1.6 mg/L). But other parameters Total hardness, Ca^{2+}, Mg^{2+}, Fe^{2+} and Ni^{2+} are higher in borehole waters than hot springs.The t-test ($p=0.05$) showed that there is significant difference of the parameters SO_4^{2-},F^- and Ni^{2+} between hot spring and borehole waters. Based on this study it is observed that 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 purposes.

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INTRODUCTION

Water is a transparent and nearly colourless liquid that is the main constituents of earth and fluid of most living organisms. Evaporation and transpiration contribute to the precipitation over land. Okoro and his coworkers identified that the large amounts of water are chemically combined or adsorbed in hydrated minerals (Okoro *et al.,* 2017). Groundwater is naturally recharged by rain water and snow melt or from water that leaks through the bottom of some lakes and rivers. Groundwater stored in the layers beneath the surface and helps protecting from contamination. However, temporal and spatial distribution of both surface and groundwater sources were not uniform and is controlled by climate and geology. 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.

The mineral contents of the water influenced by the temperature of hot spring waters and vary widely in their mineral composition with respect to the geological location of spring water. Researchers Mayo and Mnzava identified more than 15 hot springs with above 40°C near the active rift segments in Tanzania (Mnzava and Mayo, 2013). Hot springs in Tanzania mainly locatedat EastAfrican rift valley that indicates geothermal activity. The hot springs found in Dodoma and Singida regions are located at the swamp areas and bedrock surfaces. Boreholes are constructed by narrow shaft bored in the ground vertically for the extraction of water. Most of these boreholes supply water for many people of urban, rural and remote areas in Tanzania (Adekola *et al.,* 2015). Usually more number of ions will get dissolved in hot springs than normal ground water due to presence of temperature for hot springs (Pasvanoglu, 2011). Some of parameters help to define water quality are turbidity, EC, pH values, TDS, TH and other ionsCl^-, SO_4^{2-},F^-, NO_3^- as anions and others ions are K^+, Ca^{2+}, Mg^{2+}, Cd^{2+}, Zn^{2+}, Ni^{2+} and Cu^{2+} as cations. The major source of water in Singida and Dodoma regions from the central basin are borehole water and its consumption increasing year by year. Water quality assessment

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in different water sources is an important research area. In this study, water quality assessment of hot spring waters made in comparison to borehole waters. In the study area, borehole water is widely used by the people for domestic purpose compared to hot spring water, even though both are available. Therefore, physico-chemical parameters of hot springs as well as borehole waters determined from the areas Hika, Msule, Nkundi, Sambalu, Takwa, Gonga, and Kwapakacha of Singida and Dodoma respectively. This study will give the awareness to the people of Singida and Dodoma about the water quality of these sources of water and subsequently solve the water scarcity problems in this area. The quality of water was assessed by comparing the obtained values with the permissible levels of drinking water from EWURA or TBS and WHO.

MATERIALS AND METHODS

Study area: Central regions of Tanzania comprised Singida and Dodoma as shown in Figure 1. Singida region (5°30′ 00" S and 34°30′ 00" E) has two districts Ikungi and Manyoni. Ikungi district contained hot springs Msule/Manyeghi, Isanja and Mpondi/Mponde. Manyoni district contained Hika hot spring site. Dodoma region (6° 00′ 00" S and 36° 00′ 00" E)has two districts with hot springs Chemba and Kondoa. Chemba district hot springs areTakwa and Gonga while in Kondoa district Kondoa/Chemichemi hot spring. Borehole waters selected in this study are within a distance between 0.5 to 1 km from hot spring sites Isanja, Gonga and Kondoa. In all these sites people mainly depends on borehole waters except Hika village. Hika village people depend on the hot spring water for domestic purposes including human consumption due to lack of boreholes because of sandy soil nature.

Sample collection and storage:

Before collection of the water samples high density poly ethylene containers of 1 L was cleaned through washing with distilled water three to four times and rinsed with water sample in order to avoid contamination and then immediately measured the water temperature (Armannsson and Olafsson, 2007). Two kinds of water samples collected hot springs and borehole waters. Water sample collected from 10 sites with two sets of water samples to each site. A total of twenty samples collected, whereby ten samples for physical and some chemical parameters and another ten used for FAAS analysis. Hot springs were collected periodically for every 20 minutes for 1 hour, each time 300 mL of water collected. Borehole waters collected directly from the water source with 900 mL of water samples to each source. After collection in each study site all samples were labeled as observed on 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 ℃ with a thermos cool box. Ten water samples collected for the analysis of heavy metals were prepared separately by treating with 2 mL of HNO_3 for 900 mL of water sample in order to prevent adsorption on the walls of container and to stop the growth of microorganisms in the water. These samples were kept at room temperature. The water samples transported to nearest laboratories to the sites DUWASA, SUWASA, and GST laboratories for further analysis. Four methods were used to analyse nineteen physico-chemical parameters in each water 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.

Figure 1. Central region of Tanzania map showing the selected hot spring sites and borehole waters

Table 1.Coding and labeling of water samples collected

Water sampling sites	Code/Label
Hot spring sampling at Hika-Singida	HSW_1
Hot spring sampling at Manyeghi/Msule-Singida	HSW_2
Hot spring sampling at Isanja-Singida	HSW_3
Hot spring sampling at Sambalu (Mpondi)-Singida	HSW_4
Hot spring sampling at Takwa-Dodoma	HSW_5
Hot spring sampling at Gonga-Dodoma	HSW_6
Hot spring sampling at Chemichemi (Kondoa) -Dodoma	HSW_7
Borehole water sampling at Isanja-Singida	BHW_1
Borehole water sampling at Gonga-Dodoma	BHW_2
Borehole water sampling at Kwapakacha-Dodoma	BHW_3

Sample analysis with respective methods

Distilled water used for the preparation of solutions. The apparatus used were cleaned with tap water and then twice with distilled water. All chemicals used in this study were analytical grade from the manufacturer Sigma Adrich, Germany. Buffer solutions of pH's 4, 7 and 10 were used to calibrate pH meter. Conductivity standard solutions 1.5, 147 and 1413 µS/cm were used to calibrate multi meter for the analysis of EC, TDS and salinity. Standards solution of $AgNO_3$and K_2CrO_4 used to the analyze $Cl^-$by titration. A solution of disodium salts of EDTA (0.01 M) was used to determine total hardness of water by maintaining required pH with a buffer solution of NH_4Cl and NH_4OH by using EBT as an indicator. A solution of NaOH used to raise the pH while titrating Ca^{2+}alone with EDTA solution by using ammonium purpurate as an indicator. UV-Visible spectrophotometer used to analyze different ions present in water samples using respective powder pillows as coloring reagents. NitraVer 5 nitrate pillow was used for the analysis of NO_3^-at λ_{max} 500nm in water samples.

SulfaVer 4 sulphate pillows were used to analyse SO_4^{2-}at λ_{max} 450nm in water samples. SPADNS reagent used to analyse F^- with λ_{max} 580nm in water samples. FerroVer Iron pillows were used for the analysis of Fe^{2+} with λ_{max} 510 nm in water samples. Buffer powder citrate pillows with sodium periodate pillows were used to analyse Mn^{2+} with λ_{max} 525 nm in water samples. FAAS with acetylene-air gas were used for the analysis of metals Cd^{2+}, Zn^{2+}, Ni^{2+}, Cu^{2+} and K^+in acidified water samples at their respective wavelengths of 228.8 nm, 213.9 nm, 232 nm, 324.7 nm and 766.5 nm.

Data analysis

Sample collection, handling, preservation and analyses were done by following standard procedures recommended by the American Public Health Association (APHA) which ensure data quality and consistency. All the measurements made in triplicate to test the precision of the results and the data obtained was validated by using spiking experiment. The recovery obtained in the spiking experiment is within the given specifications (90-110%).Interpretation and statistical analysis of the numerical data obtained from experimental work was done using Microsoft Excel 2007. Statistical tests such as t-test and ANOVA was used for data analysis. Water quality of thesites under study is evaluated by comparing the obtained numerical data with that of TBS and WHO.

RESULTS

Results in Table 2, 3, 4 and 5 are the physico-chemical parameters analysed with respective instruments and then compared with permissible levels set by standard organisations TBS and WHO.

Table 2. Physical parameters analysed by multimeters

Samples	pH			EC			TDS			Salinity			Turbidity		
	Mean	(n=3)	RSD	Mean (µS/cm)	(n=3)	RSD	Mean (mg/L)	(n=3)	% RSD	Mean (ppt)	(n=3)	% RSD	Mean (NTU)	(n=3)	% RSD
HSW_1	8.38	0.035	0.419	508.33	9.07	1.785	249.33	2.517	1.009	0.27	0.02	7.407	6.33	0.1	1.507
HSW_2	8.19	0.026	0.323	4790.67	11	0.23	2349.3	4.509	0.192	2.53	0.21	8.217	1.06	0.04	3.324
HSW_3	7.65	0.015	0.2	2294	15.1	0.658	1126.7	4.041	0.359	1.2	0.1	8.333	513.7	1.16	0.225
HSW_4	7.91	0.025	0.318	3910.33	1.53	0.039	1916.7	5.686	0.297	2.3	0.26	11.5	2.49	0.02	0.803
HSW_5	7.87	0.153	1.942	3486.67	6.11	0.175	1703.7	3.512	0.206	1.6	0.2	12.5	1.14	0.01	0.877
HSW_6	7.38	0.025	0.341	1353.67	5.51	0.407	663.67	2.517	0.379	0.7	0.2	28.57	0.81	0.02	2.469
HSW_7	7.56	0.071	0.939	1155	15.5	1.344	572.33	3.512	0.614	0.59	0.02	2.604	7.2	0.2	2.778
BHW_1	7.23	0.045	0.623	1821.67	2.52	0.138	891.33	1.528	0.171	0.87	0.15	17.63	147.9	0.24	0.164
BHW_2	7.02	0.015	0.218	844	3.61	0.427	414.67	2.082	0.502	0.4	0.1	25	4.55	0.08	1.744
BHW_3	7.84	0.036	0.46	1149.33	2.52	0.219	567.67	2.517	0.443	0.58	0.02	2.619	3.83	0.06	1.68
EWURA&TBS		6.5-9.2			-			500-1200			-			5 to 25	
WHO		6.5-8.5			2500			1000			-			5 to 25	

Table 3. Chemical parameters analysed by titrimetric methods

Samples	Cl^-			TH			Ca^{2+}			Mg^{2+}		
	Mean (mg/L)	(n=3)	%RSD	Mean (mg/L)	(n=3)	%RSD	Mean (mg/L)	(n=3)	%RSD	Mean(mg/)	(n=3)	%RSD
HSW1	54.32	0.376	0.693	49.95	0.117	0.234	11.23	0.031	0.272	5.32	0.02	0.376
HSW2	900.52	0.064	0.007	29.93	0.066	0.219	5.18	0.015	0.295	4.12	0.02	0.485
HSW3	393.9	0.015	0.004	44.65	0.01	0.022	8.84	0.09	1.021	5.49	0.01	0.182
HSW4	774.06	0.055	0.007	16.66	0.02	0.12	4.29	0.015	0.356	1.44	0.02	1.389
HSW5	642.24	0.055	0.009	41.9	0.015	0.036	9.79	0.045	0.46	4.24	0.01	0.236
HSW6	140.53	0.1	0.071	75.94	0.113	0.148	19.26	0.04	0.208	6.76	0.01	0.148
HSW7	120.99	0.135	0.111	289.17	0.241	0.083	65.43	0.153	0.233	30.57	0.03	0.098
BHW1	356.5	0.021	0.006	69.12	0.015	0.022	26.24	0.025	0.095	0.86	0.02	2.326
BHW2	119.68	0.025	0.021	18.89	0.095	0.505	6.08	0.02	0.328	0.89	0.01	1.124
BHW3	124.25	0.248	0.2	380.63	0.153	0.04	110.3	0.03	0.027	25.22	0.06	0.238
EWURA&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
HSW1	63.30	19.79	31.30	38.33	3.512	9.161	3.7	0.04	1.12	0.05	0.01	20	1.23	0.06	4.68
HSW2	2.82	0.15	5.37	330.00	10	3.03	9.5	0.126	1.32	0.02	0.01	50	1.4	0.1	7.14
HSW3	2.57	0.05	1.96	273.33	3.06	1.118	8.5	0.09	1.06	0.09	0.01	11.11	0.6	0.1	16.67
HSW4	1.94	0.24	12.30	343.33	7.64	2.224	6.48	0.26	3.96	0	0.01	173.2	1.9	0.1	5.26
HSW5	2.38	0.20	8.33	233.33	12.58	5.393	3.89	0.05	1.295	0.03	0.02	45.83	1.3	0.1	7.69
HSW6	5.39	0.07	1.30	271.67	7.64	2.811	1.56	0.04	2.794	0.07	0.02	22.91	1.5	0.1	6.67
HSW7	0.10	0.1	100.00	124.67	3.06	2.451	0.47	0.015	3.273	0.04	0.01	25	1.7	0.1	5.88
BHW1	16.78	0.05	0.32	56.67	2.52	4.441	1.38	0.064	4.67	0.7	0.02	2.172	1.6	0.1	6.25
BHW2	14.19	0.02	0.14	42.00	1	2.381	0.75	0.076	10.05	0.03	0.01	33.33	1.5	0.1	6.67
BHW3	0.913	0.03	2.76	128.00	2	1.563	0.18	0.035	19.88	0.42	0.03	7.143	1.6	0.1	6.25
EWURA&TBS		10 to 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	

Table5. Chemical parameters analysed by FAAS methods

Samples	Cd			Zn			Ni			Cu			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	0	0	0	0	0	0.66	0.01	1.515	0.41	0.015	3.756	16	2	12.50
HSW_2	0	0	0	0	0	0	0.79	0.01	1.266	0.55	0.01	1.818	44	1	2.27
HSW_3	0	0	0	0	0	0	0.78	0.01	1.282	0.45	0.01	2.222	8	2	25
HSW_4	0	0	0	0	0	0	0.79	0.01	1.266	0.4	0.02	5.000	20	1	5.00
HSW_5	0	0	0	0	0	0	1.04	0.01	0.962	0.36	0.02	5.556	12	3	25
HSW_6	0	0	0	0	0	0	1.13	0.01	0.885	0.45	0.01	2.222	52	2	3.85
HSW_7	0	0	0	0	0	0	1.08	0.01	0.926	0.54	0.01	1.852	40	2	5.00
BHW_1	0	0	0	0	0	0	1.35	0.01	0.741	0.45	0.01	2.222	68	2	2.94
BHW_2	0	0	0	0	0	0	1.35	0.02	1.481	0.54	0.01	1.852	20	2	10.00
BHW_3	0	0	0	0	0	0	1.52	0.01	0.658	0.27	0.01	3.704	48	2	4.17
EWURA&TBS		0.05			5 to 15			0.5			1 to 3			NLS	
WHO		0.003			0.01-0.05			0.07			0.005-2			NLS	

NLS* No Limit Specified

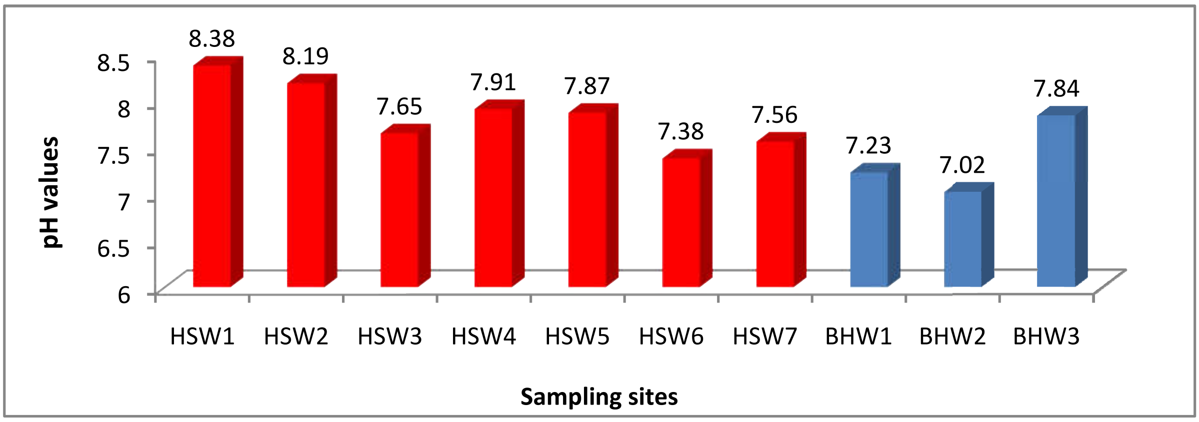

Figure 2. Spatial variation in pH of hot spring (red colour) and borehole waters (blue colour)

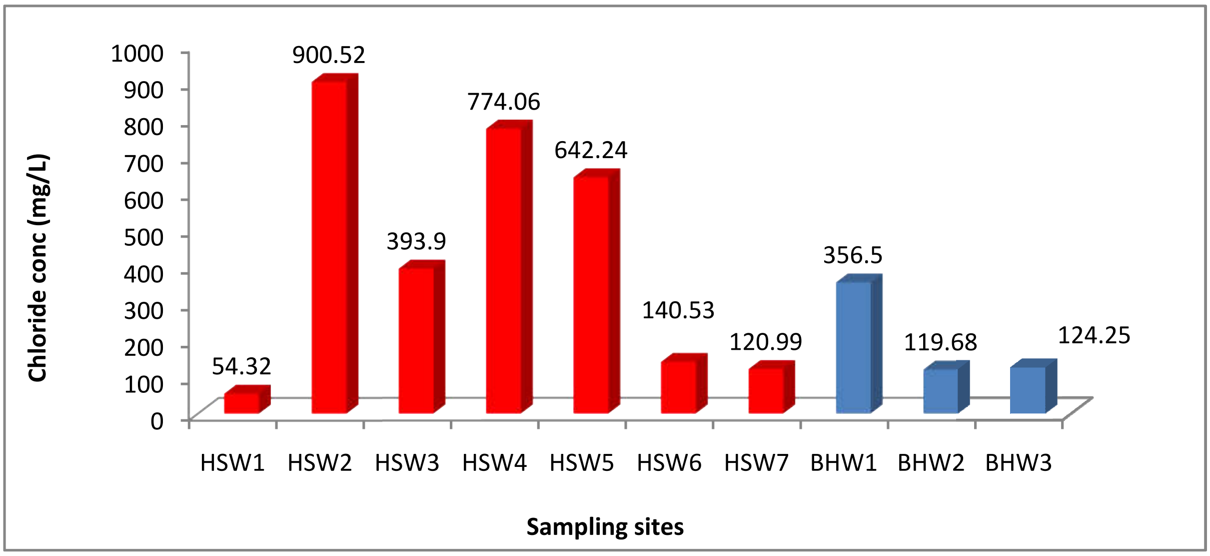

Figure 3. Spatial variations of Chloride in hot spring (red colour) and borehole waters (blue colour)

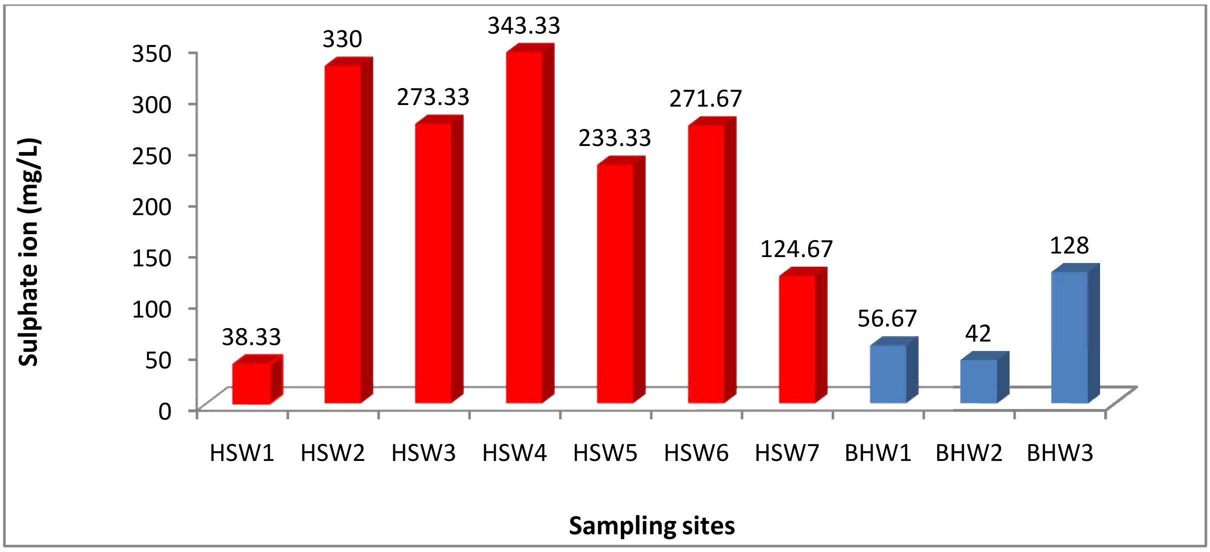

Figure 4. Spatial variations of SO_4^{2-} concentration in hot spring (red colour) and borehole waters (blue colour)

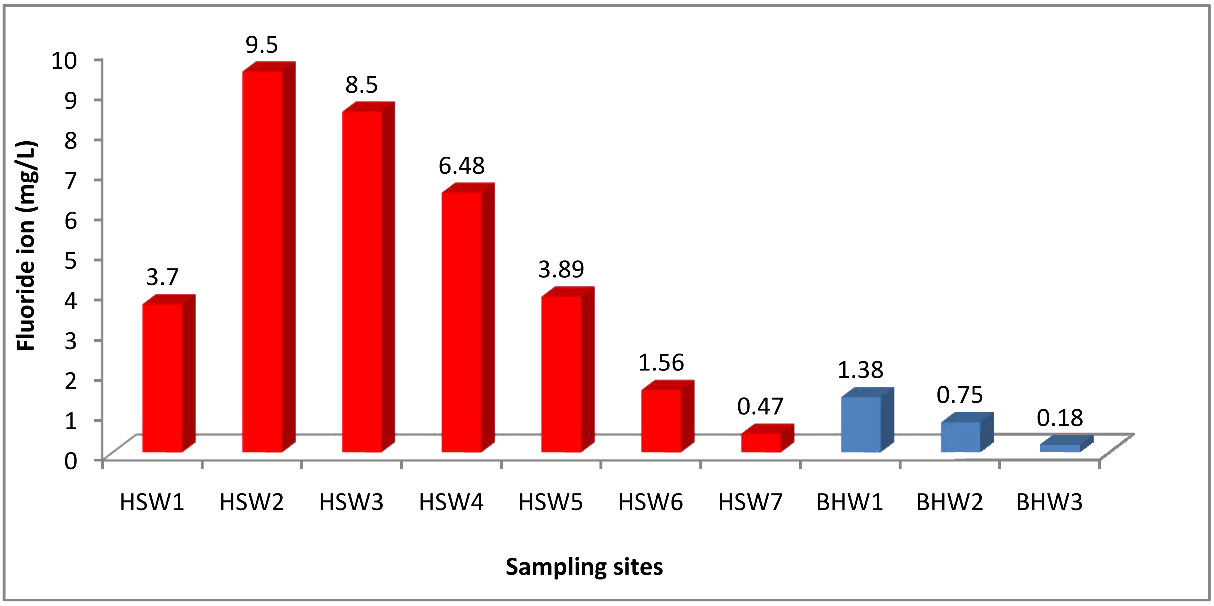

Figure 5. Spatial variations in fluoride ions of hot spring (red colour) and borehole waters (blue colour)

All the measurements represented with the respective SI units and the data analysis made in excel software for the hot springs and borehole water analysis, where by twenty (20) samples were analysed from 10 different sites. Data presented is physical and chemical parameters along with descriptive statistics.

DISCUSSION

Measurements Made by Multimeter: Table 2 shows the results of all the physical parameters in both hot spring and borehole waters determined by using multimeter.

The ranges of temperatures of hot spring water samples: Thermal activity in central Tanzania that is Singida and Dodoma regions were associated with faults and temperature measured is in the range of 34 °C–47 °C. Hot springs are used for drinking and bathing of animals and human directly from sources respectively. The temperature of hot spring water increases with depth. Groundwater temperature increases with depth which in turn increase dissolved minerals and silicates with mud pot (Pasvanoglu, 2011).

The measure of temperature helps to identify existence of hot springs in the study areas that distinguishes with borehole water at study areas. Table 2 show physical parameters with the maximum and minimum values of pH 7.02-8.38, EC 508.33-4790.67 µS/cm, TDS 249.33-2349.3 mg/L, salinity 0.27-2.53 ppt and turbidity 0.81-513.7 NTU.

pH values: Figure 2 represents variation of pH values at the different sites in the study area. Hika (HSW_1) water has higher pH value of 8.38 which is less than the permissible levels of drinking water whose ranges were 6.5-9.2 for the TBS or EWURA and 6.5–8.5 for WHO. Therefore, there might not be any health effects to the consumer of this water. It is also observed that the hot springs are having relatively higher pH than the borehole water. Toure and his coworkers identified higher pH values in hot springs 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 (Toure *et al.*, 2017). The t-test shows that there are no significant differences in pH values between hot spring and borehole water with p-value greater than 0.05 (0.05>0.18).

EC, TDS and salinity values: These values are given in Table 2.Higher values of EC, TDS and salinity observed at Msule (HWS_2) hot spring with 4790.76 µS/cm, 2349.30 mg/L and 2.53 ppt respectively. Lower values found at Hika hot spring (HSW_1) than other hot springs and hence water taste is good for domestic purposes as that of boreholes. The increase in values of EC leads to increase in TDS and salinity. EC ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds (Prasanth *et al.,* 2012). The 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 due to the mineral break down over time as there is rise in water tables (Korkmaz and Gunduz, 2015). Permissible levels of TDS according to standards of EWURA or TBS ranges between 500-1200 mg/L and that of WHO are 1000 mg/L. Msule (HSW_2), Mpondi (HWS_4) and Takwa (.HSW_5) hot springs have higher values than the permissible levels. These values are higher in hot springs than borehole waters. But, in the t–test, the obtained p-values were greater than 0.05, (EC, TDS 0.104 and salinity 0.09) which is proving that there are no significant differences of EC, TDS and salinity values between hot springs and borehole waters.

Turbidity: From Table2, it is observed that Isanja (HSW_3) hot spring contains higher turbidity because of livestock keeping at water springs as well as rainwater flows around this hot spring. Isanja (BHW_{15}) borehole has high turbidity due to poor construction. Turbid water looks muddy or cloudy due to minerals, microorganisms and particles present in water that causes water impure. Permissible levels of turbidity according to guidelines from EWURA or TBS and WHO ranges 5–25 NTU. The people consume water with the levels of turbidity above permissible levels can suffer from stomach problem such as dysentery. There is no significant difference of turbidity between hot springs and borehole waters where p–values were greater than 0.05 ($0.79 > 0.05$) in t-test.

Measurements Made by Titrimetric Methods: Table 3 shows all the results of Cl^-, total hardness, Ca^{2+} and Mg^{2+}in both hot spring and borehole waters determined by using titrimetry.

Chloride ion: Variation in Cl^- concentrations of hot spring and borehole water can be observed in Figure 3. In hot spring concentration ofCl^- ranges from 54.32 to 900.52 mg/L while in bore hole water it is from 119.68 to 356.50 mg/L. 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 (Napacho and Manyele, 2010). Permissible levels of Cl^- in drinking water according to EWURA or TBS and WHO are 200 to 800 mg/L and 200 to 600 mg/L respectively. The levels of Cl^- in all the samples under study are below permissible levels except Manyeghi/Msule-Singida (HSW_2). Water having high levels of $Cl^-$is saline and gives objectionable taste to the waters. There is no significant difference of chloride concentrations between hot spring and borehole waters from the t-test with p-values 0.16 which is greater than 0.05.

Total hardness: Table 3 shows the values of TH, Ca^{2+} and Mg^{2+} in all the sites under this study. TH increases the concentrations of $Ca^{2+}$and Mg^{2+}. Also it is observed that $Ca^{2+}$is more abundant than Mg^{2+}. TH ranges from 16.66-289.17mg/L for hot springs and 18.89 to 380.63 mg/L for borehole waters. Ca^{2+} values ranges 4.29-110.3 mg/L in both hot spring and borehole waters. There are more concentrations of Ca^{2+} in borehole than hot spring waters. Maximum value found in borehole water at Kwapakacha (BHW_3) thanits nearest hot spring at Kondoa (HSW_7), but least value of Ca^{2+} found in Mpondi (HSW_4) hot spring water which is 4.29 mg/L. Ca^{2+} in borehole water has a minimum value at Gonga (BHW_2) with 6.08 mg/L. Mg^{2+} values ranges 0.86-30.57 mg/L in both sources. Ca^{2+} and Mg^{2+} are responsible for hardness in water. Their presence is the result of dissolution when occurs as the flowing water comes in contact with rocks of carbonate minerals such as calcite and dolomite (Subtavewung *et al.,* 2005). Permissible levels of hardness are from 500-600 mg/L and 300 mg/L according to EWURA or TBS and WHO respectively. All the values obtained in this study are less than permissible levels. There is no significant difference in hardness, Ca^{2+} and Mg^{2+} between hot springs and borehole waters from t-test with p-values of 0.58, 0.46 and 0.94, respectively. In all the cases p-value obtained is greater than 0.05.

Measurements Made by UV-Visible Spectrophotometric Method: Table 5 shows the results ofNO_3^-, SO_4^{2-}, F^-, Fe^{2+} and Mn^{2+}determined by UV-Visible spectrophotometric method.

Nitrate ion: Borehole waters have higher concentration of NO_3^- which ranges from 0.91-16.78 mg/L than hot spring waters except in Hika site (HSW_1). This is due to anthropogenic activities conducted near water sources (Knox, 1980). 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 (Olatayo, 2014). 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 haemoglobin to methaemoglobin which is more susceptible to young infants (Ikechekwu *et al.,* 2015). The guideline values according to EWURA or 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 springs and borehole waters according to t-test ($p = 0.95>0.05$) conducted on the data.

Sulphate ions: Different SO_4^{2-}concentrations ranged from 38.33-343.33 mg/L for hot spring waters and 42-128 mg/L for borehole waters can be observed from Figure 4. Higher SO_4^{2-}content observed in hot spring of Mpondi (HSW_4) with a value of 343.33 mg/L and borehole of Kwapakacha(BHW_3) with a value of 128 mg/L respectively. The concentration levels of SO_4^{2-} is 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 (Prakash *et al.,* 2017). Within the waters many other reactions occur and these typically involve sulfur 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 (Karingithi and Wambugu, 2008).

$$2H_2S + O_2 \rightarrow 2S + 2H_2O$$

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$$
$$H_2S + 2O_2 \rightarrow SO_4^{2-} + 2H^+$$

The lowest taste threshold concentration for sulphate is approximately 200 to 400 mg/L from guideline of WHO. As per EWURA or TBS, permissible levels of SO_4^{2-} in drinking water range 200-600 mg/L. Obtained values are less than the permissible values. Therefore, there is no any harm to the consumers of this water. In t-test $p = 0.01 < 0.05$, it is interpreted that there are significant differences between the SO_4^{2-} concentration in hot springs and borehole waters.

Fluoride ion: Hot spring sources showed higher prevalence of F^-as compared to borehole water as can be seen from Figure 5. Among hot springs, maximum F^-concentration of 9.5 mg/L was found in Msule (HSW_2), but in borehole water maximum concentration of 1.38 mg/L found in Gonga (BHW_2). Some of the hot springs used for domestic purposes directly without any treatment which are Hika (HSW_1), Gonga (HSW_6) and Kondoa (HSW_7), also all borehole waters used for domestic purposes. More fluoride salts found in hot spring water compared to borehole water due to high temperature of hot springs (Vesuwe *et al.,* 2008). Most hot spring waters used for livestock keeping as drinking water with higher F^- especially in cattle, goats and sheep and also affected with F^-concentration levels (Gautam and Bhardwaj, 2009). 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 (Vardhan *et al.,* 2015). There is an evidence of dental fluorosis for the people in Posht-e-kooh-e-Dashtesan area in southern Iran communities because of drinking spring water with more than 3 mg/L fluoride (Battaleb-Looie, 2010). This can be mainly associated with children at Hika village who have a risk of developing severe tooth enamel fluorosis which was a condition that can cause tooth enamel loss and pitting. A majority of the report's 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 (Mohammad and Reza, 2017). Permissible levels of fluoride in drinking water according to the guidelines of EWURA or TBS and WHO ranges 1.5 to 4 mg/L and 1.5 mg/L, respectively. The t-test revealed that there is significant difference between F^- in hot springs and borehole waters in which p-value obtained is $0.02<0.05$.

Iron and manganese: Table 4 presents variation of concentrations of Fe^{2+} and Mn^{2+}in hot spring and borehole waters. Maximum value ofFe^{2+} concentrations found in both hot spring and borehole waters of Isanja (HSW_3) with0.09 mg/L and0.7 mg/L, respectively. It is observed that there is higher concentration of Fe^{2+} in borehole water compared with hot springs. Minimum concentrations of Fe^{2+} present in Mpondi (HSW_4) hot spring with 0.003 mg/L and Msule (HSW_2) hot spring with 0.02 mg/L. Table 4 shows the presence of Mn^{2+} in both hot spring and borehole waters. The higher concentration found in Mpondi (HSW_4) hot springs with 1.90 mg/L. Lowest Mn^{2+} concentration found at Isanja (HSW_3) hot spring water with 0.60 mg/L. The concentration of Mn^{2+} is almost same in all the borehole waters (1.5-1.6 mg/L). Groundwater tends to develop chemical characteristics that reflect the chemical composition of the water sources (Adekola *et al.,* 2015). 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, because these are essential elements. Fe^{2+}can change the colour of water in to brown. High levels of Mn^{2+} can turn water into a black colour. 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 (Dvorak *et al.,* 2014). According to guidelines of EWURA or TBS and WHO, the permissible levels of Fe^{2+}in drinking water ranged between 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 indicating that there is no harm in consuming this water with respect to Fe^{2+}. Permissible levels of Mn^{2+} in drinking water according to the guidelines of EWURA or TBS and WHO is 0.1-0.5 and 0.05-0.5 mg/L, respectively. Concentrations of Mn^{2+} found in this study are more than the permissible level. Therefore, it causes health problems to the consumers. The t-test ($p = 0. 0.22>0.05$ for Fe^{2+} and $p = 0.27 >0.05$ for Mn^{2+}) revealed that there is no significant difference of Fe^{2+} and Mn^{2+} between hot spring and borehole waters.

Measurements Made by FAAS Method: Concentrations of Cd^{2+} and Zn^{2+} are less than the method detection limit. But there are different concentrations of Ni^{2+}, Cu^{2+} and K^+ in both hot spring and borehole waters than can be observed from Table 5.The percolation of water through different rocks picks up a large number of heavy metals and reaches the water table system and contaminates the groundwater especially hot springs and borehole water (Alhibshi *et al.,* 2014).

Nickel ion: Most of hot springs has lower Ni^{2+} concentration than that of boreholes. Ni^{2+} concentration range is 0.66–1.13 mg/L in hot springs and 1.35–1.52 mg/L in borehole waters. Nickel can be present in some groundwater as a consequence of dissolution from nickel ore-bearing rocks (Srikanth *et al.,* 2012). The most common effect of nickel in humans is due to chronic skin contact with nickel but women are more commonly allergic to nickel exposure than men. When ingested through water, in small amounts, it is harmless to humans and in fact necessary in the diet (Giddings *et al.,* 2005). Permissible levels in drinking water are 0.5 mg/L for EWURA or TBS and 0.07 mg/L for WHO. According to this study most of the sites have Ni^{2+} concentrations more than the permissible levels. The p-value obtained is $0.0007<0.05$ from t-test which indicates that there is significant difference in nickel concentration between hot springs and borehole waters.

Copper ion: From the Table 5 it is observed that the concentration of $Cu^{2+}$is highest in Msule (HSW_2) and Kondoa (HSW_7) hot springs and the lowest in Kwapakacha (BHW_3) borehole water. Concentration ranges of Cu^{2+} was higher in hot springs from 0.36 to 0.55 mg/L than borehole water that ranges from 0.27 to 0.54 mg/L. Intake of drinking water contaminated with Cu^{2+}concentration greater than 3 mg/L in adults causes gastrointestinal effect and elicited nausea. The human body has a natural mechanism for maintaining the proper level of Cu^{2+} 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 (Toft *et al.,* 2004). The concentrations ofCu^{2+}obtained in this study are below permissible levels set by EWURA or TBS and WHO which ranges from 1 to 3 mg/L and 2 mg/L, respectively. Small amounts of Cu^{2+} are essential for good health but excess of Cu^{2+} can cause anemia and liver, kidney and brain damage. The p-value of t-test is $0.74>0.05$ indicated that there is no significant difference of Cu^{2+} between hot springs and borehole waters.

Potassium ion: Higher concentrations of K^+ observed in Gonga (HSW_6) hot spring with 52 mg/L and Isanja (BHW_1) borehole water with 68 mg/L as shown in Table 6. This is due to presence of K^+ ions in groundwater which indicate the existence of many rocks in study sites with K^+ salts. Lowest concentration of K^+ present in Isanja (HSW_3)hot springs with concentration of 8 mg/L whereas in the case of borehole waters(BHW_2) with concentration20 mg/L respectively. The sources of K^+ is likely due to silicate minerals, orthoclase, microcline, hornblende, muscovite and biotite in igneous and metamorphic rocks (Aiwerasia *et al.,* 2009). 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 EWURA or 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 volume 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 $0.33 > 0.05$.

ANOVA: The single factor ANOVA used to compare the physico-chemical parameters between hot springs and borehole water. The analysis of variance (ANOVA) was needed in order to make parametric assumptions within mean of a group. There is no significant difference in water quality between hot springs and borehole waters whereby $p>0.05$. But in most of the study sites, people depend only on borehole waters for domestic purposes by neglecting hot springs even though there is water scarcity.

Conclusion

Hot springs and borehole waters tested and compared by collecting water samples from ten different locations selected in central Tanzania. In this study physico-chemical parameters such as pH, EC, TDS, salinity, turbidity, Cl^-, total hardness, Ca^{2+}, Mg^{2+}, NO_3^-, SO_4^{2+}, F^-, Fe^{2+}, Mn^{2+}, Cd^{2+}, Zn^{2+}, Ni^{2+}, Cu^{2+}, and K^+ analyzed to predict the water quality status of hot spring and borehole waters of two regions namely Dodoma and Singida in Tanzania. Multimeter used for the analysis of physical parameters pH, EC, TDS, salinity and turbidimeter used to analyse turbidity. Titrimetric methods were used for chemical parametersCl^-, total hardness, Ca^{2+} and Mg^{2+}. UV-Vis spectrophotometric methods used for NO_3^-, SO_4^{2-},F^-, $Fe^{2+}$and Mn^{2+} and Flame Atomic Absorption methods used for Cd^{2+}, Zn^{2+}, Ni^{2+}, Cu^{2+} and K^+. The parameters EC, TDS, salinity, turbidity,Cl^-, NO_3^- , SO_4^{2-}, $F^-$and $Mn^{2+}$are higher (EC = 508.33-4790 µS/cm, TDS = 249.33-2349.30 mg/L, salinity = 0.27-2.53 ppt, turbidity = 0.81-513.73 NTU,Cl^-= 54.32-900.52 mg/L, NO_3^-= 0.1-63.30 mg/L, SO_4^{2-}= 38.33-343.33 mg/L, F^-=0.47-9.5 mg/L and Mn^{2+}= 0.6-1.9 mg/L) in hot springs than borehole waters (EC = 844.0-1821.67 µS/cm, TDS = 414.67-891.33 mg/L, salinity = 0.4-0.87 ppt, turbidity = 3.8-147.9 NTU,Cl^- = 119.68-356.50 mg/L, NO_3^- = 0.93-16.78 mg/L, SO_4^{2-} = 42.0-128 mg/L, F^-= 0.18-1.38 mg/L and Mn^{2+} = 1.5-1.6 mg/L). But other parameters TH, Ca^{2+}, Mg^{2+} Fe^{2+} and Ni^{2+} are higher in borehole waters than hot springs. The t-test ($p=0.05$) showed that there is significant difference of the parameters SO_4^{2-},F^- and Ni^{2+} between hot spring and borehole waters, but there is no significant difference of remaining all parameters. With respect to most of the parameters studied, borehole water has better quality than hot spring water based on comparison with permissible levels. But from the ANOVA for comparing cumulatively all the parameters between hot spring and borehole, there is no significant difference. 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 that is free from health hazards as well as to solve the water scarcity problems.

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Abbreviation

BHW	- Borehole waters
DUWASA	- Dodoma Urban Water Supply and Sewerage Authority
EBT	- Erichrome Black T
EC	- Electrical conductivity
EDTA	- Ethylenediaminetetraacetic acid
EWURA	- Energy and Water Utilities Regulatory Authority
FAAS	- Flame Atomic Absorption Spectrometry
GST	- Geological Survey of Tanzania
HSW	- Hot spring waters
NTU	- Nephelometric Turbidity Unit
ppt	- parts per thousand
SPADNS	- trisodium-2-parasulfophenylazo-1,8-dihydro -3,6-naphalenedisulfonate
SUWASA	- Singida Urban Water Supply and Sewerage Authority
TBS	- Tanzania Bureau of Standards
TH	- Total hardness
TDS	- Total Dissolved Solids
µS/cm	- Microsiemens per centimeter
WHO	- World Health Organization

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