EFFECTS OF HUMAN ACTIVITIES ON QUALITY OF WATER AT SELECTED POINTS OF RIVER RUPINGAZI IN EMBU COUNTY, KENYA

Somoni Prisca Bonareri [1*], Dr. Esther Kitur [1] and Dr. James Koske [2]

[1] Department of Environmental Science, School of Environmental Studies, Kenyatta University Nairobi, Kenya

[2] Department of Environmental Education, School of Environmental Studies, Kenyatta University Nairobi, Kenya

1*Corresponding author: Somoni Prisca Bonareri, Department of Environmental Sciences, School of Environmental Studies, Kenyatta University, P.O. Box 43844-00100 Nairobi, Kenya, Tel: +254723465845; E-mail: bonarerisp@gmail.com

ABSTRACT

Quality of water in rivers and lakes depends on physical, chemical and biological properties. Points in inland water resources in Kenya are under pressure of pollution from agrochemicals, municipal and other domestic wastes variably affecting water quality. This study assessed the effects of human activities on water quality of river Rupingazi and its major tributaries. The parameters studied included: temperature, pH, EC, DO, TSS, TDS, turbidity, phosphates, nitrates and nitrites. Laboratory and field data was statistically analysed ($p<0.05$) using one way ANOVA, t-Test and regression. The results obtained showed significant seasonal variation between some parameters for wet and dry seasons. Temperature and pH were significantly higher in dry season recording 22.97±0.2 ^{0}C and 8.16±0.04 respectively (n=36, p<0.05). Turbidity, DO, TSS and nitrates were all significantly higher in wet season. Recorded results were Turbidity 98.59±13.34 NTU; DO 6.64±0.31 mg/L; TSS 103.33±12.43 mg/L; Nitrates 12.16±1.88 mg/L (n=36, p< 0.05). There was no noted significant variation in EC and TDS for both seasons (n=36, p>0.05).

Key words: Water quality, physicochemical parameters, pollution, human activities, River Rupingazi.

1.0 INTRODUCTION

Rivers are fresh water ecosystems and constitute main inland water body for agricultural domestic and industrial activities (Singh *et al*., 2004; Pradhan *et al*., 2009; Hu *et al*., 2011). The river water quality has been degraded as a result of discharges of wastewater containing degradable organic substances, nutrients, domestic effluent, and agricultural waste (Dimitrovska *et al*., 2012). The discharge of untreated or partially treated pollutants from different sources such as: domestic, storm water, industrial waste water, agricultural runoff have either long term or short term effects on end users (Singh, 2007). Human influences such as urbanization, industrialization, agricultural activities, accidental chemical spills, dam construction, and natural processes like erosion and climatic conditions, could each affect surface water quality to different degrees. However, the degree to which each factor contributes to water quality degradation is not clear (Zhang *et al*., 2009).

Globally fresh water comprises 2.5 % of the total water mass with 68.7 % of the water being in ice form, 29.9 % in aquifers as underground water and 0.26 % in lakes and rivers. All these sources are susceptible to pollution hence reducing water portability (Carpenter, *et al*., 2011). The major sources of surface water include rivers, lakes, canals, ponds, wells and groundwater in shallow and deep aquifers. In Kenya and most parts of the world, rivers are a major source of water for both domestic and industrial use (Masere *et al*., 2012).

Rivers and surface water in general act as sinks for wastes generated by different human activities (Kithiia, 2011; Oluyemi *et al.,* 2010). Water quality has become an environmental issue of concern with several researches being carried in the past and present by different researches including: Masere *et al*., 2012; Singh *et al.,* 2013; Edokpayi *et al*., 2015; Ndubi *et al*., 2015 and

Shegani, 2016 to establish the effects of different human activities on physicochemical and microbial water quality. River water quality is influenced by several factors including underlying geology, climate change, human activities like discharge of domestic and industrial effluents, use of agricultural chemicals and fertilizers to boost yields and land use changes which eventually changes the composition of surface and ground water (Hussain *et al.*, 2008).

Points in inland water resources in Kenya are under pressure of pollution from agrochemicals, municipal and other domestic wastes, land use changes among others variably affecting water quality. Good quality water is needed for maintenance of ecological balance, economic growth and development activities. Due to increasing scarcity of water, there is need for proper timely planning, monitoring and management of rivers as a source of water. The quality and quantity of accessible water should be studied to make realistic and achievable the concept of sustainable use of resources (Bamgbose and Arowolo, 2007).

River Rupingazi is one of the major rivers in Embu County and plays a significant role in the county as a source of water for drinking, irrigation and other general domestic uses. Rupingazi River and its main tributaries are intensely used as sources of domestic water and for irrigation. The river flows through a densely populated agricultural area (183 persons per km^2) hence is susceptible to pollution especially after passing through settlement and agricultural farms.

The river faces several challenges which include: increasing human population, for instance, according to the 2009 population census Embu County's population was 516,212 with a population density of 183 persons per km^2. This was projected to grow to 538355 in 2012, 561447 in 2015 and 577390 in 2017 (CIDP, 2013). Growing population puts pressure and stress on both quality and quantity of river water. Other challenges are: uncontrolled river water abstraction, municipal and domestic sewage disposal into the river, loss of soil fertility, soil erosion and encroachment of riparian land that change water quality (SCMP, 2014).

There is limited documented research that relates the effects of human activities to the physicochemical quality of water in river Rupingazi and its tributaries. The available documented research is on "Distribution and abundance of freshwater crabs (*Potamonautes* spp.) in rivers are draining Mt Kenya, East Africa" by Dobson *et al.*, 2007. Drinking polluted water exposes the consumers to waterborne like cholera, typhoid, dysentery most of which cause death. Therefore it is important formulate sound water management strategies to monitor the water quality of this river since it is majorly used for drinking.

In this study the following physicochemical parameters: Temperature, pH, EC, DO, TDS, TSS, turbidity, nitrates, nitrites and phosphates were studied at different points of river Rupingazi and its tributaries.

2.0 MATERIALS AND METHODS

2.1 Study area

The study was carried out in river Rupingazi in Embu County. Embu County is located approximately between latitude 0^o 8′ and 0^o 50′ S and longitude 37^o 3′ and 37^o 9′ E. The study area experiences bi-modal rainfall with temperatures ranging from 12 ^{0}C in July the coldest month to 29 ^{0}C in the dry months. The major part of the county has soils with top soil rich in organic matter and of moderate to high fertility mainly Nitosols and Andosols. These volcanic soils are suitable for agriculture

2.2 Sample collection and data analysis

Twelve sampling points in the study area selected using Global Positioning Systems (GPS) were used. The standard procedures in APHA 1999 for collection, preservation, transportation and analysis of water samples were followed. The water samples were collected from twelve sampling sites along Rupingazi River and its tributaries during the dry and wet season. They were subjected to both *in-situ* and laboratory testing to establish the status of their physicochemical qualities. The samples were collected in pre-cleaned 1000 ml plastic bottles from the middle section of the river channel where possible.

Collection of water samples was done between 10:00 a.m- 12 noon to ensure consistency in the results. Parameters such as turbidity, temperature, pH, TDS and EC were measured *in-situ* using HANNA portable meters. The remaining parameters were measured in the laboratory immediately after transportation of samples to the laboratory.

Data was coded, entered in excel spreadsheets, errors checked and corrected before any analysis was done. Data on water quality parameters were analyzed using Anova and T-test at 95 % significance level ($p<0.05$). Anova was used to determine variation by site in both seasons. T-Test was used to determine seasonal variation.

3.0 RESULTS AND DISCUSSION

Parameters measured in this study were: temperature, pH, EC, DO, TSS, TDS, turbidity, nitrates, nitrites and phosphates. Their mean values in the dry and wet seasons were as recorded in the subsequent tables.

Table 1 is a summary of the mean values and their respective Standard Error (SE) per parameter for all the physicochemical water quality parameters measured per site during the dry season.

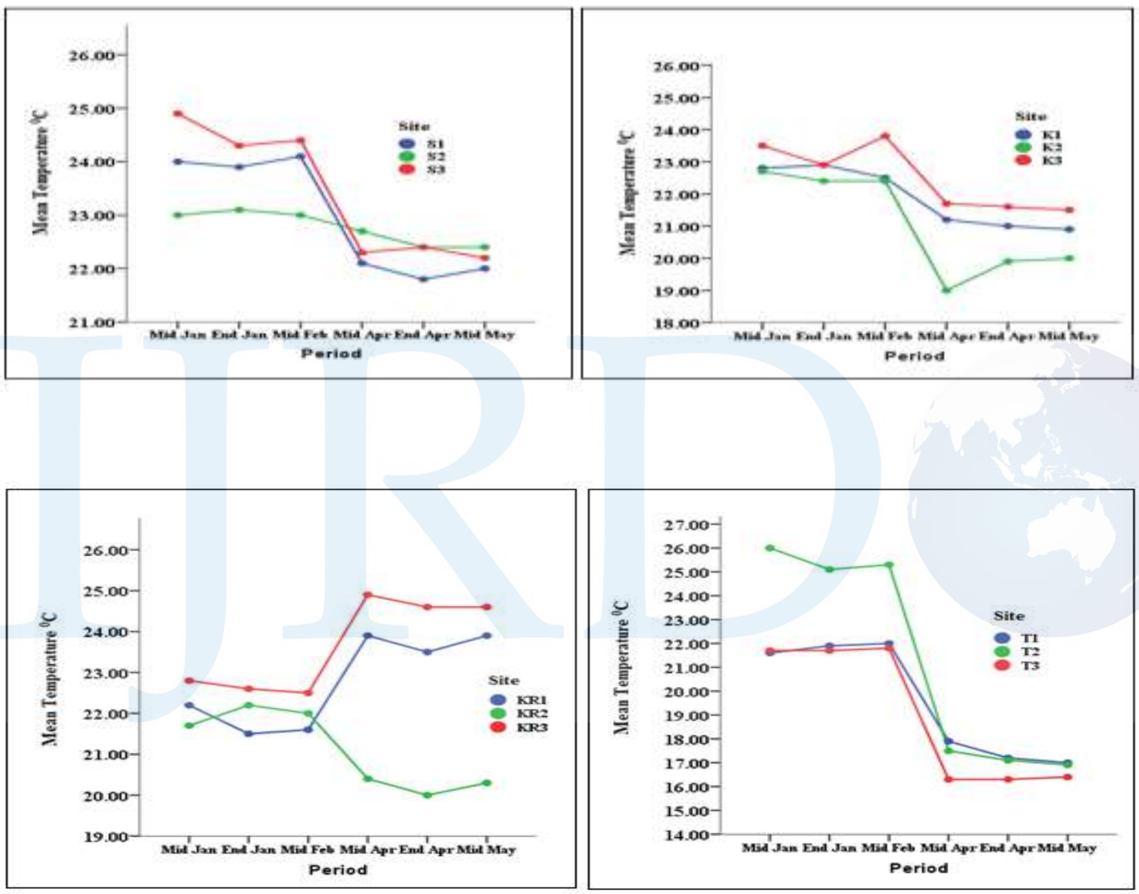
This covers months of January and February. In January rainfall recorded at the Embu meteorological station was 43.4 mm with nine wet days while in February it was 7.5 mm with three wet days.

Table 2 is a summary of the mean values and their respective Standard Error (SE) per parameter for all the physicochemical water quality parameters measured per site during the wet season. This covers months of April and May. In April total rainfall recorded at the Embu meteorological station was 373.4 mm with only six dry days while in May it was 128.2mm. Data was statistically analysed by one way ANOVA at 95 % significance level ($p<0.05$, n=36 and DF=11) for dry season and for wet seasons ($p<0.05$, n=36 and DF=11).

Table 3 is a summary showing seasonal variations of measured water quality parameters. It gives maximum and minimum values recorded per parameter per season. Statistical analysis was carried out using t-test.

3.1 Temperature (^{0}C)

During the dry season, temperature measured ranged between 21.40 ^{0}C to 24.90 ^{0}C while during the wet season temperature ranged from 16.3^{0}C- 24.7^{0}C**.** In this study temperature variation was mainly due to cloud cover fluctuation. Decrease in riparian vegetation cover due to encroachment of these lands for agriculture hence reduced canopy cover cumulatively in study area also contributed to variation in temperature. Higher mean temperatures at T2 in the dry season is as a result of direct solar heating of water surface by the sun (rainfall 7.5mm) and the slow flow rate of the water in the river due to its reduced volumes. The less the water, the slower the flow rate allowing the water to warm up faster hence increasing the temperatures cumulatively. Lowest temperature recorded at T3 can be associated with more canopy cover due the area being covered more by trees and its proximity to Mount Kenya forest. During wet season, temperature at KR3 was highest than all the other sites. This could be as a result of higher turbidity at this site (289.33±0.33, table 4.2). Materials such as clay, silt, plankton, microscopic organisms, absorb heat from the sun there by raising the water temperatures.



3.2 pH

The study showed that pH varied significantly during the study period. Table 3.1 shows that pH value recorded through the study period ranged between 7.87 at S3 to 8.49 at S2 during dry season. During wet season pH ranged between 7.3 at K2 to 8.82 at S3 (table 3.2). Wet season recorded a mean pH value of 7.81±0.07, while dry season recorded 8.16±0.04. Value in wet season was lower than value in dry season, however the two were significantly different ($p<0.05$, $F=8.168$, $DF=70$ and $t=-4.331$).

Table 1: Mean and SE of Physicochemical Parameters per Site during Dry Season

SITE	Temp(^{0}C)	pH	EC(µscm^{-1})	TDS(mg/l)	Turb(NTU)	DO	TSS(mg/l)	NO_2^-(mg/l)	NO_3^-(mg/l)	PO_4^{3-} mg/l
WHO	NS	6.5-8.5	400	600-1000	5	NS	500	3	50	0.5
P-Value	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$
K1	22.73 ± 0.12^{b}	$8.27\pm0.06b^{cde}$	114 ± 2.08^{de}	60.67 ± 1.20^{de}	15.67 ± 0.3^{e}	5 ± 0.06^{d}	82.33 ± 4.83^{e}	ND	2 ± 0.06^{b}	ND
K2	22.5 ± 0.10^{b}	7.92 ± 0.16^{a}	101.67 ± 0.33^{d}	56 ± 1.33^{cd}	11 ± 0.33^{c}	6.2 ± 0.06^{e}	42.5 ± 4.19^{bc}	ND	1.7 ± 0.10^{a}	ND
K3	23.4 ± 0.26^{c}	$8.2\pm0.01b^{cd}$	132.67 ± 0.33^{e}	70.33 ± 0.33^{e}	21.33 ± 0.3^{f}	4.5 ± 0.06^{c}	42.5 ± 4.19^{bc}	ND	2.1 ± 0.06^{bc}	ND
S1	24 ± 0.06^{d}	8.12 ± 0.03^{abc}	346.33 ± 21.05^{f}	183.67 ± 11.10^{f}	9.67 ± 0.33^{c}	2.9 ± 0.06^{b}	36.67 ± 5.46^{bc}	ND	5.67 ± 0.18^{g}	ND
S2	23.03 ± 0.03^{bc}	8.49 ± 0.02^{e}	87.67 ± 0.07^{bc}	47 ± 1.23^{bc}	14 ± 1.05^{d}	6.6 ± 0.06^{g}	27.67 ± 6.74^{ab}	ND	3.9 ± 0.06^{f}	ND
S3	24.53 ± 0.19^{e}	7.87 ± 0.07^{a}	667.33 ± 1.20^{g}	354.33 ± 0.67^{g}	6 ± 0.58^{b}	2.5 ± 0.06^{a}	34 ± 9.54^{bc}	ND	10.9 ± 0.17^{h}	ND
KR1	21.77 ± 0.22^{a}	8.06 ± 0.02^{ab}	77.67 ± 0.33^{ab}	43.67 ± 1.29^{ab}	11.17 ± 0.09^{c}	5.17 ± 0.09^{d}	21 ± 3.79^{ab}	ND	2.37 ± 0.03^{bcd}	ND
KR2	21.97 ± 0.15^{a}	8.19 ± 0.09^{bcd}	77.67 ± 0.67^{ab}	41.33 ± 0.33^{ab}	11.1 ± 0.12^{c}	5.03 ± 0.03^{d}	15 ± 2.89^{a}	ND	2.5 ± 0.06^{d}	ND
KR3	22.63 ± 0.09^{b}	7.9 ± 0.03^{a}	134.67 ± 1.20^{e}	71.33 ± 0.33^{e}	20.97 ± 1.14^{f}	6.4 ± 0.06^{f}	55.83 ± 6.67^{cd}	ND	3.53 ± 0.03^{e}	ND
T1	21.83 ± 0.12^{a}	8.40 ± 0.03^{de}	71.33 ± 0.11^{ab}	38 ± 1.33^{ab}	4.54 ± 0.11^{a}	7.43 ± 0.03^{i}	85.17 ± 4.92^{f}	ND	2.3 ± 0.06^{bcd}	ND
T2	21.47 ± 0.27^{a}	8.1 ± 0.02^{abc}	57.67 ± 3.11^{a}	$27.67\pm1.67a$	7.05 ± 0.37^{b}	7.43 ± 0.07^{i}	27.5 ± 5.20^{ab}	ND	2.37 ± 0.09^{bcd}	ND
T3	21.73 ± 0.03^{a}	8.36 ± 0.05^{cde}	72.67 ± 0.33^{ab}	37.33 ± 1.20^{ab}	4.44 ± 0.20^{a}	7.1 ± 0.06^{h}	32.5 ± 8.71^{ab}	ND	$2.47\pm0.03cd$	ND

Mean values followed by the same small letter(s) within the same column do not differ significantly from one another (One-way ANOVA), ND-Not Detected, NS-No set Standard

Table 2: Mean and SE of Physicochemical Parameters per Site during Wet Season

SITE	Temp(^{0}C)	pH	EC(µscm^{-1})	TDS(mg/l)	Turb(NTU)	DO(mg/l)	TSS(mg/l)	NO_2^- (mg/l)	NO_3^-(mg/l)	PO_4^{3-}(mg/l)
WHO	NS	6.5-8.5	400	600-1000	5	NS	500	3	50	0.5
P-Value	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05	P < 0.05	p < 0.05
K1	21.03±0.0^{e}	7.64±0.04^{b}	57.67±0.33^{bc}	30.67±0.33^{bc}	191.33±0.8^{f}	7±0.06^{d}	212.5±6.61^{d}	0.43±0.0^{b}	8.9±0.06^{g}	ND
K2	19.63±0.3^{c}	7.3±0.03^{a}	51.33±0.33^{ac}	26.33±0.67^{ac}	118.33±2.4^{d}	7.4±0.06^{e}	110±7.64^{c}	0.18±0.0^{a}	7.77±0.03^{d}	ND
K3	21.6±0.06^{f}	7.66±0.03^{b}	62±3.00^{c}	32.67±1.33^{c}	289.33±1.7^{g}	7±0.06^{d}	294.17±8.4^{e}	0.67±0.0^{c}	7.67±0.03^{c}	ND
S1	21.97±0.0^{f}	8.52±0.02^{d}	421±14.74^{f}	223.33±7.62^{f}	64.93±0.55^{b}	1.23±0.03^{a}	60.83±2.20^{a}	2.47±0.0^{d}	16.93±0.0^{i}	0.131±0.005^{a}
S2	22.5±0.10^{f}	7.78±0.10^{c}	48.33±1.45^{ac}	26.67±0.92^{b}	75.47±1.92^{c}	6.97±0.03^{d}	46.67±1.67^{a}	2.93±0.0^{e}	7.97±0.03^{e}	ND
S3	22.3±0.06^{g}	8.82±0.02^{e}	803.67±4.98^{g}	425.67±2.73^{g}	64.6±0.91^{b}	0.87±0.15^{a}	115±5.00^{c}	3.07±0.0^{f}	48.03±0.0^{j}	0.3867±0.0^{b}
KR1	23.77±0.1^{h}	7.43±0.02^{a}	78.67±2.03^{d}	41.67±0.88^{d}	114.33±5.7^{d}	6.2±0.06^{c}	78.33±1.67^{b}	0.15±0.00^{a}	7.07±0.0a	ND
KR2	20.23±0.1^{d}	7.66±0.06^{b}	44.33±0.67^{c}	23.67±0.3^{abc}	66.87±2.30^{b}	7.1±0.06^{d}	108.33±1.6^{c}	0.2±0.01^{a}	8±0.12^{e}	ND
KR3	24.7±0.10^{i}	7.44±0.04^{a}	111.67±1.76^{e}	59.33±0.88^{e}	157.33±2.96^{e}	5.23±0.09^{b}	42.5±1.44^{a}	0.41±0.01^{b}	10±0.06^{h}	ND
T1	17.37±0.27^{b}	7.85±0.06^{bc}	36.33±0.33^{a}	19.33±0.33^{a}	12.67±0.17^{a}	8.3±0.06^{g}	57.5±5.20^{a}	0.21±0.01^{a}	7.43±0.07^{b}	ND
T2	17.17±0.17^{b}	7.91±0.05^{c}	39.33±0.88^{a}	21±1.15^{ab}	14.3±0.40^{a}	8±0.06^{f}	56.6±4.54^{a}	0.2±0.00^{a}	8.23±0.09^{f}	ND
T3	16.33±0.03^{a}	7.66±0.05^{b}	36.67±1.20^{a}	19.67±0.67^{a}	13.6±1.01^{a}	8.17±0.03^{fg}	57.5±8.04^{a}	0.37±0.02^{b}	7.9±0.06^{de}	ND

Mean values followed by the same small letter(s) within the same column do not differ significantly from one another (One-way ANOVA), ND-Not Detected, NS-No set Standard.

Table 3: Mean Values of Physicochemical Parameters per Season

SN	PARA-METER	WET SEASON MIN	WET SEASON MAX	WET SEASON MEAN±SE	DRY SEASON MIN	DRY SEASON MAX	DRY SEASON MEAN±SE	WHO GV	P VALUE
1	Temp(^{0}C)	16.30	24.90	20.72±0.43	21.40	24.90	22.97±0.20	NS	<0.05
2	pH	7.270	8.860	7.81±0.07	7.73	8.54	8.16±0.04	6.5-8.5	<0.05
3	*EC(μscm-1)	35.00	813.00	149.06±37.60	53.00	669.0	161.14±28.71	400	>0.05
4	*TDS(mg/l)	19.00	431.00	79.00±19.92	28.00	355.0	85.42±15.25	600-1000	>0.05
5	Turbidity(NTU)	11.80	292.00	98.59±13.34	4.180	22.30	11.33±0.93	5	<0.05
6	DO(mg/l)	0.800	8.400	6.64±0.31	2.400	7.500	5.52±0.27	NS	<0.05
7	TSS(mg/l)	40.00	305.00	103.33±12.43	2.500	95.00	42.73±4.33	500	<0.05
8	NO_2^-N(mg/l)	0.130	3.200	0.9400±0.26	ND	ND	-	3	-
9	NO_3^-N(mg/l)	7.000	48.10	12.16±1.88	1.50	11.20	3.48±0.42	50	<0.05
10	PO_4^-P(mg/l)	ND	0.40	-	ND	ND	-	0.5	-

*not significantly different (p>0.05), ND- Not Detected, NS- No set Standard

In this study variation in pH is as a result of increase in rainfall that lowers pH value in wet season due to increase in organic matter content in the water. Surface runoff experienced during rainy seasons leads to increased imbalance of hydrogen ions in the water as excess nutrients are washed into waterway causing enrichment of water body hence causing pH variations.

3.3 Electrical Conductivity (µscm^{-1})

EC values during the dry season were in the range of 53-669 µscm^{-1} with lowest mean and SE of 57.67±3.11 recorded at T2. Highest mean value and SE of 667.33±1.20 was recorded at S3 ($p<0.05$; DF=11; F=834.53, n=36). During wet season, EC values ranged between 35-813 µscm^{-1} with the highest and lowest EC mean values of 803.67±4.98 and 36.33 ±0.33 ($p<0.05$; DF=11; F=2476, n=36) recorded at S3 and T1 respectively. For seasonal variation, EC mean values in dry and wet seasons were 161.14±28.71 and 149.06±37.60 with higher values recorded in dry season as compared with wet season ($p>0.05$, F=1.305, DF=70 and t=-0.255).

The lower values in the wet season for all sites except S3 and S1 in this study are as a result of increased rainfall and surface runoff that causes dilution of the available salt ions present in the surface water. The high values in dry season can be attributed to the influence of season since in dry season low precipitation is experienced and higher atmospheric temperature that raises evaporation rates. Temperature has a direct implication on EC values since the warmer the water the higher the EC values and vice versa.

3.4 Total Dissolved Solids (mg/l)

During the dry season TDS recorded value was in the range of 28-354.3 mg/l with the lowest TDS mean value of 27.67 recorded at T2. The highest mean TDS value of 354.33 ($p<0.05$; DF=11; F=838.13) was recorded at S3. During the wet season, TDS values ranged between

19.33-425.7 with the lowest TDS mean value of 19.33recorded at T1, while highest mean value of 425.67 ($p<0.05$; DF=11; F=2558) was recorded at S3. For seasonal variation, TDS mean value recorded in dry season was 85.42±15.25 compared to 79.00±19.92 recorded in wet season with values in dry season being generally higher. However there was no significant variation in TDS between the two seasons ($p>0.05$, F=1.287, DF=70 and t=-0.256, n=72).

Seasonal variation in TDS can be attributed to high evaporation rate and reduced water volumes especially in the dry season. Human activities like encroachment of riparian land for agriculture that leads to reduced canopy cover exposing the water to effects of temperature also contributed to higher values of TDS in dry season. During both seasons, site S3 recorded the highest concentration of TDS which is due to the sewer waste water being rich in ions that increases the TDS values, however these values reduced downstream.

3.5 Turbidity (NTU)

In dry season, turbidity ranged between 4.18-22.30 NTU with the lowest and highest turbidity mean values of 4.44±0.20 and 21.33±0.33 ($p<0.05$; DF=11; F=179.67) recorded at T3 (upstream) and K3 (downstream) respectively. In wet season, turbidity values ranged between 11.80-292.00 NTU with the lowest turbidity mean value of 12.67±0.17 recorded at T1 while the highest value of 289.33±1.76 ($p<0.05$; DF=11; F=1288) was recorded at K3. When comparing seasonal variation, the turbidity mean values for wet season was 98.59±13.34 whereas for dry season was 11.33±0.93 and were statistically significant ($p<0.05$, f=52.914, DF=70 and t=6.526).

A higher mean value of turbidity recorded in wet season was attributed to increased rainfall that led to increased surface runoff. The suspended particles responsible for elevated turbidity levels in the water are always in motion. This is due to water being in high circulation and at higher flow rate as opposed to the dry season where the particles tend to settle due to little turbulence.

3.6 Dissolved Oxygen (mg/l)

During the dry season DO values were in the range of 2.40-7.50 with lowest value of 2.50±0.06 recorded at S3 while highest value of 7.43±0.03 was recorded at T1 ($p<0.05$; DF=11; F=792.845). In wet season, DO values ranged between 0.8-8.40 with lowest and highest DO mean values of 0.87±0.15 and 8.30±0.06 ($p<0.05$; DF=11; F=779.12) recorded at S3 and T1 respectively. DO mean values were significantly different between wet and dry season with wet season recording a value of 6.64±0.31 and dry season recording 5.52±0.2 ($p<0.05$, F=0.233, DF=70 and t=2.74, n=72) respectively. DO in wet season was significantly higher than that in dry season.

Low values of DO at S3 in dry and wet season was attributed to inadequate treatment of waste water being discharged into the river; domestic waste disposal into the river and higher temperatures recorded at the same point. The low DO value of 0.8 mg/l observed at S3 during the wet season may be as a result of biodegradation of organic waste in the sewage effluent. In both seasons DO was highest at T1, T2 and T3.this was attributed to lower temperatures recorded at these sites compared with mid and downstream points.

3.7 Nitrates NO_3-N and Nitrites NO_2-N (mg/l)

In dry season, nitrates values ranged between a minimum 1.50 to a maximum of 11.20 with the highest and lowest mean nitrate values of 10.90±0.17 and 1.70±0.10 ($p<0.05$; DF=11; F=806.844, n=36) recorded at S3 and K2 respectively. Wet season minimum nitrate of 7.00 and maximum nitrate level of 48.10 were recorded with lowest mean value of 7.07±0.03 and highest mean value of 48.03±0.03 recorded at sites KR1 and S3 respectively. Recorded seasonal means were 16±1.88 in wet season and 3.48±0.42 in dry season (table 4.3) which were statistically significant ($p<0.05$, F=11.249, DF=70 and t=4.509, n=36). During wet season, nitrites values ranged between a minimum of 0.13 to a maximum of 3.20 with lowest mean value of 0.15±0.00 recorded at KR1 and highest mean value of 3.07±0.09 recorded at S3

The high nitrate value at S3 is because sewer waste water is rich in nutrients and may have been inadequately treated before being released into the river. High nitrate values in wet season can be attributed to non-point source pollution that includes run off from fertilized farms adjacent to the river, manure from livestock and other animal wastes used as organic manure in farms and from point source pollution at the point where sewer waste water was discharged into the river.

4.0 CONCLUSIONS

There was variation noted in the selected physicochemical parameters of water from river Rupingazi and its tributaries. The variation was per site and per season. Variation per site was recorded for all parameters. During dry season, lowest temperature of 21.47± 0.27 was recorded at T1 while highest of 24.53±0.19 was recorded at S3. Lowest turbidity of 4.44±0.20 was recorded at T3 while highest of 21.33±0.3 was recorded at K3. Lowest TSS of 15±2.89 was recorded at KR2 with highest of 85.17±4.92 at T1 ($p<0.05$). During wet season there was site variation noted for all parameters ($p<0.05$).Lowest pH of 7.3±0.03 was recorded at K2 with highest of 8.82±0.02 recorded at S3, lowest DO of 0.87±0.15 was recorded at S3 with highest value of 8.3±0.06 was recorded at T1 while the lowest NO_3^- of 7.07±0.0 recorded at KR1 and highest of 48. 03±0.0 recorded at S3. For seasonal variation, there was significant variation in temperature with wet season recording 20.72±0.43 that was lower than 22.97±0.20 in dry season. pH of 7.81±0.07 was recorded wet season being lower than 8.16±0.04 recorded in dry season. The other parameters such as turbidity, DO, TSS, NO_3^- recorded values of 98.59±13.34, 6.64±0.31, 103.33±12.43 and 12.16±1.88 respectively that were higher in wet season as compared to dry season ($p<0.05$). There was no significant variation noted for EC and TDS ($p>0.05$). The findings in this study show that all the measured water quality parameters were within the recommended WHO values except turbidity. Turbidity was significantly higher in both seasons.

5.0 RECOMMENDATIONS

The following are recommendations for further studies: Biological analysis of water parameters in river Rupingazi and its tributaries especially at sampling site S3; Bioaccumulation of nutrients and other parameters in crops grown along site S3 since some farmers use sewer waste water to irrigate the crops and possible impacts of soil erosion experienced in the study area on the organisms in the river.

6.0 REFERENCES

APHA (1999). *Standard Methods for the Examination of Water and Wastewater* 20th Edition: American Public Health Association, American Water Works Association and Water Environment Federation, Washington, DC.

Bamgbose, O.O. and Arowolo, T.A. (2007) Water Quality Assessment of Ogun River, South West Nigeria. *Environmental Monitoring Assess, Springer Business Media* 473-478.

Carpenter, S.R., Stanley, E.H. and Vander, M. J., (2011). State of the World's freshwater ecosystems: Physical, chemical and biological changes. *Annual review of Environment and Resources*, *36*:75-99.

CIDP (2013). Embu County Integrated Development Plan, 2013-2017

Dimitrovska, O., Markoski, B., Toshevska, B. A., Milevski, I. and Gorin, S., 2012. Surface Water Pollution of Major Rivers in the Republic of Macedonia. *Procedia Environmental Sciences*, 14, 32– 40

Dobson, M., Magana, A. M., Mathooko, J. M., and Ndegwa, F. K. (2007). Distribution and abundance of freshwater crabs (Potamonautes spp.) in rivers draining Mt Kenya, East Africa. *Fundamental and Applied Limnology*, *168*(3), 271-279

Edokpayi, J.N.; Odiyo, J.O.; Olasoji, S.O. (2015) Assessment of heavy metal contamination of Dzindi River, in Limpopo Province, South Africa. *International Journal of Natural Science Resources*, *2*, 185–194.

Hu, J., Qiao, Y., Zhou, L. and Li, S., 2011. Spatiotemporal Distributions of Nutrients in the downstream from Gezhouba Dam in Yangtze River, China. *Environmental Science and Pollution Research*, 19, 2849 – 2859.

Hussain, M., Ahmed, S.M., Abderrahman, W., (2008). Cluster analysis and quality assessment of logged water at an irrigation project, Eastern Saudi Arabia. *Journal Environmental Management, 86*, 297-307.

Kithiia, S. M. (2011). Water Quality Degradation Trends in Kenya over the Last Decade. Water Quality Monitoring and Assessment, Dr. Voudouris (Ed.)

Masere, T. P., Munodawafa, A., and Chitata, T. (2012). Assessment of Human Impacts on Water Quality along Manyame River. *International Journal of Development and Sustainability*, 1 (3), 754-765.

Ndubi, D., Oyaro, N., Githae, E. and Afullo, A. (2015). Determination of Physico-Chemical Properties of Sources of Water in Narok North Sub- County, Kenya. International Research Journal of Environment Sciences, 4(1), 47-51.

Oluyemi, E.A, Adekunle, A.S, Adenuga, A.A and Makinde, W.O (2010). Physico-Chemical properties and heavy metal content of water sources in Ife North Local Government Area of Osun State, Nigeria. *African Journal of Environmental Science and Technology, 4(10)*, 691-697

Pradhan, U. K., Shirodkar, P. V. and Sahu, B. K. (2009). Physicochemical Characteristics of the Coastal Water off Devi Estuary, Orissa and Evaluation of its Seasonal Changes Using Chemometric Techniques. *Current Sciences*, 96, 1203– 1209.

Singh, K.P., Malik, A., Mohan, D. and Sinha, S. (2004). Multivariate Statistical Techniques for the Evaluation of Spatial and Temporal Variations in Water Quality of Gomti River India-A case study. *Water Research*, 38, 3980– 3992

Singh, L.B. (2007). *River Pollution (*1st Edition), APH Publishing, New Delhi

Singh, Y, Ramteke, P.W., Mishra, S and Shukla, P. K. (2013) Physico-Chemical Analysis of Yamuna River Water. *International Journal of Research in Environmental Science and Technology, 3*(2), 58-60.

Shegani, G. (2016). Seasonal Variation of the Osumi River. *Environment and Ecology Research* 4(5): 237-243

Zhang, Q.L., Shi, X.Z., Huang, B., Yu, D.S., Öbornc, I., Blombäckc, K., Wang, H.J., Pagella, T.F., Sinclair, F.L. (2008). Surface Water Quality of factory-based and vegetable-based peri-urban areas in the Yangtze River delta region China. *Catena, 69* (1), 57-64