An Assessment of Some Physical, Chemical and Biological Characteristics of Nyanchwa - Riana River Flowing through Kisii Town in South West Kenya

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Abstract

A study was conducted to assess the water quality of Nyanchwa-Riana River flowing through Kisii town during the period May 2013 to June 2014. Sampling stations were selected on a transect covering the upper and middle reaches of Nyanchwa stream. A further two sampling stations were added after the confluence on the Riana River downstream. The water quality parameters assessed were dissolved oxygen concentration, pH, conductivity, turbidity, chlorophyll-a, total and soluble phosphate and nitrate concentrations and coliform counts. Nutrient concentrations generally increased from the source of the Nyanchwa -Riana River towards the lower reaches of the river. Soluble nutrient concentrations exhibited the same trend. The total phosphorous to total nitrogen ratio of 1:3 varied from the Redfield ratio of 1:16 commonly found in natural habitats. Total coliform counts exceeded those recommended in the international water quality standards of less than 10 coliform cells/100ml of water and those of NEMA of nil100ml^{-1}. Observations on the physical and chemical parameters showed levels stressful to aquatic life, with dissolved oxygen concentrations less than 5 mgL^{-1} in some sampling points. These findings are useful in the management of the water quality in the two streams and on the River Riana flowing through Kisii town.

Keywords: Nyanchwa-Riana, water quality, nutrients, coliform, perturbation and physic-chemical parameters

Introduction

Water is a scarce resource that requires utmost protection. It is estimated that 40 % of the world population will live in water scarce regions by the year 2025 (UNEP, 2004). Rapid population growth, urbanization, consumption and the desire for better living has placed great strain on fresh drinking water supply, especially in urban centres, with attendant health and environmental issues (Pruss-Ustun and Corvalan, 2006). Water quality of most water bodies is a growing environmental concern. Improvement in water quality is thus a major issue for the recovery of most water bodies whether stagnant or freely flowing. Tracy *et. al*. (2005), found that direct water fetching and use in the streams/rivers by local residents lowered the water quality and increased its contamination with waterborne microbes. Similarly, Twesigye, *et. al* (2011) found that the physical and chemical attributes of water quality were in higher levels along the agricultural zones of water bodies.

Most Kenyan cities and towns are either situated at the origin or on the main rivers flowing into major water systems. Kisii town is among them wherein there is an urban settlement upstream and along the Nyanchwa-Riana River. Urbanization, agriculture and industrialization are sources of organic and inorganic pollutants which impact negatively on water quality.

Mwamburi (2003) found higher levels of pollutants in surface waters which received high mixture of organic and inorganic waste from the various industrial effluents and municipal waste discharges. These discharges constitute major sources of organic and inorganic pollutants to the river systems in which the water quality is adversely affected.

This is one of the reasons why Kenya has not achieved its millennium target of providing safe drinking water to its citizens (WHO, 2007). Microbial quality of water is a concern to consumers, water suppliers and public health authorities because of water's ability to transport the microbial pathogens to a great number of people (WHO, 2003). Surface water is often more vulnerable to the immediate influence of many contamination sources which include leaking sewerages, defecation in the bushes, and pit latrines and this contamination of surface water is more frequent where these sources of pollution are not prevented (Nwachukwu and Ume, 2013).

Adetunde and Glover (2010), concur that micro-organisms play a major role in lowering water quality. Research carried out on the bacteriological quality of drinking water sources in Njoro division, Kenya, indicated that fecal coliform counts in River Njoro were beyond the WHO guidelines (Mavura *et al*., 2006). Kiruki *et al*. (2011) demonstrated that bacteriological quality of River Njoro water was poor due to heavy contamination with indicator bacteria, *Escherichia coli*. Sediment loads on to water bodies increase total dissolved solids (TDS), conductivity, turbidity color, attributes which lower water quality (Shadrack, 2012). Agricultural chemicals find their way to water bodies where they affect its quality (Odada et al., 2006) which further lead to massive fish kills and disturbances of other aquatic life, (Ochumba, 1990). Nutrient overload due to poor farming methods, partially treated effluents, organic waste dumping into water bodies and other related activities within stream catchment areas subsequently deteriorate the water quality (Mokaya et. al., 2005; Shivoga et. al., 2005). For example, Phosphorus and nitrogen loading on surface fresh waters accelerates eutrophication, leading to increased algal blooms and growth of aquatic weeds, due to agricultural sources contributing nutrients to water bodies (Daniel *et al*., 1998). The excess water fertilization leads to variations in phytoplankton biomass and water clarity which are the primary links between nutrient loading and changes in water quality (Kemp et al. 2005).

It is against the said background that it is important to assess the water quality of the Nyanchwa-Riana river flowing through Kisii municipality to establish the levels of selected nutrients; phosphorous, nitrogen and silicates; at points upstream and downstream the transect; as well as measure physical, and biological parameters of the stream transect.

Methodology

Study Area

The study was undertaken within Nyanchwa - Riana River flowing through Kisii Town (fig. 1). The town is located at an altitude of 1850 meters above sea level and stretches from longitude 34°42'36"E to 34°46'12"E and latitude 0°38'42"S to 0°41'24"S in South Western Kenya. It is situated approximately 300 km South West of Nairobi on the highway to Mwanza, Tanzania. It has a highland equatorial climate, with an average rainfall of 2000 mm yr^{-1}.

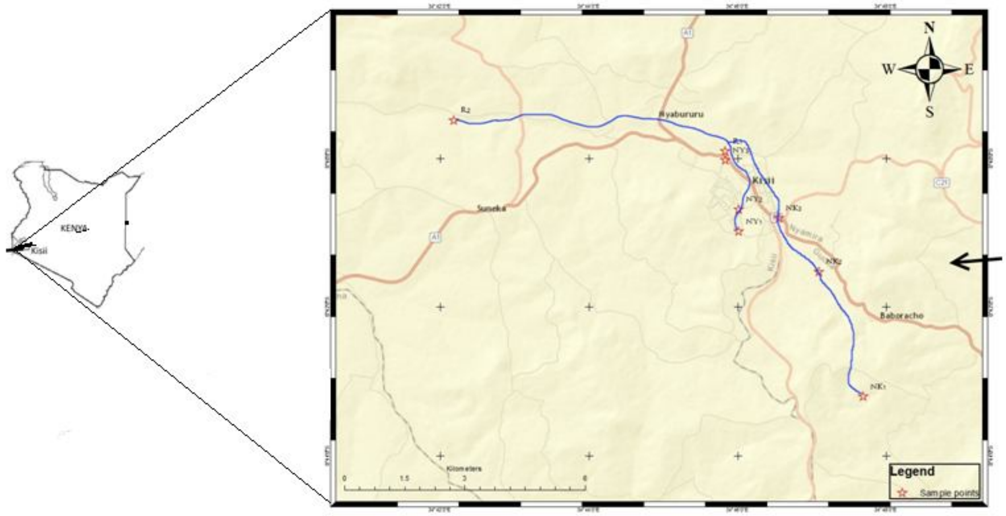


Figure 1: *Map showing the location of the study area and its sampling sites; (NY1: upstream, NY2: midstream, NY3: downstream R1 and R2 after the confluence at Daraja Mbili). NY stands for Nyanchwa and R stands for Riana.*

The municipality has an approximate population of 300 000 persons (density of 1012 persons km^{-2}). Approximately 80% of the municipality residents live in unsewered premises and are also not connected to piped water. Most of the water used in the municipality for domestic purposes is drawn raw from protected springs, rivers, streams, and boreholes.

The high population density poses a serious threat of pollution to surface and ground water sources. The Municipality has attempted to improve the water quality by improving and protecting its springs. Due to high population density in town associated with increasing anthropogenic activities, the rivers flowing through it are constantly under the threat of organic and inorganic pollutants. This is worsened by the situation of dumping of excavated soils from construction sites, waste dumpsites located close to the rivers and car washing along river lines. The high and continuous rainfall in the region ensures constant flow of pollutants such as raw sewage, dumpsite effluents and wastes from town into the rivers thus compromising water quality.

Research Design

The study used a transect survey design in which sampling sites were located purposefully randomly along the Nyanchwa stream and river Riana. The Nyanchwa stream had its source as an experimental control. Then three sampling sites were purposely selected in the stream on a transect. Two more sampling points were purposely selected downstream on River Riana thus making a transect of five sampling sites.

Sampling Methodology

Sampling procedures used standard protocols according to APHA 1998. Three measurements of the selected physical and chemical parameters were done *in situ* at each sampling site using respective meters: Dissolved oxygen concentration (mgl^{-1}) and temperature (ºC) were measured using an oxygen meter model YSI 15B; pH was measured using a Digital Mini Model 49- pH meter; turbidity (NTU) was measured using a turbidimeter model Hach 2100P; conductivity (μScm^{-1}) was measured using a conductivity meter model LF 96. All the meters that were used had a measurement accuracy of 0.01.

For laboratory analyses, four samples of water were collected from each sampling site using 500 ml plastic bottles which were pre-cleaned with non-ionic detergents and rinsed with deionized water. The bottle samples were then labeled according to the sampling sites and preserved in a cooler box containing ice blocks at 4°C.

After preservation, the samples were then transported to the Kenya Marine and Fisheries Research Institute (KEMFRI) Laboratories at Kisumu for analyses within a period of 24 hours.

Nutrients

Total Phosphorus

Total phosphorus was determined by first digesting and reducing the forms of phosphorus present in the water into the free ortho-phosphate form (SRP) using persulphate digestion method described in APHA 1998. After the digestion, the total reduced forms into the SRP formed were analyzed using the ascorbic acid method. The soluble reactive phosphates were also analyzed using the later method.

Total Nitrogen

Total nitrogen was determined by first carrying out persulphate digestion to convert the nitrogen forms into the nitrate which was then further converted to nitrite using cadmium reduction through a column (APHA, 1998). The resulting solution was then tested for nitrite concentration. The total nitrogen was estimated by adding up the concentration of ammonium-nitrogen to the value calculated from this process.

Nitrate-nitrogen (NO_3-N)

Nitrate-nitrogen was determined using the sodium-salycilate method (APHA, 1998). After the reduction nitrite-nitrogen determination is carried out using the reaction between sulfanilamide and N-Naphthyl-(1)-ethylendiamin-dihydrochlorid which gave an intense pink color with the nitrite.

Ammonium-Nitrogen (NH_4-N)

The concentration of ammonia was determined using a method described in APHA 1998. Using the reaction between NH_4Cl, Sodium salicylate and Hypochlorid solution. Followed by placing the mixture in a water bath 25 °C in the dark for 90 minutes.

Silicates

Silicates were analyzed using the ammonium molybdate method described in (APHA, 1998).

Total Suspended Solids

A defined volume of water samples were filtered using pre-weighed filters and dried at 95 ± 5°C until a constant weight was achieved (about 3 hours). The concentration of total suspended solids was then estimated gravimetrically on glass-fibre filters Whatman GFC, after drying to constant weight at 95°C. The suspended solids weight was worked out using the formulae below:

$$TSS\ (mg\ l^{-1}) = ((Wc-Wf) \times 10^{6})\ V^{-1}$$

Where TSS = Total suspended solids,
Wf = Weight of pre-combusted filter in grams;
Wc = Constant weight of filter + residue in grams;
V = Volume of water sample used in ml

T otal dissolved solid (TDS) were estimated from conductivity measurements by multiplying with a factor of 0.6

Chlorophyll-a Determination

One Sample was collected from each site for the measurement of chlorophyll-a concentration. The samples were filtered through a 7cm diameter Whatman GFC filter paper of pore size 0.45µ using a hand vacuum filter pump. The filter paper was then inserted in a 25 ml test tube containing 15 ml of ethanol. The test tube was further rubbed in aluminum foil and put in an ice cooler box over night to allow the extraction of chlorophyll-a into the ethanol solution. After the extraction, the filter paper was squeezed to remove the remaining chlorophyll-a into the test tube. 11 ml of the chlorophyll-a in the test tube was put in centrifuge cuvettes and centrifuged at 2500 rpm for 10 minutes. The supernatant chlorophyll-a solution was then decanted into 1cm pathway spectrophotometer cuvettes and then absorbance measurements carried out at wavelengths of 750 nm and 665 nm. The absorbances of chlorophyll-a concentration were obtained by subtracting the two absorbencies respectively. The chlorophyll-a concentration was calculated using the Talling & Driver (1961) formulae below:

$$\text{Chl-a}, \mu g\ l^{-1} = (11.40\ (E665 - E750) * V_1) / (V_2 * L)$$

Where:

11.40 is the absorption coefficient for chl-a,
V_1 = volume of extract in ml;
V_2 = volume of the filtered water sample in litres;
L = light path length of cuvette in cm;
E665, E750 = optical densities of the sample.

Micro-Biological Analyses (Total and Fecal Coliform Counts)

By use of hamper bottles, water samples were collected and kept in ice for further analysis in the laboratory. Multitube technique was used to determine coliform pathogens. 100ml of sample was passed through a filtration unit. The filtrate then was placed on petri-dishes containing endo broth media on a filter pad for resuscitation of microbes thereafter placed in an incubator for 18 – 24 hours, at 37ºC. The samples were removed and metallic sheen colonies counted and recorded as *E. coli*. The Oxoid media brilliant green bile agar was prepared a day prior to sampling and left to gel at 4ºC. 0.1 ml inoculum was pipetted and poured on the media in a petri-dish and aseptically spread all over the media and incubated as above time and temperature. This was to enable pathogens grow independently. After incubation period, tiny and colorless colonies were counted and results recorded as colony forming units (cfu). For confirmation, gram stain was performed and results interpreted.

Statistical Analyses

Data was analysed using excel spreadsheet program and those found to be statistically significant were subjected to Tukey pairwise comparisons by the use of Minitab software toolkit (MINITAB® Statistical Software for Windows ver. 16, 2000). Regression analysis was used for developing the standard calibration relationships and transects. Temporal variation in individual parameter levels at different sites was tested using one way analysis of variance (ANOVA) at a significance level of $p\text{-value} \leq 0.05$. The results of the analysis were presented in the form of tables, bar and line graphs. Line transect transects were prepared to depict parameter variability along the sampling transects from the source towards the mature part of the river.

Results

Physical, Chemical and Biological Characteristics of Nyanchwa Stream

The water quality parameters of Nyanchwa stream show moderate to high variability as indicated by the ranges and the standard deviations (Table 1). This implies that there was material input into the stream at different times of the thirteenth month sampling period. The dissolved oxygen concentration had the lower limit (3.29 mgL^{-1}) of the range approach concentrations in anoxic waters. Concentrations below 5mgL^{-1} are stressful to fish growth, while fish kills are observed at concentrations below 5mgL^{-1}.

The high conductivity of up to 257 µS cm^{-1} shows that at some period ionic pollutants were discharged into the stream, a case which can be supported by the lead chemicals and others from the car wash sites along the stream-river transect. Very high TDS were observed with a maximum of 1420 mg L^{-1} in the month of November 2013, which are responsible for the observed colored water in the stream. The temperature range (18.90 - 24.00) of the stream was on average suitable for survival of most tropical aquatic organisms; on the other hand, the observed upper pH range (9.0) is stressful to fish survival. The total phosphate to total nitrogen ratio of 1:3 is not the same as the average ratio 1:16 found in natural fresh waters. This shows that the stream ecosystem is perturbed by external nutrient inputs.

This can be confirmed by high soluble reactive nutrient concentrations of NO_3-N and PO_4-P (table 1). Total and fecal coliform concentrations were unexpectedly high at 639.31 and 626.08 cells/100ml respectively.

Table 1: Temporal Variation of the Physical, Chemical and Biological Characteristics of Nyanchwa-Riana River during the Period May 2013 –June 2014

Parameter	Range	Mean	SE	df	F-test	p-value
DO (mg L^{-1})	3.29 - 8.90	5.89	0.1	194	5.56	0.00
EC (µS cm^{-1})	53.70 - 257.00	109.6	2.85	194	4.06	0.00
TDS (mg L^{-1})	2.00 - 1420.00	142.59	22.68	194	4.29	0.00
TSS (mg L^{-1})	2.00- 396.00	52.33	7.02	194	8.01	0.00
Temp (ºC)	18.90 - 24.00	21.21	0.16	194	30.61	0.00
pH	5.12 - 9.00	6.76	0.07	194	12.03	0.00
TN (µg L^{-1})	6.30 - 4329.16	853.66	140.86	194	48.76	0.00
$NO_3^{-}N$ (µg L^{-1})	0.18 - 742.90	144.89	19.54	194	16.27	0.00
$NO_2^{-}N$ (µg L^{-1})	0.18 - 590.56	48.62	7.02	194	4.77	0.00
NH_3^{-}-N(µg L^{-1})	0.20 - 1324.30	198.32	24.99	194	5.61	0.00
TP (µg L^{-1})	9.90 - 1281.40	277.01	27.88	194	6.09	0.00
PO_4-P (µg L^{-1})	1.66 - 590.56	55.00	8.52	194	7.46	0.00
SiO_3-S (µg L^{-1})	0.06 - 46.11	8.97	1.88	194	98.63	0.00
Chlorophyll-a (mg L^{-1})	0.00 - 4839.00	253.88	81.6	194	18.9	0.00
TC (Cells 100ml^{-1})	0.00 - 4100.00	639.31	110.91	194	7.81	0.00
FC (Cells 100ml^{-1})	0.00 - 4100.00	626.08	111.2	194	12.01	0.00

The water quality standards of Nyanchwa- Riana River (table 2) shows that five out of the six parameter levels exceeded the National Environment Management Authority (NEMA) quality standards. The total dissolved solids (TDS) did not exceed the NEMA Standards except for the upper range. This implies external pollutants input into the stream.

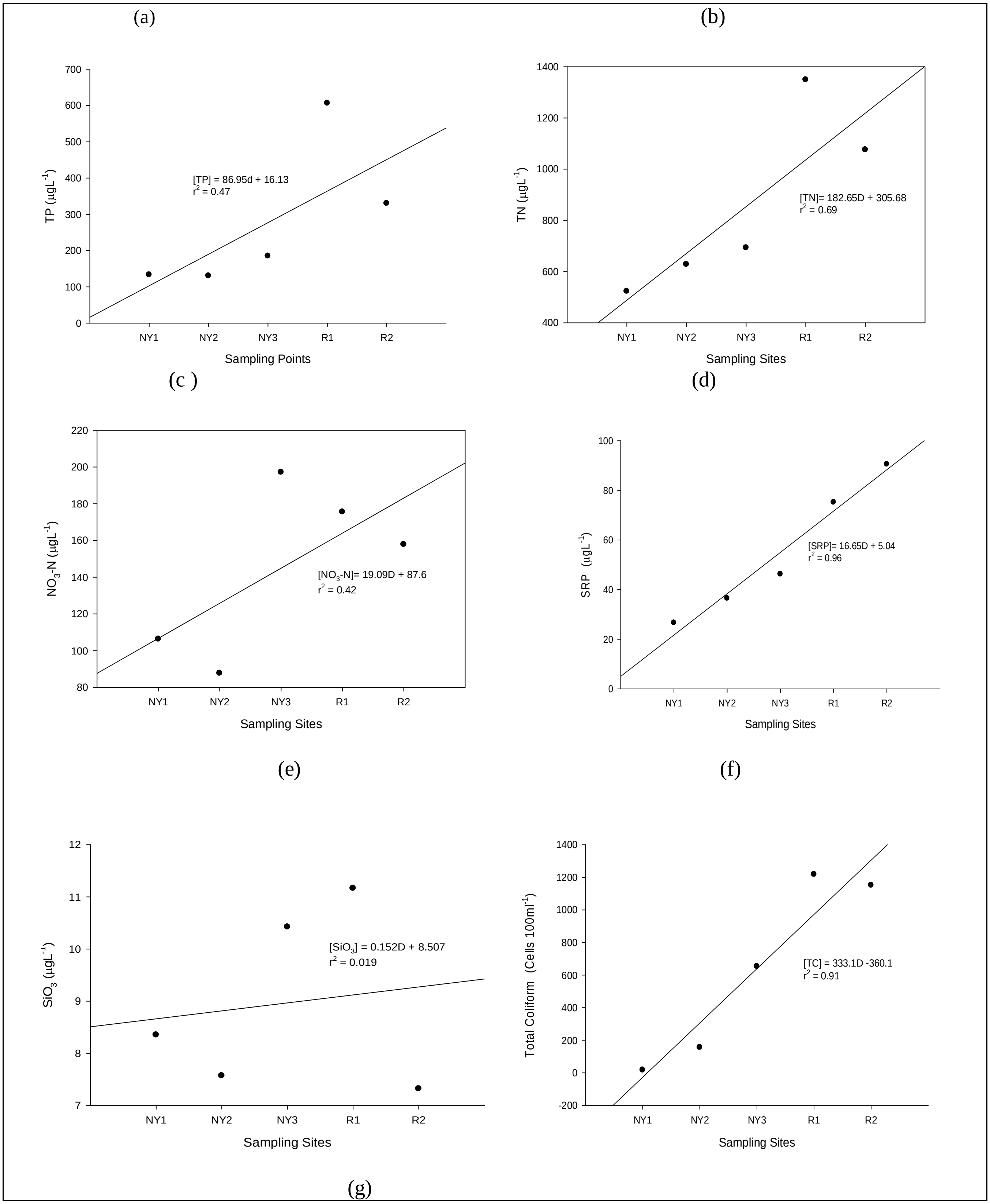
Table 2: The Mean of Physical, Chemical and Biological Characteristics of Nyanchwa -Riana River in Comparison with NEMA Standards

PARAMETER	Sample Size (N)	Range	Mean	NEMA	Comments
(DO (mg L^{-1})	195	3.29 - 8.90	5.89	8	Mean is below the NEMA
Cond (µS cm^{-1})	195	53.70 - 257.00	109.6		
(TDS (mg L^{-1})	195	2.00 - 1420.00	142.59	1200	Upper range exceeds NEMA standards
TSS (mg L^{-1})	195	2.00- 396.00	52.33	30	Mean and upper range exceeds NEMA standards
Temp (ºC)	195	18.90 - 24.00	21.21		Within NEMA range
pH	195	5.12 - 9.00	6.76	6.5 -8.5	Upper range exceeds NEMA standards
TN (μg L^{-1})	195	6.30 - 4329.16	853.66	100	Mean exceeds NEMA Standards
NO_3^--N (μg L^{-1})	195	0.18 - 742.90	144.89	10	Mean exceeds NEMA Standards
NO_2^--N (μg L^{-1})	195	0.18 - 590.56	48.62	3	Mean exceeds NEMA and EPA Standards
NH_3^--N(μg L^{-1})	195	0.20 - 1324.30	198.32	0.5	Mean exceeds NEMA and EPA Standards
TP (μg L^{-1})	195	9.90 - 1281.40	277.01		
PO_4-P (μg L^{-1})	195	1.66 - 590.56	55		
SiO_3-S (μg L^{-1})	195	0.06 - 46.11	8.97		
TC (Cells $100ml^{-1}$)	195	0.00 - 4100.00	639.31	30l/100ml	Mean exceeds NEMA water quality standards
FC (Cells $100ml^{-1}$)	195	0.00 - 4100.00	626.08	Nil/100ml	Mean exceeds NEMA water quality standards

Nutrient levels of Nyanchwa Stream

Total Phosphorous

A transect of the nutrient levels in Nyanchwa stream (Fig.2) shows that the concentrations of the total phosphorous increased from the source towards downstream. This shows that there was discharge of effluents containing phosphorous along the stream. It was observed that some raw sewage was being discharged into the stream at three different sites downstream (NY3, R1 and R2). There was also an observed two car wash points downstream (NY2 and after R1). Further, there is a market selling agricultural products straddling the river transect midway of the sampling points downstream whereby most of the agricultural waste is not well managed and is left to rot such that during the rain, its effluent and leachate are washed into the river. The Total Phosphorous concentration was related with distance (D) from the source of the stream down to its lower reaches as follows: [TP] = 86.95D + 16.13; r = 0.67 (fig 2a), this model forms the basis of reference and for tracking future changes in total phosphate concentrations in the stream.


(a)
(b)
TP (μgL-1)
[TP] = 86.95d + 16.13
r2 = 0.47
Sampling Points
TN (μgL-1)
[TN]= 182.65D + 305.68
r2 = 0.69
Sampling Sites
(c)
(d)
NO3-N (μgL-1)
[NO3-N]= 19.09D + 87.6
r2 = 0.42
Sampling Sites
SRP (μgL-1)
[SRP]= 16.65D + 5.04
r2 = 0.96
Sampling Sites
(e)
(f)
SiO3 (μgL-1)
[SiO3] = 0.152D + 8.507
r2 = 0.019
Sampling Sites
Total Coliform (Cells 100ml-1)
[TC] = 333.1D -360.1
r2 = 0.91
Sampling Sites
NY1
NY2
NY3
R1
R2
(g)

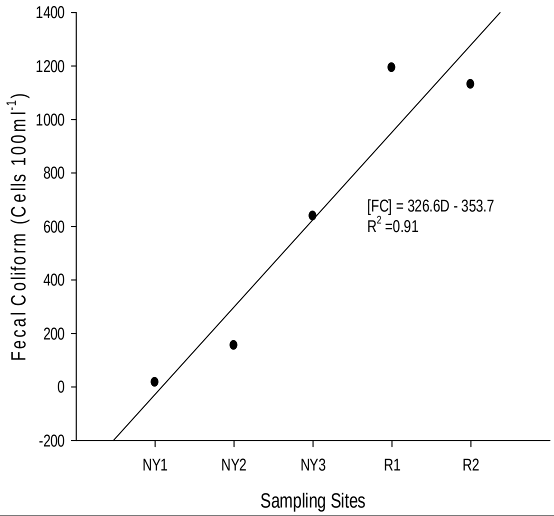


Fig. 2: Spatial Variation of mean values of (a) TP, (b) TN, (c) NO_3-N, (d) SRP, (e) SiO_3 (f) TC and (g) FC. During the 12 months sampling period, n = 195

The transect for the Total Nitrogen concentration down Nyanchwa stream (fig.2b) exhibited the same trend as that of TP. The changes in the TN concentration downstream might be due to the same sources of nutrient inputs as those elaborated above of TP concentrations. These inputs are thought to be responsible of the perturbed ratio of TP to TN concentration in the stream. The total nitrate concentration was related with distance from the source of the stream as follows: [TN] = 182.65D + 305.68; r = 0.83, the model forms the basis of reference and for tracking future changes in Total Nitrogen concentrations in the stream. Even thought TN showed a similar trend to TP, the gradient of the TN graph is steeper than that of the TP concentration, showing that the discharge of TN along the river transect was approximately twice higher than that of TP.

The transects of the soluble reactive nutrients; NO_3-N and PO_4-P exhibited the similar trend as that of the total nutrient concentrations (figs. 2c & 2d). The fluctuations of the nutrient concentrations along the stream transect can be attributed to differential nutrient input from main sources and absorption rates by algae and macrophytes downstream of Nyanchwa - Riana River. It was observed that the stream has some of its sections where the water is free-flowing and some sections where the water appears stagnant and that along the stream, there are different types of macrophytes all of which are thought to affect the NO_3-N and PO_4-P nutrient dynamics of the stream-river transect.

The soluble reactive nitrate concentrations was related with distance (D) from the source of the stream as follows: [NO_3-N] = 19.09D + 87.6; r = 0.65 (fig. 2c), this model forms the basis of reference and for tracking future changes in Soluble Reactive Nitrates concentrations in the Nyanchwa - Riana River. Similarly, soluble reactive phosphate concentration was related with distance from the source of the stream as follows: [SRP] = 16.65D + 5.04; r = 0.98 (fig 2d), the model therefore forms the basis of reference and for tracking future changes in Soluble Reactive Phosphates concentrations in the Nyanchwa - Riana River transect. The gradients of the soluble reactive nutrients (NO_3-N and SRP) are lower than those of the total nutrient concentrations (TN and TP), this might be due to active absorption of the soluble reactive nutrients by algae and macrophytes in the stream as opposed to TP and TN concentrations which are not absorbed. This is so because they are not in the form that can be absorbed by algae and macrophytes, hence they need to be converted into the soluble reactive forms before they can be absorbed. The soluble reactive silicates concentration was related with distance from the source of the stream as follows: [SiO_3] = 0.152D + 8.507, the concentrations of the silicates showed little variability downstream from the source with insignificant correlation coefficient r = 0.14.

Total and Fecal Coliform Counts

The analysis of the total and fecal coliform counts indicated the presence of pathogenic and non-pathogenic bacteria in the water at the source of Nyanchwa stream. This source is used for drawing water for domestic use hence, indicating that a large number of springs within the Kisii Municipality which provide drinking water for the majority of the residents could be contaminated by pathogenic coliform counts. The concentrations of the coliform counts showed a strong increase with distance from the source of the lower reaches of the river (figs 2f & 2g). This shows that there is an input of raw sewage or animal waste at certain points along the stream transect. It was observed that people defecate near bushes along the stream and majority of the municipality residents use pit latrines which are dug along the stream and when it rains, they overflow thus leaking into the stream which in turn become major sources of pathogenic bacteria inputs and later infections (table 3).

Table 3: The Average Infections per Hospital in the Surrounding seven Kisii Sub-County Hospitals and the Kisii County Level 6 Hospitals

Disease type	**Individuals infected of Age (0- 15 years)**	**Individuals infected of Age (above 15 years)**
Typhoid	19	25
Amoebiasis	5	10
Dysentery	9	15
Diarrhoea	35	38
Cholera	0	1

The Total Coliform concentrations were related with distance (D) from the source of the stream as follows: [TC] = 333.1D -360.1; r = 0.95, this model forms the basis for tracking future changes in Total coliform concentrations in the stream. Similarly, fecal coliform concentrations were related with distance from the source of the stream as follows: [FC] = 326.6D -353.7; r = 0.95, this model forms the basis for tracking future changes in fecal coliform concentrations in the stream.

Discussions

The observed perturbed TN to TP concentrations at the source of the Nyanchwa stream indicates nutrient rich discharge from the catchment. It also may indicate that the ratio TN: TP in the parent rock in the catchment may not be the same as the generally observed average ratio of 1:16 (Ward, *et. al*., 2013). The source of the Nyanchwa - Riana River is used for drawing water for mainly domestic use. However, there are other indications that the public use the neighborhood of the spring for washing clothes and bathing. This could be the sources of the nutrients that were measured at the source. Therefore the water quality at the source of Nyanchwa - Riana River is poor due to the mentioned anthropogenic activities within its vicinity.

The fact that both the Total and Soluble nutrient concentrations increased downstream points to the unregulated discharge of effluents from the respective parts of Kisii town through which the river flows. This include, poor management of runoff from agricultural activity, sewage discharge, and the unmanaged garbage at the Daraja Mbili market straddling the river downstream and waste dumping site near Kisii Mosque which is close to the stream.
This provides the observed nutrient inputs into the river causing them to rise as one moves from the source towards the lower reaches of the stream. The little changes shown by the silicate concentrations (fig. 2e) can be attributed to the fact that the soil formation in the catchment of the Nyanchwa - Riana River is mainly loam soil with little concentration of sand which is the main source of silicates.

The washing site of vehicles along the Nyanchwa - Riana River could be responsible for the relatively high conductivity measured (53.70 – 257.00 μScm^{-2}) (Table 1). This could be due to discharge of lead-laden and soap effluents from the washing of the cars which therefore affects the water quality.

The pH of pure water is approximately neutral (nearly 7), however, the lower pH range (5.12- 9.00) measured in the Nyanchwa stream indicates the discharge of organic or acidic effluents being discharged into the stream. This concurred with the observation of raw sewage discharged into the stream at three different sites (NY3, R1 and R2) and also the organic effluent runoff from the waste dumpsites and the Daraja Mbili agricultural products market straddling the stream downstream. Further, these discharges of organic effluents could be the result of low dissolved oxygen concentrations of as low as 3mgL^{-1} (Table 1). The dissolved oxygen in stream water was utilized in the decomposition of the discharged organic waste into the stream. The low oxygen concentrations indicates poor water quality as some aquatic organisms like fish survive poorly in waters with oxygen concentrations of less than 5 mgL^{-1}.

The presence of Total and Fecal coliform counts at the source of Nyanchwa - Riana River meant that the source water was being contaminated by raw sewage discharges from the pit latrines or defecations in the bush in the catchment hence concurring with the findings of Nwachukwu and Ume, (2013). The fact that the concentrations of the coliform counts were at times higher than those of the NEMA water quality standards (Table 2) shows that the public which draws water from this stream source for domestic consumption are exposed to the risk of pathogenic infections. Total coliform counts indicates the presence of all bacterial water borne microorganisms, whereas fecal coliform counts indicate the presence of pathogenic types like *Escherichia coli, Salmonella typhi, Salmonella paratyphi, Vibrio cholera, Amoeba Entamoeba histolytica.* These bacteria cause the outbreaks of Cholera (*Vibrio cholera*), Typhoid (*Salmonella typhi*, and *Salmonella paratyphi)*, and Dysentery (*Entamoeba histolytica*) among the inhabitants and water users. A survey by this study indicated infections of these bacteria at several dispensaries and hospitals within Kisii Municipality (table 3). The mean number of infected persons with the five waterborne diseases were indentified in the seven Sub-County hospitals and the County level 6 hospital. These infections were: typhoid, dysentery, Amoebiasis, diarrhoea, cholera (table 3). The occurrence of these pathogens in the Nyanchwa stream lower the water quality in the stream and have both environmental and economic consequences on the public within Kisii Municipality and beyond.

The anthropogenic discharges affect the water quality in the stream making it unsuitable for domestic use. It was observed that most low income families draw water for home use at different points along the stream transect. Hence these families are exposed to the dangers of waterborne related infections. There is therefore need for stringent measures to be put in place to curb water pollution along the stream in order to improve water quality. The Kisii municipality should in the first place have a water policy for the utilization and management of water in the town. This should address the provision of clean water to all homesteads in town and the provision of a sufficient sewerage network. Further, they should have a waste management policy to address organic waste produced in town and Daraja Mbili open air market.

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References

Adetunde, L. A., & Glover, R. L. K., 2010. Bacteriological quality of borehole water used by students' of University for Development Studies, Navrongo Campus in Upper-East Region of Ghana. Current Research of Biological Sciences, 2 (6), 361-364.

American Public Health Association, American Water Works Association, Water pollution control Federation., 1998. Standard Methods for the Examination of Water and Wastewater, 20th ed. Washington DC.

Daniel, T.C., A.N. Sharpley, and J.L. Lemunyon. 1998. Agricultural Phosphorus and Eutrophication: A Symposium Overview. *J. Environ. Qual.* 27:251-257.

Kemp W. M., Boynton, W. R., Adolf, J. E., Boesch, D. F., and 14 others. 2005. Eutrophication of Chesapeake Bay: Historical trends and ecological interactions. Mar. ecol. Prog. Ser 303: 1 -29.

Kiruki, S., Limo, K. M., Njagi, E. N. M., & Okemo, P. O., 2011. Bacteriological quality and diarrhoeagenic pathogens on river Njoro and Nakuru Municipal water, Kenya. *International Journal for Biotechnology and Molecular Biology Research,* 2 (9), 150-162.

Mavura, W. J., Ngari, M. S., Matofari, J. W., Muliro, P. S., Perry, J., Harden, A., et al., 2006. How safe is the Water we drink? Determination of Chemical and Bacteriological Quality of various Water Sources in Njoro, Nakuru District, Kenya. *Egerton Journal of Science and Technology*, 6 (1), 16-30.

MINITAB .2000. Minitab Release 13.30. Statistical Software for Windows. Minitab Inc.

Mokaya S. K., Mathooko, J. M., and Maria L., 2005. Influence of anthropogenic activities on water quality of a tropical stream ecosystem. Article DOI: 10.1111/j.1365-2028.2004.00521.x

Mwamburi, J., 2003. Metal sources and distribution in rivers within the Lake Victoria (Kenya) catchment area. In Lake Victoria Fisheries: Status, biodiversity and management Edited by M. Van der Knaap and M. Munawar. Aquatic Ecosystem Health and Management Society www.aehms.org

Nwachukwu, E. and Ume, C.A., 2013. Bacteriological and Physicochemical Qualities of Drinking water Sources in Local Area of Eastern Nigeria. *Journal of Environmental Science and Water Resources*. Vol. 2(9), pp 336-341.

Ochumba P. B. O., 1990. Massive fish kills within the Nyanza Gulf of Lake Victoria, Kenya. *Hydrobiologia* 208: 93–99.

Odada, E.O., Olago, D.O. and Ochola, W., Eds., 2006. Environment for Development: An Ecosystems Assessment of Lake Victoria Basin Environmental and Socio-economic Status, Trends and Human Vulnerabilities, UNEP/PASS

Pruss-Ustun, A., & Corvalan, C., 2006. Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease. Geneva, Switzerland: World Health Organisation.

Shadrack M. K., 2012, Effects of Sediments Loads on Water Quality within the Nairobi River Basins, Kenya. International Journal of Environmental Protection. Vol. 2 Iss. 6 PP. 16-20. www.ij-ep.org

Shivonga WA, Muchiri M, Kibichi S, Odanga J, Miller SN, Baldyga TJ, Gichaba CM. 2005. "Impact of land use on water quality in River Njoro Watershed, Kenya.". In: XX International Grassland Congress: Offered Papers. Wageningen- Netherlands: Wageningen Academic Publishers;.

Tracy J. B, Siân M., Scott M., Desterio O. and Shivoga W. A., 2005, Institutions, Environment and Water Use: the River Njoro Watershed and Lake Nakuru. Working paper 2005-104, Department of Agricultural and Applied Economics, University of Wyoming, Laramie, Wyoming, USA 82071.

Twesigye, C. K., Simon M. O., Getenga, Z. M., Mwakalila, S. S. and Nakiranda J. K.. 2011. The Impact of Land Use Activities on Vegetation Cover and Water Quality in the Lake Victoria Watershed. The Open Environmental Engineering Journal, 4, 66-77

United Nations Environment Programme Financial Initiative, 2004. Challenges of water scarcity- A business case for financial institutions. Stockholm, Sweden: Stockholm International Water Institute

World Health Organisation., 2003. Emerging Issues in Water and Infectious Diseases. World Health Organization, Geneva. http://www.who.int/water_sanitation_ health/emerging/en/emerging.pdf,

World Health Organisation, 2007. Combating waterborne disease at the household level. Geneva, Switzerland: World Health Organisation