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THE IMPACT OF STORM WATERS TO WATER QUALITY IN SPRINGS AND RIVERS OF KISII MUNICIPALITY, KISII COUNTY, KENYA

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ABSTRACT

Storm water causes a major contamination for surface and subsurface waters in both urban and rural areas. In Kisii municipality it is observed that the major source of contaminants are non-point source pollution from farms and urban markets/garages. The study is carried in Kisii municipality on two rivers and five spring sampling a total of nine points, springs (4) and rivers (5) between 2019-2020 were identified through water sampling. Water quality parameters (Ammonium, Turbidity, Total Dissolved Solids, Electrical Conductivity, Total Coliform Count, Fecal Coliforms, Total Nitrates, PH, Hardness, Colour, Dissolved Oxygen Concentration and Total Suspended Solids) were measured and determined using Gebesys 10S VIS Spectrophotometer at Kenya Marine Fisheries Research Institute laboratories in Kisumu. Overall mean of five parameters (Ammonium, Total Nitrates, Total Phosphates, fecal and total coliforms) exceeded recommended World Health Organization and National Environmental Management Authority standards. Maximum values of turbidity, total dissolved solids, dissolved oxygen and hardness exceed these standards during the wet period.

Keywords: Water Quality, Storm Drainages, Domestic Water

1.0 INTRODUCTION

Water is known to be essential in sustaining life, and its availability must be adequate, safe and easily accessible to all [1]. Being safe means that the quality of water should be within a certain range of parameters as stated by the National Environment Management Authority [2] and the WHO [3] [4]. Deterioration of drinking water quality has been found to emanate from introduction of chemical compounds into the water supply system through leaks and cross connections[5].

Improving access to safe drinking water can result in tangible benefits to health. Every effort should be made to achieve a drinking-water quality as safe as practicable. Safe drinking water is suitable for all usual domestic purposes, including personal hygiene [3] [4]. According to WHO the quality of drinking water may be controlled through a combination of protection of water sources, control of treatment processes and management of the distribution and handling of the water

The type and nature and form of domestic drinking water standards varies among countries. There are no universally single approach to water quality parameters that is universally

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applicable. It is essential in the development and implementation of standards that the current and planned legislation relating to water, health and local government are taken into account and that the capacity to develop and implement regulations is assessed. Approaches that may work in one country or region will not necessarily work on other countries or regions. It is essential that each country review its needs and capacities in developing a regulatory framework [3].

In Kenya water quality is controlled by National Environmental Management Authority (NEMA). The authority is responsible for setting the guidelines on water quality for domestic use. It implements and advices the government on regulations of water for domestic and industrial purposes; water used for fisheries and wildlife purposes, and water used for any other purposes. Different standards apply to different modes of usage. These regulations provide for the protection of lakes, rivers, streams, springs, wells and other water sources [2]. The NEMA guidelines are as shown in Table 1 below: -

Table 1. WHO and NEMA water quality standards.

Parameters Maximum	WHO permissible limit	NEMA
Al	0.2 mgL^{-1}	0.2 mgL^{-1}
Ca	75 mgL^{-1}	75 mgL^{-1}
Fe	0.3 mgL^{-1}	0.3 mgL^{-1}
Mg	50 mgL^{-1}	50 mgL^{-1}
NO3	50 mgL^{-1}	50 mgL^{-1}
PH	6.5-8	6.5-8
TDS	100 mgL^{-1}	100 mgL^{-1}
E.Coli	0	0
Total Phosphorus	35	35

Water quality is adversely affected by urban surface runoff, which washes away from markets, garages, spillage from stations and bus parks. The quality of urban runoff and floodwaters is generally overlooked [6], even in comprehensive flood risk assessments such as the European Union (EU) directive 2007/60/EC on the assessment and management of runoff risk. The various aspects of urban runoff only pertain to runoff extent, water depth, and flow velocity, whereas there is no mention of flood water quality [7]. This is due to the fact that deterioration of surface water quality is considered acceptable as an exception during flash floods and runoff [8].

1.1 Nitrates in water

Nitrates and nitrites are naturally occurring ions of Nitrogen compounds that are part of the nitrogen cycle. The nitrate ion (NO_3^-) is the stable form of combined nitrogen for oxygenated systems. Although chemically unreactive, it can be reduced by microbial action. The nitrite ion (NO_2^-) contains nitrogen in a relatively unstable oxidation state [9].

Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Under aerobic conditions, nitrate can percolate in relatively

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large quantities into aquifers, this occurs when there are no plants growing to take up the nitrate or when the net movement of soil water is downward to the aquifer.

In most countries, nitrate levels in drinking water derived from surface water do not exceed 10 mgL-1. In some areas, however, concentrations are higher as a result of runoff and the discharge of sewage effluent and certain industrial wastes. According to WHO, in fifteen (15) European countries, the percentage of the population exposed to nitrate levels in drinking water above 50 mgL-1 ranged from 0.5% to 10% [3]; this corresponds to nearly 10 million people. According to [3], individual wells in agricultural areas throughout the world especially contribute to nitrate-related toxicity problems, and nitrate levels in the well waters often exceed 50 mgL-1.

The world permitted levels of Nitrates on water varies globally with WHO setting a standard of 50 mgL-1 while Kenya through its regulatory body NEMA sets the maximum allowed level of Nitrates at 10 mgL-1.

1.2 Total coliforms

Coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in their wastes. According to Pal (2017) the definition of coliform bacteria differs slightly depending on the country or on the organization in charge of the microbiological monitoring regulations. In Canada, the definition is the same as in the US, and differs in some European countries.

Most coliform bacteria do not cause disease. However, some rare strains of E. Coli, particularly the strain 0157:H7, can cause serious illness. Recent outbreaks of disease caused by E. Coli 0157:H7 have generated much public concern about this organism [10]. The E. Coli 0157:H7 has been found in cattle, chickens, pigs, and sheep [11] [12]. Most of the reported human cases have been due to eating under cooked or raw foods [13]. Cases of E. Coli 0157:H7 caused by contaminated drinking water supplies are rare [14].

1.3 Fecal coliforms

Fecal coliform (FC) bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock and wildlife [15]. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being E. coli. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals [16].

In the United States, the new United States Environmental Protection Agency (USEPA) coliform rule requires major monitoring changes by the drinking water industry. The testing requirements for drinking water are markedly increased. Not only is the number of routine coliform tests increased, especially for the smaller utilities, but also a new regulation requires automatic repeat testing from all sites that show a total coliform positive. The WHO standards and NEMA for Total coliforms dictates that water for domestic use should not have any traces of either TC or FC, at all times all tested samples should be Nil/100 ml [2].

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2.0 STUDY AREA

This research was conducted in Kisii Municipality, the Municipality is located at the southern end of the western Kenyan highlands at an average altitude of about 1660 m above sea level (A). Its terrain is hilly, with elevations ranging from 1596 m in areas around Daraja Mbili which is the lowest point, to about 1841 m ASL in the areas around Nyanguru satellite, with an overall slope towards the west. Its slope ranges from approximately 2% at areas around Daraja Mbili to 9% in areas around Nyanguru.

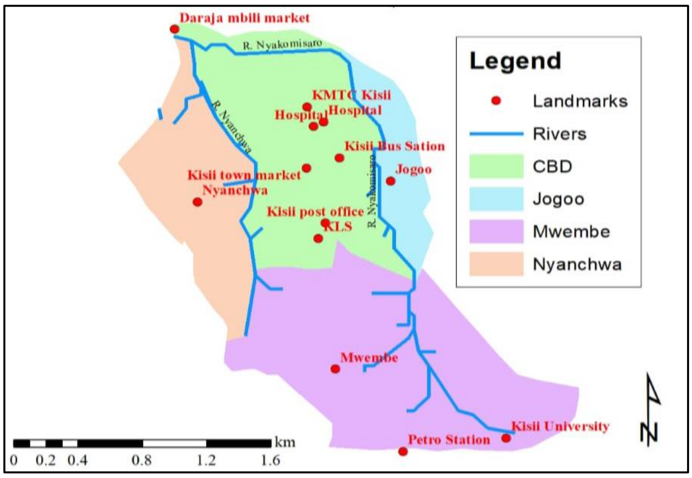

Figure 1. Study area.

3.0 METHODS OF DATA COLLECTION

Water samples, during dry (January, February, and July 2020) and wet periods (September, October, November and December 2020), were collected from springs and rivers at nine sampling points. These points were; five points in rivers Nyanchwa and Nyakomisaro and four points in springs.

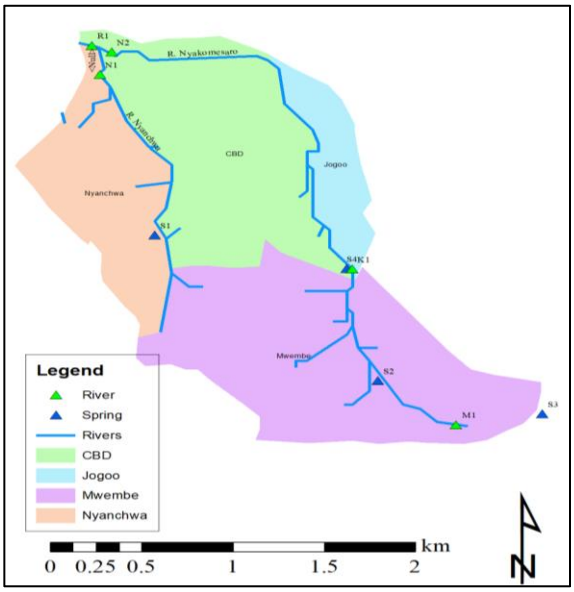

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Figure 2. Sampling locations for springs and rivers in Kisii municipality

The water samples were collected using 500 ml plastic bottles and placed in ice cooler boxes, at a temperature of approximately 4 degrees Celsius, making sure that the bottle tops were above the ice in the box. The samples were then transferred to Kenya Marine and Fisheries Research Institute (KMFRI) laboratories in Kisumu and analyzed within 8 hours, for determination of water quality. The results were used to make conclusion on the quality of water and the environment. Each sample was identified by their location and coordinates taken by a GPS gadget. Water parameters measured included; Turbidity (Turb), Total Dissolved Solids (TDS), total phosphates (TP), Conductivity (Cond), Temperature (Temp), Ammonium, Total Coliform Count (TCC), fecal coliforms, pH, hardness (Hard), Total Nitrate (TN), Dissolved oxygen concentration (D.O), Alkalinity and Total suspended Solids (TSS).

Collection of water samples during the dry months was important because they would act as control of the pollutants during the wet seasons. The same sampled areas were sampled again during the (wet) rainy season and the average variations were obtained for data on physical and chemical parameters and on fecal and total coliform counts. Water samples for estimation of coliform counts were estimated and analyzed following methods described in USEPA, (2002). The samples were collected in polypropylene (plastic) bottles with leak proof lids.

Table 2. Sample locations coordinates

New assigned number	Sample station	Type	Coordinates
1	R1	River	-0.665, 34.773
2	N1	River	-0.666, 34.775
3	N2	River	-0.668, 34.775
4	K1	River	-0.68, 34.777
5	M1	River	-0.69, 34.782
6	S1	Spring	-0.668, 34.767
7	S2	Spring	0.687, 34.778
8	S3	Spring	-0.689, 34.786
9	S4	Spring	-0.68, 34.777

4.0 RESULTS

4.1 Water quality results

The computed differences between the physical and chemical properties of water from springs and rivers in Kisii municipality was analyzed and it was deduced that a significance difference in concentration was noted in the parameters.

Notable differences were seen in the average concentrations of total nitrates, total phosphates, total suspended solids and turbidity. Springs were found to have a higher average concentration of total nitrates, total phosphates and turbidity than rivers. On the other hand, rivers had a higher average concentration of ammonium and total suspended solids.

The overall mean (of springs and rivers) of concentration of five parameters (Ammonium, Total Nitrates, Total Phosphates, Dissolved Oxygen and Hardness) exceeded the maximum

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allowable limit for consumption. The rest of the parameters had their overall mean being within the allowable limits of the WHO and NEMA.

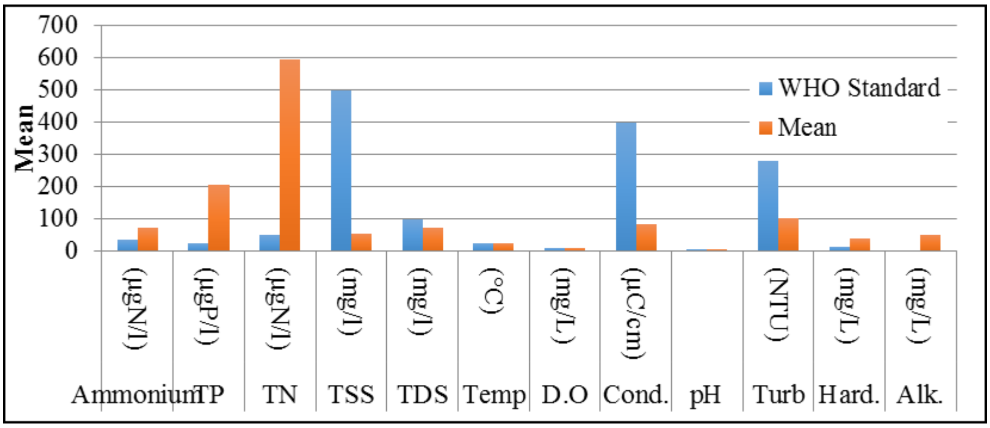

Figure 3. Overall means compared to WHO.

4.2 Nitrates concentration

Ammonium is known to be one of the many forms of nitrogen which exist in aquatic environments. According to WHO, the maximum permissible levels of ammonium in drinking water is 35 mg/l. The overall mean ammonium levels in the sampled water from springs and rivers in Kisii municipality exceeded WHO recommendations (74.3 ± 43.88 SD mg/l). During the dry period, ammonium concentrations ranged from 395.88 – 10.19 mg/l while during the wet period, concentrations ranged from 137.5 to 0.99 mg/l. Overall mean of ammonium concentration during the dry period was (94.68 ± 87.84 SD mg/l) while that of the wet period was (59.10 ± 31.95 SD mg/l). One way analysis of variance indicated that there were significant differences in ammonium concentrations among different sampling locations with $p<0.05$ level for the three conditions [F (1, 187) = 0.90 p = 0.764]

4.3 Turbidity

Turbidity is a key parameter when monitoring surface water quality, not only because of its relation to suspended sediment concentration, but also because of its effect on the environment. According to WHO, the maximum permissible levels of turbidity in drinking water is 280 NTU. The overall mean of turbidity levels in the sampled water from springs and rivers in Kisii municipality did not exceed WHO recommendations (102.90 ± 59.65 SD NTU). However, levels of turbidity during some days in the wet period exceeded the WHO recommendations, the maximum turbidity level during this period being 329.6 NTU.

During the dry period, turbidity ranged from 272.80 – 57.70 NTU while during the wet period, it ranged from 329.6 – 5.35 NTU. The mean turbidity during the dry period was (116.93 ± 50.24 SD NTU) while that of the wet period was (92.37 ± 64.05 SD NTU).

One way analysis of variance indicated that there were significant differences in turbidity among different sampling locations with $p<0.05$ level for the three conditions [F (1, 187) = 0.90 p = 0.764]. This indicated that there was a significant relationship between the seasons

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and turbidity in water. The turbidity levels however increased downstream for rivers contrary to that of springs.

The water turbidity in the some of the sampled locations portrayed a higher value than WHO threshold limit of 280 NTU. Water sampled from Spring S2 in the Wet months of July 2020 had the lowest turbidity level of all the water sources. The average turbidity for rivers was 100.45 NTU while that of springs was 105.96 NTU. Photographs of water flowing in river across Daraja Mbili and from a spring at Daraja moja.

Figure 4. Turbid waters of Daraja Mbili and Daraja Moja.

Highest turbidity (329.l60 NTU) was recorded at sampling station M1 in the month of September 2019. The mean water turbidity in the study area was found to decrease on average from December 2019 to July 2020 with a sharp increase in the month of October 2019 to December 2020.

4.4 Total suspended Solids (TSS)

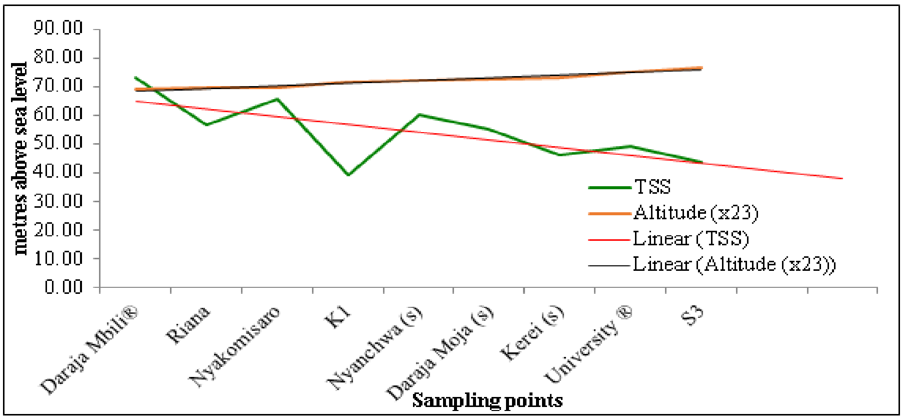

Figure 5. Overall mean of TSS versus altitude.

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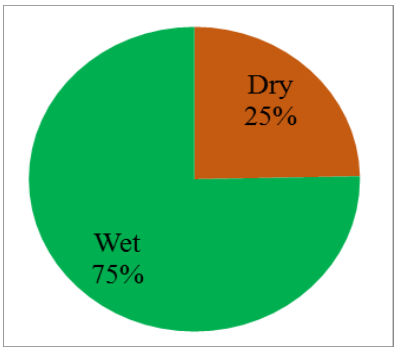
The maximum permissible levels TSS in drinking water, as recommended by WHO, is 500 NTU. The overall mean of TSS in the sampled water from springs and rivers in Kisii municipality did not exceed WHO recommendations (53.40 ± 36.81 SD NTU). During the dry period, TSS ranged from 117.00 – 2.00 NTU while in the wet period, it ranged from 124.10 – 5.00 NTU. The mean turbidity during the dry period was (42.23 ± 32.11 SD NTU) while that of the wet period was (61.69 ± 37.99 SD NTU). One way analysis of variance indicated that there were significant differences in TSS among different sampling locations with $p<0.05$ level for the three conditions [F (1, 187) = 0.90 p = 0.764].

Highest deposits of TSS were established to be in sampling point R1 in Daraja Mbili (72.93 mgL-1). The altitude was scaled down by a factor of (23) to conform to TSS levels. The TSS levels were computed from Daraja Moja upstream to University and Spring 3 (S3), the levels for TSS and Altitude were plotted and it was observed that the TSS increased downstream (Figure 5).

4.5 Total nitrates

Nitrates occur naturally in drinking water. The nitrates level in water indicated that they exceeded both the WHO and NEMA standards of 50 mgL-1. The overall mean of total nitrates in the sampled water from springs and rivers in Kisii municipality exceeded both the WHO and NEMA recommendations (542.91 ± 913.91 SD mgL-1). During the dry period, total nitrates concentrations ranged from 745.80 – 0.25 mgL-1 while in the wet period, it ranged from 3771.79 – 0.19 mgL-1. The mean total nitrates concentration during the dry period was (272.78 ± 226.74 SD mgL-1) while that of the wet period was (832.26 ± 1136.31 SD mgL-1). One way analysis of variance indicated that there were significant differences in TSS among different sampling locations with $p<0.05$ level for the three conditions [F (1, 187) = 0.90 p = 0.764].

The concentration of total nitrates in springs was higher (708.48 mgl-1) than that of 500.94 mgl-1. Total Nitrate concentration during the dry and wet period. The high concentration of Nitrates during the wet season could be attributed to the high surface runoff experienced in Kisii Municipality at such times.



4.6 PH

The permissible levels PH in drinking water, as recommended by WHO and NEMA is 6.5 – 8.0. The overall mean of PH in the sampled water from springs and rivers in Kisii municipality was within the WHO and NEMA recommendations (7.5 ± 0.46), except for

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sampling location S1 which had a PH level of 8.55. During the dry period, PH ranged from 8.55 – 6.82 while in the wet period, it ranged from 8.56 – 6.42. The overall mean of PH during the dry period was (7.59 ± 0.42 SD) while that of the wet period was (7.56 ± 0.49 SD). One way analysis of variance indicated that there was no significant effect of seasons on PH with $p > 0.05$ for the three conditions [$F(1, 187) = 0.90$ $p = 0.764$].

The means of PH for springs and rivers ranged from 7.3 to 7.7 at River Nyanchwa (N1) and University Pond (M1) respectively. Highest PH levels of 8.55 were recorded at Spring 1 (Nyanchwa) during the rainy season.

The reducing PH levels downstream and at Nyanchwa, can be attributed to collection of urban waste and waste food products from markets which are dumped straight into the rivers by vendors.

Figure 7. Rotting organic matter at Daraja Mbili (N1) sampling point

4.7 Total dissolved solids (TDS)

The maximum permissible levels TDS in drinking water, as recommended by WHO and NEMA, is 100 mgL-1. The overall mean of TDS in the sampled water from springs and rivers in Kisii municipality did not exceed WHO recommendations (72.78 ± 46.67 SD mgL-1. However, maximum values of TDS during the dry and wet periods exceeded the WHO and NEMA recommendations, with the dry period having a range of 327.95 – 6.38 mgL-1 while in the wet period, it ranged from 212.10 – 8.00 mgL-1. The mean TDS during the dry period was (77.15 ± 53.67 SD mgL-1) while that of the wet period was (69.54 ± 40.69 SD mgL-1). One way analysis of variance indicated that there was no significant effect of seasons on TDS at $p > 0.05$ level for the three conditions [$F(1, 187) = 0.90$ $p = 0.764$].

Water samples from rivers had a high mean value (72.9 mgL-1) of TDS as compared to that of springs (72.67 mgL-1).

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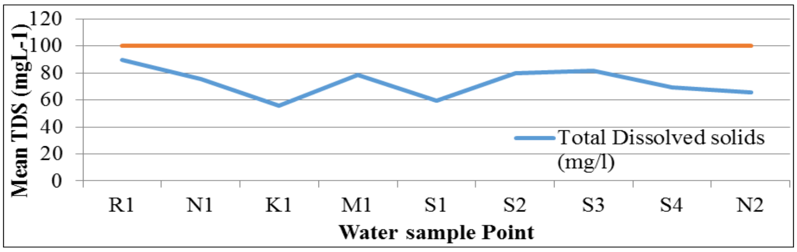

Figure 8. Levels of TDS in water samples

4.8 Dissolved oxygen

The oxygen concentrations of springs and rivers in Kisii municipality catchment are presented in Table 3. The concentrations were generally higher during the wet season than during the dry one. The overall mean oxygen concentration for all sampling sites in springs and rivers was 8.16 ± 5.4 SD mgL-1. Most of the oxygen concentration fell within the range which is acceptable by WHO and NEMA i.e., 5.5-9 mgL-1. However, some sampling locations had some concentrations which were higher than permissible levels (10 – 11mg/l) during the wet season.

Table 3. Dissolved Oxygen concentrations in springs and rivers within Kisii municipality

Sample Point	Wet	Dry	Mean
R1	6.79	5.48	6.23
N1	6.79	6.18	6.53
K1	11.30	6.61	9.29
M1	10.67	6.61	8.93
S1	11.23	5.68	8.85
S2	11.59	7.22	9.72
S3	11.38	6.73	9.39
S4	10.85	6.19	8.85
N2	5.79	5.41	5.63
Mean	9.60	6.23	8.16

The D.O concentration varied, with wet seasons having a mean of 9.59 ± 6.81 SD mgL-1 while dry season had a mean of 6.23 ± 1.09 SD mgL-1. A one-way ANOVA was conducted to establish whether there were significant differences between and among mean DO concentrations of the wet and dry seasons. There was a significant difference between and among the means $p<0.05$ with [F (1, 187) =19.34, p = 0.000]. In comparison, the mean oxygen concentration for springs was higher (9.2 mgL-1) than that of rivers (7.3 mgL-1)

4.9 Total and fecal coliform counts

The fecal and total coliform counts of water samples from springs and rivers in Kisii Municipality. They were found in all the water samples from sampling locations and exceeded the minimum permissible levels of WMO and NEMA (0 counts/100ml). They were generally higher during the dry season (68 counts/100ml) than during the wet one. The overall mean of total and fecal coliform counts for all sampling sites in springs and rivers was 66.47 ± 38.26 SD counts/100ml. Rivers has a higher mean of total and fecal coliform (76.69 ± 42.90 SD counts/100ml) than springs (56.47 ± 93.26 SD counts/100ml). Mean

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concentration of fecal and total coliform counts during wet period was found to be high (67.89 ± 41.26 SD counts/100ml) than during the dry period (64.33 ± 34.94 SD counts/100ml). A one-way ANOVA was conducted to establish whether there were significant differences between and among mean Total and fecal coliform counts of the wet and dry seasons. There was a significant difference between and among the means $p<0.05$ with [$F (1, 187) = 19.34$, $p = 0.000$].

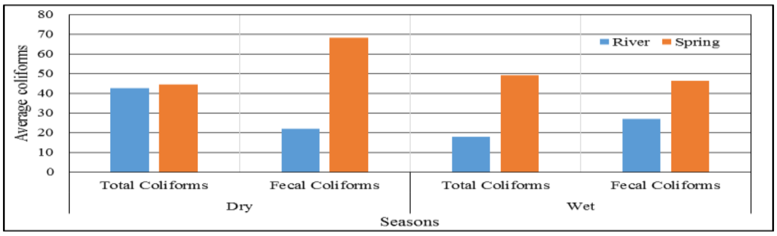

Figure 9. Average of coliform.

Sampling point S1 (spring) had the highest number of total and fecal count (150.00 and 100.00 counts/100ml respectively), while in rivers, K1 had the highest number of total and fecal count (120.00 and 67.00 counts/100ml respectively). A map of the mean distribution of fecal coliforms in the study area.

A map of the mean distribution of total coliform count in sampling locations in springs and rivers within Kisii municipality. There was a downstream increase in the total coliform count in springs and rivers during the wet season, except at sampling location S3 (spring) where this trend was broken by the higher coliform count 87.00 counts/100ml.

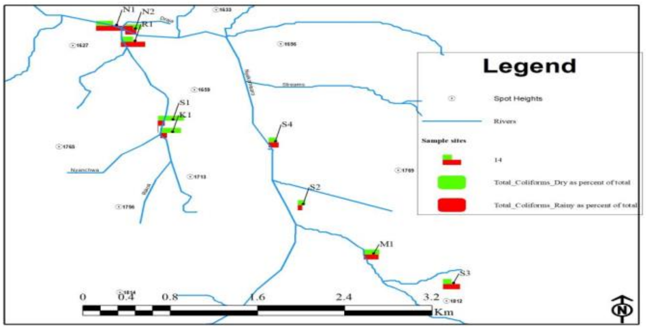

Figure 10. Total coliforms count distribution.

5.0 DISCUSSION

Impacts of storm water on water quality Storm water is a major contributor to poor water quality in surface and ground water sources in Kisii municipality. It is known to typically contain large number of pollutants such as litter, sediments, hydrocarbons, fecal pathogens, sediments, pesticides and heavy metals to name a few, which are known to negatively impact on water quality. Five of the water quality parameters measured for Kisii municipality had their quality surpassing the NEMA and WHO standards, meaning that the water in the study area was not suitable not only for aquatic life, but also for human consumption. These included Ammonium, total phosphates, total nitrates, fecal and total coliforms. This can be supported by the observation that at times the domestic tap water supply contains mud and

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silt. Also, the maximum values of turbidity, total dissolved solids, dissolved oxygen and hardness exceeded recommended NEMA and WHO standards, indicating that storm water had an impact on water quality.

In Kisii municipality sources of heavy metal pollutants can include numerous car washes along surface water sources, metal workshops, petrol or Gasoline stations and garages.

Other sources of pollutants are the aerosols, sprays used in households for combating mosquitoes, cockroaches and other household pests including rats. Washings from the house contain these contaminants which can be carried downstream by storm water thereby affecting water quality and lives of human, livestock and wildlife.

In the rivers, the pollutants affect not only the water quality but also biodiversity by reducing it and changing its composition. They are also responsible for mortality in aquatic invertebrates and fish. The pollutants have serious consequences in downstream users. They transmit to them poor quality water, aquatic diseases and carcinogenic compounds which cause diseases. further storm water renders water to be unsuitable for domestic, industrial and agricultural purposes. For example, the manufacture of bottled drinks such as beer and wines require water of high quality. Contaminated water containing sewage and silt may contaminate agricultural crops downstream when flooding occurs on farms. The water is unsuitable for drinking by wildlife and livestock.

The observed high levels of nutrients; total nitrates and total phosphates in springs could be attributed to surface runoff and contamination of water resulting from leached agricultural fertilizers, sewerage and garbage leachate. The major contributor of nutrients is human and domestic waste. For example, [17] noted that most adults release about 75-100 mgL-1 of nitrates per day which is eventually released into the sewerage system. The ratio of total phosphate to total nitrates (P:TN) of surface waters in Kisii municipality was high and differed from that of 1: 16 respectively found in natural waters. This indicated that there was a discharge of nutrient rich effluents through storm water into surface waters. More often there is breakdown of municipal sewage resulting to discharge of these effluents into open ground. This effluent is nutrient rich and contains pathogens that causes diseases in humans, livestock and wildlife.

Effluents from Kisii municipality could have far reaching consequences to downstream users and the Lake Victoria ecosystem. The municipality sits on a major tributary, river Riana which drains to river Gucha which finally drains into Lake Victoria at Luanda Konyango near Sori Karungu town. The nutrient and pollutant reach effluent from the town contribute to the degradation of the downstream water quality as well as that of Lake Victoria by causing eutrophication. Eutrophication is the enrichment of a water body with nutrients. It leads to heavy proliferation of aquatic algae and macrophytes (aquatic plants), which both affect profoundly the water quality, fish survival as well as that of other aquatic organisms. Examples of the eutrophication are the menace of the water hyacinth proliferation of Lake Victoria which has caused the public and government billions of shillings and also other losses such as decline in fish production, poor water quality and diseases associated with it such as malaria, bilharzia.

Algae resulting from nutrient enrichment causes extensive algal blooms in the lake which in turn produce algal toxins responsible for serious illness and death to aquatic life, wildlife, livestock and humans. For example, extensive kills in fish in Lake Victoria can be attributed to algal toxins associated with algal blooms. If animals and other humans consuming, he dead fish also get affected.

5.1 Nitrate's concentration

The presence of high nitrates in water can be attributed to human activities such as the overuse of chemical fertilizers and improper disposal of human and animal wastes. These fertilizers and wastes contain nitrogen compounds that are converted to nitrates in the soil. The concentration of nitrates in Kisii Municipality was found to be life threatening to aquatic, livestock, wild life and humans. Although, nitrates are unlikely to be harmful, even at elevated levels, their breakdown product (nitrite), when occurring in concentrations exceeding WHO, standards cause the blue baby syndrome (methaemoglobinaemia) in babies. Another concern regarding nitrate ingestion is that it may contribute to the development of some types of cancers. Also, lifetime exposures to nitrates and nitrites can cause an excessive discharge of urine, increased starchy deposits and hemorrhaging of the spleen (Ma, 2018). Nitrate in groundwater was of concern not only because of its toxic potential, but also because it may indicate that the groundwater was contaminated with other substances. The source of the nitrate may be a clue as to other contaminants that may be present. If the water is contaminated by animal waste or effluent from septic tanks, it may also contain disease-causing bacteria, viruses and protozoa. If the water is contaminated by fertilizers, it may also contain other agricultural chemicals besides nitrates, such as pesticides (Dozier, 2008) which might indicate the availability of coliforms and heavy metals.

5.2 Turbidity

High turbidity in water is undesirable as it affects the survival of aquatic organisms as well as the quality of water for domestic, industrial and agricultural use. There were observed changes in turbidity between the dry and wet season, for example the reduced water turbidity during the dry season can be attributed to reduction in surface runoff, which was reflected in the measured low TSS in the water. Several studies [18] have demonstrated a strong relationship between discharge and suspended sediment concentration in water, with different time lags depending on the geological characteristics of the catchment. The observation that turbidity levels in the rivers and springs during the wet period exceeded WHO standards of 280 NTU, can be attributed to storm water pollutants from the sub catchment areas, mainly of domestic, developmental, agricultural and industrial origin.

5.3 Total Dissolved Solids

TDS refers to natural or added solutes present in water, which includes the dissolved and suspended solids. Basically, Solids are particles of sand, silt, clay, and organic materials found in the water and are usually measured as a concentration, milligrams per litre (mgL-1). The TDS WHO standard recommended for domestic drinking and use is 100mgL-1 mean standard was 72.7mgL-1. The water had permissible limits on all the sampled sources for TDS. However, the junction of Daraja Mbili (R1) had the highest TDS at 89.9mgL-1. This is due to the fact that storm after effluent arriving at Daraja Mbili came from the more

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developed and larger part of the municipality. Therefore, the elevated TDS was due to the cumulative effects of storm water effluents from the larger southern part of the municipality. Therefore, the high TDS at Daraja Mbili was attributed to the collection of debris and waste from all streams and channels upstream as well as human activities along the sub catchment.

5.4 Dissolved Oxygen Concentration

Dissolved oxygen refers to the presence of pure uncombined oxygen also known as free oxygen in water and is a major parameter in water quality assessment. The importance of dissolved oxygen is second only to water itself for aquatic organisms. Low dissolved oxygen concentrations below the recommended WHO standard of 5mg/l as well as higher concentrations above the supersaturation range, that is above 9.5 mg/l are dangerous to aquatic life. The former leads to suffocation of fish and other aquatic life, while the later causes gas bubble disease often leading to death of fish and invertebrates.

Overall mean of dissolved oxygen concentration was established to be within the WHO acceptable level of 6.5-8.5 mgL-1. For drinking water, WHO recommended standards are 5.5-9 per litre. However, during the wet period, some sampling points in the rivers had their oxygen concentration exceeding the WHO and NEMA standards, thus lowering the quality of water. The poor quality could be attributed to storm water effluent rich in organic matter originating from garbage dams, sewerage, from open ground defecation and dislodged by storm water from latrines during heavy downpour as well as from breakdown of sewage systems and uncollected organic matter in the sub catchments and the CBD. These, once carried downstream, by storm water decompose and therefore consume or absorb oxygen from the water column leading to a reduction in its concentration.

5.5 Coliforms in water

Fecal Coliforms, for example Fibrio and Escherichia coli (E. coli) are bacteria whose presence indicates that the water may be contaminated with human and animal wastes which contain pathogenic agents. Coliform group has been used extensively as indicators of water quality and has historically led to the public health protection concept. Microbes in these wastes can cause cholera caused by the bacterium fibrio cholerae, dysentery caused by shigella species and amoeba and typhoid caused by the bacterium salmonella species. These microbes are present in water contaminated with sewerage.

WHO recommends that the permissible coliforms counts in domestic drinking water is Zero (0) cells, colonies or filaments per ml of drinking water. However, the samples from storm and surface waters of Kisii municipality indicated that in the wet and dry seasons the coliform counts were far above the WHO permissible levels. Hence this water could be the sources of the diseases mentioned here, often inflicting the municipal community. It was therefore deduced that the presence of coliforms in water indicated a poor water quality standard. Past studies have shown that E. coli is the only member of the total coliform group of bacteria that is normally found in the intestines of mammals, including also human beings.

The poor water quality conveyed by storm water from Kisii municipality pollutes the rivers flowing into Lake Victoria and affects downstream users, E.g., through the pathogenic contaminants and the high concentration of nutrients in the effluents. The high concentration of total nitrates and phosphates are conveyed down into Lake Victoria where they cause the phenomena of eutrophication. Therefore, River Riana, which originates from Kisii municipality conveys all the pollutants down into Lake Victoria. Storm water causes environmental degradation in form of sheet and gulley erosion where large loads of silt or sediments are brought down by River Riana to Lake Victoria and deposited at its delta, thus reducing the water depth and destroying fish and other aquatic life habitat as well as interfering with water quality. This means that its water is of poor quality and affected by eutrophication. Eutrophication causes excessive growth of blue-green algae which causes algal blooms in Lake Victoria which affects its quality rendering it useless riparian communities. Further, the algae produce toxins which cause serious sickness to humans, livestock and wild life and hence adversely affecting the water quality, both in the river and in the lake. The downstream users cannot use the water for drinking or agricultural or industrial activities.

Poor water quality reduces the consumptive, aesthetic and touristic values of the water along the river and Lake Victoria. Reports have indicated that Kisii municipality authorities are planning to make it attain city status. This means that the city will expand beyond its present boarders, its population will increase as well as the volume of storm water generated. Therefore, there is need to plan on how storm water from the municipality will be managed so that the users in both in Kisii and downstream in the Lake Victoria environment are not adversely affected by poor quality of water.

6.0 CONCLUSION

The quality of Domestic water in Kisii municipality was determined and linked to storm ways instability. The Physical properties of domestic water were within WHO standards. Nitrates and coliforms were found to have surpassed the safe levels. The properties tested included Total nitrates (0.59 mg-1), Total suspended solids (53.4 mgL-1), total dissolved solids (72.78 mgL-1), conductivity (84.27 Uccm-1) and Turbidity. The overall mean of turbidity on major water ways (Nyanchwa and Nyakomisaro) was 100.5NTU. This was within the WHO standards of 290NTU. Total suspended solids increased with increase in altitude at Daraja Mbili the TSS were >70 mgL-1 and at Kisii University>50mgL-1.

Test for PH on springs and rivers ranged from 7.3 to 7.7. The highest PH level was at Kisii University (M1) 7.7 and this was within the WHO limits of 6.5-8. The effect of seasons on water PH was conducted using an ANOVA and it was established that there was a significant relationship between seasons and change in PH.

Total coliforms on springs and rivers were conducted. The coliform counts indicate presence of animal or human waste on domestic and surface waters. The Fecal count on domestic water according to WHO should be at zero. However, water in Kisii had a fecal count greater that 100 on springs in dry seasons. The coliforms count on springs was higher during the dry seasons at 68ppml-1. This amount was very high since the WHO recommends safe drinking water to have coliform count of 0ppml-1.

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