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Microbiological Water Quality of Urban Streams and the Health Implications: Case Study of Sosiani River Eldoret Municipality, Kenya

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Abstract
This study sot to assess the seasonal and longitudinal variations in microbiological properties of water quality in Sosiani River and the health implications on the residents of Eldoret Municipality, Kenya. In an experimental design, water samples were collected upstream midstream and downstream of Eldoret town from 13 effluent discharge points for a period of one year during the dry and wet seasons. Samples were analysed using APHA, 2012 water sampling procedures. Survey data on waterborne diseases was collected from the two government hospitals in Eldoret town: MTRH and Uasin Gishu County Hospital. Results were analysed using SPSS version 20 for ANOVA and correlation analysis. Sosiani River exhibited high mean levels of faecal and total coliform (1708.96CFU/100ml and 776.76CFU/100ml respectively) above WHO/NEMA standards of nil CFU/100ml. Faecal coliform varied significantly downstream ($F=77.89$ $P< 0.001$) just like the total coliform ($F=93.92$ $P<0.001$). Total and faecal coliform increased significantly during the wet season ($P<0.17$, $P< 0.039$ respectively). The coliform content showed a positive significant correlation with waterborne diseases which were identified as diarrhoea, typhoid and dysentery. The study concludes that water from Sosiani River is polluted and is not suitable for human consumption and or recreation purposes. Water sourced from Sosiani River should be treated before consumption.
Keywords: Sosiani River, Microbiological water quality, Faecal and total coliform, waterborne diseases

1. Introduction

Anthropogenic activities alter the natural composition of water through disposal of chemicals and microbial matter, wastes, municipal effluent, industrial discharges, urban activities, affecting water quality (Shaw, 2004; Moyo, 2013; Van, 2013). Contaminated water contains pathogenic bacteria which cause waterborne diseases like diarrhoea, typhoid, dysentery, poliomyelitis, respiratory diseases, meningitis, hepatitis and cholera. In addition, water related diseases like: malaria, yellow fever and filariasis are transmitted by insects that have aquatic larvae (Burton & Robert, 2001; WHO, 2004).

In this regard, nearly 500 million people lack access to safe drinking water worldwide. This accounts for the deaths of more than 14,000 people daily (EPA, 2007), not to mention four million cases of diarrhoea with a corresponding 2.2 million infant mortality deaths for children under age of five years (WHO, 2007). It is also reported that 10 per cent of the people living in the developing world have intestinal worms due to contaminated water (WHO, 2004). In Africa alone, over 300 million people lack access to safe drinking water while 85 per cent of diseases in children under the age of 5 years are attributed to waterborne diseases (WHO, 2004).

Microbiological analysis of water samples focused on faecal and total coliforms as indicators of pathogenic bacteria in the water. Total coliform and faecal coliform tests are a primary indicator of potability or suitability of water for consumption (Prasai, 2007). Coliform was used as an indicator of pathogens since they are easy to isolate and enumerate (Chandra *et al.*, 2006 and Ashbolt, 2004). They are present in intestines of warm blooded animals hence their presence in water is an indicator of faecal matter and pathogens.

2. Materials and Methods

This study used an experimental design along Sosiani River which traverses Eldoret town in Uasin Gishu County of Kenya. Sampling points were selected from effluent discharge points upstream midstream and downstream of Eldoret town (Figure 1). This river originates from two river dam in Kaptagat a confluent of two streams Elengerini and Endoroto whose source is Kaptagat Forest (Figure 1). Sosiani River then flows through Eldoret town and discharges into Kipkaren River in Turbo which subsequently drains into Nzoia River. The larger Nzoia River Basin then drains into Lake Victoria the second largest freshwater Lake in the world (RoK, 2013). Eldoret town lies between latitude 00^0 03´S and 0^0 55 ´N and longitudes 34^0 50 ´E and 35^0 17 ´E (RoK, 2013).

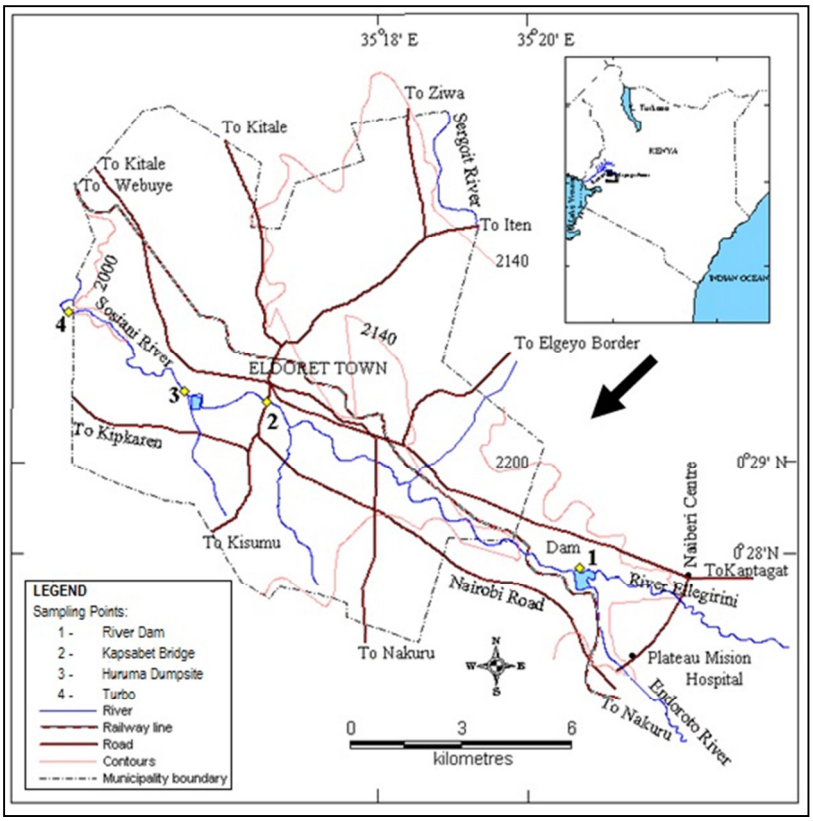

Figure 1: Map showing flow of Sosiani River
Source: Moi University Geography Department, 2015

Composite water samples 200ml were collected during the dry and wet season from 13 sampling sites, upstream, midstream and downstream of Eldoret town for a period of one year. These were identified as point sources of effluent discharge along the river. Total and Faecal coliforms were measured in accordance with Standard Method 9222D, the membrane filtration technique. Red colonies indicated total coliforms while the blue colonies indicated Faecal coliform and were reported as colony forming units (CFU) per 100ml of water. Data on trends in waterborne diseases in Eldoret municipality were collected from Moi Teaching and Referral Hospital (MTRH) and Uasin Gishu County hospitals with the help of prepared checklists. The two hospitals are the main government institutions in Eldoret town serving the area residents.

3. Results and Discussion

Sosiani River traverses Eldoret town draining effluent discharged from several anthropogenic activities. This includes Huruma dumpsite and Huruma sewage treatment plant (Plate 1).

Plate 1: Sosiani River between Huruma Dumpsite and Sewage plant
Source: Survey Data, 2016

Table 1 Mean variation of Coliforms along Sosiani River

Sampling points	TC (CFU/100ml)	FC (CFU/100ml)
Two River Dam	6.9±0.9d	6.5±1c
Zena Flowers	740.8±70.1cd	112±12.3c
Sukunanga Car Wash	54.3±5cd	23.9±3c
Munyaka Stream	126.4±14.3cd	52.4±6.4c
Car wash at Naivash	7907.2±730.3a	5351.1±562.9a
Kapsabet bridge	4526±363.5b	2809.3±291.1b
Oldonyo dairies	963.8±68.8cd	260.9±25.8c
Kipkaren bridge	827.8±75.6cd	74.3±10.2c
Raiply effluent	428.7±33.4cd	22±3c
Bondeni Estate	4672.4±353.8b	397.1±38.8c
Huruma sewage	1211±97.7b	789.4±83.4c
Huruma dumpsite	486.3±39.3cd	160.7±18.6c
Turbo	264.9±23.1cd	38.3±4.5c
F value	93.92457	77.89728
p value	<0.001	<0.001

3.1 Total coliform

Microbial analysis revealed that on average there were high levels of mean total and faecal coliform (1708.96CFU/100ml and 776.76CFU/100ml respectively) in Sosiani River above NEMA standards of nil CFU/100ml (Figure 2). Hence this water is not suitable for human consumption or for recreation purposes (recommended limit 500CFU/100 ml).

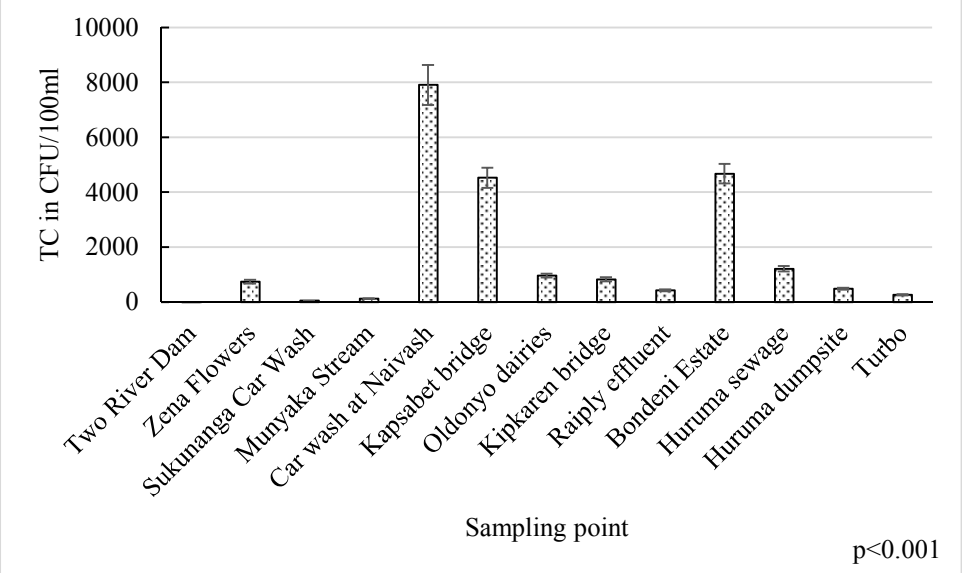

Figure 2: Variations in Total coliform along Sosiani River

Source: Survey Data, 2016

Total coliform varied significantly along the river course (F=93.92 P<0.001). The highest mean total coliform content was recorded at Naivash car wash effluent discharge point 7907.2±730.3CFU/100 ml (Figure 2). This was followed by samples at Bondeni estate discharge point (4672.4±353.8CFU/100ml) and Kapsabet Bridge (4526±363.5CFU/100ml) which varied significantly from all the other sampling sites. This is attributed to poor faecal matter disposal hence poor sanitation at Naivash car wash and Bondeni slums. At Kapsabet Bridge Street children living under the bridge use the river as a public toilet and dumpsite. The lowest total coliform concentration was at Two River Dam which is fenced and protected from encroachment. The total coliform varied significantly with changing season P<0.17 (Figure 3).

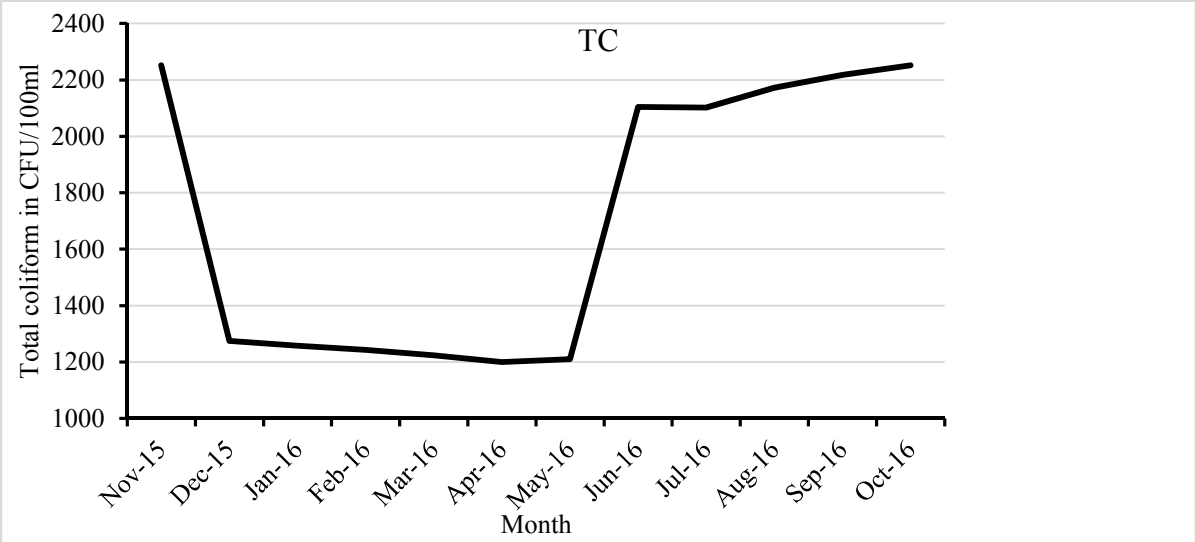

Figure 3: Monthly variations in total coliform
Source: Survey data, 2016

3.2 Faecal coliform

Faecal coliform also varied significantly downstream (F=77.89 P< 0.001). The highest mean faecal coliform content was recorded at Naivash car wash discharge point 5351.1±5262.9CFU/100ml. This was followed by samples from Kapsabet Bridge discharge point 2809.3±291.1CFU/100 ml and Huruma sewage treatment plant discharge point 789.4±83.4CFU/100ml (Figure 4; Table 1).

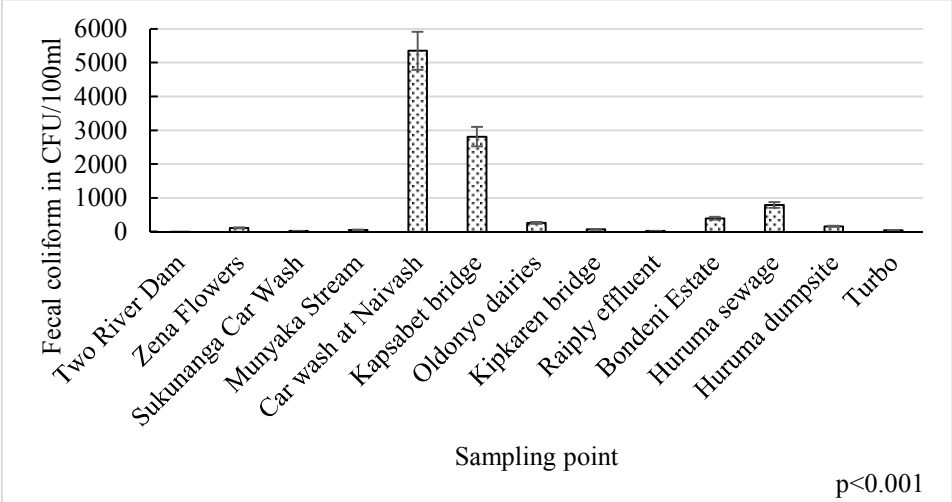

Figure 4: Variations in Faecal coliform along Sosiani River
Source: Survey Data, 2016

The high levels of faecal coliform are similarly attributed to poor sanitation, lack of public toilets, leaking sewers. This is also linked to high levels of total suspended solids. The lowest faecal coliform along river Sosiani was recorded two river dam. Faecal coliform at Sukunanga car wash and at Kipkaren Bridge was not significantly lower than that at Rai plywood and at Turbo. The Faecal coliform increased significantly during the wet season P< 0.039 (Table 2; Figure 5).

Table 2 Seasonal comparison Coliform content

Parameter	Dry	Wet	Mean difference	t value	Sig. (2-tailed)
TC	1234.8	2183.1	-948.2	-2.42*	.017
FC	508.5	1045.0	-536.5	-2.08*	.039

*. Means are significantly different at 0.05
**. Means are significantly different at 0.01

Table 3 Mean monthly variations of coliforms in Sosiani River

Month	TC	FC
November	2251.77±893.09	1086.85±603.54
December	1274.77±497.73	523.92±290.13
January	1257.77±490.76	516.23±286.77
February	1242.77±485.35	510.23±284.9
March	1223.77±476.92	500.92±281.97
April	1200.38±464.51	497.85±281.56
May	1209.62±466.05	501.92±281.78
June	2103.69±848.34	993.08±565.71
July	2101.92±848.29	1001.77±566.67
August	2172.31±855.27	1040.08±585.24
September	2217.08±881.93	1061.46±594.02
October	2251.77±893.09	1086.85±603.54
Annual average	1708.97±199.28	776.76±130.1
F value	0.5	0.37
p value	0.9	0.965

Source: Survey Data, 2016

In general, the total and faecal coliform content of Sosiani River were extremely high than the recommended guidelines for drinking water, irrigation and recreation purposes by NEMA and WHO standards. Total coliform was higher than faecal coliform in all sampling sites. The total and faecal Coliforms were highest during the rainy season which is attributed to increased surface run off which drains faecal matter and waste into the river. There is poor sanitation and faecal matter disposal in unplanned settlements of Huruma, Bondeni and Langas. High faecal coliform counts have been positively related to poor urban planning and development, inadequate provision of sewer services and poor waste management (Mehaffey *et al.*, 2005).

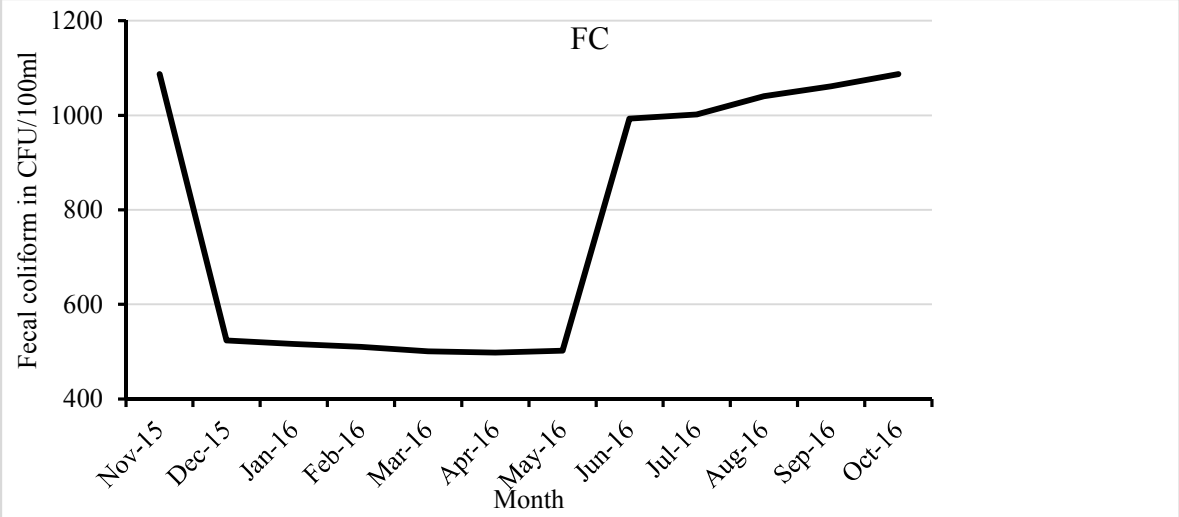

Figure 5: Monthly variations in faecal coliform

Source: Survey data, 2016

Bacterial counts in rivers tend to increase during high flows and decrease during base flows as a result of surface runoff (Medema *et al.*, 2003). A significant source of pollutants in rivers and streams increases with storm water runoff which can include sediments and bacteria (Malin *et al.*, 2000). The high density of coliform was also linked to high TSS levels. The suspended particles facilitate their survival and growth as the particles protect them from attack by bacteriophage and UV-radiation and provide organic and inorganic nutrient and attachment areas to the bacteria.

3.3 Waterborne diseases

Survey of medical data indicates that prevalent waterborne diseases in Eldoret are respiratory diseases especially upper tract infections, diarrhoea, dysentery and typhoid. There were no cases of Poliomyelitis and meningitis recorded in Uasin Gishu County hospital in the last 7 years and hepatitis is a rare occurrence. However, a few cases of hepatitis and meningitis have been reported at Moi Teaching and Referral Hospital. High incidences of respiratory diseases are also attributed to high altitude and cold temperatures which predispose the residents to infection.

3.3.1 Annual Trends in Waterborne diseases

Records from Moi Teaching and Referral Hospital (MTRH) and Uasin Gishu County Hospital (UGH) indicate that cases of waterborne diseases especially diarrhoeal diseases have been on the increase in the last seven years. These waterborne diseases are associated with poor sanitation and hygiene and use of contaminated water. Waste is openly dumped in Huruma where the local residents scavenge for food and livelihood on the banks of Sosiani River. Sanitation and hygiene is poor in unplanned settlements of Huruma, Langas, Kamukunji and Bondeni where sewer connectivity is very low 4-5% (RoK, 2013). Leachates from Huruma dumpsite drain into Sosiani River while Huruma sewage treatment plant discharges poorly treated effluent into the river affecting the physicochemical and microbiological water properties. The high faecal and total coliform in this river is an indicator of presence of pathogenic bacteria which cause waterborne diseases. There has been an increase in incidences of waterborne diseases treated at MTRH and Uasin Gishu annually between 2010 and 2016 (Figures 6 & 7).

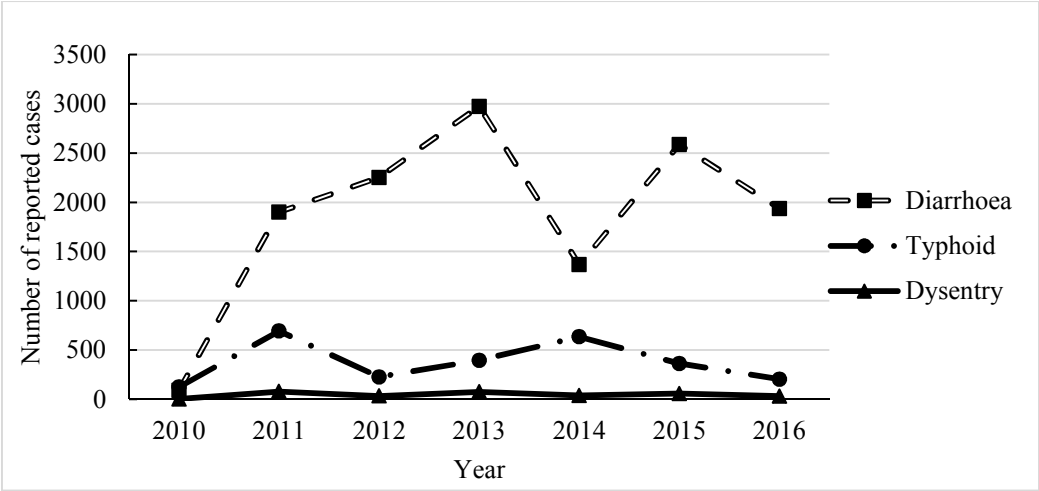

Figure 6: Annual Trends in waterborne diseases from MTRH
Source: MTRH, 2017

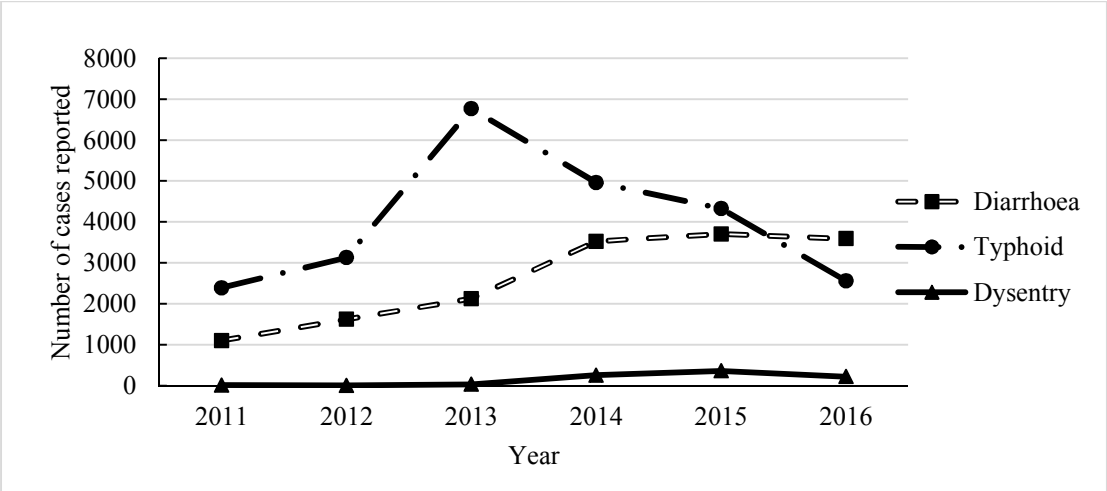

Figure 7: Annual trends in waterborne diseases at UGH
Source: Uasin Gishu County Hospital, 2017

3.3.2 Monthly trends in waterborne diseases

The common waterborne diseases recorded at MTRH and UGH during the period of study in 2016 were diarrhoea, dysentery and typhoid. However Poliomyelitis, cholera, meningitis and hepatitis were very rare diseases in Eldoret municipality. Monthly records indicate that cases of waterborne diseases increased with the onset of the wet season from May to September (Figures 8 & 9). This can be attributed to increased surface run off which drains open sewage and faecal matter into Sosiani River hence increasing faecal coliform content. However towards the dry season October to February the incidences subside. There was a positive correlation between spread of waterborne diseases and faecal coliform which varied with the onset of the rain season. Analysis of data from Uasin Gishu Hospital showed that there was a strong positive correlation between Faecal

coliform and cases of diarrhoea (r=0.513, P<0.05) typhoid (r=0.470 P<0.05) Dysentery (r= 0.544 P<0.05) Intestinal worms (r=0.746 P<0.01). However there was no significant correlation between Faecal coliform and Hepatitis (r=0.026 P<0.05) and respiratory diseases (r=0.164 P< 0.05). There were no cases of cholera meningitis and poliomyelitis hence no correlation (Table 4).

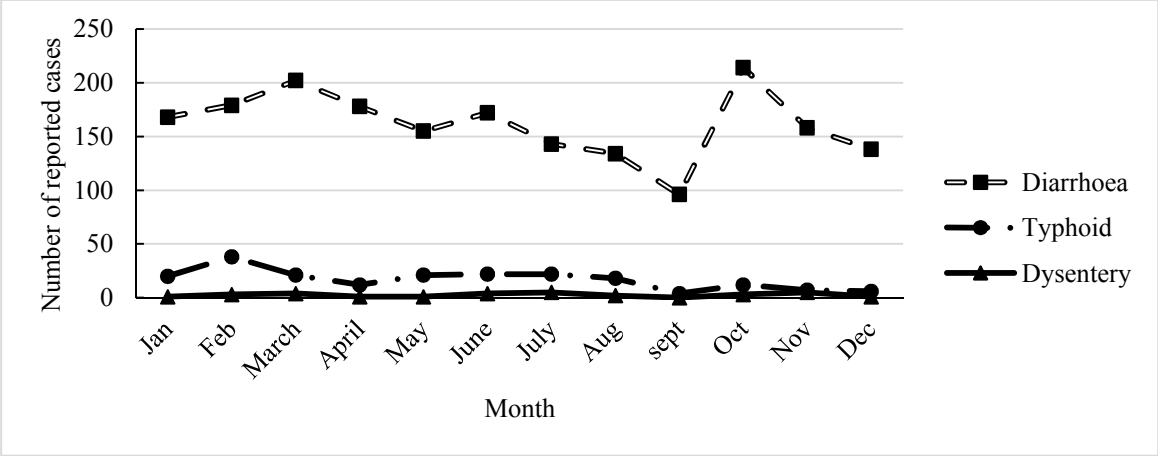

Figure 8: Monthly trends in waterborne diseases at MTRH
Source: MTRH, 2017

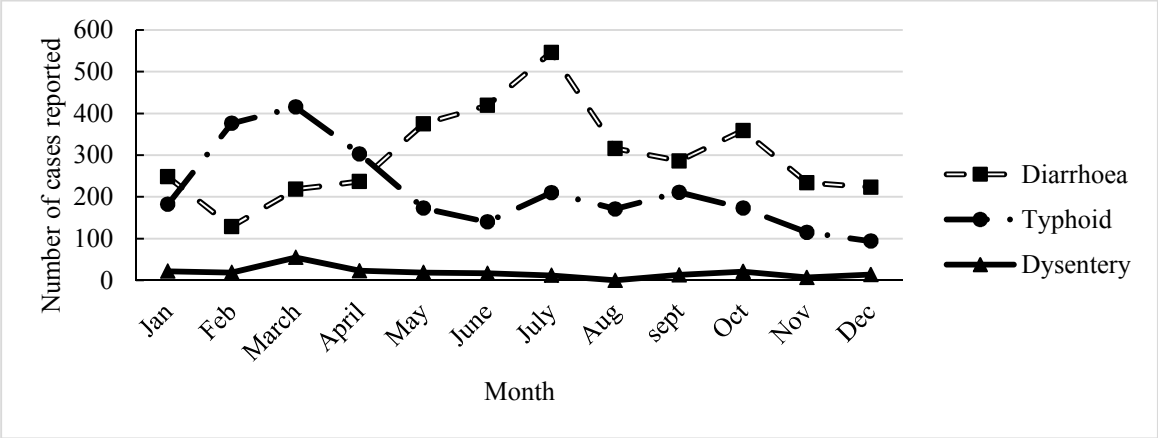

Figure 9: Monthly trends in waterborne diseases at UG Hospital
Source, Uasin Gishu Hospital, 2017

Correlation Analysis of waterborne diseases and faecal coliform

Table 4: Correlation between coliform and water borne diseases

	Moi Teaching and Referral Hospital		Uasin Gishu Hospital	
Disease	TC	FC	TC	FC
Cholera	.[b]	.[b]	.[b]	.[b]
Diarrhoea	.277	.274	.509	.513
Typhoid	.352	.353	.473	.470
Dysentery	.378	.378	.543	.544
Poliomyelitis	.[b]	.[b]	.[b]	.[b]
Meningitis	.152	.164	.[b]	.[b]
Hepatitis	.017	.018	.016	.026
Other diseases of respiratory system	.086	.087	-.161	-.164
Intestinal worms	.544	.547	.748**	.746**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

b. Cannot be computed because at least one of the variables is constant.

Source: Survey data, 2017

These waterborne diseases could be attributed to use of contaminated water from Sosiani River. Sewage connectivity in Bondeni, Kamukunji and Huruma is poor 4-5% (RoK, 2013). At the same time the capacity of Huruma sewerage treatment plant is only 11,000m^3 of waste water per day hence it is overloaded. This implies wastewater holding time is limited which results into discharge of poorly treated waste water into River Sosiani. This increases pathogenic bacteria in water responsible for diarrhoeal diseases. A discussion with the County Director Public Health indicates that the only time cholera was reported in Eldoret municipality was in 2008 during the post election violence that saw the death of 50 people. This was attributed to poor living conditions, hygiene and sanitation in IDP (internally displaced persons) camps following the post election violence.

These findings are consistent with studies in Njoro River Watershed which established that Nakuru, Molo and Njoro Districts are endemic for diarrheal diseases as a result of poor water supply conditions (Tiwari & Jenkins, 2008). Major enteric diseases faced by residents of Njoro include; cholera, hepatitis, amoebiasis, bacillary dysentery and salmonellosis (Kimani& Ngindu, 2007; Kinuthia *et al.*, 2012). These findings are also consistent with Al-Bayatti *et al.*, (2012) who observed that Al-Shula region had prevalence of diarrheoa cases attributed to high total coliform 1795-63,000CFU/100ml and E. coli 385- 39,000CFU/ 100ml. A study on quality of water slum dwellers use in Langas, Eldoret revealed that 95% of the residents use wells as a source of drinking water which is polluted by faecal coliforms from nearby toilets (Kimani *et al.*, 2007).

4. Conclusions

Sosiani River exhibited high levels of mean total and faecal coliform above the National Environment Management Authority (NEMA) and WHO standards. The faecal coliform and total coliform increased midstream the river within Eldoret town and with the onset of the rainy season but further declined downstream the river in Turbo town. Perhaps this is an indicator of self cleansing ability of this stream. Hence we conclude that the microbial characteristics exhibited spatial temporal variations along Sosiani River and with changing seasons. Survey of medical data indicates that the common waterborne diseases in Eldoret Municipality are diarrhoea, dysentery and typhoid however poliomyelitis, cholera, meningitis and hepatitis are rare waterborne diseases in Eldoret municipality. There was a significant positive correlation between faecal coliform and waterborne diseases which increased with the rainy seasons. Surface runoff increases sediments and coliform in the river which exposes residents to waterborne diseases. The study concludes that water from Sosiani River is polluted and not suitable for human consumption and or for recreation purposes and perhaps this explains why diarrhoea dysentery and typhoid have been on the increase in the last seven years in Eldoret Municipality.

5. Recommendations

This study recommends that residents of Eldoret and Turbo towns and all those living along the riparian corridor of Sosiani River should treat drinking water sourced from Sosiani River due to high coliform content. Water treatment could be by filtration, boiling and adding sodium hypochlorite solution. The County government NEMA and Water resource Management Authority (WRMA) should enforce waste water management regulations which require all facilities discharging effluent to construct wetlands and frequently monitor the effluent discharge points monthly. The County government should extend the sewer services in informal settlements along Sosiani River like Langas and Huruma and build communal ablution blocks to increase sanitation and hygiene. Facilities encroached on the riparian corridor of 30m should be relocated including the street families living under Kapsabet Bridge on Sosiani River who use it as a public toilet. The County government, Public Health Department, ELDOWAS, NEMA and all stakeholders should enhance community education and public awareness on proper hygiene and sanitation practises and involve the residents in river cleanup activities.

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References

Al-Bayatti, K. A., Al-Arajy, K. H. & Al-Nuaemy, S. B.(2012). Bacteriological and Physico Chemical Studies on Tigris River near the Water Purification Stations within Baghdad Province, *Journal of Environmental and Public Health*, 2012, 1-8.

Ashbolt, N. J. (2004). Microbial Contamination of Drinking Water and Disease Outcomes in Developing Countries, *Journal of Toxicology*, 1, 229–238

Burton, A. Jr.,& Robert, P.(2001). *Storm Water Effects Handbook: A Toolbox for Watershed Managers,*

Scientists, and Engineers, New York, Lewis Publishers.
Chandra, R., Singh, S., & Raj, A.(2006). Seasonal Bacteriological Analysis of Gola River Water Contaminated with Pulp Paper Mill Waste in Uttaranchal, India, *Environ. Monit. Assess*, 118, 393–406.
EPA,(2007). Washington, DC "The National Water Quality Inventory: Report to Congress for the 2002 Reporting Cycle – A Profile." October 2007.
Kimani, M., Wambui, E.,& Ngindu, A. M.(2007). Quality of Water the Slum Dwellers Use: The Case of a Kenyan slum. *Journal of Urban Health*, Bulletin of the New York Academy of Medicine, 84 (6), 829-838.
Kinuthia, G. K., Afolayan, F. I. D., Ngure, V., & Anjili, C. O.(2012). Selected Practices among Rural Residents Versus the Prevalence of Amoebiasis and Giardiasis in Njoro District, Kenya, *African Journal of Health Sci,* 20, 11-20.
Mallin, M. A., Williams, K. E., & Cartier, E. E.(2000). Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds, *Ecological Applications*, 10 (4), 1047-1056.
Medema, G. J., Shaw, S., Waite, M., Snozzi, M., Morreau, A., & Grabow, W.(2003). Catchment Characterization and Source Water quality: In Dufour, A., Snozzi, M., Koster, W.(Eds).*Assessing Microbial Safety of Drinking Water: Improving Approaches and Methods,* WHO, OECD, London, 111–158.
Mehaffey, M. H., Nash, M.S.,& Wade, T. G.(2005). Linking Land Cover and Water Quality in New York City Water Supply Watersheds, *Environment Monitoring and Assessment*, 107, 29-44.
Moyo, N.A. G. (2013). An Analysis of the Chemical and Microbiological quality of Ground Water from Boreholes and Shallow Wells in Zimbabwe, *Phys. Chem. Earth*, 66, 27–32.
Prasai, T. (2007) *Microbial Analysis of Drinking Water for Kathmandu Valley* Nepal, Kathmandu, Nepal, Academy of Science and Technology.
RoK, (2013). *Uasin Gishu County Development Profile*, Government printers, Nairobi.
Shaw, E. (2004). *Hydrology in Practice*, London Stanley Thornes publishers.
Tiwari, S. K. & Jenkins, M. W.(2008). Point-of-use Treatment Options for Improving Household Water quality among Rural Populations in the River Njoro Watershed, Kenya. Research Brief 08-02-SUMAWA; Global Livestock Collaborative Research Support Programme, University of California, Davis: April 2008. http://glcrsp.ucdavis.edu/publications/SUMAWA/08-02-SUMAWA.
Van Vuuren, L. (2013) Institutional Conundrum Sinking Groundwater Supply in North West Town, *Water Wheel*, 12, 17–19.
WHO,(2004). Report on Water, Sanitation and Hygiene Links to Health, Geneva, WHO.
WHO,(2007). Combating Waterborne Diseases at the Household level: World Health Organization Report; Geneva, WHO.

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