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Assessment of Dry and Wet Season in Surface Water Quality in River Rwizi, Uganda, East Africa

[1]Abdikadir Osman Mohamed, [2]Dr. Zubeda Ukundimana, [3]Dr.K.Ambiga, [4]Ninsiima Emmanuel

[1]Research Scholar, [2,3]Senior Lecturer, [4]Research Coordinator, [1,2,3,4]Department of Civil Engineering, School of Engineering and Applied Sciences, Kampala International University, Western Campus, Kampala, Uganda, Africa. [1]jananka09@gmail.com, [2]ambigak@kiu.ac.ug, [3]zubeda.ukundiamana@kiu.ac.ug, [4]emmanuel.ninsiima@kiu.ac.ug

Abstract Water is the most fundamental requirement of human, plant and animal life. River Rwizi in Uganda is among the rivers that serve large percentage of the population with water for domestic purposes, agricultural and industrial use. However, water pollution is on a rise due to industrial and domestic wastewater discharge and surface water runoff from agricultural and urban areas. This has led to high prevalence of diseases rendering the water unsafe. The current study assessed the seasonal variations of physicochemical and the biological parameters of River Rwizi between the month of April and August 2022 representing the wet and dry season. Three Sample Stations were selected and three points were chosen in each station. Selection of parameters such as pH, EC, Turbidity, TDS, BOD, COD, E-coli were analysed as per National Standards during wet and dry season. The interpretation of the results depict that the river is gradually getting polluted with E-coli, COD and turbidity which may soon suffocate life. The latter is worsened during rainy seasons when waste material including feces and surface runoff from farmlands are released in the river. As such, there is need for routine monitoring of river water quality and effluents release by the nearby treatment plant. The NEMA wastewater management instrument needs to be strictly implemented by industries, markets and urban areas to control contamination since Mbarara has gained a city status thus expected population explosion. Sensitization of the community on proper waste management and its dangers is important for intrinsic motivation.

Keywords — Analytical parameters, Sample stations, Seasonal Variation, Standard, Surface water, Waste Management.

I. INTRODUCTION

Water is the most fundamental requirement of human, plant and animal life. Water and water resources are very important for maintaining an adequate food supply and a productive environment for the all living organisms [1]. It is also a vital resource for agriculture, manufacturing, transportation and many other human activities. Assessment of surface water quality is important for sustainable development since safe water is the door way to health which is the pre-requisite for progress, social equity and human dignity [2]. Access to safe and dependable (clean and fresh) water is the fundamental/basic right of humans. Access to water was one of the main goals of UN-Millennium Development Goals and it is also one of the main goals of the UN-Sustainable Development Goals [3].

In Terms of Africa, after Australia, Africa is the second driest continent. With 15% of the world's population, it has only 9% of renewable freshwater resources. Water is unevenly distributed, with Central Africa holding 50.66% of the continent's total inland water, and Northern Africa only 2.99%. Thus, in all regions except Central Africa, water availability per person is below the African and global average [4]. Uganda, as a whole, has more than enough freshwater. Estimates indicate 66 cubic kilometres (16 cu mi) of renewable water resources per year, which correspond to approximately 2,800 cubic metres per person and year. Rivers, lakes, and wetlands cover about 18 percent of Uganda's total surface, including Lake Victoria [5].

Urban areas in most developing countries do have several wastewater management systems some of which are very effective and meet international standards, but many others are plagued with poor designs, maintenance problems, and expansion including poor investment in wastewater management systems. Most rural and poor communities often do not have any form of wastewater management systems. Effluents from large- and small-scale industries are usually channelled to surface water courses, which often result in pollution, loss of biodiversity in the aquatic ecosystem, and possibly health risk to humans. Studies in Uganda have shown that most water resources are easily contaminated from anthropogenic activities especially in urban areas [6]. River Rwizi in Uganda is among the rivers

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that serve large percentage of the population, supplying water for domestic purposes, agricultural and industrial purposes. However, the pollution loads are continually increasing in the river due to industrial and domestic waste water discharge and surface water runoff from agricultural and urban areas [7]. This has led to high prevalence of diseases like typhoid, cholera, and hepatitis among others [8]. Despite the indicator's, limited studies have been done to quantify the level of contamination of River Rwizi. For the few studies that exist such as [9], have largely focused on the integrated water resource management and community conservation practices towards climate stabilization around River Rwizi, The current study therefore will fill this information gap by assessing the level of chemical and biological contamination of River Rwizi. It is expected that the results of this study would contribute to designing appropriate water resource management strategies by the legislators, conservationists and the broader community.

The main objective of this study was to assess the level of pollution of river Rwizi in Mbarara District/Uganda.

i). To assess the physicochemical, organic matter and microbiological characteristics of Rwiz i river

ii). To assess the seasonal variations in physicochemical, organic load and micro biological properties of the river

II. MATERIALS AND METHODS

A. Study Area

Mbarara District is a district in South Western Uganda. In 2019 Uganda cabinet approved part of Mbarara the then Mbarara municipality, to be upgraded to a city status in July 2020. Mbarara District is located between coordinates: 00 49'S, 300 19'E and 00 10'S, 300 46'E in Western Uganda. It is bordered by Ibanda District to the North, Kiruhura District to the Northeast, Buhweju District to the Northwest, Sheema District to the West, Ntungamo district to the South and Isingiro District to the Southeast. The district has 11 subcountries,1 Municipality with 6 Divisions. Sub-counties include: Bubaare, Bukiiro, Kagongi, Kashare, Rubaya, Rubindi, Rwanyamahembe, Bugamba, Mwizi, Ndeija and Rugando sub-countries. The six Divisions in Mbarara Municipality include: Biharwe, Kakiika, Kakoba, Kamukuzi, Nyakayojo and Nyamitanga Divisions. Figure 1 shows the administrative boundaries, gazetted areas and geomorphology of Mbarara District (MRDPM).

The study was carried out on River Rwizi in a stretch covering about 10km from upstream to downstream. The upstream and downstream sites are about 1km before and after the river traverses Mbarara City in Ndaija Parish at a Latitude of 30.613855 and Longitude of -0.615599, Nyakayojo Parish at a Latitude of 30.6625 and Longitude of-0.620833 and Kyahi/Kakiika Parish with a Latitude of 30.698928 and Longitude of-0.607261. The study was conducted within a period of 12 months that is from August 2021 to August 2022, long enough to acquire all necessary required data covering both rainy and dry seasons.

River Rwizi was the glory of the western region in the 1950s due to its ecological, economic and social vitality like the luxuriant riparian vegetation, water bucks and other aquatic life like mud fish. However, all these benefits are bound to be lost if no interventions are put in place. The river supplies water for domestic and industrial use to a population of over 275,388 people in Mbarara City and Sheema district. Manufacturing companies surrounding the river like Century Bottling Company (coca cola), and Nile Breweries are beneficiaries of the river [10]. Unlikely the water quality of river Rwizi has increasingly become a concern at community, district and national levels, [11].

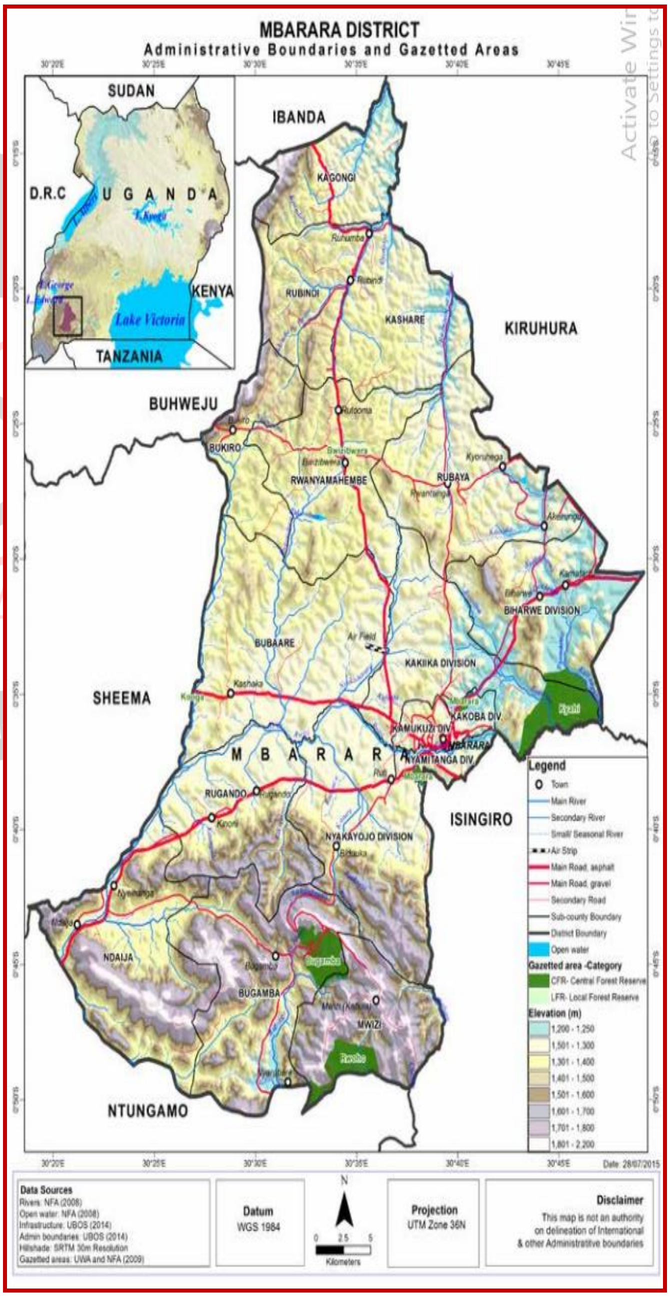

Figure 1. Mbarara District. Source: MRDPM

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Figure 2. Water sampling site location on River Rwizi

The surface water sample station was collected manually from the river which were approximately equally distributed all over Mbarara as shown in the Figure 2. The samples were analysed using standard procedures in the laboratory. The list of samples collected was given in Table. 1

A. Statistical analysis

Analysis of the results followed descriptive statistics package of Excel to find means and standard errors of data. The results represented as averages and mean differences. The findings were then compared to WHO and Uganda-East Africa Community Water Standards for water quality as shown in Table 2 and Figure 3.

Table 1. Distribution of Sample sites

Location	Code	BR (*before rainfall season)*	AR (*after rainfall season)*	Total samples	GPS Coordinates	
					Latitude	Longitude
Ndaija	S1	3	3	6	30.613855	-0.615599
Nyakayojo	S2	3	3	6	30.662555	-0.620833
Kyahi/Kakiika	S3	3	3	6	30.698928	-0.607261

Table 2. Average water quality during wet and dry season

Sample site	Water quality parameter													
	pH		EC (uS/cm)		TDS (mg/L)		Turbidity (NTU)		BOD (mg/L)		COD (mg/L)		E_Coli	
	wet	Dry	Wet	Dry	Wet	Dry	wet	Dry	wet	Dry	wet	Dry	wet	Dry
Kyani/Kakiika	6.43	6.19	118.33	135.00	59.00	68.00	116.67	55.77	3.53	2.41	11.13	36.37	117.00	50.00
Ndiaja	5.65	6.31	52.67	92.00	26.33	46.00	71.87	51.50	3.40	4.97	9.67	27.70	144.00	52.67
Nyakayojo	6.08	6.06	108.67	106.00	54.33	52.67	94.00	63.23	3.47	4.02	11.27	45.00	101.33	57.67
NS	5.5 – 9.5		2500		1500		25				10		50	

NS: Permissible limit of the national standards for potable natural water

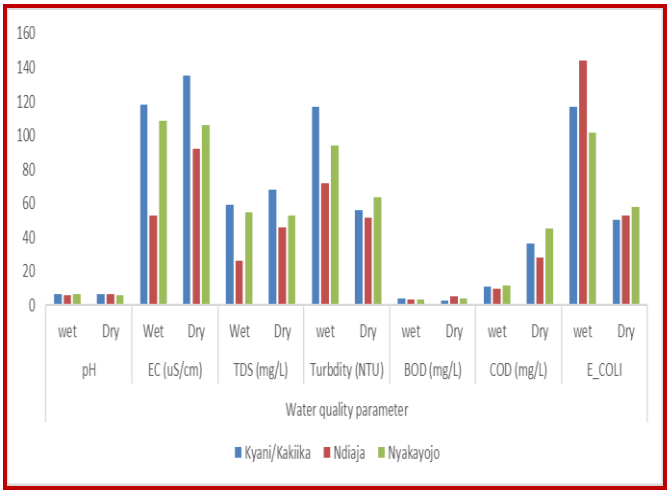

Figure 3. Physicochemical, organic matter and microbiological characteristics of Rwizi river at different sampling points.

III. RESULT AND DISCUSSIONS

Results from figure 3 above indicate different Physicochemical, organic matter and microbiological characteristics of Rwizi river from different sample sites of Kakiika, Ndiaja and Nyakayojo. Results show that pH was at 6.43, 5.65 and 6.08 at Kakiika, Ndiaja and Nyakayojo respectively during the wet season. It is further presented that Electric Conductivity was measured at 118.33, 52.67 and 108.67 at Kakiika, Ndiaja and Nyakayojo respectively during the rainy season. Following the results in figure 4.1,

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Total dissolved substances were measured at 59.00, 26.33 and 54.33 at Kakiika, Ndiaja and Nyakayojo respectively during the wet season. Turbdity (NTU) was found to be at 116.67, 71.87 and 94.00 at Kakiika, Ndiaja and Nyakayojo respectively during the rainy season.

In addition to the above, results were indicated that 3.53, 3.40 and 3.47 was recorded for Biochemical Oxygen Demand at Kakiika, Ndiaja and Nyakayojo respectively during the wet season. Moreso, Chemical Oxygen Demand was recorded at 11.13, 9.67 and 11.27 along Kakiika, Ndiaja and Nyakayojo respectively during the wet season. Following results in figure 4.1, E-coli was measured at 117.00, 144.00 and 101.33 along Kakiika, Ndiaja and Nyakayojo respectively during the wet season.

Seasonal variations in physicochemical, organic load and micro biological properties of the river

A. Seasonal variations of pH

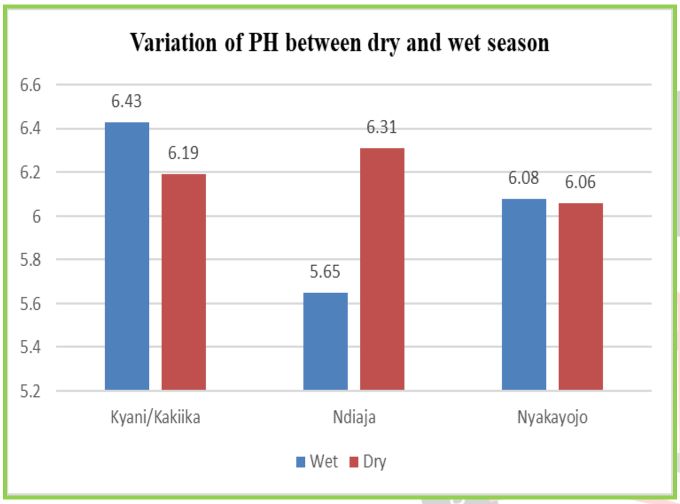

Figure 4. Seasonal variation of PH at the different locations.

From the study findings, it emerged that pH of the river Rwizi was acidic during both dry season than wet season as clarified by 6.43 and 6.19 during wet and dry season respectively at Kyani/Kakiika as shown in Figure 4. These findings were supported by [9] who found mean pH of Rwizi as follows upstream 6.23; midstream 6.92 and downstream 7.99. The findings are further supported by [11] who analyzed seasonal variations of Muni-Pomadze Ramsar Site and its catchment area. Highest acidity value was recorded in wet season at Ndiaja and lowest at Kyani/Kakiika. Based on the pH results of river Rwizi, it has been mentioned that the increasing pH appear to be associated with increasing use of alkaline detergents in residential areas and alkaline material from wastewater in industrial areas [12]. A study by [13] has indicated that pH of the water body is also determined by the underlying parental rock material. If the pH is less than 6.5, it discontinues the making of vitamins and minerals in the human body. More than 8.5 pH values cause the taste of water saltier and causes eye irritation and skin disorder for pH of more than 11.

B. *Seasonal variations of Electric Conductivity (EC)*

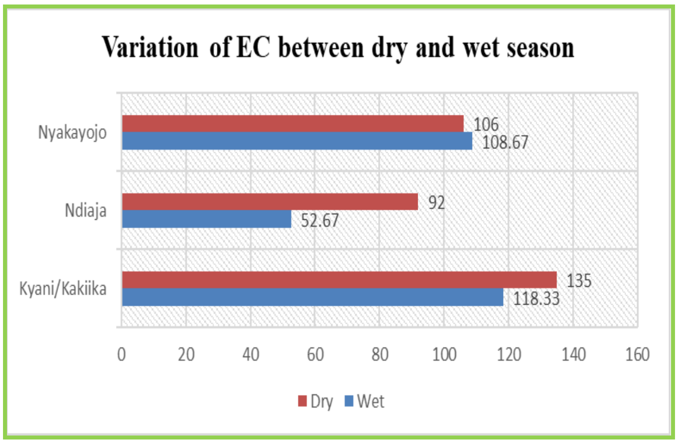

Figure 5. Seasonal variation of EC at the different locations**.**

From the study findings, it was revealed that a significant increase in Electric Conductivity during dry season was recorded throughout the study area indicating the dilution effect of water during wet season as shown in figure 5. The highest average EC recorded at Kyani/Kakiika 135.00(uS/cm) in dry season could have been as a result of waste water discharge in the river from urban and industrial parks [13]. Waste water from urban areas and industries are characterized by heavy deposition of metal irons into the river through surface runoffs, channels and sewage effluents [9][14].

Furthermore [19] stressed that River Rwizi was highly disturbed by anthropogenic activities which result in water pollution. The increase in Electric Conductivity can be justified by a 2018 study by [19] which found a significant positive correlation between EC and Mg, CaCO3, Cl, PO4, NO3, 4 NH+ which supports the fact that dissolved solids such as calcium, chloride, magnesium and other ionized substances in water samples are responsible for high electrical current through water and they become more concentrated in dry seasons. [13] also reported the presence of various ions like K+, Na+, SO4 2-, Cl-, Ca2+, Mg2+ as major drivers of high EC. Similarly reported elevated concentration of heavy metals in the water as a driver of high EC.

C. *Seasonal variations of Total dissolved substances (TDS)*

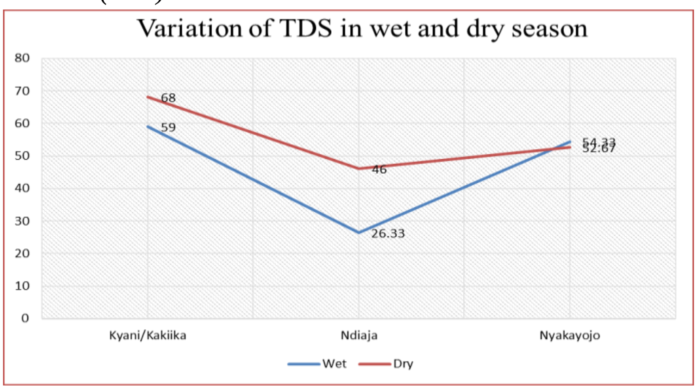

Figure 6. Seasonal variation of TDS at the different locations.

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The concentration of total dissolved solids (TDS) within seasons indicated that dry season was more concentrated than the wet season as reflected by the value of 68 obtained at Kakiika in dry season and 59 obtained at the same site during the wet season as shown in the figure 6. This is as a result on uncontrolled discharge of waste water from Mbarara city where the river flows through. A study by [11] indicated similar results of dry seasons being more polluted than wet season. On contrary high TDS results were recorded in some sites during wet season. According to high TDS in wet season is largely connected to runoff that carry soluble particles from nearby fields and streams. However, all results indicated that the river was safe because all TDS values were within the permissible limits of the National Standards for untreated water set at 1500. This parameter is very important because in controls both biotic and abiotic factors of water system. It is also directly associated with the heavy metal concentration in a water body [13]. Moreover, TDS can also explain the degree of water salinity thus its effect on other physicochemical parameters

D. Seasonal variations of Turbidity

From the study findings, sseasonal variations of turbidity indicated that River Rwizi was very turbid in wet season and this was observed by a value of 116.67 recorded during the wet season at Kakiika site and a value of 55.77 recorded during the dry season as shown in the figure 7. According to the high turbidity values in wet season are associated with loading of material from agricultural fields in the catchment such as soil particle. However, a slightly higher turbidity in Nyakayojo during dry season could be attributed to the emission of coloured particles and metallic materials into the streams especially those generated from Mbarara municipality from paints and metal works etc [9] Sand dredging and high level of chlorophyll are another factors that increases water turbidity during wet season. Chlorophyll concentration is mainly attributed to aquatic organisms' growth after an eutrophication period in wet season.

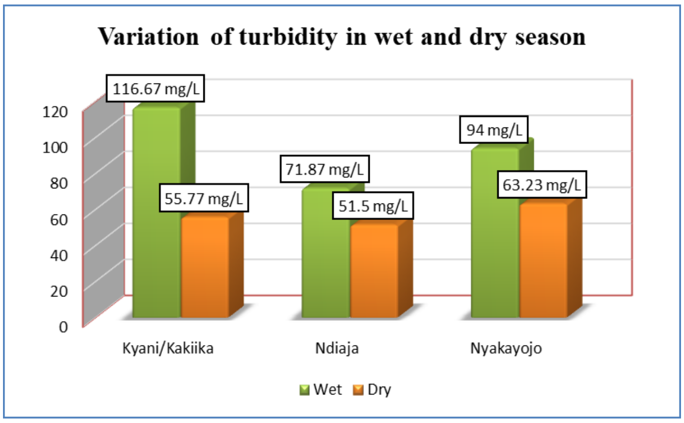

Figure 7. Seasonal variation of Turbidity in wet and dry season.

E. Seasonal variations of Biochemical Oxygen Demand (BOD)

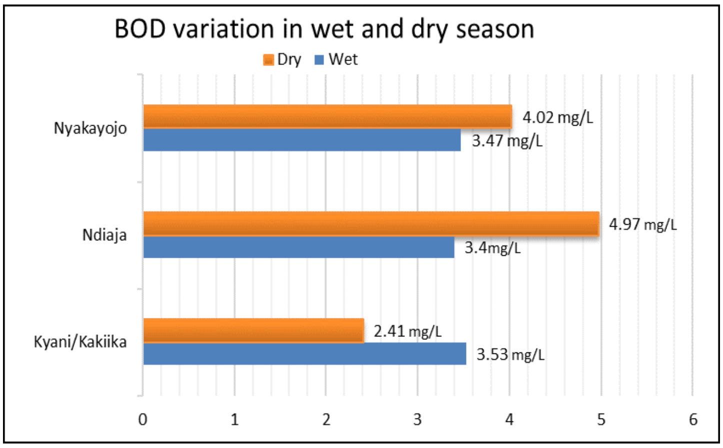

Figure 8. Seasonal variation of BOD at the different locations in different seasons

According to the study findings, it was revealed that Biochemical Oxygen Demand was higher in dry season as indicated by the values of 4.97 and 4.02 recorded at Ndiaja and Nyakayojo respectively as shown in figure 8. BOD gives idea about the presence of biologically active organism in the water body [13] [14] adds that it is an indicator of pollution whose higher values indicate high pollution and the vice versa. Seasonal variability of BOD presented a slightly higher concentration of BOD in dry season than wet season. This could have been a result of less dissolved oxygen in the water due to consumption by heavily multiplied microorganisms. Besides in the dry season water volume and velocity is low and temperature is high which supports multiplication of life.

F. Seasonal variations of Chemical Oxygen Demand (COD)

The study findings established that Chemical Oxygen Demand all COD values were beyond the permissible of 10(mg/L) except for Ndiaja indicating water pollution. The highest average COD values was recorded in Nyakojo 45.00(mg/L) in dry season and the lowest in Ndiaja 9.67(mg/L) during wet season as shown in figure 9. According to [16], the low COD in wet season is associated with high undecomposed material load in the river due to runoff. As the dry seasons sets in, water level reduces causing increased temperature thus increased microbial activity which further reduces dissolved oxygen in the water. A positive correlation between temperature, TDS and BOD and a negative relationship with DO has been reported by [16] Similar high COD results in dry season has been reported by other scholars e.g. [17] High COD values in the dry season indicate a great amount of oxidizable material deposited in the river during the past rainy season [16].

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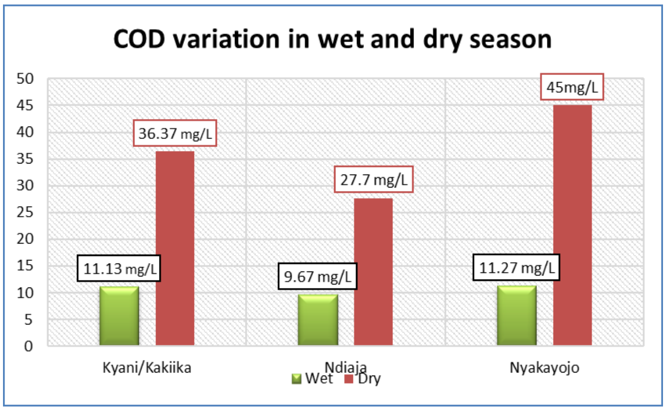

Figure 9. Seasonal variation of COD at the different locations.

G. Seasonal variations of E-Coli

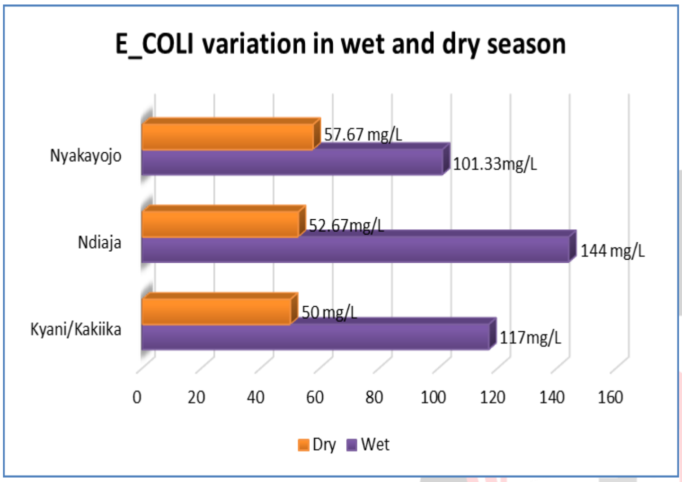

Figure 10. Seasonal variation of e-Coli at the different locations.

From the study findings, it emerged that E-coli concentration exceeded the permissible limit of the National Standards for untreated river water set at 0(CFU/100mL) in all sites and seasons. E-coli was measured at 117.00, 144.00 and 101.33 along Kakiika, Ndiaja and Nyakayojo respectively during the wet season as shown n figure 10. Wet season was more polluted than the dry season and this is can be attributed to discharge of fecal matter into the river by urban dwellers. There was a wastewater treatment plant near the river which may have accounted for the observable results as well. [18] assessed seasonal variations of water quality and found high positive correlation between E-coli and precipitation. Similarly, he pointed out urban runoff, combined sewer overflow and resuspension from deposited sediments as the major sources.

IV. CONCLUSIONS

Based on the findings of the study, the river is gradually getting polluted with E-coli, COD and turbidity which may soon suffocate life. The recorded high levels of E-coli indicate that the river water is not safe for use for domestic purposes. The latter is worsened during rainy seasons when all sorts of waste material including feces are released in the river. The wastewater treatment plant near the river needs to be closely monitored because it may become a point of water contamination. Therefore, there is need for routine monitoring of river water quality and effluents release by the treatment plant. The NEMA wastewater management instrument needs to be strictly implemented to industries, markets and urban areas to control contamination since Mbarara has gained a city status thus expected population explosion. Sensitization of the community on proper waste management and its dangers is important for intrinsic motivation.

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