Assessment of Amakera spring water quality: A case study of Musanze district, Rwanda

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Abstract**—** *Water pollution from various types of pollutants is not only a serious environmental issue but also an economic and human health problem. This study investigated Amakera water springs located in Musanze District which is consumed by local people and tourists due to its taste. These springs take their source from underground aquifers. However, its quality is uncertain, therefore, its investigations come into prominence for its usability. Analysis of Physico-chemical and Bacteriological parameters to check its potable perspective in comparison with the international standard of drinking water was the main purpose. Samples were taken at three different sources in the dry season of 2020. In general, the results showed that the water is potable. Nevertheless, some parameters are present in high content especially dissolved salts which affect the taste of water and iron which affect the color of the river bed. The conductivity was found to vary from 8120µS/cm to 11,010 µS/cm while total hardness was found to be 637.50 mg/l as* $CaCO_3$*, 3,875.00mg/l as* $CaCO_3$ *and 1,852.50mg/l as* $CaCO_3$ *and TDS values were in the same range (3,800-3070mg/l), iron content were 8.90, 3.10, and 2.45 mg/l. The analysis indicated that all the three points are practically the same and can be consumed fresh. However, their protection is highly recommended to avoid the possible pollution.*

Keywords**— *Bacteriological, Physico-chemical parameters, pollution, Water quality.***

I. INTRODUCTION

Water covers over 70% of the earth's surface and is the utmost valuable natural resource that exists on the earth [1,2]. Its world distribution indicates that only 2.5% and 97.5% constitute freshwater and saline water respectively [2]. Freshwater is indispensable in various domains of human daily life [3], moreover, it is generally seen as an essential input to human production and an effective tool of economic improvement [4]. Regrettably, in many countries around the world, including Rwanda, some drinking water supplies have become contaminated mainly due to both anthropogenic activities and natural processes [5,6] and the deteriorated quality of ground and surface waters is becoming a critical issue in many parts of the earth [1]. Water pollution from various types of contaminants is not only a serious environmental issue but also an economic and human health problem [7]. Many scientific techniques and tools have been developed to evaluate water contaminants [9,10,11]. These techniques include the analysis of different parameters such as pH, turbidity, conductivity, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), heavy metals, and microbes. These parameters can affect the drinking water quality if their values are in higher concentrations than the safe limits set by the East African Community and other regulatory bodies [8,11].

Freshwater sources in Rwanda exist as lakes, rivers, natural springs, and groundwater. The water supply for drinking purposes comes mainly from natural springs and underground water sources [18]. In this study, 3 water sources of Amakera Water namely Cyabararika, Rubindi and Kigombe were assessed. All these spring sources are located in Musanze District of Northern province of Rwanda. Cyabararika Cold Spring (site 1) takes its source from underground aquifers and was protected by the construction of delimitation walls many years ago to maintain its special quality, different from other surrounding water, unfortunately, they were damaged. This spring does not flow but instead, it is bubbling up from between two old constructed walls due to gases from underground [19]. The spring is surrounded by a small wetland alongside the Mpenge River and it is used for different human activities. Whereas, Rubindi Cold Spring (site 2) collects its water from three small springs which take their sources from Karisimbi volcano and meet to form a large spring. The water quality of Rubindi spring depends on the surrounding environment and human activities around the spring. The spring is surrounded by cultivated land and it flows between residences of people around there. Discharge from agricultural and residential areas may change the natural quality of the spring. Site 3, Kigombe water spring is also located in Musanze city, near horizon Sopyrwa factory. For all these springs, a large number of local populations fetch the water for drinking purposes. Many people like the taste of this water which is like "carbonated water" without being aware if it meets the drinking water standard, subsequently, its quality investigations come into prominence for its usability [10,19]. This study aimed at analyzing the Physico-chemical and Bacteriological parameters to check its potable perspective in comparison with the international standard of drinking water.

II. MATERIAL AND METHODS

2.1 Site description

This study was conducted in Northern part of Rwanda, Musanze district. The samples were taken in 3 sites as shown in Fig 1. Cyabararika Cold Spring (site 1) is a small spring located in Musanze city, alongside the Mpenge River. This spring takes its source from underground aquifers. Whereas, Rubindi Cold Spring (site 2) is located in Gataraga village of Musanze District in Northern Province about 8 km Northwest of Musanze town. This spring is located at the footstep of Karisimbi volcano in Virunga Volcanic Range 600 meters below the park boundary. Site 3, is also located in Musanze city, near horizon Sopyrwa factory.

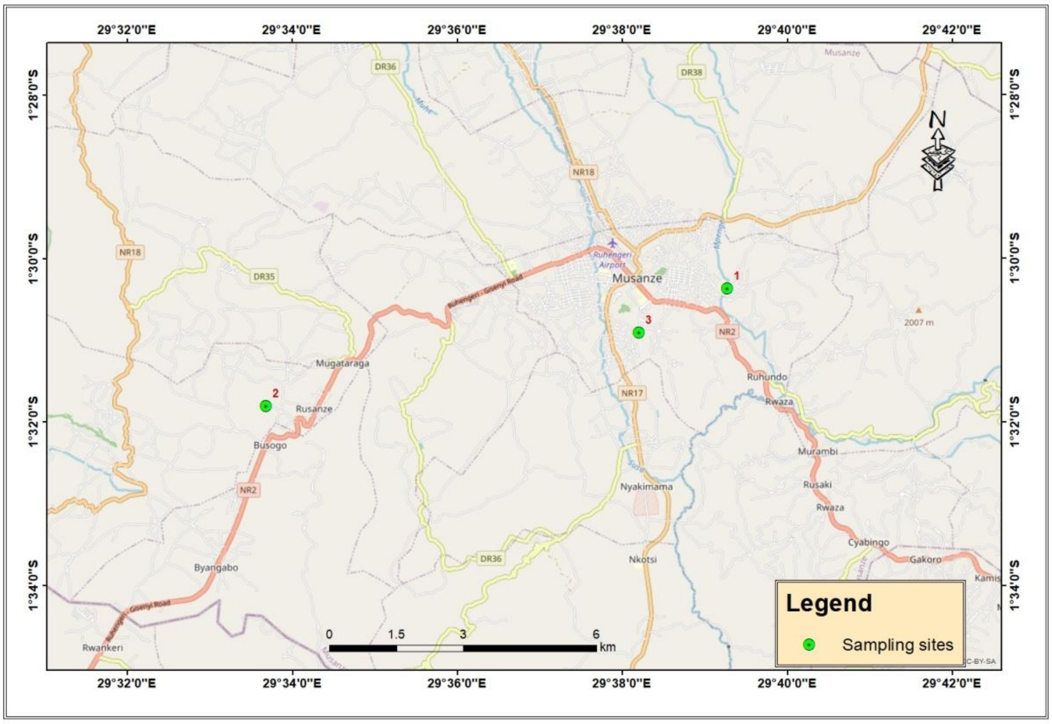

FIGURE 1: Sampling sites

2.2 Sampling and analysis

All samples were taken in well cleaned and identified bottles and were transported and kept at a low temperature of 4°C. Physico-chemical parameters (pH, temperature, and EC) were tested in situ using a high-accuracy multiparameter water quality meter called Bante instrument 900, TDS was analyzed using a TDS-meter (ST20T-B). The turbidity of water was measured in situ using a turbidity meter. Total suspended Solid (TSS) was measured after vacuum filtration using cellulose filters (0.45μm) and oven-dried at 105±1°C for 1hour. Total Hardness (TH) was determined by the EDTA titration method with eriochrome black T indicator. A spectrophotometer UV-Visible (Palintest 8000) with compatible kits was used to analyze anion SO_4^{2-}, nutrients (NO_3^-, NH_3 and PO_4^{3-}) while the iron content was determined using the Atomic Absorption Spectrometric method. Chloride was determined using a titrimetric method with silver nitrate and potassium chromate as an indicator. Enumeration of Escherichia Coli (E. Coli), Total Coliforms (TC) bacteria, and Faecal Coliform (FC) were done by membrane filtration method with corresponding culture media.

III. RESULTS AND DISCUSSION

3.1 Physico-chemical results

The results of Temperature, pH, Turbidity, TDS, EC, TSS, Nitrates, Phosphates, Sulphates, Ammonia, Chlorides, Iron, and Total hardness content of all the sampled sites were found to be within the acceptable limit as shown in Table 1.

TABLE 1
RESULTS OF PHYSICO-CHEMICAL PARAMETERS

Parameters	Unit	Amakera site 1	Amakera site 2	Amakera site 3	EAC (2018)
Temperature	^oC	19	18.2	18.2	
pH	-	5.2	6.78	6.82	5.5-9.5
Turbidity	NTU	0	0	0.98	5
TDS	Mg/L	3,800.00	3,070.00	3200	1500
EC	µS/Cm	11, 020.00	10,100.00	8120	2500
TSS	Mg/L	0	0.1	0.2	Not detectable
Nitrates	Mg/L	4	1.9	2.6	45
Phosphate	Mg/L	1.35	2	2.18	2.2
Sulphates	Mg/L	7	59	60	400
Ammonia	Mg/L	0.55	0.12	0.205	0.5
Chlorides	Mg/L	24.99	26.13	25.1	250
Iron	Mg/L	8.9	3.1	2.45	0.3
Total Hardness	Mg/L	637.5	3,875.00	1,852.50	600

pH: The pH was carried out and the values were ranged from 5.20 to 6.82, according to several organizations including RSB, EAC the potable water specification, pH acceptable limit ranges between 5.5 and 9.5 [11]. For this study, the pH of all sites were showing the acidic character where two sites fall in the normal range while the third one is slightly below the limit, which could be due to the contamination from the human activities around the area.

Electrical conductivity: The electrical conductivity is commonly used to indicate the total concentration of ionized constituents of water [12]. According to EAC (2018) standard, the acceptable limit for potable water is 2500 µS/cm [11]. The conductivity was found to be high for all samples varying from 8120µS/cm to 11,010 µS/cm, this might be due to high mineral content in water.

Total Dissolved Solids (TDS)**:** Total dissolved solids describe the number of inorganic salts mainly salts of calcium, magnesium, sodium, among others, and the small percentage of organic matter present in the water [12]. In this study, TDS values were in the same range (3,800-3070mg/l) and above the permissible limit which is 1500mg/l [11]. This confirms with the EC values showing high inorganic salts content and the water may be saline. Total dissolved solids (TDS) level of less than about 600 mg/l is normally considered to be acceptable for drinking purpose, it becomes significantly and increasingly unpalatable at TDS levels greater than about 1500 mg/l which is the case for this study. The presence of high levels of TDS may cause unpleasant taste to consumers [11,12].

Total Suspended Solids (TSS)**:** The EAC has set that TSS must not be detectable in potable water [11]. The TSS values of all water samples studied are shown in Table 1. The results showed that Amakera site 1 of the study area was within acceptable limit while Amakera site 2 and 3 were slightly above the permissible limit with 0.1 and 0.2mg/l TSS contents respectively. This could be due to the agricultural activities in the area and other anthropogenic activities.

Nitrates (NO_3^-): Nitrate in groundwater is generally of anthropogenic origin and associated with the leaching of nitrogen from agriculture plots. The EAC standard has set the maximum limit of 45mg/l [11]. During this study, the maximum value of nitrate was found to be 4.0mg/l which is within permissible limit for drinking water.

Phosphate: The phosphate content found were 2.18 mg/l, 2.00 mg/l, and 1.35 mg/l for Amakera site 3, site 2, and site 1 shown in table 1 respectively. They are all within the acceptable range [11].

Sulfate: The sulfate level of natural waters is a key factor in assessing their acceptability for public and industrial usage; a high sulfate concentration can cause respiratory difficulties in humans [13]. SO_4^{2-} was recorded as 7mg/l, 59mg/l and 60mg/l for site 1, 2 and 3 respectively. All the values obtained were below the maximum limit of 400mg/l as per EAC [11].

Ammonia: The acceptable limit of ammonia is 0.5mg/l as set by EAC potable water specification [11]. During this study, high ammonia content was found to be slightly above the acceptable value of 0.55mg/l for site 1, whereas the two remaining sites were within limit 0.12 and 0.205mg/l for site 2 and site 3 respectively. Ammonia contamination can arise from bacterial or bioorganic materials contamination [14].

Chloride: A high concentration of chlorides is regarded a pollution indicator because it causes a salty taste in drinking water and accelerates corrosion of water pipelines and irrigation water, which can harm agricultural products and produce foliar burns on crops when deposited on leaves [15]. Between the three sites, the chloride content indicated only minor differences in sampling points. The values found were 24.99 mg/l for site 1, 26.13 mg/l for site 2, and 25.1 for site 3. By comparison, all of the results were within the acceptable chloride limit defined by the EAC for drinking purposes, which is 250 mg/l [11].

Iron: The results found were high compared to the maximum defined by EAC standard, while the maximum value is 0.3 mg/l [11], the following values 8.90, 3.10, and 2.45 mg/l were found for site 1, 2, and 3 respectively. Iron is found in the form of iron (II) salts, which are unstable and precipitate as insoluble iron (III) hydroxide, which settles out as rust-colored silt, due to the high amount of iron-containing wastes or soil and rocks weathering and Staining of laundry and plumbing may occur at concentrations above 0.3 mg/l this agrees with the fact that Amakera water is not used in washing or cooking because they get colored [16]. Despite its high concentration, it does not have a negative health effect [16].

Total hardness: The main hardness-inflicting cations are particularly the divalent calcium, magnesium and occasionally strontium, ferrous iron, and manganous ions [13, 15]. Total hardness was found 637.50 mg/l as $CaCO_3$, 3,875.00mg/l as $CaCO_3$ and 1,852.50mg/l as $CaCO_3$ for site 1, 2 and 3 respectively. Hardness for all sites was high compared to the permissible limit; this might have caused an increased concentration of salts [15]. The hard water doesn't give lather with soap, this might be the reason the local people don't use Amakera for washing.

3.2 Bacteriological results

The results of the bacteriological analysis are represented in Table 2. All tested parameters were found to meet the requirements of drinking water therefore; drinking this water cannot cause water-borne diseases [11].

TABLE 2
RESULTS OF BACTERIOLOGICAL PARAMETERS

Parameters	Unit	Amakera site 1	Amakera site 2	Amakera site 3	EAC Limit
E.COLI in 100ml	CFU/100ml	0.00	Absent	Absent	Not detectable
Feacal coliform	CFU/ml	$2.3*10^{-3}$	0	0	Not detectable
T.Coliform in 100ml	CFU/100ml	0.00	Absent	Absent	Not detectable

IV. CONCLUSION

The purpose of this research was to assess the quality of Amakera water located in Musanze District. In general, the results showed that the water is potable. However, some elements are present in high content especially dissolved salts which affect the taste of water and iron which affect the color of the river bed. It was found also that this type of water is used fresh because of a high content of iron which gets oxidized with time.

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