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Quality Analysis of Water from Kitagata Hot Springs in Sheema District, Western Region, Uganda.

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Abstract – *The presence of water is a prerequisite condition for the existence and sustainability of life on the planet. Potable water is that which is fit for human and animal consumption, cooking, and sanitary purposes. In Uganda, there is still an inadequate supply of potable water for the population. The objective of this study is to perform a quality analysis of water obtained from Kitagata Hot Springs, Sheema District, Western Uganda. The temperature at water source points was measured and an average temperature of 62.3^{0}C was obtained. Standard procedures and equipment as recommended by American Public Health Association were adopted for the analysis. Physical, Chemical and Biological parameters of water quality considered for the analysis include electrical conductivity, turbidity, colour, total suspended solids, total dissolved solids, pH, iron, sulfates, nitrates, hardness, alkalinity, faecal coliforms, and e. coli. The result of the quality analysis of water samples showed average values as follows: electrical conductivity – 427.6 µS/cm, turbidity – 7 NTU, colour – 37.7 ptco, total suspended solids – 4.3 mg/l, total dissolved solids – 273.7 mg/l, pH – 5.63, iron – 0.4 mg/l, sulfates – 45 mg/l, nitrates – 4.1 mg/l, hardness – 86.3 mg/l, alkalinity – 58.3 mg/l, faecal coliforms – 2 CFU/100ml and e.coli – 0.67 CFU/100ml. The quality analysis revealed that 70% of the parameters had values that were not acceptable when compared to the Ugandan National Standards for potable water. From the foregoing, it is safe to conclude that water obtained from Kitagata hot springs does not satisfy the requirements to be considered as potable water. The study recommends the erection of physical barriers around the water source and the application of water treatment procedures to remediate the water and make it suitable for human consumption.*

Keywords: Quality, Analysis, Water, Kitagata, Uganda

1. INTRODUCTION

Water is a prerequisite condition for the existence and sustainability of life on the planet. Water is essential for sustainable development and a critical factor for socio-economic development and healthy ecosystems [1]. Drinking water obtained from sources contaminated with faeces is consumed by at least 2 billion people all over the world. The occurrence of water-borne diseases such as diarrhoea, cholera, dysentery, typhoid, and polio is a direct consequence of the consumption of contaminated water. Contaminated drinking water is estimated to cause 485,000 diarrhoeal deaths each year [2]. Access to potable water is in the range of 40% to 80% of the entire population of Sub-Saharan Africa. Nearly 4.2 billion people worldwide had access to tap water, while another 2.4 billion had access to wells or public taps [3].

In Uganda, sources of water for human consumption and sanitary activities include surface water, groundwater, and rainwater. Uganda has estimated renewable groundwater reserves of 7.661 billion gallons/year (or 29.0 million m3/year) [4] comprising 20,000 deep-wells, 3000 shallow-wells, 12,000 protected springs [5], and over 200,000 springs [6] in rural communities. Deep-wells and springs are the most important potable water sources for the people in rural communities, especially in Eastern and Northern regions where they provide over 80% of domestic water supply [7]. Uganda's population; like other developing countries still experiences an inadequate supply of potable water for consumption and sanitary purposes. A majority of the populace resort to water originating from eutrophic surface water sources and untreated groundwater [8],[9]. Poor solid waste management and inadequate spring protection lead to contamination of generally accepted spring water sources with pathogenic bacteria of clinical significance [10]. Protected springs provide a portion of the domestic water supply for an estimated 60% of the low-income population [11].

A spring with water at reasonably higher temperatures than the air in its immediate vicinity is known as a hot spring [12]. The oldest literature on the Ugandan geothermal systems dates way back to the late 19th Century with the description of the salt works at Lake Katwe crater, and measurement of the temperature of the lake and one of the hot springs in the crater as 29.1 and 32.5°C, respectively [13],[14]. In 1930, brief reconnaissance investigations of the geothermal resources were done to explore natural hot water in Uganda. Some of the waters in these areas, with low total dissolved solids content, could be used as mineral water [15]. In Sheema district, Western Uganda, the communities use water obtained from Kitagata hot springs for drinking and other domestic purposes.

Water Quality can be defined as the chemical, physical and biological characteristics of water, usually in respect to its suitability for a designated use [16]. Water quality analysis is carried out to quantify the chemical, physical and biological characteristics of water with a view to recommending the appropriate use in accordance with globally established standards. Guidelines have been provided by the World Health Organization [17], to provide information for water quality analysis with respect to drinking water and water for other sanitary purposes. In 2014, The Ugandan National Bureau of Standards published a specification of standards for potable water [18]. Subsequently, in 2019, the Ugandan National Bureau of Standards resolved to adopt the [19] standard for drinking and wastewater services.

2. MATERIALS AND METHODS

2.1 Description of Location

Google maps application was used to display the specific location of Kitagata Hot Springs, Sheema District, Western, Uganda; from where the water sample was collected.

2.2 Measurement of Temperature

Measurement of temperature was done in situ at the point of sample collection. Three different source points were randomly chosen for temperature measurement. The measurements were obtained using a standardized mercury-filled glass thermometer. The procedure provided by [20] was carefully followed to obtain the measurement values.

2.3 Water sample collection

This was done in strict observance of [21] standard procedure. A total of three water samples were collected from three water source points, chosen at random. Water samples were collected using sterilized 500ml plastic bottles. All water samples were collected in triplicate, covered in ice packs, placed in an 'ice chest', and transported to the laboratory. 5ml of concentrated Hydrogen Trioxonitrate (v) acid (HNO_3) was added to every 500ml of water sample obtained for water quality analysis. This treatment was used to minimize the adsorption of metals on the container walls.

2.4 Digestion of water samples

The standard procedure of open digestion set by the [21] was employed for the digestion of water samples. 50 ml well-mixed, acid preserved water sample was measured and transferred into a beaker. 5 mL of concentrated HNO3 was added to 50 ml of the water sample. The mixture was heated slowly to evaporate to a volume of about 15 – 20 ml on a hot plate. Continuous heating and adding of concentrated HNO3 as necessary was employed until digestion was complete as shown by a light-coloured, clear solution. The walls of the beaker were washed down with double distilled water and then filtered with a 0.45 µm pore filter paper. The filtrate was transferred to a volumetric flask and was topped to the 50ml mark with distilled water.

2.5 Quality analysis of water samples

Standard procedures and equipment as stipulated by [21] for water quality analysis were adopted.
Equipment used include:

- HANNA HI 83141 pH meter
- WAGTECH 7100 microprocessor turbidity meter
- Spectra 220 atomic absorption spectrophotometer

The following physical, biological and chemical parameters were considered in the analysis.

- Physical parameters
  - Temperature:
  - pH:
  - Electrical Conductivity (EC)
  - Turbidity
  - Colour
  - Total suspended solids
  - Total dissolved solids
- Chemical Parameters
  - Iron
  - Sulfate
  - Nitrates
  - Hardness
  - Alkalinity
  - Hardness
- Biological parameters
  - E. Coli
  - Faecal coliforms

2.6 Reference standard

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The results of the quality analysis will be compared with a reference standard, to establish its suitability for human consumption. For this study, the reference standard adopted is the Ugandan National Standard; Potable water – specification [18].

3. RESULTS AND DISCUSSION

3.1 Location of sample collection

The water samples for this study were collected from Kitagata hot springs located approximately 2 kilometres, by road, southeast of the town of Kitagata. It is one of the urban centres in Bushenyi – Sheema District Western, Uganda. Figure 1 shows the specific location as obtained from the Google maps application. The coordinates of Kitagata Hot Springs are 0°40'42.0"S, 30°09'38.0"E (Latitude: 0.678346; Longitude: 30.160556), [22].

Fig 1. *Specific Location of Kitagata Hot springs, Kitagata*

3.2 Water Temperature

The results of temperature measurements at the sampling points are shown in table 1.

Table 1. Results of temperature measurements at the sample points.

	Unit	Sample 1	Sample 2	Sample 3	Average
In – situ measured temperature	^{0}C	62.1	62.5	62.3	62.3

The temperature of water is a factor that influences its properties such as palatability, viscosity, solubility, odour, and chemical reactivity [21]. Groundwater at high temperatures has the ability to dissolve more minerals from the surrounding rock. Water at 10 – 15^{0}C is considered most palatable to humans [23]. Water obtained from Kitagata Hot Spring has an average temperature of 62.3^{0}C, which is not acceptable for human consumption.

3.3 Water Quality Analysis

The results of the analysis carried out on the samples based on the biological, chemical, and physical parameters of water quality are displayed in table 2. The table shows the mean values of the parameters and a comparison with [18].

Table 2: Results of quality analysis of water samples and the mean value of the parameters in comparison with Ugandan National Standards for potable water.

Parameters	**Unit**	**Sample 1**	**Sample 2**	**Sample 3**	**Mean value from quality analysis**	**Ugandan National Standards for potable water (Maximum acceptable)**	**Remarks**
Physical Parameters							
Electrical Conductivity	µS/cm	428	425	430	427.6	1000	Acceptable
Turbidity	NTU	6.2	8	6.8	7	5	Un –acceptable
Color	ptco	30	48	35	37.7	15	Un –acceptable
Total suspended solids	Mg/l	3	6	4	4.3	0	Un –acceptable
Total dissolved solids	Mg/l	273.92	272	275.2	273.7	700	Acceptable
Chemical Parameters							
pH	N/A	5.8	5.4	5.7	5.63	6.5 to 8.5	Un –acceptable
Iron	Mg/l	0.38	0.46	0.35	0.4	<0.3	Un –acceptable
Sulfates	Mg/l	48	47	40	45	200	Acceptable
Nitrates	Mg/l	3.8	3.6	5	4.1	5	Acceptable
Hardness	Mg/l	88	84	87	86.3	500	Un –acceptable
Alkalinity	Mg/l	57	60	58	58.3	500	Un –acceptable
Biological Parameters							
Fecal Coliforms	CFU/100ml	0	4	2	2	0	Un –acceptable
E. Coli	CFU/100ml	0	2	0	0.67	0	Un –acceptable

- Electrical conductivity: The electrical conductivity (EC) of water is a measure of the ability of water to carry or conduct an electrical current. The quantity of dissolved substances, chemicals, and minerals present in water influences electrical conductivity. Electrical conductivity increases with a high amount of these impurities. Pure water is not a good conductor of electricity [24]. The analyzed samples have electrical conductivity values ranging from 430 to 425 µS/cm, with a mean value of 427.6 µS/cm. This falls within the value of 1000 µS/cm [18].
- Turbidity: Turbidity is the measure of the relative clarity of a liquid. It is measured by the ability of light to pass through a water sample. It is caused by suspended materials such as clay, silt, organic material, plankton, and other particulate materials in water [24]. Turbidity makes water visually unattractive. Disinfection of water may be rendered ineffective due to suspended particulates providing hiding places that shield harmful microorganisms [25]. Human activities that disturb land such as construction, mining, and agriculture can lead to high turbidity in nearby water sources. Analysis of the samples showed turbidity values in the range of 8 to 6.2 NTU, with a mean value of 7 NTU. This is higher than the threshold of 5 NTU [18].
- Colour: Color is one of the aesthetic and visual qualities of potable water. Colour is imparted to water from decaying organic matter, suspended or dissolved organic matter. The water samples have mean values for the colour parameter as 37.7 ptco, which is higher than 15 ptco [18].
- Total Suspended Solids: This refers to waterborne particles that exceed 2 microns in size [26]. In terms of water quality, high levels of total suspended solids will increase water temperatures and decrease dissolved oxygen (DO) levels [27][27]. The mean concentration value of total suspended solids in the analyzed water samples is 4.3 mg/l. This is way above the value of 0 mg/l [18].
- Total Dissolved Solids: This refers to inorganic salts and organic matter that are dissolved in water. The inorganic salts are typically: sodium, calcium, potassium, sulfates, bicarbonates and chlorides [28]. Water can be classified into fresh, brackish and saline water, depending on the quantity of total dissolved solids it contains [29]. The analyzed samples have a mean concentration value of total dissolved solids as 273.7 mg/l. This value is below 700mg/l which is the threshold value [18].
- pH: pH is one of the most important parameters of water quality. It is defined as the negative logarithm of the hydrogen ion concentration [30]. It is a dimensionless number indicating the strength of an acidic or a basic solution [31]. The pH values of the samples range from 5.8 to 5.4, with a mean value of 5.63 which indicates acidity. This may be due to the exposure of the spring to direct rainfall as normal rainfall has a pH of approximately 5.6 (slightly acidic) due to the dissolution of atmospheric carbon dioxide gas to form H_2CO_3; a weak acid [21]. This deviates from value of 6.5 to 8.5 for potable water [18].
- Iron: The presence of iron in drinking water doesn't pose any significant health hazard. Iron in water is more of a visual/aesthetic nuisance. This happens when soluble Fe^{2+} ions come in contact with air to form insoluble Fe^{3+} ions which precipitate out of solution to give water a turbid appearance. These ions can also cause black or brown stains on laundry and plumbing fixtures [32]. Iron at even low concentration levels also imparts a bitter taste to drinking water [33]. Quality analysis results show that iron levels ranging from 0.35 to 0.46 mg/l, with a mean value of 0.4 mg/l. This is not in conformity with the value of <0.3 mg/l [18].
- Sulfates: Sulfates (SO_4^{2-}) are found in most naturally occurring waters. This is due to the leaching of sodium sulfate or magnesium sulfate. The presence of sulfates in high concentrations imparts an unpleasant taste to drinking water and has a

laxative effect. The maximum permissible value for sulfate content. is 200mg/l [18]. The analyzed samples have sulfate content in the range of 40 to 48mg/l with a mean value of 45 mg/l. This is below the acceptable threshold.

- Nitrates: Nitrates in high concentrations pose a significant health risk. It inhibits the transfer of oxygen by reacting with hemoglobin in the blood. This causes methemoglobinemia in infants below 6 months old. It can also lead to cardiovascular disease, lung disease and other metabolic problems [21]. Results of the quality analysis show a nitrate concentration value in the range of 3.8 to 5 mg/l and an average value of 4.1 mg/l. This is an acceptable value according to [18], with a threshold of 5mg/l.
- Hardness: Hardness in water is the property that makes it difficult for soap to lather. It also causes problems of 'scaling' in hot water pipes, kettles used for boiling water etc. Hardness caused by carbonates and bicarbonates of calcium or magnesium can be removed by boiling the water [21]. Quality analysis of the water samples gives values of hardness ranging from 84 to 88 mg/l, with an average value of 86.3 mg/l. This is less than 500 mg/l, which is the threshold value of [18].
- Alkalinity: Alkalinity is the water's capacity to resist changes in pH that would make the water more acidic [34]. The alkalinity of water is measured in mg/l as calcium carbonate and is important to determine the amount of lime and soda required for water softening [35]. The alkalinity of the water samples is in the range of 57 to 60 mg/l with a mean value of 58.3 mg/l. This is below the maximum permissible limit of 500 mg/l according to [18].
- Fecal Coliforms: Fecal coliform bacteria indicates the contamination of water by fecal matter of man or animals. This contamination might be through the entry of sewage or directly from humans or animals. This further relates to the presence of disease-causing bacteria, pathogens and viruses that exist in fecal matter. The analyzed samples show fecal coliform concentrations of 0 – 4 CFU/100ml, with an average value of 2 CFU/100ml. This is above the recommended permissible limit of [18].
- E. Coli: Escherichia Coli (E. Coli), is a particular specie of coliforms found in domestic waste. E. coli bacteria are mostly harmless but their presence draws attention to the risk of other pathogenic organisms that are found in human feces. The water samples have E. Coli presence of 0 to 2 CFU/100ml and an average value of 0.67 CFU/100ml. This is a deviation from 0 CFU/100ml which is the acceptable value [18].

4. CONCLUSION AND RECOMMENDATIONS

Quality analysis was carried out on water samples obtained from Kitagata Hot Springs, Sheema District, Western Uganda. Water temperature was measured in – situ and an average temperature 62.30C was recorded. Physical, Chemical, and Biological parameters of water quality were considered for the analysis. Standard procedures and equipment for water quality analysis [21] were utilized. The parameters considered are electrical conductivity, turbidity, colour, total suspended solids, total dissolved solids, pH, iron, sulfates, nitrates, hardness, alkalinity, faecal coliforms and e. coli. The result of the quality analysis of water samples showed average values as follows: electrical conductivity – 427.6 µS/cm, turbidity – 7 NTU, colour – 37.7 ptco, total suspended solids – 4.3 mg/l, total dissolved solids – 273.7 mg/l, pH – 5.63, iron – 0.4 mg/l, sulfates – 45 mg/l, nitrates – 4.1 mg/l, hardness – 86.3 mg/l, alkalinity – 58.3 mg/l, faecal coliforms – 2 CFU/100ml and e.coli – 0.67 CFU/100ml. The quality analysis revealed that 70% of the parameters had values that were not acceptable when compared to the Ugandan National Standards for potable water. From the foregoing, it is safe to conclude that water obtained from Kitagata hot springs does not satisfy the requirements to be considered as potable water.

This study should be adopted by the local authority as a guide in the provision of potable water supply to the communities surrounding the Kitagata hot springs. The quantity of water from the spring might be adequate but the quality is clearly below the acceptable standard. Protective structures should be erected around the spring to deter physical pollution by humans and animals. Water treatment procedures should be applied to the water to remediate the non – conforming physicochemical parameters of the water quality.

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