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The effects of human activities on spring water quality in Rwanda-Case study of the City of Kigali, Rwanda

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ABSTRACT: Quality of Spring water like any other water resources from rivers and lakes depends on physical, chemical and bacteriological properties. Spring water quality in Rwanda is affected by human activities that generate pollution from agrochemical, municipal and other domestic wastes. The aim of this study was to assess the effects of human activities on the selected springs of Giticyinyoni, Sahara and Umushumbamwiza located in Gasabo, Kicukiro and Nyarugenge Districts of the City of Kigali, Rwanda. The parameters selected as water quality indicators were: pH, Temperature, Turbidity, DO, EC, TDS, Total hardness, Nitrate, Total Phosphate Fluoride, E-Coli and Total Coliforms. The methodology of data collection was measuring pH, Temperature, turbidity, DO EC, TDS, TSS was measured onsite by the researcher using calibrated MPS-D8 Multiparameter water quality probe, SebaHydrometrie GmbH whereas hardness was measured using Hach 8204, nitrate using Hach 8039, Total Phosphate using Hach 10072, Fluoride using Hach 8029, E-Coli using EPA SM 9223B, second edition and Total Coliform measured using EPA SM 9223B, Second edition analytical methods. This study shows that the majority of physcico-chemical parameters meet the standard limit except the pH of Umushumbamwiza and Giticyinyoni that are above the standard limit compared to RS-EAS 12:2018- untreated potable water and DO of all springs that are also below the acceptable standard limit of WHO guidelines for drinking water.E-coli of Sahara,and Total coliforms of the selected spring water are out of the standards limit, compared to RS-EAS 12:2018- untreated potable water. The study found out indication of biological pollution to all selected spring water and recommended prior treatment before its use and recommended the further researchers to conduct a complete biological assessment of remaining springs used for drinking and domestic purpose in the City of Kigali.

Key words: Spring water, human activities, City of Kigali.

I. INTRODUCTION

Water is necessary resource for life on the planet. Its availability has often affected the pattern of human habitation throughout history. Human survival is mostly dependent on fresh water supplies, which account for less than 1% of all water on the planet. Ground or spring water is a valuable supply of drinking water, industrial, agricultural, and recreational desires and groundwater has been sought as the source in many developing and underdeveloped countries. However, its quality is currently challenged by over-abstraction as well as microbiological and chemical contamination resulting from human-made activities such as such as industry, agriculture, and household influence on the quality of groundwater sources, pollution of water is also diminishing the amount of safe drinking water available in addition to desertification. (Unicef, 2008).

In the last decades, the use of freshwater resources has been risen due to population growth, economic growth, urbanization, changing lifestyles and changing the patterns of consumption (Okello&et al., 2015).Water sources resources and aquifer can be contaminated from agricultural activities, livestock, rural industrial units, and urbanization through agricultural fertilizers and pesticides, industry, domestic waste, landfill leaks, and pit latrines. (Akhtar&et al., 2021).

In developing countries the potential consequences of drinking water contaminated with pathogenic microorganisms is the infectious diarrheal diseases that may affect children (Tyagi, 2014).

Human pathogenic pathogens should not be present in water used for drinking, food and beverage preparation, or personal hygiene. Bacteria, fungus, algae, and viruses are among the microorganisms that can contribute to water contamination, leading in a range of discharges and death outbreaks. The presence of Fecal Coliforms in drinking water sources as an indicator of harmful bacteria may contribute to the spread of waterborne illnesses. (Mahmud&et al., 2019).

To protect public health, water for human consumption must be free of pathogens, chemical pollutants, and be physically clear and tasty. It is also critical that water used for home, agricultural, or industrial purposes be not more acidic or alkaline than what is allowed by standards. (Haile, 2015).

One of the most important environment issues today is groundwater contamination and the diversity of contaminants that affect water resources. The natural chemical quality of groundwater is generally good, but elevated concentrations of a number of constituents can cause problems for water use.In the rainy season, fecal matter from pit latrines and open sources is washed into water bodies, thereby contaminating the water. (Ahmad2, 2016).

The City of Kigali has various water sources such as: rivers, springs, and wells. Even though the majority of the population is supplied with treated water for domestic uses but it has been observed that in period of abstraction of treated water and for peoples living in the vicinity of spring waters in many places of the City of Kigali, they frequently use spring water sources for drinking and domestic purposes without prior treatment (nisr, 2019).

The various researches done for some physico-chemical parameters of different springs in Rwanda suggested the further study of the bacteriological status of spring water in Rwanda and elsewhere in the world due to its important use for drinking and irrigation purposes (Nsengimana & et al, 2012). In order to have comprehensive and good information about the qualities of spring water it is necessary to ensure the suitability of these water sources prior to various use where physical, chemical and bacteriological characteristics need to be regularly monitored (Omer, 2019).

Therefore, the present study analyzed the quality of spring water sources in the City of Kigali where the following physicochemical and bacteriological indicators such as: pH, Temperature, turbidity, DO, EC, TDS, TSS, hardness, nitrate, Total Phosphate, Fluoride E-Coli and Total Coliforms were determined and compared to RS-EAS: 18-Potable drinking water and WHO guidelines for drinking water to show their suitability.

II. METHODS AND MATERIALS

2.1 Description of study area

The City of Kigali is the capital of Rwanda and it is located at Rwanda's geographical heart. The City of Kigali has rapidly grown in a modern city in the last decade and it has not only become Rwanda's most important business center but also the main port of entry.

The City of Kigali is 730 Km 2 made up of three Districts namely Gasabo, Kicukiro and Nyarugenge.

It is presently inhabited by approximately 1.2 million inhabitants. Kigali is 70% rural with a population The City of Kigali is located at -1.9666 Latitude and 30.1166 Longitude, 1° 57′ 60″ South, 30° 6′ 60″ East. Its altitude is 1,413 m and It has Tropical savanna climate.

The study area will cover specifically springs of Umushumbamwiza located at latitude 1^0 57'29.99448''S and longitude 30^0 7′ 39.04392'', Kimironko Sector, Gasabo District, Sahara located at latitude 1^0 58'11.37612''S and longitude 30^0 6′ 36.29052''E, Niboye Sector, Kicukiro District and Giticyinyoni located at latitude 1^0 56'53.38932''S and longitude 30^0 1′ 32.1726''Ein Kigali Sector, Nyarugenge District.

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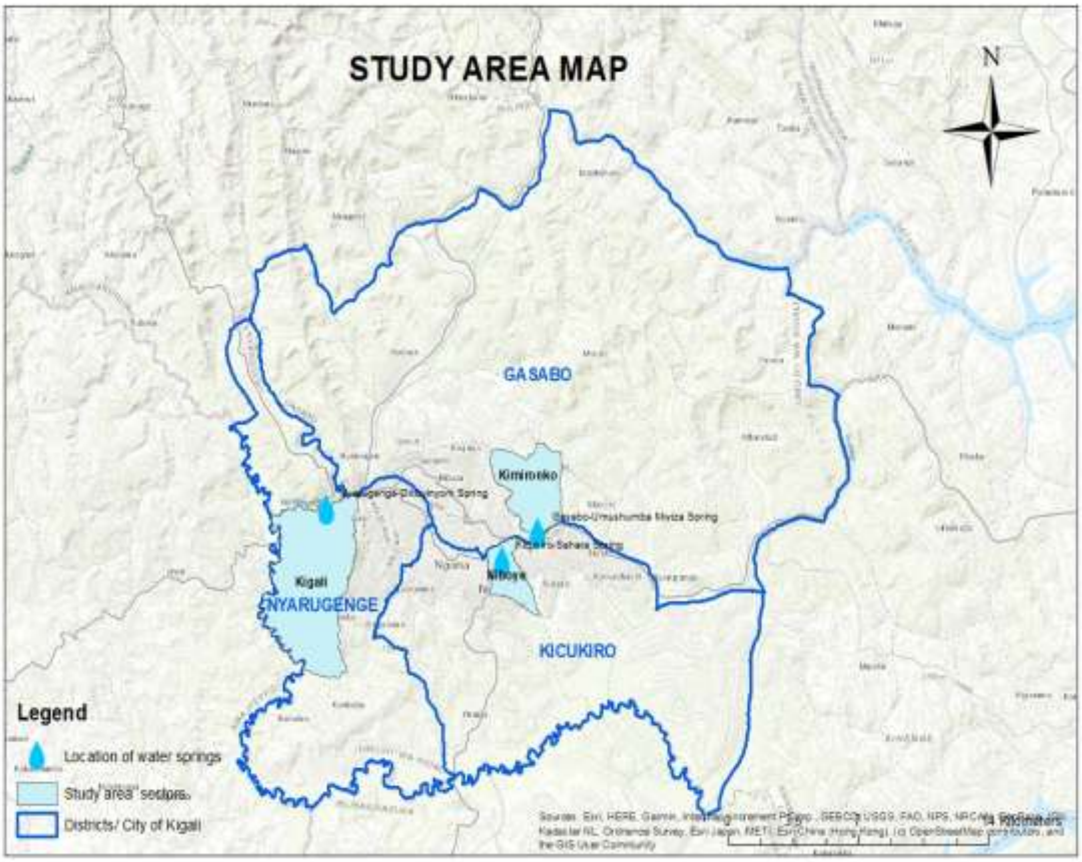

Figure 1: Map showing selected springs of the City of Kigali

Urban and industrial development like Settlement and small businesses are the economic activities that observed nearby Umushumbamwiza spring, Kimironko Sector, Gasabo District and Sahara spring, Niboye Sector Kicukiro District produce domestic waste water discharge whereas at Giticyinyoni spring Kigali Sector, Nyarugenge District no economic activity found at the source of the spring. For Giticyinyoni spring water can be contaminated through fetching period because no water pipe at the spring.

2.2 Sampling procedure and analytical methods

pH, Temperature, turbidity, DO EC, TDS, TSS, hardness, nitrate, Total Phosphate, Fluoride, E-Coli and Total Coliform parameters were analyzed for each spring water in the selected springs of Umushumbamwiza,Sahara and Giticyinyoni.

The following parameters pH, Temperature, turbidity, DO EC, TDS, TSS was measured onsite by the researcher using calibrated MPS-D8 Multiparameter water quality probe, SebaHydrometrie GmbH; hardness, nitrate, Total Phosphate, Fluoride will be done by sampling water at each spring by respecting the standards operating procedures and were measured by University of Lay Adventist of Kigali (UNILAK) laboratory with the support of Laboratory Technician then after E-Coli and Total Coliform parameters will be measured by sampling water and measurement by Water and Sanitation Corporation (WASAC) Central Water Laboratory after paying the cost of laboratory analysis.

The parameters selected as water quality indicators were: pH, Temperature, Turbidity, DO, EC, TDS, Total hardness, Nitrate, Total Phosphate Fluoride, E-Coli and Total Coliforms. The methodology of data collection was measuring pH, Temperature, turbidity, DO EC, TDS, was measured onsite by the researcher using calibrated MPS-D8 Multiparameter water quality probe, SebaHydrometrie GmbH by the researcher whereas hardness measured using Hach 8204, nitrate using Hach 8039, Total Phosphate using Hach 10072, Fluoride using Hach 8029 by UNILAK laboratory, E-Coli using EPA SM 9223B, second edition and Total Coliform measured using EPA SM 9223B, Second edition analytical methods by WASAC.

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III. RESULTS AND DISCUSSION

The results in table2 shows the physico-chemical and bacteriological status of three selected springs

Table 1: Results of physico-chemical and Bacteriological parameters analyzed

Parameters	**WHO Guidelines 2011**	**RS-EAS 12:2018-Potable water**	**Unit**	**Spring 1**	**Spring 2**	**Spring 3**
Temperature		increase of 3 °C	°C	23.94	24.35	23.62
pH	6.5-8.5	5.5-9.5	-	4.785	5.577	5.298
EC	250	<2500	µs/cm	663	571	287
TDS	500	<1500	mg/l	444	383	192
Turbidity	1-5	<25	NTU	0.401	0.467	2.373
DO	>5.5	-	mg/l	3.686	4.689	3.868
Total hardness	300	<600	mg/l	27.2	24.8	16.1
Fluoride		<1.5	mg/l	0.54	0.35	0.22
Nitrates	50	<45	mg/l	12.7	20.8	6
Total phosphates		<2.2	mg/l	1.2	0.37	0.24
E-Coli	Not detectable	Not detectable	MPN/10^0ml	$<1*10^0$	$12.4*10^0$	$<1*10^0$
Total coliforms	Not detectable	Not detectable	MPN/100ml	$11.1*10^0$	$118.4*10^0$	$200.5*10^0$

Spring 1: Umushumbamwiza
Spring 2: Sahara
Spring 3: Giticyinyoni

Temperature
In our current studythe temperature of different sampling spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 23.94°C, 24.35°C and 23.62°C.

pH
The pH of different sampling spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 4.785, 5.577 and 5.298. It was observed that only pH Sahara spring that was slightly low but meet standard limit, the pH of Umushumbamwiza and Giticyinyoni were below the standard limit compared to RS-EAS 12:2018-Potable drinking water where pH standard is between 5.5-9.5.

In our current study the decrease of pH at Umushumbamwiza and Sahara is attributed to pollution with detergent releases into water that produces nutrients enrichment and high organic matter that decreases pH but also with natural phenomena caused by the type of rock like granite that decreases pH of water body.

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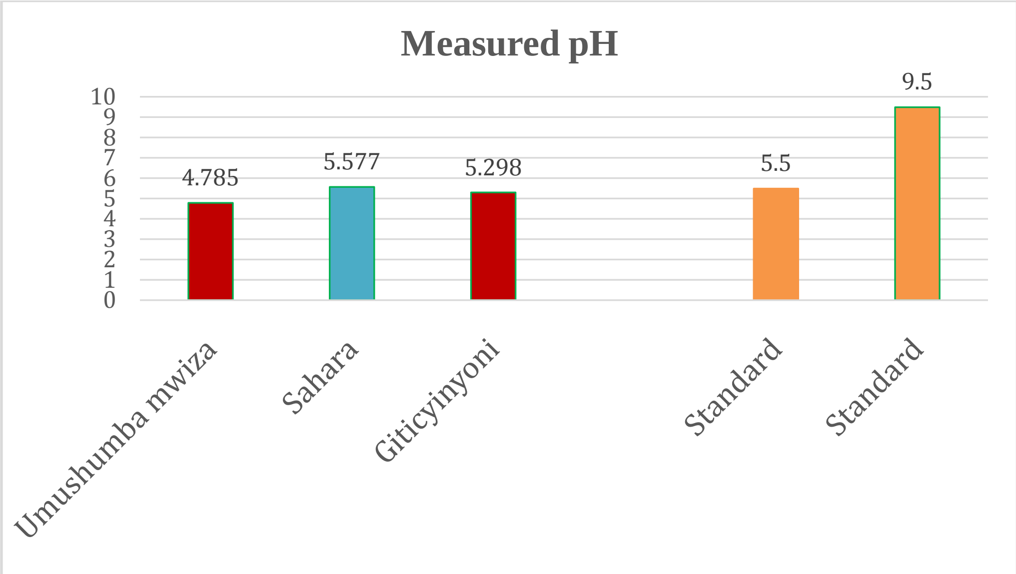

Figure 2: Compared measured pH to standard

Source: Research data (2022)

Electrical Conductivity

The EC of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 663,571, and 287 µs/cm. It was observed that EC of all selected springs meet standard limit, compared to RS-EAS 12:2018-Potable drinking water where EC standard limit which is 2500 µs/cm.

Total Dissolved Solids

In our current study TDS of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 444, 383,192 mg/l. It was observed that TDS of all selected springs meet standard limit, compared to RS-EAS 12:2018-Potable drinking water where TDS standard limit which is 1500mg/l.

Turbidity

In our current study the Turbidity of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 0.401, 0.467 and 2.373 NTU. It was observed that Turbidity of all selected springs meet standard limit, compared to RS-EAS 12:2018-Potable drinking water where Turbidity standard limit which is 25NTU.

Dissolved Oxygen

In our current study the DO of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 3.686, 4.689 and 3.868 mg/l. It was observed that DO of all selected springs were below standard limit, compared to WHO,2011 Guidelines for drinking where DO standard limit which should not be below 5.5 mg/l.The decrease of DO in all selected springs is attributed to the high presence of organic presence in water that cause decomposition that uses oxygen reducing availability of Dissolved Oxygen. Waste water discharge high in organic and nutrient content is another cause attributed to DO decrease of the selected springs.

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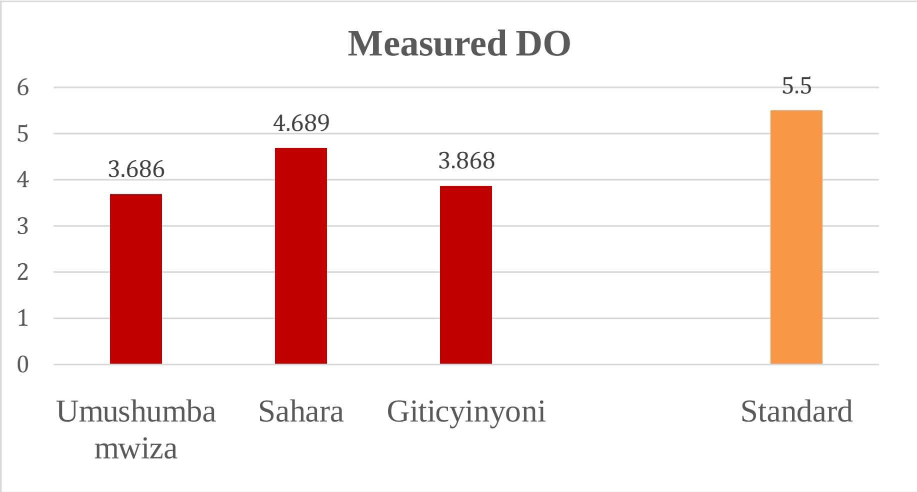

Figure 3: Compared measured DO to standard

Source: Research data (2022)

Total hardness

In our current study, the Total hardness of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 27.2, 24.8 and 16.1 mg/l. It was observed that Total hardness of all selected springs meet standard limit, compared to RS-EAS 12:2018-Potable drinking water where Total hardness standard limit which is 600 mg/l.

Fluoride

The results of our current study reveals that the fluoride of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 0.54, 0.35 and 0.22 mg/l. It was observed that Fluoride of all selected springs meet standard limit, compared to RS-EAS 12:2018-Potable drinking water where Total hardness standard limit which is 1.5 mg/l.

Nitrates

In our current study the Nitrates of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 12.7, 20.8 and 6 mg/l. It was observed that Nitrates of all selected springs meet standard limit, compared to RS-EAS 12:2018-untreated potable water where Total hardness standard limit which is 45 mg/l.

Total phosphates

The results of our current study indicate that Total Phosphates of different sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively 1.2, 0.37 and 0.24 mg/l. It was observed that Total Phosphates of all selected springs meet standard limit, compared to RS-EAS 12:2018-Potable drinking water where Total hardness standard limit which is 2.2 mg/l.

E-Coli

E-Coli was analyzed in sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively $<1*10^0$, $12.4*10^0$ and $<1*10^0$.It was observed that only Umushumbamwiza and Giticyinyoni meeting standard limit RS-EAS 12:2018- Untreated Potable water where E- Coli standard must not be detected in water.The presence of E-coli in Sahara spring is attributed to the contamination with fecal matter resulting from informal settlements linked to lack of sanitation facilities and poor protection of the spring to waste water discharges from households as well as soak pits and use of pits latrine that percolate and contaminate the water table.

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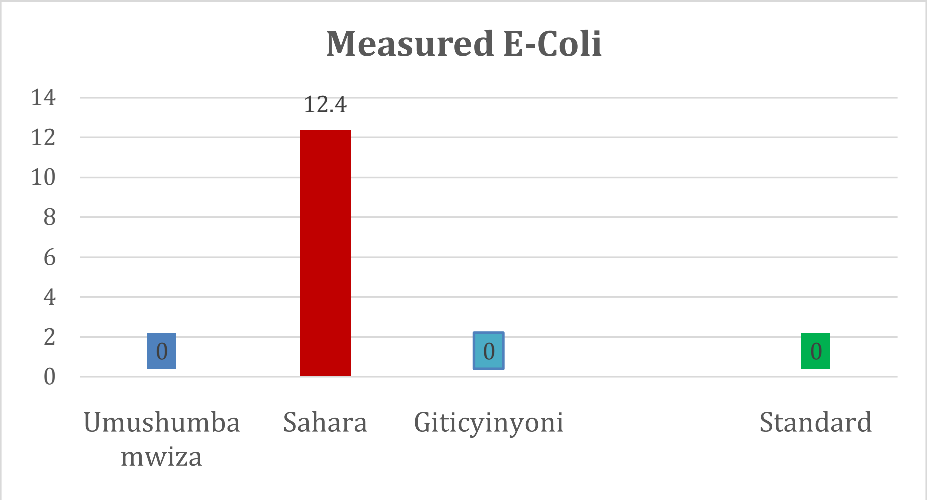

Figure 3: Compared measured E-coli to standard

Total coliforms

Total coliforms were analyzed in sampled spring water of Umushumbamwiza, Sahara and Giticyinyoni are respectively $11.1*10^0$, $118.4*10^0$ and $200.5*10^0$.It was observed that all the sampled spring water don't meet the standard RS-EAS 12:2018-Untreated Potable water where Total Coliforms must not be detected in water.Total coliforms are used as indicator to examine the cleanliness of as well as indicator of biofilms in water.The presence of Total coliforms into selected spring is attributed to poor clean of water that is contaminated by waste water discharge, pit latrine, domestic waste nearby the spring. The water from the selected spring need be disinfected prior to use for domestic purposes.

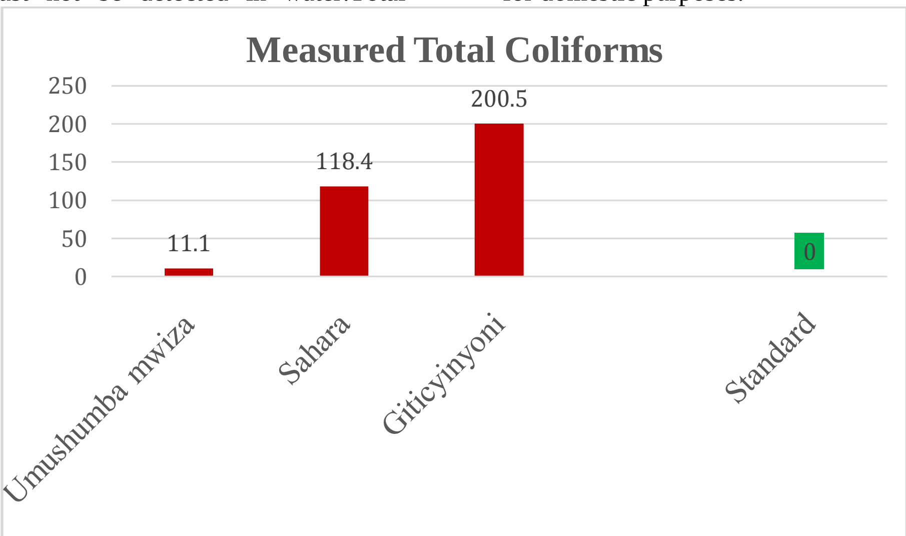

Figure 3: Compared measured Total coliforms to standard

IV. CONCLUSION

The levels of parameters pH, Temperature, turbidity, DO EC, TDS, TSS was measured onsite by the researcher using calibrated MPS-D8 Multiparameter water quality probe, SebaHydrometrie GmbH; hardness, nitrate, Total Phosphate, Fluoride will be done by sampling water at each spring by respecting the standards operating procedures and were measured by UNILAK laboratory with the support of Laboratory Technician then after E-Coli and Total Coliform parameters were measured by sampling water and measurement by WASAC Central Water Laboratory and compared to RS-EAS 12:2018-Untreated Potable water. This study shows that majority of physcico-chemical parameters meet the standard limit except the pH of Umushumbamwiza and Giticyinyoni,DO of all springs that was below the standard limit of WHO. For biological parameters, Total coliforms of all selected springs that were out of the standard limit together with E-coli of Sahara spring. After analysis the water quality of the study springs is impaired due to the effects of rapid urbanization and anthropogenic activities, which makes them unfit for direct human consumption.

Human activities identified in the study area such as informal settlements and urbanization lead to domestic waste water discharge, urban runoff and percolation of septic tanks,linked to spring water are the main cause of E-Coli and Total coliforms found in the selected springs of Umushumbamwiza and Sahara. Giticyinyoni spring was affected by poor protection caused by damage of the existed pipe. Total coliform indicators observed for all springs are indicators unclean water caused by cross-contamination of soil and water. Pathogen indicators that were found in the selected springs warn the population using the spring in study for drinking and domestic purposes as the water may cause water borne diseases if used without prior treatment or disinfection.Consequently, urgent measures are needed to limit future deterioration of spring water quality while improving it so as to protect the public

Acronyms and abbreviations

BOD: Biochemical Oxygen Demand
Cd: Cadmium
Cu: Copper
Cr: Chromium
DO: Dissolved Oxygen
DIN: Dissolved Inorganic Nitrogen
EC: Electrical Conductivity
E-Coli: Escherichia Coli
EICV5: EnquêteIntégrale sur les Conditions de Vie des ménages 5
EPA: Environmental Protection Agency
F.C: Fecal Coliforms
Fe: Iron
NH4: Ammonia
Mn: Manganese
NST1: National Strategy for transformation
Pb: Lead
SM: Standard method
TDS: Total Dissolved Solid
TH: Total hardness
TP: Total phosphorus
TSS: Total Suspended Solid
UNICEF: United Nations International Children's Emergency Fund
UNILAK: University of Lay Adventists of Kigali
WASAC: Water and Sanitation Corporation
WHO: World Health Organization
Zn: Zinc

Conflicts of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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