The Effluent Quality Discharged and Its Impacts on the Receiving Environment Case of Kacyiru Sewerage Treatment Plant, Kigali, Rwanda

Sindikubwabo Theoneste[1], Nsanzumukiza Martin Vincent[2], Nshimiyimana François Xavier[3]

Department of Environmental Economics and Natural Resources Management, Faculty of Environment Studies, University of Lay Adventist of Kigali, P.O. Box 6392 Kigali-Rwanda.

Abstract— *The study evaluates the performance of Kacyiru Sewage Treatment Plant and its effluent impacts on the receiving wetland. Influent and effluent wastewaters as well as receiving wetland water qualities were measured from April to September 2019, at Kacyiru estate. The average removal efficiency (%) of the parameters such as TN, TP, COD, BOD_5 were recorded as 46.57; 61.49; 50.51; 66.79 respectively. The parameters such as pH, TDS, temperature value, were recorded within the prescribed limit of Rwanda standards for domestic wastewater discharge. The other parameters such as NTU, TN, TP, TSS, BOD_5 and Fecal coliforms were not complying with National standards requirements for domestic wastewater discharge. The finding showed that the excess nutrient observed may present potential sources of pollution in wetland and decrease the oxygen levels which affect the water living organisms. The discharged effluents contain microbes which can negatively devastate the receiving environment, thus the effect of discharged wastewater on environment is significant.*

Keywords— Bacteriological parameters, physico-chemical parameters, receiving environment, sewage treatment plant, wastewater.

I. INTRODUCTION

Discharged sewages are foremost contributors to the diversification of the physical and biological contamination of the environmental water bodies. Therefore, inappropriate sewage treatment systems, sewage and effluent frequently released in the environment arising to contamination. Around 33% of potable water demand of the world is acquired from freshwater, embankment, reservoirs and watercourse. These water sources receive also all municipal and industrial wastes (Joshua et al 2017).

Worldwide, effective management of domestic used water becomes increasing challenges in small and large towns and cities. In big cities and towns of low- and middle-income countries, only conventional sewage treatment facilities are put in place, and not yet provided or forethought in small and areas with many citizens. As reported by(Kathy et al 2003),in densely populated areas and highly urban populated areas (slum) there is a need of transitional and complementary solutions for on-site sewage disposal which is frequently unfortunate.

In developing countries, especially in Rwanda, there is enormous constraint for preserving the available natural resources. Inadequate sanitation has a great environmental economic as well as people's well-being implications. To minimize these impacts, the Government of Rwanda took several measures including increase of investment in sanitation sector (MININFRA , 2016), and involving the private and public campaigns to improve sanitary conditions countryside (Umuhoza et al 2010). This ensured in improving the status of sanitation for the coming years. Indeed, the actual condition of sanitation services in Rwanda is at 87.3% as reported in (EICV5 , 2018). In fact, WASAC ltd as a private institution owned by the Government, has a target to cover sanitation services at 100% in whole country by 2024. But, the technologies and their efficiency in treatment are still being serious challenge.

The degradation of environment is mainly caused by the aimless dumping of municipal wastes. Discharged waste water to the land or into water is a menace to public health as well as a violation of the fundamental Right to Clean Environment (Edokpayi , 2016)**.**

Therefore, this study aims to assess the physico-chemical and bacteriological quality of discharged final effluent of Kacyiru Wastewater treatment Plant, in Kigali city, and its impacts on the receiving environment.

II. MATERIAL AND METHODS

2.1 Operation of the Sewage Treatment Plant

The Sewage Treatment Plant is located in Kacyiru sector, Gasabo District in the City of Kigali with the geographical coordinates of 1^{o}56'08.1"S and 30^{o}05'08.5"E.A sewer network that generates black water and grey water from Kacyiru Rwanda Social Security Board (RSSB) estate buildings is in place. This estate was rehabilitated in 2016 and has 100 buildings and the sewage treatment plant capacity is 100m^3/day. The sewage treatment plant consists of; the inlet facility which is comprised of one screen and grit channel, primary sedimentation tank and bioreactor with attached growth and two vertically mounted mechanical aerators, and sedimentation tank. The excess sludge in secondary clarifier is returned in aerobic tank with recycling. To meet the discharge standards, the effluent from the secondary clarifier undergo the disinfection process before being discharged into the wetland.

FIGURE 1: Pre-treatment unit (a), Primary settler, Bioreactor, secondary settler (b)

The receiving wetland environment has been used for agriculture activities such as, vegetables, sweatpotatoes, maize, beans, sorghum,

2.2 Sampling Methods

To ascertain the physico-chemical and microbiological quality of wastewater, a total of six sampling campaigns (every two weeks) were conducted from May to September 2019. Wastewater samples from inlet of Sewage Treatment Plant (S1), outlet Sewage Treatment Plant (S2), mixed point of discharged effluent and wetland driver (S3), upstream wetland river (S4) and downstream wetland river (S5)were collected according to EPA sampling guidelines(EPA , 2007).Grab sampling method was used to collect all samples. It gives an instant sample and thus preferred for some tests (DCCL , 2010). Working conditions were carefully selected and strict measures were adhered in avoiding contamination of samples during sampling; handling and storage and all samples were analyzed within 24hours after sampling.

2.3 Parameters Analyses

2.3.1 Physico-chemical Analyses

Temperature, Electrical conductivity (EC), Total dissolved solids (TDS) were determined using a calibrated microprocessor EC/TDS meter (HANNA Instrument version HI 98360) equipped with probe, pH with a calibrated potable HACH SensION MM156 and Turbidity with a Turbid meter Model HACH 2100Q NTU.

The 5-Day BOD Technique was measured. Dissolved oxygen was measured initially and after incubation, and the BOD was computed from the difference between the initial and final DO.

The COD was measured according to IS 3025-58 (2006) method. A known quantity of water sample was mixed with a known quantity of standard solution of potassium dichromate ($K_2Cr_2O_7$) and the mixture heated for 2 hours at 150^{0}C. The organic matter was oxidized by the potassium chromate in the presence of sulfuric acid (H_2SO_4) and the oxygen used in oxidizing the water was determined. All samples taken for COD analysis, a standardization of Ferrous Ammonium Sulfate was done by diluting 10 ml of standard $K_2Cr_2O_7$ to about 100 ml and adding 30 ml of concentrated H_2SO_4 then cooling. Total nitrogen (TN) and total phosphorus (TP) were determined by cadmium reduction and ascorbic acid methods, respectively (ALPHA , 1995). Both TN and TP samples were digested with potassium persulphate and autoclaved for 30 minutes at about 121°C. For digestion of TN samples, potassium persulphate and sodium hydroxide were used simultaneously. Colorimetric determination for TN and TP was by HACH DR 6000 UV-VIS spectrophotometer at a wavelength of 500nm and 880nm, respectively.

The TSS was determined using the photometric method (HACH 8006). After blending at high speed 500 ml of sample, 10 ml was immediately poured into a sample cell according to (HACH , 1997). The Color was measured using Platinum-Cobalt Standard Method (HACH 8025). A 200ml of sample was placed into 400ml beaker and filtered using 0.45 micron membrane filter. The blank was prepared by pouring 10ml of filtered de-ionized water and placed into the cell holder. Next the 10ml sample was measured using HACH DR 6000 UV-VIS spectrophotometer and the results were taken in mg/l PtCo (HACH , 1997)

2.3.2 Bacteriological Analyses

Total coliforms bacteria, fecal coliforms bacteria, and E. coli are all considered indicators of water contaminated with fecal matter. Colilert 18 Hr. Method with Quanti-Trays set was used to detect bacteria. The method is based on IDEXX's patented Defined Substrate Technology (DST) where, when total coliforms metabolize Colilert-18's nutrient-indicator, ONPG, the sample turns yellow and E. coli metabolize Colilert-18's nutrient indicator, MUG, to turn sample in fluoresce. The MPN table specific to the type of quanti-trays used (51 well or 97 well type of quanti-trays) to obtain the Most Probable Number per 100ml of sample.

III. RESULTS AND DISCUSSIONS

3.1 Sewage Treatment Plant Performance

The Sewage Treatment Plant performances were evaluated in term of organic matter and nutrients removal. The COD removal efficiency was 50.51%, with BOD5 removal efficiency of 66.79%. The nutrients removals were characterized with parameters such as total phosphorus, total nitrogen with removal efficiencies value of 61.49% and 46.5% respectively. The other parameters removal efficiency was indicated in Table 1. The recorded value indicated low removal efficiency.

TABLE 1
SEWAGE TREATMENT PLANT (STP) PERFORMANCE

Parameters	unit	Influent	Effluent	Efficiency (%)
Turbidity	NTU	568.90	94.58	83.37
Total dissolved solids (TDS)	mg/l	745.58	411.00	44.88
Total nitrogen (TN)	mg/l	64.78	34.61	46.57
Total phosphorus (TP)	mg/l	14.05	5.41	61.49
Color	mg/l PtCo	2047.16	738.66	63.92
Chemical Oxygen Demand (COD)	mg/l	501.66	248.28	50.51
Biological Oxygen Demand (BOD_5)	mg/l	221.25	73.48	66.79
Total Suspended Solids (TSS)	mg/l	511.75	137.16	73.20
Iron	mg/l	0.16	0.15	6.25
Copper	mg/l	0.06	0.04	33.33
Lead	mg/l	0.02	0.01	50.00
Total coliforms (TC)	MPN/100ml	241960.0	131258.33	45.75
Fecal Coliforms (FC)	MPN/100ml	68143.33	42973.33	36.94
E.Coli	MPN/100ml	36043.33	20048.33	44.38

3.2 Influence of STP effluent to the wetland water quality

Wetland water quality were assessed, the table 2 illustrates the influence of wastewater treatment plan to the water quality of the wetland. The downstream cod was very low in comparison to the wastewater treatment plan effluent and mixed point of discharged effluent and wetland stream.

The turbidity values of the influent recorded were fluctuated from168.4 NTU to 849.0 NTU with a mean value of 568.9±108.58 NTU at the inlet of the wastewater treatment plant, the outlet of the treatment plant showed a little performance with the range from 57.6 NTU to 124 NTU with a mean value of 94.58 ±9.02 NTU , however, the joint point of wastewater treatment plant and wetland showed a greater performance with42 NTU to 68 NTU with a mean value of 54.36±4.22 NTU due to the dilution theory., the upstream and the downstream of the wetland showed low turbidity concentration, Table 3. The Rwandan turbidity target for effluent discharge is 30 NTU (RWANDA STANDARDS , 2017). Analysis of variance at 95% confidence level showed that the turbidity variations are significant different ($p<0.05$) between effluent and wetland water bodies sampling sites (S2 and S3, S4 & S5), and these average values are totally exceeding maximum permissible limits for effluent discharging. During the study period the turbidity of water shows high significant positive relationship ($p<0.01$) with TDS ($r = 0.971$), TP ($r = 0.978$), Color ($r = 0.991$), BOD ($r = 0.984$) and TSS ($r = 0.996$) Table 3.This showed that the effluent affects the receiving environment and increase the wetland water pollution. The high turbidity is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms (Mandal , 2014). It affects all aquatic life through the blockage of sunlight penetration into water. A study conducted by (Smith & Davies , 2001) showed that, if light get too low; algae may also die. (Hoko , 2005), reported also that the high turbidity increases the possibility for waterborne diseases, as particulate matter may port microorganisms and excite the bacteria growth, thereby causing health risk to water body users. Highly turbid conditions in water can cause also problems with water treatment/purification processes such as flocculation and filtration which may increase treatment cost (DWAF , 1996).

TABLE 2
THE CONCENTRATION'S RANGE, MEAN ±SE VALUES OF THE PHYSICO-CHEMICAL PARAMETERS/VARIABLES AT SELECTED SAMPLING SITES (N=6)

Sampling sites	S1	S2	S3	S4	S5	
	N1: 6	N2: 6	N3: 6	N4: 6	N5: 6	n=30
Parameters						RSB MPL
Temp. (℃)	24.83±0.39	24.08±0.22	24.8±0.45	23.6±0.41	24.33±0.31	**3℃ variation**
pH	7.65±0.05	7.57±0.09	7.83±0.23	7.51±0.11	7.50±0.05	**5.0 - 9.0**
Turb. (NTU)	568.9±108.58	94.58±9.02	54.36±4.22	46.06±3.66	47.4±4.51	**30**
TDS(mg/l)	745.58±67.06	411±41.50	274.98±25.56	253.41±27.58	239.5±18.19	**1500**
TN (mg/l)	64.78±8.92	34.61±2.99	12.54±1.40	8.92±0.93	10.38±1.95	**30**
TP (mg/l)	14.05±1.67	5.41±0.32	2.18±0.18	1.71±0.13	1.76±0.16	**5**
Color (mg/l PtCo)	2047.16±231.43	738.66±85.65	409.5±48.11	350.16±42.80	375.83±50.26	**200**
COD (mg/l)	501.66±37.26	248.28±11.72	77.86±9.98	57±9.48	54.05±9.12	**250**
BOD5 (mg/l)	221.25±26.79	73.48±12.79	28.83±5.29	19.71±4.72	17.70±3.95	**50**
TSS (mg/l)	511.75±89.38	137.16±17.87	65.9±8.91	48.16±11.94	53.1±11.07	**50**
Iron (mg/l)	0.16±0.03	0.15±0.05	0.25±0.05	0.21±0.03	0.31±0.07	*****
Mn (mg/l)	0.04	0.05±0.01	0.02	0.02	0.08±0.03	*
Cu (mg/l)	0.06±0.01	0.04±0.01	0.02	0.02	0.02	*
Pd (mg/l)	0.02	0.01	0.02	0.02	0.03	*
TC (MPN/100ml)	241960±0.00	131258.33±20489.54	92333.33±18573.35	52236.66±14102.36	66235±16882.25	*
FC (MPN/100ml)	68143.33±18580.94	42973.33±15869.19	25873.33±5192.15	17193.33±1370.14	20883.33±2131.47	**< 400**
E.Coli (MPN/100ml)	36043.33±12857.33	20048.33±6263.42	15011.66±3761.43	9043.33±937.60	12640±1570.14	*****

S1: Influent of Sewage Treatment Plant; S2: Effluent of Sewage Treatment Plant; S3: Mixed point of discharged effluent and wetland stream;
S4: Upstream wetland water body; S5: Downstream wetland water body; * Permissible limit value not specified by the standards

The TDS average values recorded in both sites were within the permissible limits (≤1500 mg/l) for wastewater discharge, Table 2. The TDS recorded showed high significant positive relationship ($p<0.01$) with some parameters such as Total nitrogen (TN) with ($r = 0.991$), TP ($r = 0.99$), color ($r = 0.994$), COD ($r = 0.992$), BOD ($r = 0.998$), TSS ($r = 0.989$), Cu ($r = 0.963$), Total coliforms ($r = 0.988$), Fecal coliforms ($r = 0.993$) and E. coli ($r = 0.984$),Table 3.According to (Akua , 2014), an increase of Total Dissolved Solids parameters will cause depletion of dissolved oxygen which will affect the aquatic life in the receiving water bodies. (Celenza , 2015), reported that effluents characterized by elevated TDS and high organic content are produced by food, petroleum and petrochemical facilities. Discharged effluent with high TDS level would have an impact on aquatic life and worsen corrosion in water networks (LVEMP , 2002).

3.3 Correlation coefficient of physico-chemical and bacteriological parameters

To test the relationship between physico-chemical and bacteriological parameters of the effluent, the Pearson's Product moment correlation coefficient were used. Throughout the study period, sizeable numbers of significant positive correlation were experienced among the physico-chemical and bacteriological parameters Table 3.

3.3.1 Nutrients (TN&TP)

The TN values obtained in this study ranged from 42 mg/l to 98mg/l with a mean value of 64.78±8.92 mg/l at the inlet of wastewater treatment plant (S1), the outlet of the plant (S2), the effluent concentrations ranged from 28 mg/l to 48.5mg/l with a mean value of 34.61±2.99 mg/l, total nitrogen concentration showed low value in the joint areas of wastewater effluent and wetland due to the dilution concepts, Table 2. The TP values revealed in this study ranged from 9.8 mg/l to 19.8 mg/l with a mean value of 14.05±1.67 mg/l at the inlet, the outlet showed low value of TP with the range, from 4.55 mg/l to 6.84 mg/l with a mean of 5.41±0.32 mg/l, however, the joint point of effluent and wetland illustrated low value of TP from 1.80 mg/l to 2.98 mg/l with a mean value of 2.18±0.18 mg/l The TN and TP values varied significantly along all sites ($p<0.05$).

TABLE 3
CORRELATION COEFFICIENT BETWEEN PHYSICO-CHEMICAL AND BACTERIOLOGICAL PARAMETERS OF EFFLUENT SAMPLED

Correlations																	
	WT	pH	Turb.	TDS	TN	TP	Color	COD	BOD	TSS	Fe	Mn	Cu	Pd	TC	FC	E.Coli
WT	1																
pH	.729	1															
Turb.	.541	.143	1														
TDS	.498	.146	**.971****	1													
TN	.474	.118	.934*	**.991****	1												
TP	.506	.131	**.978****	**.999****	**.988****	1											
Color	.526	.135	**.991****	**.994****	**.973****	**.997****	1										
COD	.460	.116	.935*	**.992****	**1.000****	**.988****	**.973****	1									
BOD	.518	.149	**.984****	**.998****	**.982****	**.999****	**.999****	**.982****	1								
TSS	.537	.146	**.996****	**.989****	**.963****	**.993****	**.999****	**.964****	**.996****	1							
Fe	.038	-.057	-.562	-.709	-.741	-.681	-.635	-.755	-.670	-.615	1						
Mn	-.001	-.578	-.078	-.094	-.038	-.065	-.061	-.059	-.085	-.072	.444	1					
Cu	.419	.051	.881*	**.963****	**.990****	.958*	.935*	**.989****	.948*	.921*	-.759	.038	1				
Pd	-.047	-.194	-.219	-.441	-.534	-.408	-.338	-.538	-.386	-.306	.820	.241	-.605	1			
TC	.603	.257	.948*	**.988****	**.987****	**.986****	**.977****	**.985****	**.984****	**.971****	-.677	-.082	**.963****	-.486	1		
FC	.539	.195	.919*	**.983****	**.995****	**.978****	**.962****	**.994****	**.973****	.952*	-.726	-.048	**.986****	-.561	**.993****	1	
E.Coli	.627	.244	.952*	**.984****	**.982****	**.984****	**.978****	**.979****	**.983****	**.974****	-.633	-.031	.958*	-.447	**.998****	**.989****	1

** *Correlation significant at the 0.01 level (2-tailed)* **.Correlation significant at the 0.05 level (2-tailed)*
TDS: Total Dissolved Solids, TN: Total Nitrogen, TP: Total phosphorus, COD: Chemical Oxygen Demand, BOD: Biochemical Oxygen Demand, TSS: Total Suspended Solids, Fe: Iron, Mn: Manganese, Cu: Copper, Pd: Lead, TC: Total Coliforms and FC: Fecal Coliforms

The average for TN and TP downstream wetland values are greater than upstream wetland values, this indicates how the effluent affect the receiving wetland water body as there is increase of nutrients downstream wetland water bodies (S3 & S5).

The content of Nitrogen in wastewater is in the form of nitrogenous compounds present in it. (Akua , 2014), reported that the nitrogenous organic presents in sewage undergo decomposition or oxidation and(Mosley et al , 2004), reported that phosphates go through waterways from human and animal wastes, phosphate rich bedrock, wastes from laundry cleaning and industrial processes, and fertilizer runoff. If a large amount phosphate is present, algae and water weeds grow wildly, choke the water way and use up large amount of oxygen resulting into death of aquatic living organisms.

The TN throughout the study period shows strong significant positive correlations ($p<0.01$) with TP ($r =0.988$), color ($r =0.973$), COD ($r =1$), BOD ($r =0.982$), TSS ($r =0.989$), Cu ($r =0.990$), TC ($r =0.987$), FC ($r =0.995$) and E. coli ($r =0.982$) while the TP shows also strong significant positive relationship ($P<0.01$) with Color ($r =0.997$), COD ($r =0.988$), BOD ($r =0.999$), TSS ($r =0.993$), TC ($r =0.986$), FC ($r =0.978$) and E. coli ($r =0.84$) Table 3. According to (Augustina & Anthony , 2009), nutrient enrichment of river water can generally contribute to algae blooms and depleting the dissolved oxygen, dropping water quality and creating unfavorable environments for water living animals. Both nitrogen and phosphorus may cause an increase of aquatic biological productivity resulting in lowing dissolved oxygen and eutrophication of lakes, rivers, estuaries and marine waters (Perry et al 2007).

(Perry et al 2007), revealed also that it is not possible to find a high phosphate reading if the algae are already blooming, as the phosphates will already be in the algae but not in water. This explains the low levels of total phosphorus values recorded along the wetland water body sampling sites (S3 & S5) because algae were observed at some sections along other sites of the wetland stream.

The enhancement of the wetland water body by nutrients compounds such as nitrogen and phosphorus, present in the effluent led to the alteration of the aquatic environment of the wetland water body which is progressively changing from freshwater body to a swamp due to continuous deposit of silt and accelerated growth of algae and higher forms of plant life to produce an unwanted disturbance to the equilibrium of organisms present in the water and to the quality of the water.

3.3.2 Color (mg/l PtCo)

The colour concentration values ranged from 1248 mg/l PtCo to 2689 mg/l PtCo with a mean value of 2047±231.43 mg/l PtCo at the inlet of STP, from 508 mg/l PtCo to 1041 mg/l PtCo with a mean values of 738.66±85.65 at the outlet of STP, from 256 mg/l PtCo to 564 mg/l PtCo with a mean value of 409.5±48.11 mg/l PtCo at the mixing point of effluent from STP and wetland stream water, from 198 mg/l PtCo to 502 mg/l Pt Co with a mean value of 350.16±42.80 mg/l PtCo at upstream wetland river and from 208 mg/l PtCo to 534 mg/l PtCo with a mean value of 375.83±50.26 mg/l PtCo at downstream wetland river Table2.The color concentration values revealed in this study were exceeding Rwandan standard requirements for discharging (RWANDA STANDARDS , 2017).

Comparing downstream and upstream values, there is an impact of effluent discharge on downward of wetland water bodies as the average values of S3 and S5 are greater than average value recorded upstream wetland water river (S4). The color of water shows high significant positive correlations ($p<0.01$) with COD ($r =0.973$), BOD ($r =0.999$), TSS ($r =0.999$), TC ($r =0.977$), FC ($r =0.962$) and E. coli ($r =0.978$) Table 3. According to (Walakira 2011), Color in wastewater can be caused by a number of dissolved organics and if colored wastewater is discharged to nature; photosynthesis activity is limited because colors interfere with penetration of light; which will cause detrimental effects on aquatic ecosystems.

3.3.3 Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD)

The analysis of variance at 95% confidence interval revealed statistically significant differences for COD and BOD values ($p<0.05$) along sites. The COD of water throughout the study period shows strong significant positive correlation ($p<0.01$) with BOD ($r =0.982$), TSS ($r =0.864$), Cu ($r =0.989$), TC ($r =0.985$), FC ($r =0.994$) and E. coli ($r =0.979$) while the BOD of water during the same study period shows high significant positive relationship ($p<0.01$) with TSS ($r =0.996$), TC ($r =0.984$), FC ($r =0.973$) and E. coli ($r =0.974$) Table 3.The strong significant positive correlation between COD and BOD_5 in effluent is environmental concern because an increase of COD also leads to an increase of BOD_5. Thus, there is a greater amount of oxidizable organic and inorganic materials which will reduce dissolved oxygen levels and lead to anaerobic conditions which is deleterious of many aquatic life forms (Akua , 2014).

The high mean values of COD and BOD_5 in effluent exceeding the maximum allowable limits indicates a pollution of the receiving environment, thus suggesting the inefficiency of sewage treatment facility in removing the substances causing both COD and BOD_5. As reported by (Koushik et al 1999), high values of COD recorded in effluent indicate a load of organic and inorganic pollution that require more oxygen to be oxidized and this will have effect on environment as the dissolved oxygen will be decreased. The high values of BOD_5 in effluent indicate the presence of a high content of biodegradable organic pollutants in the effluent of Sewage Treatment Plant. As reported by (Walakira , 2011), the continued disposal of biodegradable organic wastes into the stream will lead to increased consumption of dissolved oxygen thus affecting the aquatic life.

3.3.4 Total Suspended Solids (TSS)

The TSS of water shows high significant positive relationship ($p<0.01$) with TC ($r = 0.971$) and FC ($r = 0.974$) Table 3. The high TSS in effluent refers to suspended organic particles or dissolved matter and it is related to both specific conductance and turbidity. High TSS can block sunlight from reaching aquatic plants and this has the effect on photosynthesis which slows down. At the same time the reduced photosynthesis rates will reduce also dissolved oxygen in water which will lead to aquatic life problems (Bilotta and Brazier , 2008).

According to (Abuenyi , 2010), municipal wastewater effluents are responsible for a long-term continuous input of suspended solids to the receiving environment. (Horner et al 1994), reported that suspended solids released into receiving waters, principally from wastewater effluent discharges, can cause a number of direct and indirect ecological effects, including reduced sunlight penetration, smothering of spawning (RWANDA STANDARDS , 2017) grounds, physical harm to fish, and toxic effects from contaminants attached to suspended particles. The growth and survival of some species may also be affected, either through direct effects or throughout indirect effects caused by changes in the food web or interference with dispersal or migration. Such effects can manifest themselves on various time scales.

3.3.5 Heavy metals

The heavy metals were analyzed in influent and effluent of wastewater treatment plant, joint point of effluent and wetland water and down –upstream wetland, Manganese, Copper and Lead. The average concentration values Fe, Mn, Cu and Pd were recorded 0.15±0.05 mg/l, 0.05±0.01 mg/l, 0.04±0.01 mg/l and 0.01 mg/l respectively, Table 2. The Cu concentration showed high significant positive correlation ($p<0.01$) with TC ($r = 0.963$) and FC ($r = 0.986$), Table 3.

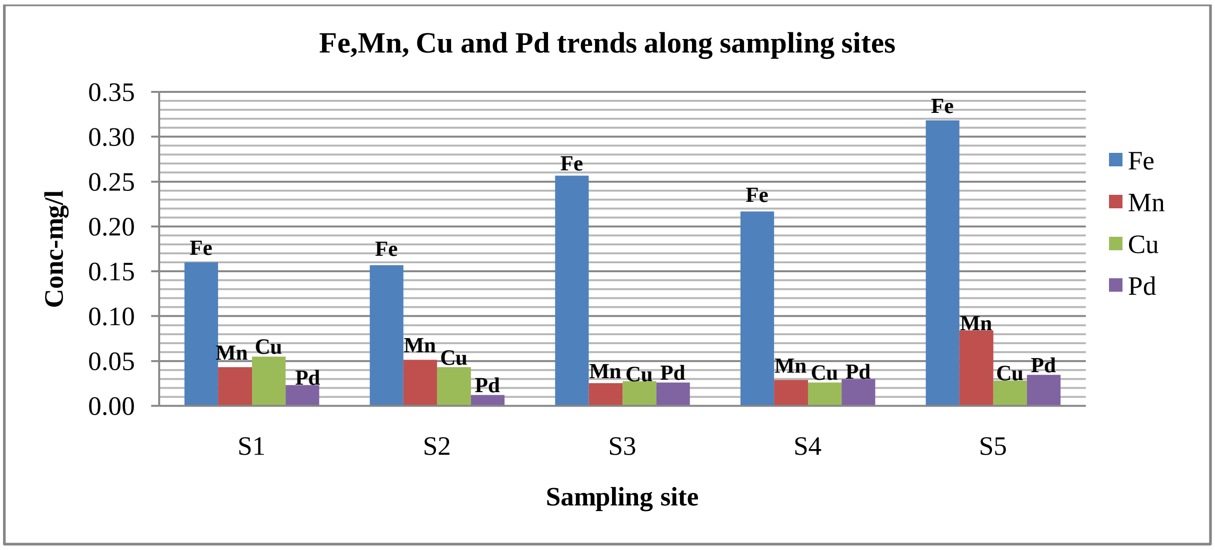

FIGURE 2: Heavy metal concentration at five different sites

The wetland showed high concentrations of iron, probably due to the wastewater discharged in wetland from nearby industry, Figure 2. Although heavy metals are naturally present in small quantities in all aquatic environments, it is almost entirely throughout human activities that these levels are enlarged to the levels of toxic (Nelson and Campbell , 1991).

(Akpor & Muchie , 2011), reported heavy metal cannot be degraded but amass during the food chain, producing likely human health risks and ecological disturbance. According to (Fuggle , 1983), the danger of heavy and trace metal contaminants in water body lies in two aspects of their impacts. Lead (Pd) seems to have low toxic effect on plant growth due to its strong affinity on organic matter, for some environmental conditions for example the change in pH it may become mobile (Muwanga & Barifaijo , 2006).

3.3.6 Bacteriological parameters

The Total coliforms (TC), Fecal coliforms (FC) and E. coli in effluent (S2) were recorded in with the following value: 131258.33±20489.54 MPN/100ml, 42973.33±15869.19 MPN/100ml and 20048±6263.42 MPN/100ml respectively; the average values recorded for TC, FC and E. coli in mixing point of effluent and wetland water body were 92333.66±14201.36 MPN/100ml, 25873±5192.15 PMN/100ml and 15011.66±3765.43 MPN/100ml respectively. At upstream wetland water body, the mean values for TC, FC and E. coli recorded were 52236.66±14102.36 MPN/100ml, 17193.33±1370.14 MPN/100ml and 9043.33±937.60 MPN/100ml respectively, Table2. The analysis of variance at 95% confidence interval revealed statistically significant differences for total coliforms, fecal coliforms and E. coli ($p<0.05$) between effluent and wetland water bodies sampling sites (S2 and S3, S4 & S5). During the study period, the TC of water shows strong significant positive correlation ($p<0.01$) with Fecal coliforms (FC) ($r=0.993$) and E. coli ($r=0.998$) Table 3.

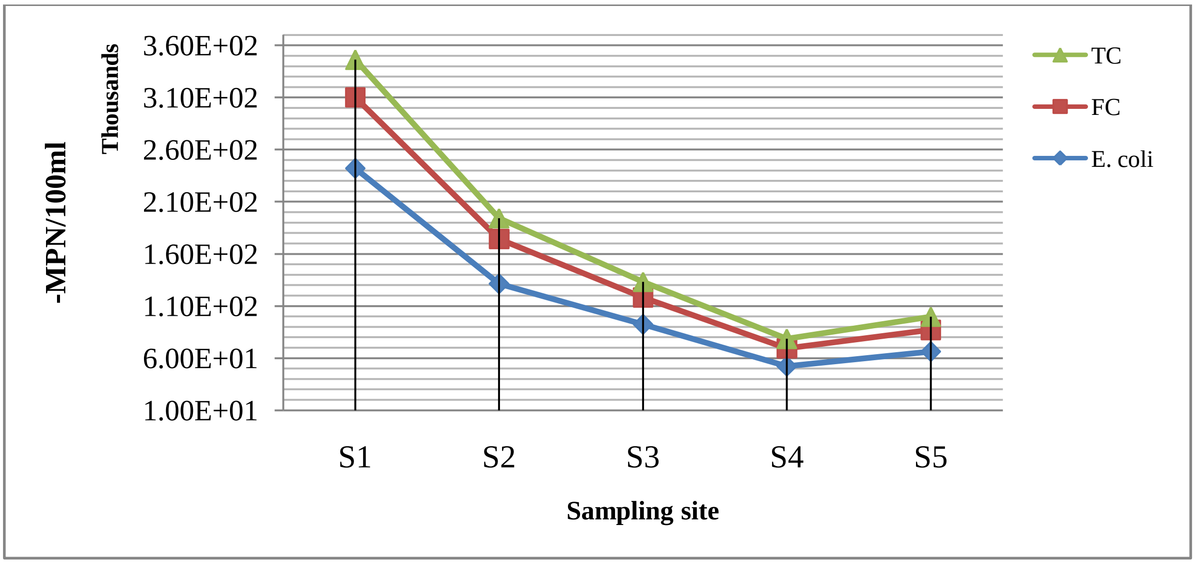

FIGURE 3: Total coliforms, fecal coliforms and E. coli mean variation of samples at five different sites

The presence of fecal coliforms in water samples often indicates fecal pollution. All coliforms bacteria are indicator of a potential public health risk. Total and fecal coliforms bacteria are insightful and frequently used as indicators of bacterial pathogen contamination of natural waters. According to (Modi , 2011), fecal coliforms bacteria have a strong link with fecal contamination of water from warm-blood animals.

The high concentrations of E. coli in sites S3, S4 and S5 revealed that a risk to human health exists especially for farming people in the wetland. Fecal coliforms and E. coli levels from Sewage Treatment Plant effluent were significantly high due to very low performance of the treatment plant, Table 1. Furthermore, the irrigation of vegetables in the wetland with effluent of poor quality in terms of bacteria needs to be avoided due to its potential for the widen of diseases-causing microorganisms to both farmers while handling such water and consumers. E. coli is the main cause of wide range of infections, including urinary tract infections and diarrhea diseases in all age groups (Amoah et al 2006).

IV. CONCLUSION

The study highlighted that the effluent from Kacyuru Sewerage Treatment Plant have serious impact on the quality of water of receiving wetland stream. This is portrayed by the fact that there is increase of concentration of physico-chemical and bacteriological parameters downstream wetland river as opposed to upstream wetland river.

Generally, the study revealed that the physico-chemical parameters such as Turbidity, Total Nitrogen, Total Phosphorus, Color, Chemical Oxygen Demand, Biochemical Oxygen Demand, Total Suspended Solids and bacteriological parameters such as Total Coliforms, Fecal Coliforms and E.coli of effluent at the outlet of Sewerage Treatment Plant (STP) were exceeding the Rwandan National permissible wastewater discharge. On the other hand, the parameters such as Temperature, pH, Total Dissolved Solids, Iron, Manganese, Copper and Lead were in compliance with standard requirements. The results of this study revealed that the poor effluent quality is due to poor maintenance and treatment operations of the sewerage treatment plant; this is reason why its efficiency removal for some key parameters was low.

Moreover, downstream concentrations of most parameters were higher than upstream concentrations after the effluent discharge point in wetland stream. The effect of polluted water on human health, aquatic life and on various economic activities including agriculture, industry and recreation can be devastating. Therefore, it can be concluded that waste water effluents from Kacyiru Sewerage Treatment Plant has a negative effect on the wetland streams.

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