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Response Analysis of Water Quality Integrity for Sebeya River, Rwanda

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Abstract:- Over geological time, the collapse of the pit of Lake Kivu and the riser of the Congo-Nile process occurs on the base flattened prior to the cretaceous tertiary then determining the entry into operation of the chain of volcanoes. The erection of the Congo-Nile rushed erosion, clearing the hills and expanding new vulnerabilities in different valleys in opposition to the flow of rivers, which in plains and lakes. The present article was produced in this geographical region of high altitude mountain forest where Sebeya River and its tributaries were formed. The river powers a hydroelectric system that provides electricity to the town of Gisenyi and to the local brewery.

The sources of SEBEYA water may be more easily contaminated by animal and human wastes and chemicals from runoff. This water may also be at risk of algal blooms. Due to the potential for contamination, SEBEYA water is not recommended as a source of drinking water unless filtered and disinfected. Unless drinking water quality can be assured through disinfection and routine testing, SEBEYA water should only be utilized for purposes other than drinking such as toilet flushing, garden watering and irrigation. Treatment may still be necessary for such non-drinking uses. The analysis of Water Quality Integrity for Sebeya river requires the analytical testing and treatment of waste water to improve the quality integration and free water usage from Rwandan water bodies for its population healthcare.

The data recorded from the river's stations and tributaries and concerned agencies (MINEMA, MININFRA, GISENYI Meteo and MINAGRI), the sample treated in WASAC-Kimisagara and IPRC Kigali laboratories showed that Sebeya river water is a mixture of chemicals, mineral elements and biological/micro-organisms. The findings from laboratory experiment conducted on sample taken in May 2019, the laboratory treatment and water quality analysis conducted show the turbidity of 68.9, the TDS of 3218mg/l, the TSS of 21mg/l, the pH of 6.07, the BoD_5 of 51.16mg /l, the coli form of 3218col/ml, the total iron of 2.1mg/l, the chloride of 1730mg/l and total alkalinity of 153.3 mg/dm^3.

The recommendations were given to water engineers, water and sanitation policy makers to set the appropriate measures for Rwandan rivers protection, river beds and hillsides protection against soil erosion, rivers content and water treatment approaches to boost the infrastructural development.

Keywords:- *Sebeya River[1], Water Determinants[2], Quality Integrity[3], Lab Results[4], Impact[5].*

I. INTRODUCTION

Water is indispensable for human health and wellbeing and is used for a wide range of activities including drinking, cooking, bathing, gardening and washing clothes. Thus it is of the utmost importance that water distribution systems provide water of a quality that will support and not harm health and wellbeing (Hakorimana, 2019).

Physical, hydraulic and water quality integrity are essential for providing adequate and safe water to the public. Due to indispensability of water, its effective development and management have become an important goal of society. The water quality integrity became a must for all livings, countries and organizations. To achieve the goal, the chemicals and minerals were identified and treatment of water from Sebeya river was conducted to obtain water quality integrity.

By the system integrity, water is distributed in the settlement from the river after treatment process and to ensure the quality of distributed water, the distribution system that consists of a complex combination of components, including pipes, fittings, pumps, reservoirs, valves, hydrants, meters and backflow preventers are to properly be checked. A water distribution system acts as a conduit to reliably transport adequate quantities of safe drinking water to consumers. To achieve this, the system needs to work as intended and maintain a physical barrier between the water inside the network and the external environment.

System integrity is defined as the state that a water distribution system has to be in to ensure that it fulfills its purpose (ZYL, 2014). Three types of integrity can be identified:

- ***Physical integrity*** means that the system components are able to function as intended and provide a barrier between the water in the system and external threats.
- ***Hydraulic integrity*** means that the system is able to provide the flows and pressures required for the required level of service.
- ***Water quality integrity*** means that the system is able to deliver water of acceptable quality to all its users (assuming that it receives source water of acceptable quality).

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II. DESCRIPTION OF STUDY AREA

A. Sebeya Catchment Delineation

The Sebeya River is a river in Western Province, Rwanda that empties into Lake Kivu just south of the town of Gisenyi. It is drained by a number of small rivers but main ones are Bihongora, Gatare and Karambo upstream and further downstream Pfunda river. The Sebeya river originates in the mountains of Rutsiro District. Its watershed basin area includes 286 km^2 (110 sq mi) of the districts of Rutsiro, Ngororero,Nyabihu and Rubavu. It flows past the mission of Nyungo, established in 1901 on the banks of the river about 12 kilometres (7.5 mi) upstream from Gisenyi (Weber, 2012).

The catchment of Sebeya river extends to its upstream branch, on one part of Rutsiro and Ngororero Districts on an area of 180 km² and its downstream arm extends over an area of 40 km ² and then till the site of Nyundo bridge in Rubavu District. It is located at 1°42′21″S and 29°15′39″E at Elevation of 1,460 m (4,790 ft).

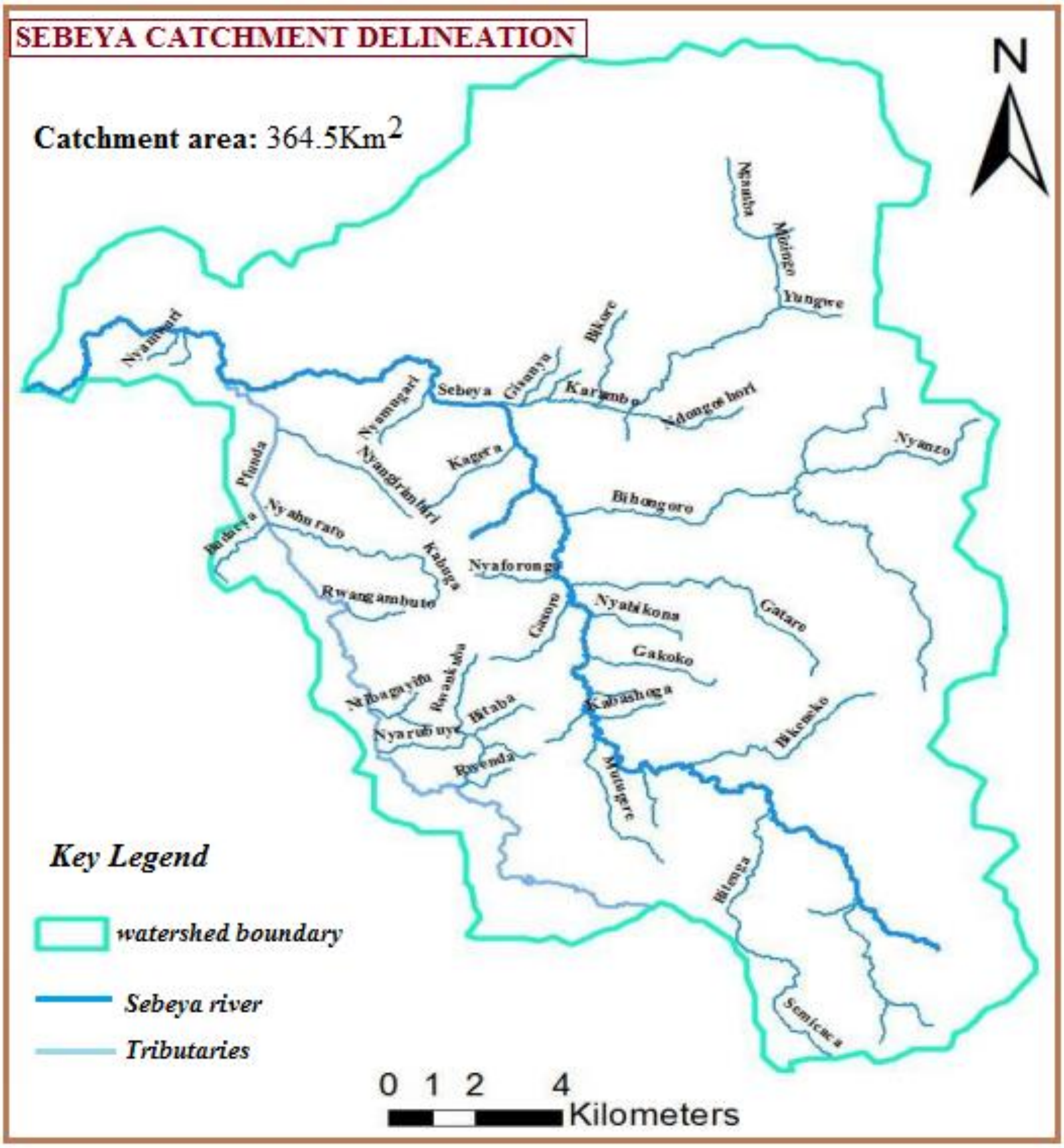

Fig 1:- The hydrological components of Sebeya catchment.

B. Sebeya Catchment Climatology Characterization

The characteristics of study area show Gisenyi/Rubavu nearest Airport as a reference climate station of the climate of the region near the Sebeya river catchment with the coordinates: longitude 29˚ 15' south latitude and 1˚ 40' at an altitude of 1554m. The annual climate characteristic at Gisenyi airport shows the presence of two wet seasons and two dry seasons as a small rainy season from mid-September to mid-December; a short dry season from mid-December to mid-February; a great rainy season from mid-February to May and a long dry season from June to mid-September.

The average temperature of the region is 20˚ C with a maximum of 30˚ C and a minimum of 9 degrees Celsius. The relative humidity is 82% in the rainy season and varies from 60 % to70% during the dry season. The daily evaporation is estimated at 2.7 mm, the wind speed of 1 to 2m/s and the daily exposure varies around 5 hours/day. The total annual average rainfall (TAAR) in, near Sebeya river catchment and at its tributaries was presented below. (Munyaneza, 2014).

Station	Gisenyi Aiport (1554m)	Kanama	Rambura (2300m)	Muramba	Pfunda	Murunda (1875m)	Crete Congo Nile(2700m)
TAAR	1185.4	1338.0	1415.7	1350.0	1319.0	1344.7	1393.7

Table 1:- Annual Rainfall fixtures in SEBEYA Tributaries

III. RESEARCH DESIGN

Some of the present data of this article were captured from the Rwanda Natural Resources Authority (RNRA) and Rwanda meteorological Service reports and others were manually recorded from the field (sample taken from Sebeya River) and hydraulically analyzed in laboratories and analytical method through treatment was used to get results.

A. General Composition of Sebeya Water Quality Determinants

Generally, Water River contains different categories of contaminants such as physical water determinants (colour, pH, total dissolved solids, turbidity etc), chemical water determinants (organic and inorganic chemicals) and microbiological determinants.

➢ *Allowable Water Quality Properties*

- The Physical water quality determinants for Sebeya river are disinfectant residuals, colour, turbidity, pH, test and odour, electrical conductivity and total dissolved solids(TDSs) and the allowable values are shown below.

Determinand	**Measuring units**	**Allowable values**
Free chlorine	Mg/L	≤5
Monochlorine	Mg/L	≤3
Colour	Pt-co	≤15
Conductivity	mS/m	≤170
Taste and odour	-	inoffensive
TDSs	Mg/L	≤1,200
Turbidity	NTU	≤1
pH	-	5≤pH≤9.7

Table 2:- Physical Quality Determinants

- The chemical water quality determinants for Sebeya River are inorganic and organic determinants of which their allowable values are shown in table 3 & 4 below.

Determinant	**unit**	**Allowable value**
Nitrite as N	mg/L	≤ 0.9
Nitrate as N	mg/L	≤11
Sulphate as SO_4^{2-}	mg/L	≤250
Fluoride as F^-	mg/L	≤1.5
Ammonia as NH_4^-	mg/L	≤ 1.5
Chloride as Cl^-	mg/L	≤ 300
Zinc as Zn	mg/L	≤ 5
Sodium as Na	mg/L	≤ 200
Cobalts as Co	µg /L	≤ 500
Iron as Fe	µg /L	≤ 300
Manganese as Mn	µg /L	≤ 100
Copper as Cu	µg /L	≤ 2,000
Mercury as Hg	µg /L	≤ 6
Lead as Pb	µg /L	≤ 10

Table 3:- Chemical Water Quality Determinants (Zyl, 2014)

Various organic compounds found in water can cause water quality problems and concerns. They are ***Dissolved organic substances (***originate from biological activity), ***Trihalomethanes (***disinfectant by products that form when chlorine reacts with organic substances) and ***Phenols (***chemical compounds originate from industrial pollution) and are shown below:

Determinant	unit	Allowable value
Total organic carbon: C	mg/L	≤ 10
Trihalomethanes: -Chloroform -Bromoform -Dibromochloro-methane -Bromodichloro-methane	 mg/L mg/L mg/L mg/L	 ≤0.3 ≤0.1 ≤0.1 ≤0.06
Phenols	μg/L	≤10

Table 4:- Organic Water Quality Determinants
Source: SANS 241

- The Micro-organisms, such as viruses, bacteria and protozoa in water can cause diseases, taste and odour problems and corrosion of concrete and metals in the distribution system.

Determinand	Units measure	Allowable values
Total coliforms	Count per 100mL	≤10
E.Coli/faecal coli forms	Count per 100mL	Should not be present
Heterotrophic plate count	Count per mL	≤1,000
Cytopathogenic viruses	Count per 10L	Should not be present
Protozoan parasites	Count per 10L	Should not be present
Somatic coliphages	Count per 10mL	Should not be present

Table 5:- Microbiological Water Quality Determinants

B. Determination of Sebeya Water Quality Determinants

To analyze the water quality from Sebeya river, the sample of polluted water from the river was taken and put into laboratory(hydrologic laboratory) for treatment and analytical experiment was conducted to study the presence rate of solids(TSS), minerals and biological as well as biochemical oxygen demand(BoD and CoD). The laboratory tests conducted include:Chemical tests of wastewater to analyze chemical nature of water, Solids testing (Total Suspended Solids), pH of wastewater, Chlorides, Chlorine demand, Nitrogen and its compounds, Biochemical Oxygen Demand (BoD) and Chemical oxygen demand (CoD) as well as dissolved oxygen, (DO), Phosphorus, Oil and Grease and Toxic Metals. (MacDonald, 2015)

➢ *Organic Content Measurement*

The both biological and biochemical oxygen demand (BoD), are the most widely used parameters of organic pollution applied in both wastewater and surface water. It is empirical tests based on principle of determination of dissolved oxygen before and after incubation for a specified period at a standard temperature.

- *Biochemical/logical Oxygen Demand (BOD):*

A measure of the strength or concentration of wastewater with respect to organic matter content. Micro-organisms consume the organic substances in the wastewater for energy and growth. In the process of microbial respiration dissolved oxygen is taken up from the water by the micro-organisms. Because the oxygen uptake is measured over a period of 5 days, it is also denoted as BoD_5. It is also the amount of oxygen that is required to bio-chemically convert organic matter into inert substances; an indirect measure of the amount of biodegradable organic matter present in the water or wastewater. (M.Sykes, 2003)

The sample taken was suitably diluted in laboratory with specially prepared dilution water and adequate nutrients and oxygen were availed in during incubation period to ensure meaningful results are obtained. The data are presented in table 6.

Sample volume(mL) 500	Incubation period(days)	5
	Temperature (^{O}C)	20
	BoD bottle volume (mL)	750
	Immediate DO of diluted sample (mg)	38.5
	DO of seed before incubation (mg)	17.8
	Status of the BoD test	Seeded& unseeded

Table 6:- Data used in determination of BOD

- *Principles of Experimentation*

The BoD of the sample was estimated from DO of sample and the blank immediately after preparation and 5days incubation at 20°C in two cases:

- **When dilution water is not seeded:** BoD [mg/L] $=\frac{D1-D2}{P}$ (1)
- **When water is seeded:**

BoD[mg/L]$=\frac{(D1-D2)-(B1-B2)f}{P}$ (2) With:

D1=DO of diluted sample immediately after preparation, mg/L

D2=DO of diluted sample after 5days incubation at 20°C, mg/L

B1=DO of seed control (dilution water) before incubation, mg/L

B2= DO of seed control (dilution water) after 5days incubation at 20°C, mg/L and D1-D2= DO: depletion in diluted sample

B1-B2= DO depletion in dilution water alone.

P= Decimal volumetric fraction of sample used=$\frac{Sample\ volume\ [mL]}{BOD\ bottle\ volume\ [mL]}$ (3)

f = ratio of seed in sample to seed in control=$\frac{\%seed\ in\ D1}{\%\ seed\ in\ B1}$ (4)

And the final BoD_5 results calculated after 5-days of incubation and dilution of water are presented in the table 7.

PARAMETERS	CALCULATED VALUES	BOD5 RESULTS
D1 (mg/L)	77	-
D2 (mg/L)	42.72	-
B1 (mg/L)	35.6	-
B2 (mg/L)	29.4	-
P	0.67	-
$f=(\frac{68.38}{31.62})$	2.16	-
Seeded water	-	90.53
Not seeded water	-	51.16

Table 7:- BoD_5 Laboratory Results

The results of BoD found after 5days of incubation for the sample of water from Sebeya River shows that water is contaminated by micro-organisms. The results show that during laboratory experiment, when water is seeded, BoD_5 is 90.53mg/L and when not seeded, BoD_5 become 51.16mg/L. The results show that water is biologically contaminated at level of 51.16mg in one litter of water.

- *Total Solids (TS)*

The total solids of wastewater are defined as all the matters that remain as residue upon evaporation at 103 to 105°C. Each category of solids may be classified on the basis of their volatility at 550°C. The organic fraction was oxidized and driven off as gas at this temperature. Inorganic fraction remains behind as ash. Terms "Volatile Suspended Solids" and "Fixed Suspended Solids" refer, respectively to the organic and inorganic (or Minerals) content of the suspended solids.

It was found a big problem at Sebeya downstream (Mwali site) of assessing the state of pollution by sediments transported by the bed of the river Sebeya (see Table 8). It is noted that the said river is polluted mainly by human activities in relation to mining and agriculture and livestock. (Omar, 2004)

While there are different techniques to evaluate the sediment transport, e.g., tracer techniques (fluorescent, dye-market sand or color sand), study of sediment physical features (sand size analysis and mineral decomposition), and the usage of large scale sediment traps (groins and inlets).

Dates	Rivers	Coordinates	Flow m^3/s	Max.Flow m^3/s	Turbidity mg/l	Total Sediment load g/sec
3/5/2019	Sebeya source	Alt.2417m Lat.1°45'S Long.29°21'E	0.003	0.009	4	0.004
3/5/2019	Sebeya upstream	Alt.1940m Lat.1°45'S Long.29°22'E	0.530	1.6	161	34.65
4/5/2019	Sebeya downstream (Nyundo station)	Alt.1940m Lat.1°45'S Long.29°22'E	0.423	2.1	3372	1171.4
4/5/2019	Nyaforongo tributary	Alt.1940m Lat.1°45'S Long.29°22'E	0.021	0.12	97	3.6
4/5/2019	Bitega tributary	Alt.1940m	0.078	0.3	23.5	7.025

		Lat.1°45'S Long.29°22'E				
4/5/2019	Gakoko tributary	Alt.1940m Lat.1°45'S Long.29°22'E	0.012	0.08	-	-
5/5/2019	Gasoro tributary	Alt.1940m Lat.1°45'S Long.29°22'E	0.002	0.05	-	-
5/5/2019	Pfunda tributary	Alt.1940m Lat.1°45'S Long.29°22'E	0.31	1.08	1212	970.2
5/5/2019	Gatare tributary	Alt.1940m Lat.1°45'S Long.29°22'E	0.210	1.76	1031	234.6
5/5/2019	Nyamugali affluent	Alt.1940m Lat.1°45'S Long.29°22'E	0.04	0.09	-	-
5/5/2019	Mpomboli tributary	Alt.1940m Lat.1°45'S Long.29°22'E	0.02	0.07	4.0	0.04

Table 8:- Water Flow Rates and Total Sediment Load of Sebeya River and its Tributaries.

It was noted from table 8. Above that close to the measurement site on Sebeya river at Nyundo station called Sebeya downstream, in the middle of tea growing areas, quantities of measured sediments were evaluated at 1171.4g/s. If we consider that the sediments represent 1kg/s at Sebeya-Nyundo station, the annual evaluation of the quantities of sediment passing the station are estimated at 36,942 tons per year. It will be necessary to take into account this figure for sebeya river water treatment and control. Sediment control by terracing a large proportion of the catchment at hillsides, however, may well reduce sediment yield by over 50% (Minagri, Water sediment transport and control in rivers of Rwanda, 2011).

Moreover, the soil stabilization by planting herbs at the bed and around the river is significant anti-soil erosion and water pollution control by sediments from soil degradation and will be a solution measures that prevent or reduce the rate of sediment transport.

- *Laboratory Analysis of Solids*

The laboratory test analysis conducted in water and sanitation laboratory at Kigali presentedd the results of Total solids(TS), Volatile solids(VS), suspended solids(SS) and Volatile suspended solids(VSS) on the wastewater sample of 50mL as given in table 9:

S No	Item name	Notation	Quantity
1	Wastewater sample	A	50mL
2	Evaporating dish Tare mass	B	53.5433g
3	Evaporating dish mass+residue after evaporation at 105°C	C	53.5793g
4	Evaporating dish mass+residue after ignition at 550°C	D	53.5742g
5	Tare mass of Whatman GF/C filter	E	1.5433g
6	Residue on Whatman GF/C filter after drying at 105°C	F	1.5553g
7	Residue on Whatman GF/C filter after drying at 550°C	G	1.5531g

Table 9:- Laboratory Analysis of Sebeya River's Wastewater, 2019.

The elemental analyzer method was used and the laboratory results found after analyzing the river water sample of the table 9, are detailed and calculated in table 10 below;

Parameters	Formulation	Values(mg/L)
Total Solids (TS)	$\frac{(C-B)*1000mg/g}{A}$	720
Volatile Solids(VS)	$\frac{(C-D)*1000mg/g}{A}$	102
Suspended Solids (SS)	$\frac{(F-E)*1000mg/g}{A}$	240
Volatile suspended solids(VSS)	$\frac{(F-G)*1000mg/g}{A}$	44

Table 10:- Water And Sanitation Laboratory Results

C. Presentation of Laboratory Results

The laboratory results, in addition to in situ turbidity and total sediment from all Sebeya tributaries shown in table 8, are presented and interpreted referring to International standard of water quality, *IS 10500-2012*.

The analytical laboratory results from the sample measured and tested are presented in table 11 below;

S/N	Parameters	Results	Maximum Limits As per IS:10500-2012	Observation
1	Physical examination	Slight sediment	Colorless	Grey
2	pH	6.07	6.5-8.5	Non stand
3	Appearance(after filtration)	Clear	Clear(Colorless)	Stand
4	Total hardness	1240	300	excess
5	Total suspended solid (mg/l)	960	10	excess
6	Total dissolved solid mg/l	146	500	Stand
7	Turbidity as NTU	68.9	2.0	excess
8	Total iron mg/l as Fe	2.1	0.3	excess
9	Calcium as Ca (mg/l)	360.2	100	excess
10	Conductivity at 250c	5710	1000	excess
11	Magnesium (mg/l) as Mg	67	0.2	excess
12	Chloride as Cl (mg/l)	1730	250	excess
13	Total coli-form (colony/ml)	231	0	Excess
14	Total alkalinity CaCo2 mg/dm^3	153.3	100	Excess
15	Sulphate mg/l as SO4	324	200	Excess
16	Silica	52	----	-----

Table 11:- Analytical Laboratory Test Report, Sebeya 2019.

On basis of the above test results, water from Sebeya river DOESN'T MEET international standard IS: 10500-2012 as well as Rwandan standard RS277:2015, thus qualitatively, this water is much polluted and can be used for neither drinking nor consumption purpose (standard I. , 2004).

➢ *How to Prepare the Analytical Laboratory Report?*

Once the lab has completed testing your water, you will receive a report that looks similar to Figure 11. It will contain a list of contaminants tested, the concentrations, and, in some cases, highlight any problem contaminants. An important feature of the report is the units used to measure the contaminant level in your water. Milligrams per liter (mg/l) of water are used for substances like metals and nitrates. A milligram per liter is also equal to one part per million (ppm) that is one part contaminant to one million parts water. About 0.03 of a teaspoon of sugar dissolved in a bathtub of water is an approximation of one ppm. For extremely toxic substances like pesticides, the units used are even smaller. In these cases, parts per billion (ppb) are used. Another unit found on some test reports is that used to measure radon--picocuries per liter. Some values like pH, hardness, conductance, and turbidity are reported in units specific to the test.

In addition to the test results, a lab may make notes on any contaminants that exceeded the PADEP drinking water standards. For example, in Figure 11 the lab noted that total coli form bacteria, iron and other tested parameters, all exceeded the standards.

Retain your copy of the report in a safe place as a record of the quality of your water supply. If polluting activities such as mining occur in your area, you may need a record of past water quality to prove that your supply has been damaged.

D. SEBEYA Water Test Parameters 'Analysis

The present section provides a general guideline to common water quality parameters that may appear on SEBEYA water analysis report. The parameters are divided into three categories like health risk parameters, general water quality indicators, and nuisance parameters. These guidelines are by no means exhaustive. However, they will provide you with acceptable limits and some information about symptoms, sources of the problem and effects.

➢ *Health Risk Parameters*

The parameters in Table 11 are some commons ones that have known health effects. The table lists acceptable limits and gives an idea on potential health effects, possible uses and sources of the contaminant.

➢ *General Water Quality Indicators*

General Water Quality Indicators are parameters used to indicate the presence of harmful contaminants. Testing for indicators can eliminate costly tests for specific contaminants. Generally, if the indicator is present, the supply may contain the contaminant as well. For example, turbidity or the lack of clarity in a water sample usually indicates that bacteria may be present. The pH value is also considered a general water quality indicator. High or low pHs can indicate how corrosive water is. Corrosive water may further indicate that metals like lead or copper are being dissolved in the water as it passes through distribution pipes. Table 12 shows some of the common general indicators.

Indicator	Acceptable Limit	Indication
Ph value	6.5 to 8.5	pH can alter corrosivity and solubility of contaminants. Low pH will cause pitting of pipes and fixtures or a metalic taste. This may indicate that metals are being dissolved. High pH indicates water as slippery feel or soda taste.
Turbidity	< 5NTU	Clarity of water can indicate contamination
TDS	500mg/l	Dissolved minerals like iron, manganese increase TDS. High TDS can indicate hardness(scaly deposits) or cause staining or a salty, bitter taste.

Table 12:- General Water Quality Indicators

➢ *Nuisance Contaminants*

These contaminants are a third category of contaminants. While these have no adverse health effects, they may make water unpalatable or reduce the effectiveness of soaps and detergents. Some nuisance contaminants also cause staining. Nuisance contaminants may include iron bacteria, hydrogen sulfide, and hardness. Table 13 shows some typical nuisance contaminants found on our laboratory water analysis report. (standard N. w., 2004)

Contaminant	Acceptable Limit	Effect
Chloride	250mg/l	Salty or blackish taste; corrosive or blackens and pits stainless steel
Copper (cu)	1.3mg/l	Blue-green stains on plumbing fixtures
Iron(Fe)	0.3mg/l	Metalic taste, discolored beverages, yellowish stains
Manganese (Mn)	0.05mg/l or 5ppb	Black stains on fixtures and laundry, bitter taste
Sulfate ($S0_4$)	250mg/l	Laxative effect and greasy feel
Iron bacteria	Present	Orangeish to brownish slime in water

Table 13:- Common Nuisance Contaminants and their Effects.

The findings of laboratory water testing in table 11 and maximum limits of parameters from tables 12 and 13 show that SEBEYA water is effectively and overall polluted. This water may be used in different demand other than drinking after deep treatment by filtration and disinfection.

IV. CONCLUDING REMARKS

The findings of this research show that the relative humidity in SEBEYA catchment is 82% in the rainy season and varies from 60 % to70% during the dry season. The daily evaporation is estimated at 2.7 mm, the wind speed of 1 to 2 m/s and the daily exposure varies around 5 hours/day. The total annual average rainfall (TAAR) in, near Sebeya river catchment and at its tributaries was ranging between 1185 to 1415mm and the SEBEYA water contain a lot of contaminants that are primary cause of pollution of this river.

The analysis of SEBEYA water quality integrity from all its tributaries gives the status of SEBEYA water contaminants. The sample taken in May 2019, the laboratory treatment and water quality analysis conducted show the turbidity of 68.9, the TDS of 146mg/l, the TSS of 960mg/l, the pH of 6.07, the BoD_5 of 51.16mg /l, the coli form of 3218col/ml, the total iron of 2.1mg/l , the chloride of 1730mg/l and total alkalinity of 153.3 mg/dm^3.The results show that all parameters tested exceed the water quality standard values for usage purpose. This article could help water engineers, water and sanitation policy makers to set the appropriate measures for Rwandan rivers protection, rivers content and water treatment approaches to boost the infrastructural development.

V. RECOMMENDATIONS

The hydrographic catchment of Rwanda contains many rivers with raw and polluted water from various contaminants. The findings of this research show that SEBEYA water flow goes with various high rates of contaminants which lower the integration of water quality standard. The WASAC, MINEMA, MINIRENA and other water and environment related stakeholders were recommended to contribute to the amelioration of environment protection by afforestating rivers bank and hillsides, rivers protection and set a sustainable water treatment plan to sustain the Rwandan infrastructures and rivers as well.

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