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Impact Assessment of Seasonal Variability on the Rwakibirizi Spring Water Quality in Rwanda

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ABSTRACT
Rural areas frequently use spring water. In general, spring water is of good quality. Pathogenic contamination is unlikely if the source meets certain criteria. Rwakibirizi spring water is among the 22,300 springs in Rwanda. It has capacity to supply water to a number of 27500people among population living in three Cells such as Nyamata Ville, Kayumba and Kanazi of Nyamata sector in BugeseraDisrtict. Early, during long rainy period, this spring started to be contaminated and taken many hours or days to become clean. This study assessed the impact of rainy and dry season on the water quality of the Rwakibirizi spring. It also intended to know the main factors that lead spring into contamination, the level of pollution and the correlation of spring pollution with the seasons.Laboratory analysis for Physicochemical and bacteriological parameters were done during rainy and dry season and compared to the Rwanda Standard Board guidelines as well as East African Standard for Natural potable water. The period of Study were from February to April 2020 for the rainy season and from June up to August 2020 for the dry season. Three Water samples were taken in one month. The Physicochemical parameters that have been assessed, were: turbidity, pH, Color, Iron, Manganese, Phosphate, Nitrate, Ammonia Nitrogen, Organic matter, TDS. Microbiological analyzed parameter were: Total coliforms and E-coli. During rainy season the laboratory results revealed that four physicochemical parameters averages exceeded the limit: turbidity (52.34NTU), Color (458.22TCU), Iron (1.17mg/l) and Organic Matter (6.3mg/L) compared to standard of 25NTU, 50TCU, 0.3mg/l and 3mg/l respectively. Both two microbiology analyzed parameters present contamination of water. However, during dry season, all test for physicochemical and microbiology parameters were under range of acceptable natural potable water. The study carried out, revealed that Rwakibirizi spring water was contaminated during rainy season. The main causes found are rain water runoff and the rapid infiltration of the surface water. The researcher recommended adequate prevention measures which include;full spring water treatment process during rainy season before human consumption, rehabilitation of the spring intake and the lastly is water disinfection in all season.

Key words: Spring water, Rwakibirizi spring, water quality, spring contamination.

I. INTRODUCTION

Water is a fundamental element to all forms of life for various functions such as drinking, cleaning, as a reproductive medium and as habitat for aquatic organisms and for irrigation purposes (Ninhoskinson, 2011). Throughout the world, 3.8 billion people suffer from water shortages (WHO ,. , 2006). The freshwater that can be accessed most easily is in rivers and lakes, but 25% of the world populations have to rely on groundwater or deep aquifers for water supplies (Joseph Mmbando et al, 2007). Contaminated water is responsible for the cause and spread of 80% of the world's disease including cholera, typhoid and dysentery. Lack of access to safe drinking water, poor sanitation, and illnesses associated with poor sanitationkill 2.2 million people, mainly children in LEDCs each year (WHO ,. , 2006).

The Eastern Province, where Bugesera District is located, has the lowest percentage of households using improved drinking water source (83%) in Rwanda according to the EICV5 report (2018) (REMA, Rwanda Compendium of Environment Statistics 2018, 2019). Clean and safe water is a basic requirement of life and one of the most importantglobal issues. It will continue to be so as demand increases. The natural chemical quality of groundwater is generally good, but high concentrations of many components can cause water use problems. Intensively irrigated agricultural emissions to groundwater can significantly change the quality of groundwater. These human interventions in groundwater pose a serious threat to groundwater users.

Poor agricultural practices, mining on steep slopes, and the discharge of wastewater from domestic and industrial plants are the main causes of poor water quality in Rwandan waters, including aquatic ecosystems, reservoirs and river subsidence. Excessive nutritional load, which may affect the quality of drinking water (RWFA, 2017).

Knowledge regarding Rwanda's groundwater resources is still very limited, RWFA has begun construction of groundwater monitoring infrastructures, inventorying groundwater wells and geophysical investigations of groundwater resources. These actions will ensure a better understanding of groundwater usage trends and the availability of future annual water status reports. Currently, the overall trend in groundwater availability is not known exactly. Therefore, this study intended to get information (data) about the impact of Seasonalvariability on water quality of Rwakibirizi spring in Bugesera district and then provide adequate recommendations against spring contamination.

II. MATERIALS AND METHODS

1.1 Study Area

Rwakibirizi Spring is located in Nyamata Sector, Bugesera District in the Eastern Province of Rwanda. It is situated on the plateau agro-ecological zone of Rwanda at approximately 1358m. The annual range of rainfall in Bugesera is 1200 mm–1400 mm. Rwakibirizi spring is among the improved springs in Bugesera District. Before supplying water, treatment process applied to Rwakibirizi spring is the disinfection only, because of clarity of the spring in normal conditions. Its water quality is monitored regularly to ensure that people are having water complying with RSB drinking water standards as well as WHO. Water production of Rwakibirizi varies between 500 to 650m3 per day depends on the season. The spring supplies water in Seven Villages: Rwakibirizi I, Rwakibirizi II, Rugarama I, Rugarama II, Nyagatovu, Rwanza and Rugando of the Cells of Nyamata Ville, Kayumba and Kanazi in Nyamata Sector. Nowadays, the additional water in that area comes from other Water Treatment Plant in Bugesera Such as Ngenda WTP, Kanyonyomba WTP and Kanzenze WTP.

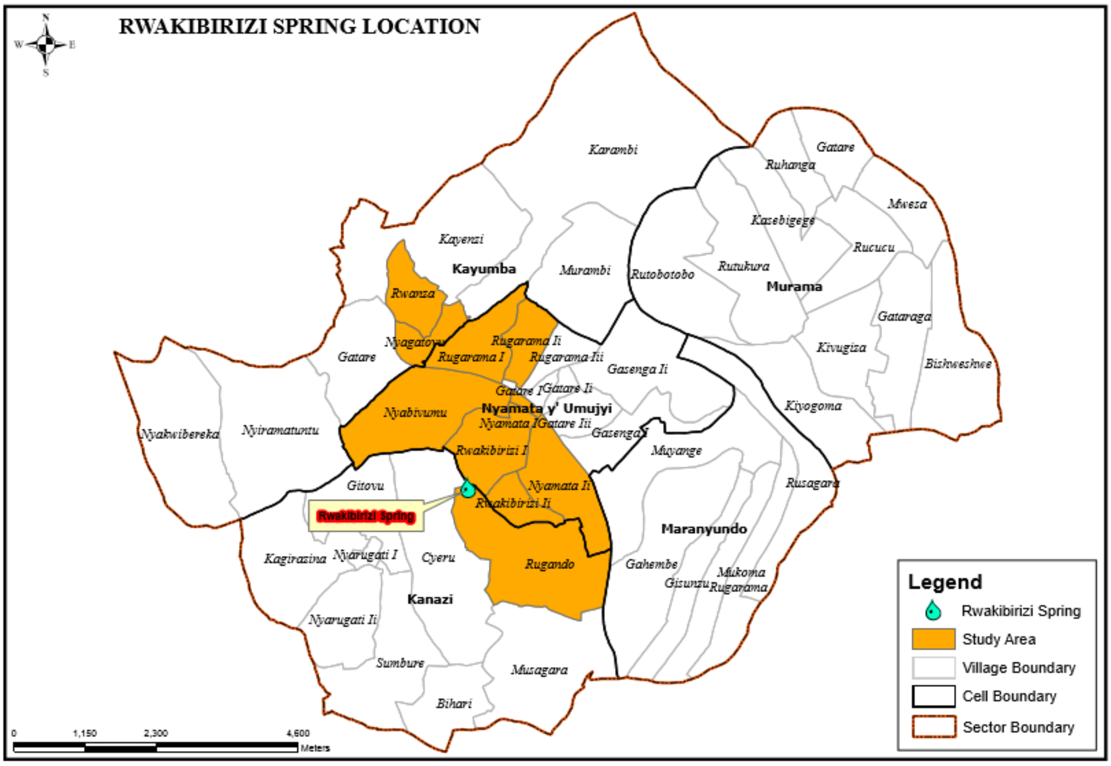

Figure1: Rwakibirizi spring location and supply area

Source: Researcher, 2020

1.2 Methodology

The Researcher used quantitative methodology. Quantitative methodology is regarded as a process that is systematic and objective in its ways of using numerical data from only a selected subgroup of a universe to generalize the findings to the universe that is being studied (Maree& Peterson, 2013). Spring water quality in long rainy period from February to April 2020 has been analyzed and compared with the RSB's drinking water guidelines and on the other hand the spring water samples in dry season from June to August 2020 were analyzed in order to have data of both seasons and find out if there were the significant impact of rainy season on the spring water quality. Furthermore, Linear Regression Model using SPSS statistics with 95% confidence interval was used to demonstrate the correlation between rainfall and water quality change.

III. WATER SAMPLING

The samples were taken three times a month, from February to April 2020 and from June up to August 2020. Samples were collected and stored in 500ml plastic bottles. The plastic bottles were washed and rinsed with distilled water before use. Samples for microbiological tests were collected in sterile grass bottles 500ml. Samples were put in a cooler box for preservation during transportation to the Ngenda WTP laboratory for analysis. Then, samples were kept in a fridge at 4^{o}C to avoid any external contamination while preparing the laboratory equipment and reagents to be used in testing of different selected physico-chemical parameters and incubation for microbiology test. The following parameters have been analyzed: Turbidity, pH, Color, Iron, TDS, Manganese, Phosphate, Nitrate, Ammonia Nitrogen, Organic Matter, Total coliforms and E-coli. In general, the selection of parameters for monitoring is based on their indicative character.

Samples were analyzed using RS EAS 12:2018 standards procedures for testing potable water.

Table 1: Laboratory analytical method and equipment used

Parameter	Equipment	Used Method	Unit
Turbidity	Turbiditmeter 2100Q	ISO 7027	NTU
pH	pH meter HI99131	ISO 10523	-
Color	Spectrophotometer DR1900	ISO 7887	TCU
Iron	Spectrophotometer DR1900	ISO 6332	mg/l
TDS	Conductometric	ASTM D 5907	mg/l
Organic Matter	Titration	-	mg/l
Manganese	Spectrophotometer	ISO 6333	mg/l
	Spectrophotometer	ISO 15681	mg/l
Phosphate	Spectrophotometer	ISO 7890	mg/l
	Spectrophotometer	ISO 11732	mg/l
Nitrate			
Ammonia Nitrogen			
Total Coliform	Membrane Filtration	ISO 4832	Cfu/100ml
E-Coli	Membrane Filtration	ISO 9308-1	Cfu/100ml

IV. RESULTS AND DISCUSSIONS

1.3 Annual rainfall

The annual rainfall in Nyamata Sector in Bugesera District during year 2020 was 1069.4mm. (source, Meteo Rwanda 2020). The graph below shows monthly rainfall distribution along the year.

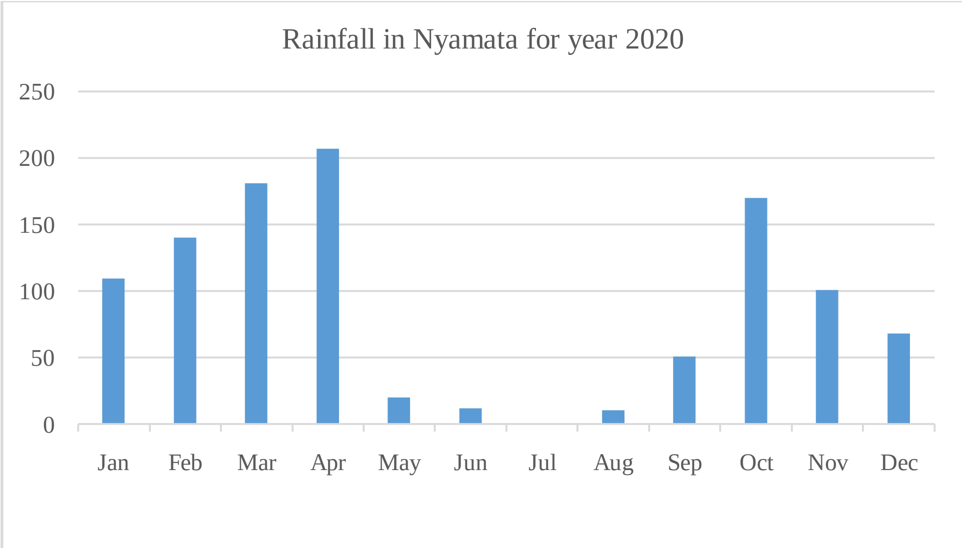

Figure 2: Rainfall in Nyamata Sector, year 2020 [mm]
Source Meteo Rwanda, 2020

According to the above graph, the rainfall increased from January to April. The highest level of 206.9mm, occurred in April as usual. The months of May and June were characterized by considerable reduction of rainfall. During July, there was no rain precipitation in Nyamata. Month of October showed enough rain which decreased at high rate until December. The long period of rainfall occurred from January to April while long dry season appeared from May to August. The daily rainfall are shown in Appendix.

3.2 Laboratory Physico-Chemical parameters Results and discussions

The below table shows the monthly average laboratory results from water sample taken at Rwakibirizi spring three times a month from February to April and from June to August 2020. It shows also the average results for the season. The first period was considered as the rainy period and the second one as dry season.

Table 2: Monthly average physicochemical parameters results

No	Parameter	Unity	Limit for Natural Potable Water	Rainy Season			Dry Season			Season Average	
				February	March	April	June	July	August	Rainy Season	Dry Season
1	Turbidity	NTU	25.00	37.93	50.37	68.73	1.52	1.43	1.45	52.34	1.47
2	pH		5.5-9.5	6.10	6.17	5.77	6.17	6.17	6.40	6.01	6.24
3	Color	PtCo	50	325.33	429.67	619.67	7.00	8.33	6.67	458.22	7.33
4	Iron	mg/l	0.3	1.04	1.29	1.18	0.07	0.08	0.06	1.17	0.07
5	Manganese	mg/l	0.1	0.03	0.04	0.04	0.02	0.01	0.03	0.04	0.02
6	Phosphate	mg/l	2.2	1.79	1.65	1.83	1.78	0.96	1.35	1.76	1.36
7	Nitrate	mg/l	45	2.47	2.44	4.57	1.73	1.97	1.47	3.16	1.72
8	Ammonia Nitrogen	mg/l	0.5	0.25	0.23	0.21	0.02	0.12	0.06	0.23	0.07
9	Organic Matter	mg/l	3	5.43	5.97	7.50	1.67	1.67	1.52	6.30	1.62
10	TDS	mg/l	1500	54.73	59.23	83.17	49.93	50.03	49.70	65.71	49.89

Source: Researcher, 2020

During rainy season, some parameters excided the limit for natural potable water set by EAS Standard; among 10 parameters, four exceeded the limit whereas six remaining complied with standard. All sample taken in dry period complied with the EAS Standard. Therefore, the rainfall

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occurred in February to April had polluted the water quality of Rwakibirizi Spring.

- Turbidity Results

The Monthly average Turbidity of samples taken in rainy and dry period varied between 1.43NTU to 68.73NTU. The season average were 52.34NTU and 1.47NTU for rainy and dry months respectively. The Turbidity standard for natural potable water is 25NTU.

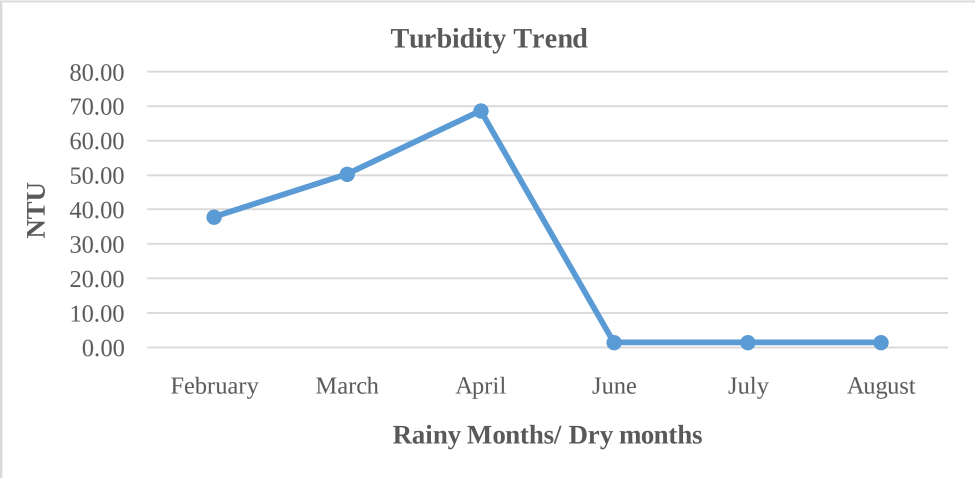

Figure 3: Monthly average turbidity

The above curve presents the trend of turbidity that increased from February to April and fallen down in dry months. In rainy season, the samples tested, gave the following monthly average: 37.93; 50.37; 68.73NTU, all those are beyond the acceptable range of natural potable water. This could be attributed to the effect of cumulative runoff into the catchment area. The high turbid month was April. Moreover, the highest turbidity of 140NTU was tested in April on the 18th as shown in Appendix 1. In dry season, the sample tested, gave the following monthly average: 1.52; 1.43; 1.45NTU all those values comply with EAS Standard. The curve showed relationship between turbidity and the rainfall because of similarity of their trends. The average rainfall were 140.3mm in February, 181mm in March and 206.9mm in April while 12.1mm reached in June, 0mm in July and 10.5mm in August.

-pH Results

The monthly average pH varied from 5.77 to 6.4. The season average were 6.01 and 6.24 in Rainy and dry season respectively. All tested pH comply with the EAS natural potable water Standard.

The monthly average pH are shown in table 3.

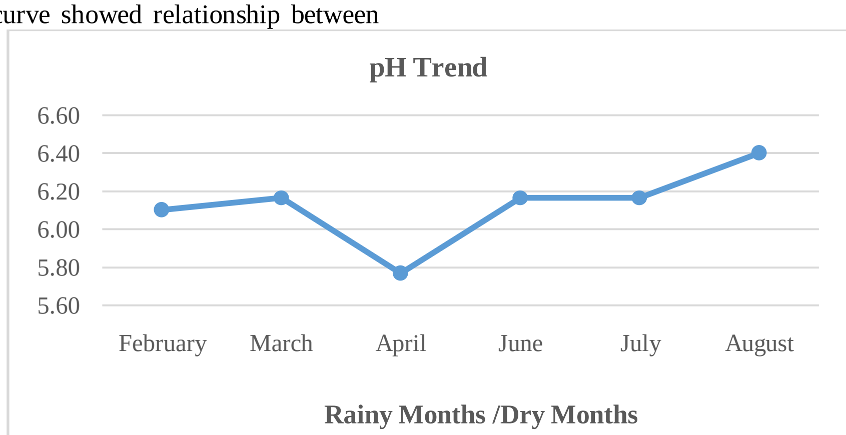

Figure 4.Monthly average pH

The above curve shows how the pH trend increased slightly from rain to dry months. The lowest average pH appeared in April. The same way, the lowest pH of 5.00 was tested on the sample taken in April.

- Color Results

The Monthly average Color of samples taken in rainy and dry period varied between 6.67 and 619.67TCU. The season average were 458.22 and 7.33TCU in rainy and dry months respectively. The EAS Color standard for natural potable water is 50TCU.

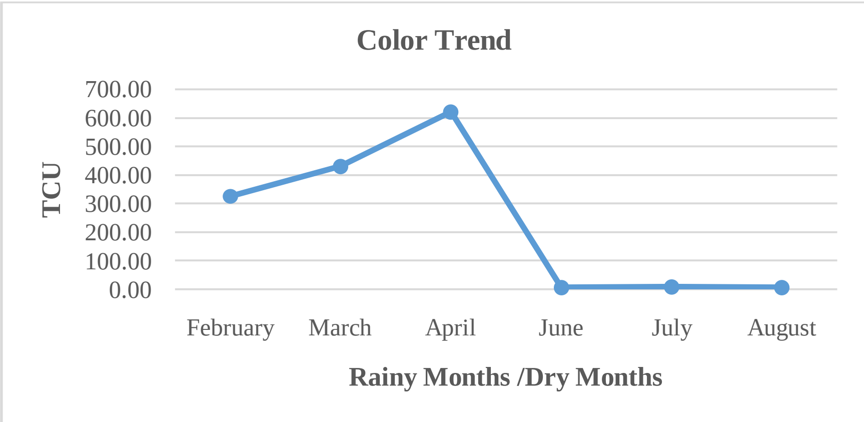

Figure 5.Monthly average Color

The above trend indicates that during rainy period, the color increased from February up to April while in dry months, shows how the tested color were at low level. The water samples tested in rainy season, gave the following monthly average: 325.33; 429.67; 619.67TCU all those are beyond acceptable range of potable water. This could be attributed to the effect of cumulative runoff into the catchment area. The highest color of 1,185TCU was tested in April on the 18th as shown in Appendix 1. In dry season, the samples tested, gave the following monthly average: 7.0; 8.33; 6.67TCU all those values comply with EAS Standard. The curve showed relationship between color, turbidity and the rainfall because of similarity of their trends.

- Iron Results

The Monthly average Iron of samples taken in rainy and dry period varied between 0.06 and 1.29mg/l. The season average were 1.17 and 0.07mg/l in rainy and dry months respectively. The EAS iron standard for natural potable water is 0.3mg/l.

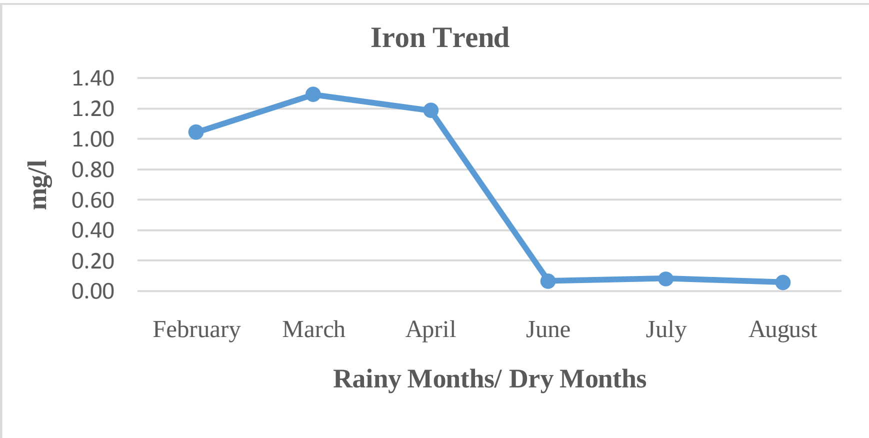

Figure 6.Monthly average Iron

The above trend indicates high level values of iron during rainy season compared to dry season. The water samples tested in rainy season, gave the following monthly average: 1.04; 1.29; 1.18mg/l all those are beyond acceptable range of potable water. This shows impact of rainfall and runoff into catchment area. In dry season, the samples tested, gave the following monthly average: 0.07; 0.08; 0.06mg/l all those values comply with EAS Standard. The curve showed relationship between iron, color, turbidity and the rainfall because of quite similarity of their trends.

- Manganese Results

The Monthly average Manganese of samples taken in rainy and dry period varied between 0.01 and 0.04mg/l. The season average were 0.04 and 0.02mg/l in rainy and dry months respectively. The EAS Manganese standard for natural potable water is 0.1mg/l.

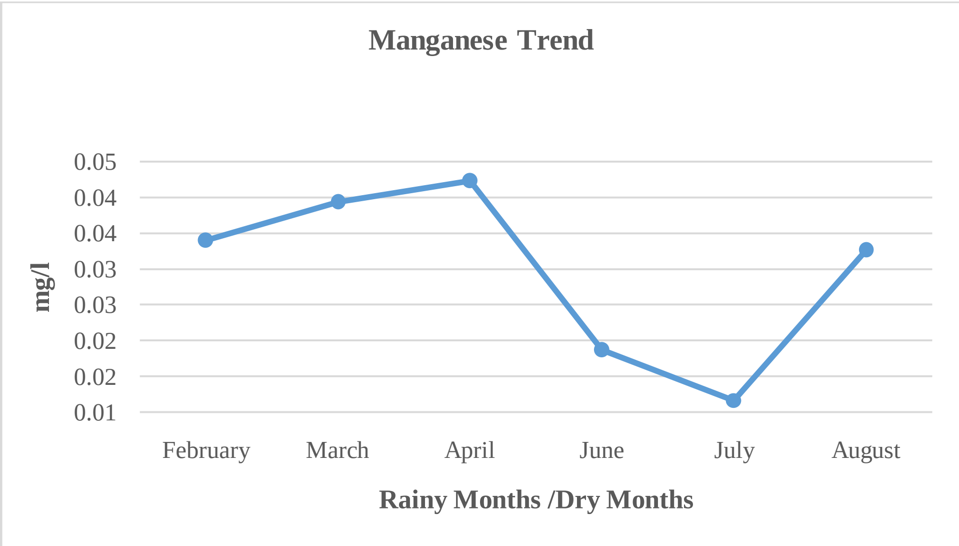

Figure 7.Monthly average Manganese

The above manganese trend indicates higher level values in rainy season than dry season. The water sample tested in rainy season, gave the following monthly average: 0.03; 0.04; 0.04mg/l, all those are within acceptable range of potable water. In dry season, the monthly average of manganese were: 0.02; 0.01; 0.03mg/l, all those values comply with EAS Standard.

- Phosphate Results

The Monthly average Phosphate of samples taken in rainy and dry period varied between 0.96 and 1.83mg/l. The season average were 1.76 and 1.36mg/l in rainy and dry months respectively. The EAS Manganese standard for natural potable water is 2.2mg/l.

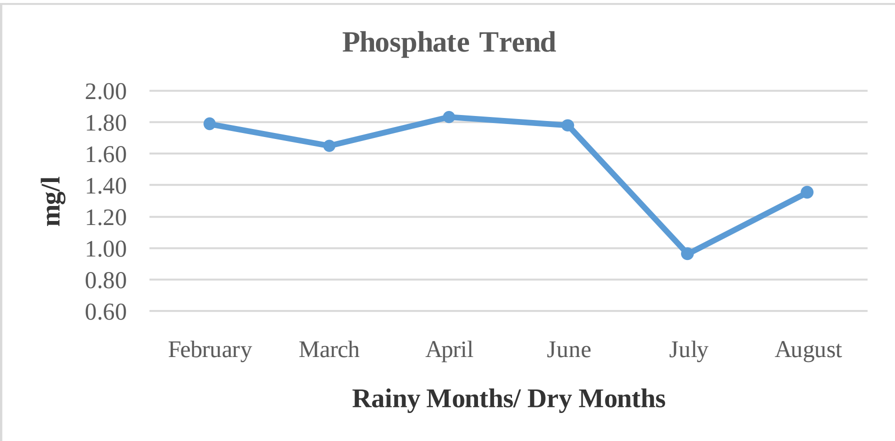

Figure 8.Monthly average Phosphate

The above Phosphate trend indicates higher level values in rainy season than dry season. The water samples tested, gave the following monthly average: 1.79; 1.65; 1.83mg/l in rainy season and 1.78; 0.96; 1.35 mg/l in dry season, all those values comply with EAS potable water standard.

- Nitrate Results

The Monthly average Nitrate of samples taken in rainy and dry period varied between 1.47 and 4.57mg/l. The season average were 3.16 and 1.72mg/l in rainy and dry months respectively. The EAS Nitrate standard for natural potable water is 45mg/l.

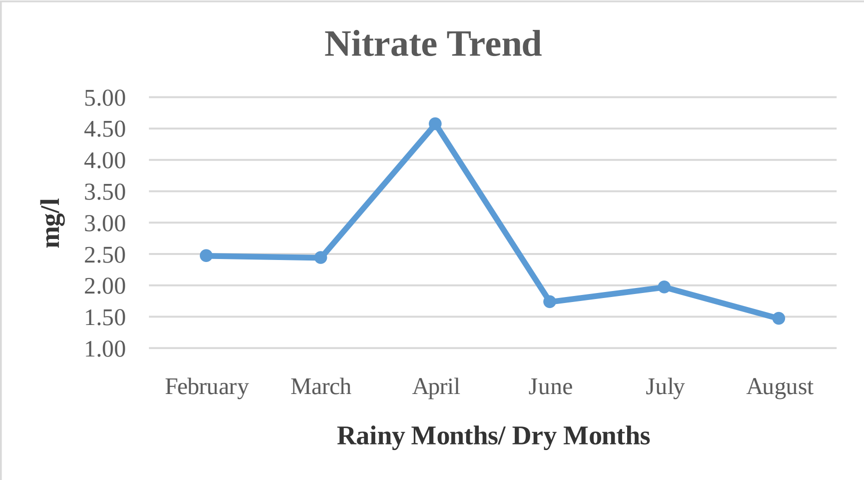

Figure 9.Monthly average Nitrate

The above Nitrate trend indicates higher level values in rainy season than dry season. The water samples tested, gave the following monthly average: 2.47; 2.44; 4.57mg/l in rainy season and 1.73; 1.97; 1.47 mg/l in dry season, all those values comply with EAS potable water standard.

- Ammonia Nitrogen Results

The Monthly average Ammonia Nitrogen of samples taken in rainy and dry period varied between 0.02 and 0.25mg/l. The season average were 0.23 and 0.07mg/l in rainy and dry months respectively. The EAS Ammonia Nitrogen standard for natural potable water is 0.5mg/l.

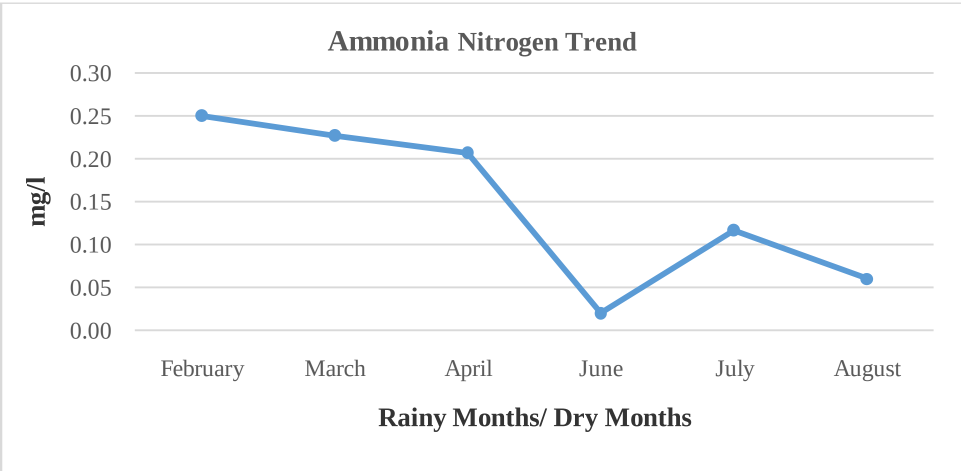

Figure 10.Monthly average Ammonia Nitrogen

The above Ammonia Nitrogen trend indicates higher level values in rainy season than dry season. The water samples tested, gave the following monthly average: 0.25; 0.23; 0.21mg/l in rainy season and 0.02; 0.12; 0.06 mg/l in dry season, all those values comply with EAS potable water standard.

- Organic Matter Results

The Monthly average Organic Matter of samples taken in rainy and dry period varied between 1.52 and 7.5mg/l. The season average were 6.30 and 1.62mg/l for rainy and dry months respectively. The EAS Organic Matter standard for natural potable water is 3mg/l.

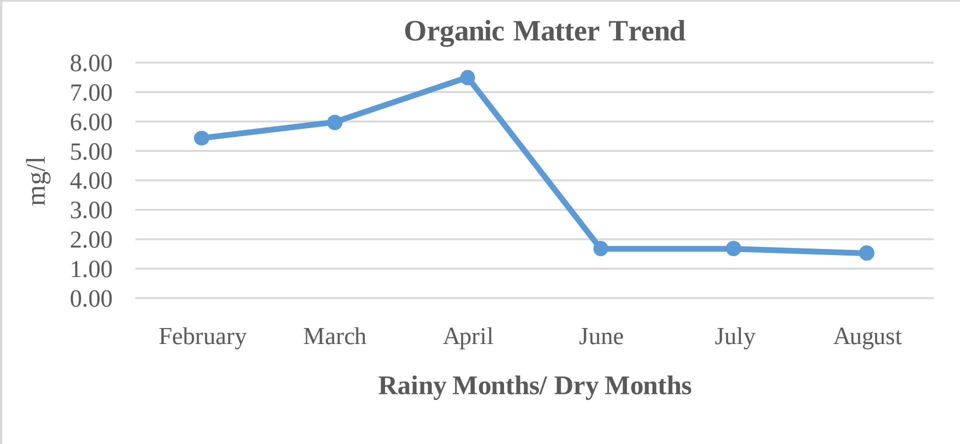

Figure 11.Monthly average Organic matter

The above organic matter trend indicates that during rainy period, the OM increased from February up to April while in dry months, shows how the results were at low level. The water sample tested in rainy season, gave the following monthly average: 5.43; 5.97; 7.5mg/l, all those are beyond acceptable range of potable water. This could be attributed to the effect of cumulative runoff into the catchment area. The highest OM of 10mg/l was tested in April on the 18th as shown in appendix 1. In dry season, the samples tested, gave the following monthly average: 1.67; 1.67; 1.52mg/l, all those values comply with EAS Standard. The curve showed relationship between OM, turbidity and the rainfall because of similarity of their trends.

- TDS Results

The Monthly average Total Dissolved Solid of samples taken in rainy and dry period varied between 49.70 and 83.17mg/l. The season average were 65.71 and 49.89mg/l in rainy and dry season respectively. The EAS TDS standard for natural potable water is 1500mg/l.

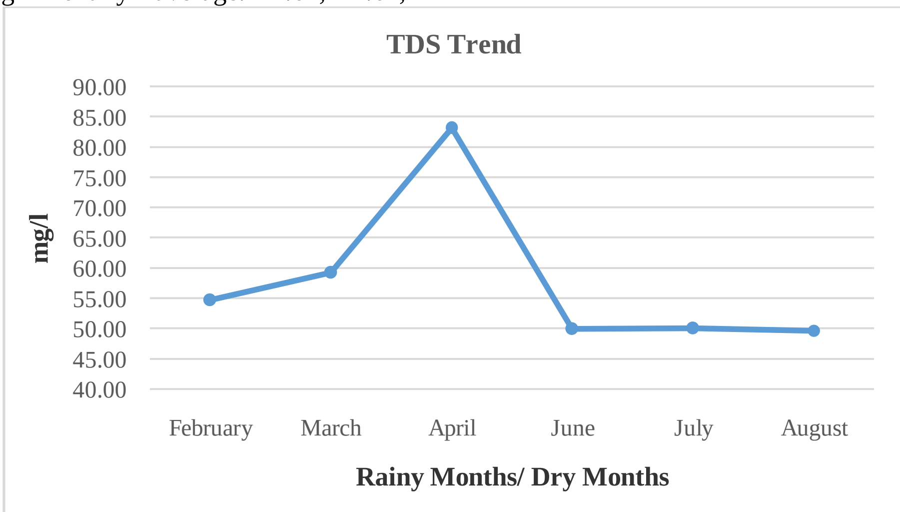

Figure 12.Monthly average TDS

The above TDS trend indicates higher level values in rainy season than dry season. The water samples tested, gave the following monthly average: 54.73; 59.23; 83.17mg/l in rainy season and 49.93, 50.03, 49.7mg/l in dry season, all those values comply with EAS potable water standard.

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3.3 Microbiology Analysis
The microbiology tests done during this study were limited to the Total coliforms and E-Coli analysis. The researcher has chosen them as good indicators of microbiology contamination in water. The table below, shows the results obtained from test conducted in rain period as well as in dry season.

Table 3: Monthly average of microbiological parameters results

No	Parameter	Unity	Limit for Natural Potable Water	Rainy Season			Dry Season			Season Average	
				February	March	April	June	July	August	Rainy Season	Dry Season
1	Total Coliforms	Cfu/100ml	0	630	660	1070	0	0	0	787	0
2	E-Coli	Cfu/100ml	Abs.	Pres	Pres	Pres	Abs	Abs	Abs	Pres	Abs

The table shows the microbiological contamination during rainy period. The water samples tested in rainy season, gave the following monthly average of total coliforms: 630;660; 1070Cfu/100l and presence of E-Coli. Whereas in dry season no any microbiological contamination tested.All samples tested during dry seasonmet EAS potable water standard.

3.4 SPSS Correlation Analysis and Interpretation of Rainfall and Spring Water quality
The below table shows correlation analysis between rainfall and Rwakibirizi spring water quality done by using SPSS linear regression during the study period.

Table 4: Correlation analysis between rainfall and spring water quality

Parameter	Correlation Coefficient (r)	Significance Level/ P-Value
Turbidity	0.991	0.000
pH	-0.704	0.118
Color	0.986	0.000
Iron	0.984	0.000
TDS	0.796	0.058
Organic Matter	0.993	0.000
Manganese	0.844	0.035
Phosphate	0.646	0.166
Nitrate	0.805	0.053
Ammonia Nitrogen	0.866	0.26
Total Coliforms	0.979	0.001
E-Coli	0.974	0.001

Inorder to interpret the results, following point must be considered:

- Strength (Strong, Moderate, Weak)
- Nature (Positive, Negative)
- Significance (Significant, insignificant).

▪ Correlation Coefficient Value lies between:

0.7 < r < 1: Strong

0.3 < r < 0.7: Moderate

r< 0.3: Weak.

▪ Significance Level 0.05 (5%):

P-Value > 0.05: Insignificant

P-Value < 0.05: Significant

According to table number 4, the SPSS correlation analysis between rainfall and Rwakibirizi spring water quality showed that all parameters analyzed have presented the positive coefficient of correlation (which vary between 0.646 to 0.993), except the pH presented negative coefficient of correlation(-0.704). Furthermore, the analysis of SPSS revealed that Turbidity, Color, Organic Matter, Manganese, Iron, Total Coliforms and E-Coli have the significance correlation (P<0.05) with rainfall whereas pH, TDS, Ammonia Nitrogen, Nitrate and Phosphate presented insignificance correlation (P>0.05) withthe rainfall.

The SPSS analysis confirmed that rainfall affects the water quality of the Rwakibirizi spring. It is in the same way as the Researcher called KASANZIKI C.M revealed during his research in 2018 entitled "Status of water quality in the springs of Huye town, Rwanda" where his results showed that in rainy season, all springs were polluted with feacal coliforms, Streptococcus and Total coliforms.

V. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Clean water is one among the basic needs for human being. Rwakibirizi spring water provide water to about 27,500 Population in Nyamata Sector of Bugesera district. Early the spring started experiencing pollution during the rainy season. This study aimed to assess the impact of seasonal variability on the Rwakibirizi spring water quality. The researcher chose then physicochemical and two microbiological water parameters that are able to evaluate water quality of the spring. Chosen Physicochemical were Turbidity, pH, Color, Iron, Manganese, Phosphate, Nitrate, Ammonia Nitrogen, Organic Matter and TDS. Microbiological parameters were Total coliforms and E-Coli. The study assessed two periods; rainy and dry. The laboratory results were compared to the RSB guideline which are the same as East Africa potable water Standard (EAS). Weather data; Rainfall and temperature from Meteo Rwanda during the period of study were also used in the assessment. Total rainfall from February to April was 528mm and from June to August the rainfall was 22.6mm. The average temperature maximum were 27.5^{o}C and 28.4^{o}C during rainy period and dry season respectively.

After gathering data and analysis, the Researcher draw the following conclusion:

- During rainy season, four physicochemical parameters, exceeded the limit of potable water: Turbidity (52.34NTU), Color (458.22TCU), Iron (1.17mg/l), and Organic matter (6.3mg/l).
- Microbiology results showed significant level of contamination of the spring during the rainy season; presence of Total coliforms and E-Coli.
- During dry Season, All physicochemical parameters met the RSB as well as EAS Natural water potable standard.
- No microbiological contamination detected in the sample during dry season.
- SPSS analysis showed correlation of season with Rwakibirizi spring water quality

All those points confirmed that the rainy season affects the water quality of Rwakibirizi Spring

4.2 Recommendations

In order to always have potable water atRwakibirizi spring, the Researcherrecommend the following actions:

- Rehabilitation of the spring intake
- Disinfection of Rwakibirizi spring before human consumption during rainy season
- Proper runoff drainage around the spring intake
- Full water treatment process of Rwakibirizi spring during rainy season.

REFERENCES

[1]. Jakhrani. (2009). Impact of Urban Sprawl on Water Quality in Eastern Massachusetts, USA.
[2]. Jianfeng Zhu1, Q. Z. (2016). Spatio-temporal Effect of Urbanization on Surface Water Bodies.
[3]. Jones, B. (2007).
[4]. Joseph Mmbando et al, M. K. (2007). Longman secondary Atlas for East Africa, Dar-es-Salaam, Tanzania.
[5]. Kadewa, W. M. (2005). Assessment of the impact of industrial effluents on water

quality of receiving rivers in urban areas of Malawi.
[6]. Kibena, J. N. (2014). Assessing the relationship between water quality parameters and changes in landuse patterns in the Upper Manyame River. Zimbabwe.
[7]. MEULI, C. ,. (2002). Spring Catchment, Series of Manuals on Drinking Water Supply (Vol. 4). St Gallen, Switzerland: The Swiss Centre for Development Cooperation in Technology Management (SKAT).
[8]. Ninhoskinson. (2011). Water Pollution: Humans Contributing to their downfall. Ninhoskinson.
[9]. NISR. (2012). Rwanda 4th population and housing census.
[10]. REMA. (2019). Compendium of Environment Statistics, Rwanda, 2018.
[11]. Republic of Rwanda. (2018). Green growth and climate resilience National strategy for climate change.
[12]. Rwanda, R. o. (2017). 7 years Government programme: National Strategy for Transformation (NST 1) 2017-2024.
[13]. RWFA. (2017). Annual water status report 2016-2017.
[14]. WHO. (2004). Water Treatment and Pathogen Control: Process Efficiency in Achieving Safe Drinking Water. London, UK.: IWA.
[15]. WHO. (2006). Guidelines for Drinking – Water Quality. seconded, Health Criteria and Other Supporting Information. Switzerland.