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INFLUENCE OF RAINFALL INTENSITY ON FAECAL CONTAMINATION IN RIVER NYANGORES OF MARA BASIN, KENYA: AN ECO-HEALTH INTEGRITY PERSPECTIVE

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Abstract–River Nyangoresis one of the major perennial tributaries of the famous Mara River. Rise in anthropogenic activities coupled with environmental factors have posed an effect onits water quality. This study investigated the influence of rainfall intensity on microbiological water quality of River Nyangores. It involved the use of Membrane Filtration Technique and Heterotrophic Plate Count to determine the densities of total coliforms, *Escherichia coli*, intestinal enterococci, *Clostridium perfringens,Salmonella spp.* and total heterotrophic bacteria. Physico-chemical parameters of the water were also measured. The collected data was analyzed using SPSS software with 95% confident level. The results indicated that variation in rainfall eventshas an influence on the densities of faecaland easily degradable organic matter contaminants $P<0.05$. The study showed the need for better understanding and inclusion of hydrological characteristics of NyangoresRiver in improving its bacteriological water quality for its efficient ecological integrity restoration.

INTRODUCTION

The Mara River which originates from the Mau forest, is the home to one of the wonders of the world involving massive migration of wild beast. The river runs through the Massai Mara Game Reserve on the Kenyan side and the Serengeti National Park on the Tanzanian side, and eventually flows into Lake Victoria (Mati and Mutunga, 2005). People living along the Mara River and its basin area increasingly facing water shortages, poor water quality and environmental degradation as a result of pollution, agricultural runoff, large-scale irrigation projects, and mining and other industrial activities (Birdlife International 2008).

The Mau forest covering over 400 000 ha, is the largest of the five "water towers" of Kenya and over the last decade a large portion of the forest have been encroached. Currently over 43 700 ha of the Mau forest is under human settlement (Government of Kenya and United Nations Environmental Program (GOK and UNEP) 2008). Indeed, previous studies showed that this forest was reduced by about 48% to agricultural land which increased from 27.4% to 41% and settlement from 14.6% to 21.5% in the period between 1986 and 2001 with significant change noted to have occurred in the period between 1995 and 2001 (Mustafa *et al.*, 2005). This has been based on the desirability of this forest area for agriculture that attracts a rapidly growing population and has led to rapid conversion of large areas of forest to farmland, settlements and urban centers (Department of Resource Surveys and Remote Sensing (DRSRS) and Kenya Forestry Working Group (KFWG), 2006). Such extreme land cover changes can have serious consequencesboth within the forest and downstream in the form of water shortages, health risks, desertification, habitat

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destruction, sedimentation, erosion and even alteration of the micro-climate. (Birdlife International 20008).

River Nyangores is one of the major perennial tributaries of the larger Mara River (Rop*et al.*, 2014). This tributary originates from Mau Escarpment within the Mau forest and also flows through an area with intensive anthropogenic activities such as agriculture, deforestation, urbanization and settlement(Mati and Mutunga, 2005). These anthropogenic activities are proving to be the major causes of degradationto the quality of water within Rivers Nyangores, Mara as well as in the water of Lake Victoria where Mara River eventually drains (Dadswell, 1993). The greatest concern is the rise of faecal contamination of the rivers within the entire Mara catchment resulting from poor sanitation practices. In fact, the Nyangores River has been the most affected as it flows across the densely populated part of the catchment within Bomet Town with the most numerous and intense anthropogenic activities. In addition,its upper catchment has been encroached up to the river banks to pave way for human settlement and inhabitation (Rop *et al.*, 2014).

Sanitary facilities within households occurring close to river Nyangores are also inadequate or ineffective and peoples from those homes still defecates in bushes (Rop *et al.*, 2014). This has resulted to discharge of raw sewage into the river especially during rains. The situation has increased faecal pollution into Nyangores River through surface run-offs and underground percolation and seepage as has been evidenced in many other parts in Kenya (Donde *et al.*, 2013). In addition, rapidly growing towns like Bomet Municipality with unplanned developments adjacent to the river bank together with other mashrooming urban centres along the river with no sewerage treatment plants also dischargeraw sewage into the River.All these activities have resulted to the massive degradation of the microbial water quality ofthe river and consequently exposing the local communities which heavily depend on its water for domestic use to incidences of waterborne and water related diseases(Venter *et al.*, 2001; Obi *et al.*, 2002; Mati and Mutunga, 2005). This has continued to add more burdens on medical cost to already impoverished citizens(World Health Organization [WHO], 2002).

Faecal pollution of water sources increases risk to the health of the community utilizing such contaminated water for various domestic and agricultural purposes. In fact, it is believed that 80% of all diseases in the world are caused by inadequate sanitation, polluted water or unavailability of water (WHO, 2002). Both direct contact and consumption of water contaminated with faeces of ill individuals can lead to human illness and even death. The poor health also impacts negatively to the communities due to costs of hospitalization and drugs as well as low economic productivity due to loss of working hours(United State Environmental Protection Agency [USEPA], 1995).

Since faecal pollution is the major cause of diarrheal cases, there is need for better understanding of all the factors (both biotic and abiotic) that are involved in controlling the abundance of Faecal Origin Diseases Causing Micro-organisms (FODCM) in water. Indeed, there is a misunderstanding on whether rainfall do lower the densities of FODCM through dilution or whether it increases their densities through surface run off that washes these micro-oganisms from sewers and bushes into the rivers(Cooperative Research Centre for Fresh Water Ecology [CRCFWE], 2001; Fikrat*et. al.,* 2007). This study therefore explored potential influence thevariation in rainfall intensity could be causing to the densities of FODCM and easily degradable organic matter pollutants indicators. This was to provide abaseline information necessary to the relevant authorities; Water Resource Management Authority, Kenya Forest Services, Kenya Wildlife Services and other interested stakeholders like the Nyangores Water Resource User's Association among others. The information was to help in providing recommendations necessary for the appropriate management of the Mara Riverwith a view to improve its ecological integrity, ecosystem services and for a better ecological health.

MATERIALS AND METHODS

Study area

Rivers Nyangores and Amala are the two major permanent tributaries of Mara River which is located in Mau escarpment. The source of Mara River is entirely in Kenya and flow through Tanzania before draining into Lake Victoria. The catchment of the Mara River is estimated to be 13,504 km^2 which is distributed between Kenya and Tanzania in the ration of three to two. The Mara river basin is located between longitudes 33.88372^0 and 35.907682^0 West, latitude -0.331573^0 and -

1.975056^0 South (Mati and Mutunga 2005; Rop*et al.*, 2014).The life of Mara catchment entirely relies on the Mau-Complex Forest which is found within the Southern part of the Rift valley. From the source to the mouth, the Mara river covers a total distance of 395 Km.This study mainly focused on Nyangores River from its upper reaches where pollution was not or least expected to the point where it joins Amala River. Along the river, eight points were established for this study where points and non-point sources of pollution, settlement intensity, riparian vegetation cover and urbanization were given consideration. (Fig. 1).

Sampling

The study was conducted for five months (February 2012 to June 2012), it involved two sampling episodes per month from each sampling station and covering both wet and dry months. (Figure 2). Sampling of water was done in triplicates from the eightstudy sites within theNyangores River. Field studies, sampling and laboratory analytical procedures followed the procedures in (American Public Health Association [APHA], 2005) and sterilized glass sample bottles were used to collect samples from the middle point of the river at a depth of 30 cm below the surface. The months of February and March were relatively drier than the months of April, May and June. During sampling *in-situ* measurements was carried out where the values of the following physico-chemical parameters weredetermined; Temperature, pH, Electrical Conductivity (EC), Total Dissolved Solutes (TDS) by use of H1 991301 portable pH/EC/TDS/Temp meter. Values for Dissolved Oxygen (DO) were determined using of H1 9143 microprocessor. Turbidity was measured using 2100 isoTurbidimeter.Labeling of all the samples was correctly done and cool box with ice cubes was used to transfer the samples to laboratory for analyses which was done within 6 hours after sampling to avoid unnecessary growth or die of the microorganisms.

Sample analysis

Samples were analyzed based on the procedures provided by [10, 9]. Heterotrophic Plate Count

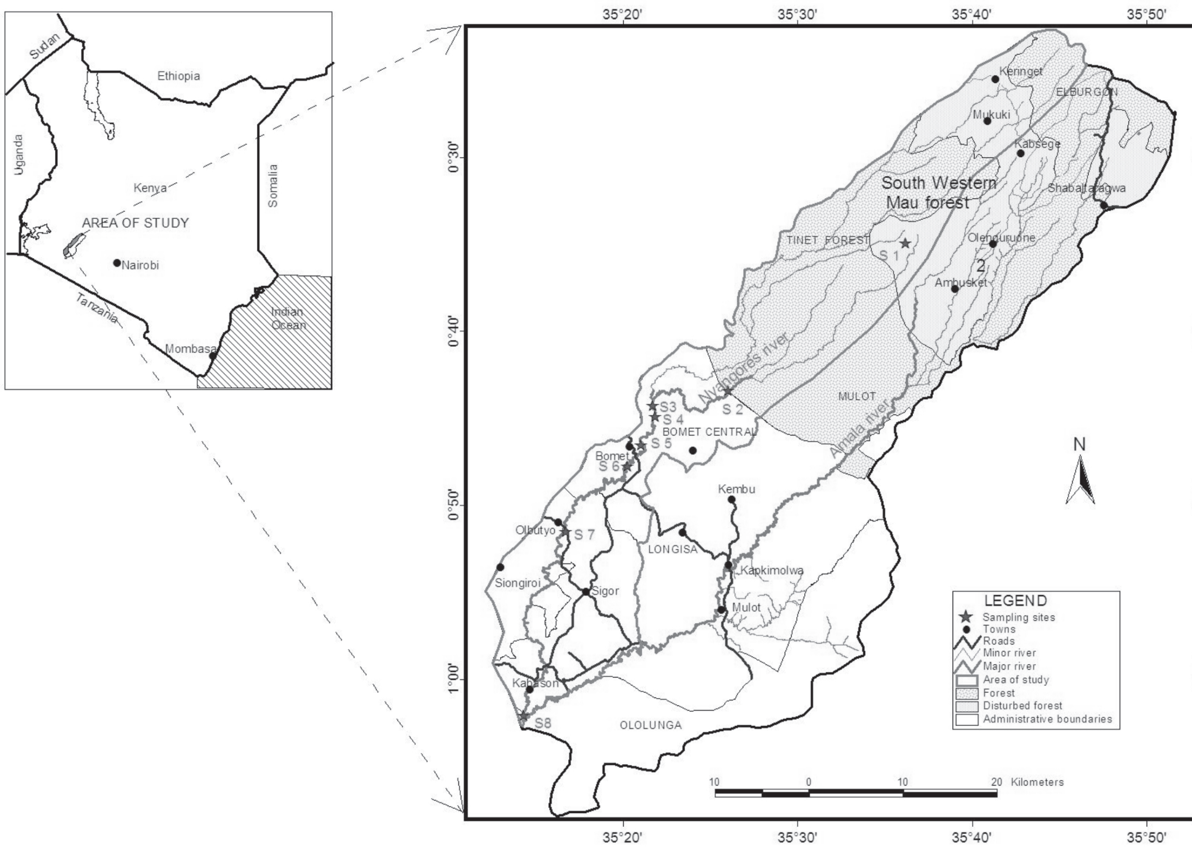

Fig. 1. Map of Kenya highlighting study area.

(HPC) procedure was used in determining the number of live heterotrophic bacteria while Membrane Filtration Technique (MFT) was used in the determination of the values for faecal contamination indicator organisms. The values for HPC bacteria were determine using plate count agar, while total coliforms and *E. coli* counts,chromocult agar (Merck) was used with incubation being made at 37°C for 24 hours. Values for intestinal enterococci were determined using enterococci agar (Merck) with incubation being made at 44°C for 48 hourswhile*C. perfringens*values were determined usingTryptoseSulphiteCyclocerine (TSC) agar plateswhich were incubated anaerobicallyat 44°C for 24 hours. For*Salmonella typhi* filters were placed onHiCrome™ Salmonella agar improved plates and incubated at 37°C for 24 hours. In addition, BOD measurements was done for samples collected. This was done by collecting water samples in 250ml aluminium foil-coated BOD bottles, the samples were appropriately analyzed using BOD OxiTop® meterwith an incubation at 20°C for 5 days. The BOD_5 results were thereafter obtained directly from the meterreading(Yuan *et al.*, 2001).The monthly rainfall data was obtained from the Bomet District Metrological station (Station No. 504) for the entire study duration.

Data analysis

Graphs and chats were constructed using MS office Excel version 2013 and Statistical Package for Social Sciences (SPSS) version 17 software was used in the analysis.95% level of significance was used as the critical point (P= <0.05). The collected data on the physic-chemical parameters, density of indicator organisms and HPC from the water sources were appropriately subjected to statistical analysis to find their corresponding mean variations.The means were compared using one wayAnalysis of variance (ANOVA) and Least Significance difference (LSD) used in separating the meansunder the *post hoc* test.

RESULTS

Rainfall intensity and otherPhysico-chemical parameters

The rainfall intensity values are presented Fig1. February and March had low values for rainfall intensity. The value increased in April and were lowest in May and June. Rainfall intensity showed significant variation with respect to month, F= 25.92, P= 0.000 and df= 4 and 150. The values for Temperature, pH, Electrical Conductivity (EC), Total Dissolved Solutes (TDS), dissolved oxygen and turbidity are described in (Rop*et al.*, 2014).

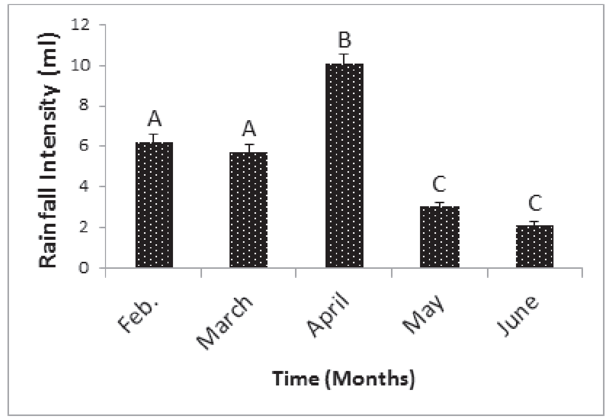

Fig. 2. Gra phs showing variability in rainfall intensity at different months of sampling.

Variationin faecal contamination indicators

Monthly variations in the values of *E. coli* and total coliforms are shown in Fig 3. For all the parameters, there was a clear indication in the values sampled in different months based on rainfall intensity with the

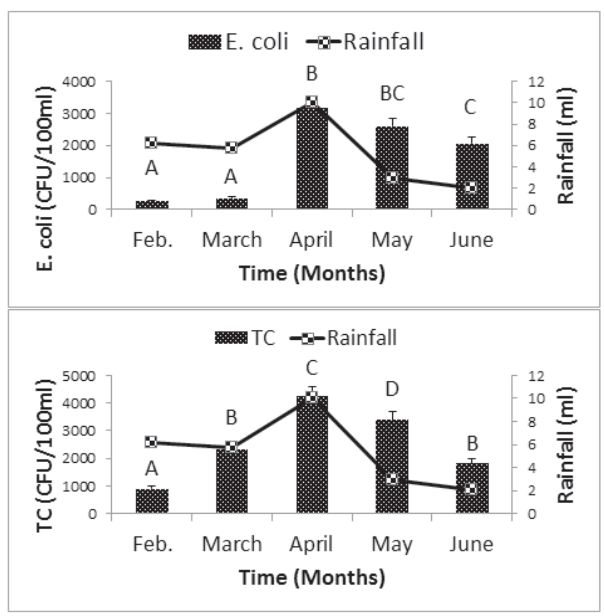

Fig. 3. Graphs showing variability in *E. coli* and TC based on sampling time and rainfall intensity. *TC (total coliforms). Time is in months (February, March, April, May and June). Vertical bars indicate standard error of mean and sites with significant mean differences are shown by different letters at P<0.05.*

highest means for all indicators occurring in April which was the wettest months. *E. coli* showed statistical variation with reference to sampling months (February, March, April, May and June 2012), F= 40.35, P= 0.000 and df= 4 and 239. Total coliforms also showed significant variation with respect to month of sampling, F= 26.464, P= 0.000 and df= 4 and 239.

TC (total coliforms). Time is in months (February, March, April, May and June). Vertical bars indicate standard error of mean and sites with significant mean differences are shown by different letters at P<0.05.

Monthly variations in the values of *C. pefringens*and intestinal enterococci are shown in Fig.4. For all the parameters, there was a clear indication in the values sampled in different months based on rainfall intensity. *C. pefringens*showed significant variation with respect to month of sampling, F= 25.96, P= 0.000 and df= 4 and 239. Intestinal enterococci also showed significant statistical variation with respect to sampling months (February, March, April, May and June 2012), F= 17.49, P= 0.000 and df= 4 and 239.

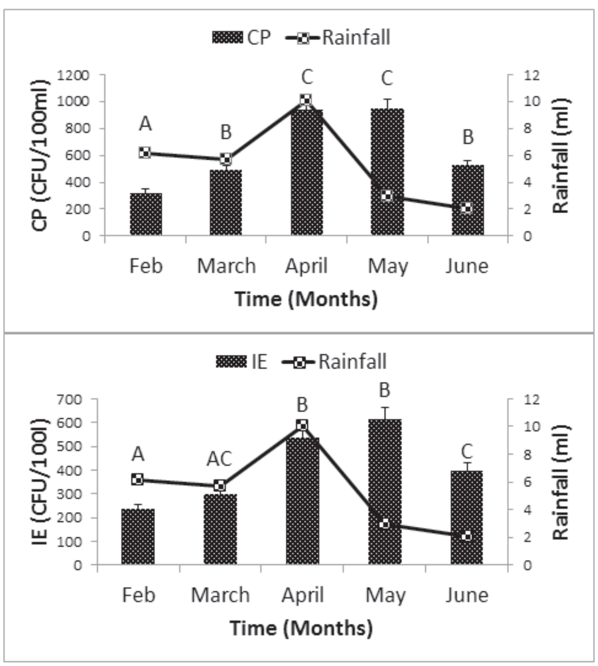

Fig. 4. Graphs showing variability in CP and IE based on sampling time and rainfall intensity.
IE (intestinal enterococci), CP (Clostridium perfringens). Time is in months (February, March, April, May and June). Vertical bars indicate standard error of mean and sites with significant mean differences are shown by different letters at P<0.05.

IE (intestinal enterococci), CP (Clostridium perfringens). Time is in months (February, March, April, May and June). Vertical bars indicate standard error of mean and sites with significant mean differences are shown by different letters at P<0.05.

Detection of *salmonella* spp

The results of *salmonella* spp. detection are as shown in Table 1. All the samples from Site 1 were free from *salmonella* spp. while all the remaining other samples indicated presence of *salmonella* spp. at particular sampling dates.

From all the sites*salmonella* spp were detected in 58 out of a total 80 samples. This gave 72.7% pollution level by *salmonella* spp. while only 27.5% of the samples were free of this disease causing pathogen (Fig.5).

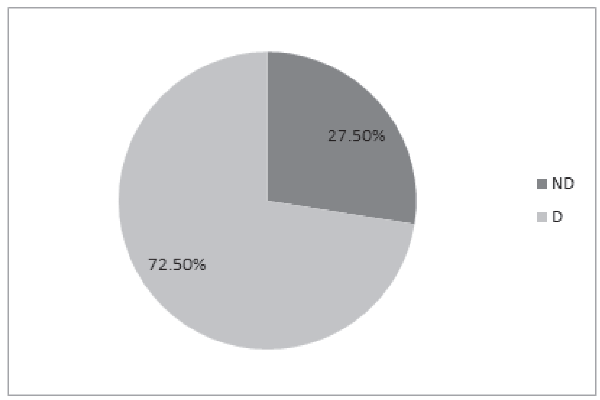

Fig. 5. Percentage of samples polluted by *salmonella* spp. *ND= Not detected/not polluted, D= Detected/polluted.*

Variation in indicators of organic pollution

Monthly variations in the values of HPC and BOD are shown in Fig.6. For all the parameters, there was a clear indication in the difference in values sampled in different months based on rainfall intensity. HPC showed significant variation with respect to month of sampling (February, March, April, May and June 2012), F= 7.496, P= 0.000 and df= 4 and 239. BOD also showed significant statistical variation with respect to sampling months, F= 84.861, P= 0.000 and df= 4 and 239.

DISCUSSION

Variation of faecal contamination indicators

All the feacal contamination indicator organisms had low mean values in samples obtained during

Table 1. Results of the *salmonella* spp. detection from different sites at different sampling dates and rainfall intensities

Sampling date	Average Monthly Rainfall Intensity	SITES							
		1	2	3	4	5	6	7	8
04/02/2012	6.0 mL	ND	ND	ND	ND	ND	ND	ND	ND
25/02/2012		ND	ND	ND	ND	ND	ND	ND	ND
10/03/2012	5.8 mL	ND	ND	ND	ND	ND	ND	ND	ND
24/03/2012		ND	D	D	D	D	D	D	ND
07/04/2012	10.0 mL	ND	D	D	D	D	D	D	D
21/04/2012		ND	D	D	D	D	D	D	D
05/05/2012	3.0 mL	ND	D	D	D	D	D	D	D
19/05/2012		ND	D	D	D	D	D	D	D
02/06/2012	2.1 mL	ND	D	D	D	D	D	D	D
16/06/2012		ND	D	D	D	D	D	D	D

ND= Not Detected and D= Detected.

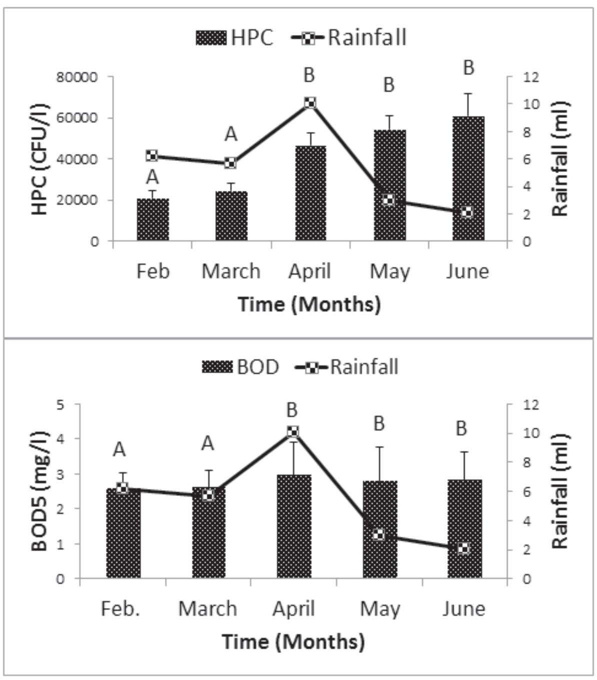

Fig. 6. Graphs showing variability in HPC and BOD based on sampling time and rainfall intensity.*Time is in months (February, March, April, May and June), Vertical bars indicate standard error of mean and sites with significant mean differences are shown by different letters at P<0.05.*

the months of February and March, the month of April had the highest while in May and June the values were higher. The highest values in April were due to increase in rainfall intensity which resulted to overland flow sweepingfeacal wastes from the bushes and flooded urban centers into the river. In the month of May and June, there was reduction in rainfall intensity, this consequently resulted to lowering ofmean values of feacal contamination indicator organisms.It was found that the presence of surface run offs as a result of rain do lower the densities of these faecal contamination indicators if rains are prolonged. Studies have revealed that the city sewage discharge agriculture and urban run-off were affecting the water quality of Shatt Al Hilla River in Iraq (Fikrat*et al.*, 2007). However, a study on River Brada had the opposite finding where there was existence of many forms of bacteria especially during rainy season. This could have probably been caused by sampling immediately after a rainfall event.It had also appeared that in-stream *E.coli* re-growth is a seasonal pattern and therefore could be contributing to its temporal variation (Cooperative Research Centre for Fresh Water Ecology [CRCFWE] 2001). Another study on the effects of time and watershed characteristics on the concentration of *Cryptosporidium* Oocysts in River Water had actually confirmed time as one of the factors influencing the density variation of microbes. In that study, the results and the discussion led to several conclusions. One of the conclusion was that*Cryptosporidium* oocysts were present in river water of both inhabited and uninhabited areas at concentrations above the detection ability of the study method used i.e., about 0.05 to 0.15 oocysts per liter. It also concluded that Oocyst concentrations in watersheds of appreciable size were continuous as opposed to intermittent seasonal factors, including runoff of land drainage. These factors may affect oocyst concentrations by 10-fold. The character and intensity of both human and domestic animal activities in a watershed was also found to affect oocyst concentrations in the surface water by as much as 10- to 15-fold. Final conclusion in that study was thatpublic water supply watershed management practices of limiting human activity may reduce oocyst concentrations by as much as fivefold (John and Jerry, 1991).A similar study on microbial load of drinking water reservoir tributaries during extreme rainfall and runoff highlighted that for every situation at a watercourse an individual analysis had to be carried out, taking into account geo-ecological conditions in catchment areas as well as variability in precipitation and runoff. Additionally, it was important to evaluate systematically the environmental conditions of the catchment areas and their roles in microbial contamination of surface water as well as routine analytical monitoring of chemical and microbial parameters of water samples (Kistemann*et al.*, 2002).However, the findings of this study on Nyangore River that the precipitation intensity shown a positive contribution to microbial load was not supported by that argument. Indeed, a clear influence of rainfall effects could have been noted if the frequency of sampling was increased during rainy days.

Detection of *salmonella* spp

Salmonella species are pathogenic microorganisms with potential of causingtyphoid in human beings (Nye *et al.*, 2002). Even though, *Salmonella* spp. were found to be present in majority of samples obtained from different sites, their presence did not show reliance on the rainfall intensity.This result was an indication of how risky it would be to use the water from this river for human consumption without proper purification. In addition, it also points out that there is high contamination rate of the water in this river by faeces from ill individuals or healthy carriers as evidenced by the presence of raw sewage discharge from the hospital and other settlements. Nyangores River may therefore stand a chance of inhabiting other disease causing microorganisms which were not considered under this study. The absence of *Salmonella* spp in samples obtained during wet period could be due to their low densities; this could not be detected in 100 mls samples. Based on the presence of *Salmonella* Spp together with faecal contamination indicator organisms (*E. coli, C. perfringens* and intestinal enterococci) it shows that these indicators are adequate tools in studying the safety of river water for human consumption.

The microbial quality of Alcantara estuarine waters had also appeared to be strongly influenced by the contributions of domestic and agricultural waste, discharge of effluents from wastewater plants, and several feacal sources. The presence of bacterial pathogens in the Alcantara estuarine waters not only showed a major health concern, but also might had prevented the utilization of these waters for important economic resources, such as fishing, aquaculture and mussel farming (Concetta *et al.*, 2009). The same result had also been found by (Marrita and Okemo, 2008), who showed that thecorrelation of faecalcoliforms with *Salmonella* sp. and *Vibrocholerae* was 85% and 2% respectively. For the faecal streptococci, correlation with*Salmonella* sp. and *V. cholerae*was 78% and 12% respectively. This indicated that faecal streptococci should be included asindicatororganisms of the potential health hazards of polluted water. Most international drinking water quality guidelinesand standards include bacterial indicators as a measure of microbial water quality, and for compliance reporting. Theresults from the study of the bacteriological quality of Nyangores River support the idea of using both the faecal streptococci and coliforms as indicators of faecal pollution.

Variation in indicators of organic pollution

The presence of temporal variation in the densities of organic pollution indicators where dry season had higher density values for indicators of organic pollution than wet season was an indication that seasonality in precipitation has a role in the amount of organic pollution being found in a water body. Much of the organic pollutant is getting swept from the allochthonous sources and brought into the river by surface run off but the dilution effect lowers the density of these parameters. A seasonal change had also been observed by (Etleva*et al.*, 2012), in their study of VjosaRiver. This study showed that for every situation at a watercourse an individual analysis has to be carried out, taking into account geoecological conditions in catchment areas as well as variability in precipitation and runoff. It is important to evaluate systematically the environmental conditions of the catchment areas and their roles in microbial contamination of surface water, in addition to routine analytical monitoring of chemical and microbial parameters of water samples. In addition, another study on the bacterial indicators of faecal contamination which was done at the source of Gangetic River system had also factored in the effect of pollutant variability on the level of pollution indicators. It involved studies on microbial ecology in the runoff of the glacier in relation to pollution levels. It clearly revealed that there was significant presence of bacterial indicators of faecal pollution in middle and lower stretch. That situation of Gangotri glacier was not very serious but alarming. Presence of bacterial indicators of faecal contamination in different altitudes of runoff of Gangotri glacier clearly revealed the bacteriological status of the water at various sites in various times (Vinay *et al*., 2005).

CONCLUSION

The variation inabiotic factors plays a greater role on the level of faecal contamination. Based on the results from this study, it is evident that apart from poor faecal waste disposal practices, rainfall intensity also equally plays significant role in determining the concentration of disease causing faecal microorganisms and other organic contaminants into water. The level of contamination tend to be highest during heavy rains, however, the low water volume during dry seasons also result to rise in concentration per water volume for these contaminants. Therefore any bacteriological water quality treatment measure needs take into account the intensity of rainfall. This will provide adequate knowledge on the appropriate treatment approach to apply for efficient water quality improvement. Based on this,it is recommended that proper sewage treatment facilities should be put up in the existing homes, towns and hospitals. Consequently, rainfall events also need to be put into consideration when carrying out water quality management, this will enhance efficient elimination of disease causing microorganisms in water sources and reduce the likelihood of disease outbreak. The ultimate result will be improved ecological integrity of River Nyangoesand consequently result to restoration of its ecological services and ecosystem health.

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