Seasonal and Longitudinal Variations of Water Quality in an Urban Stream: Case Study of Sosiani River Uasin Gishu County, Kenya

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Abstract
The study sought to analyse longitudinal and seasonal variations in physico-chemical properties of water quality in Sosiani River in Eldoret town, Kenya. An experimental design was used to collect water samples upstream midstream and downstream of Eldoret town for a period of one year during the dry and wet seasons. Samples were collected from effluent discharge points in accordance with APHA, 2012 water sampling procedures. Sosiani River exhibited significant variation in physico-chemical water parameters along the river and during rainy seasons. TSS varied significantly across the river at F= 185.52 P < 0.001 and during the wet season (P< 0.045). TDS varied significantly along the river (F= 59.0129 at p<0.001) with a significant positive correlation at P< 0.001 during wet season. Turbidity varied significantly along the sampling points F= 32.41 P< 0,001 and varied significantly p<0.028 during the rainy season. BOD varied significantly along the river (F= 78.95 & P < 0.001) with a significant positive correlation P<0.038 during the rainy season. COD varied significantly along the river (F=77.64 & P<0.001) and during wet season. Water temperature varied significantly along the river (F=185.52, p<0.001) and with the onset of the rainy season (P<0.013). Water pH varied significantly along the sampling points (F= 159.85 & P <0.001). However, pH did not vary significantly during the wet season (P<0.616). This river is polluted, turbid with low dissolved oxygen and high BOD hence not suitable for aquatic life. However the water quality improves downstream perhaps due to self cleansing ability of the river. Hence the water is not suitable for human consumption and or recreation purposes. The water should be treated and municipal effluent channelled into effluent treatment works for pre-treatment.
Keywords: Sosiani River, physicochemical water quality, seasonal and longitudinal variations

1. Introduction

Rivers and streams are vital sources of fresh water for both domestic and industrial use. They provide livelihood, fresh water resources, water for irrigation and recreation purposes. Besides, they also play a key role in assimilation of municipal and industrial effluent through a complex process of influx of surface and ground water, hydrolysis, biological or chemical processes such as sedimentation, coagulation, volatization, precipitation of colloids and biological uptake (Edward, 2000; McKinney & Schoch, 2003;). However, they have become susceptible to pollution since water bodies are perceived to be limitless dumping grounds for wastes. As a result rivers are used as sinks for urban effluent hence a pathway for heavy metal translocation worldwide (David, 2008). Apparently, owing to the large quantity of effluent discharged to the receiving waters, the natural processes of pathogen reduction are inadequate to protect public health. Hence some rivers are unable to self purify as waters flow downstream (Alavi *et al.*, 2007; Maina *et al.*, 2010). By and large water pollution has become a major global problem as effluent management deteriorates. This is as a result of increasing populations, urbanization, industrialization and increased use of chemicals (Burton & Robert, 2001; Hogan, 2010).

Haphazard effluent discharge alters the physico- chemical and bacteriological properties of water which affects water use, ecosystem functions and human health. In light of this, water pollution can be defined as the change in physical, chemical and biological properties of water quality that has harmful effect on living things (WHO, 2003). It is a critical resource that supports life and makes up to 50-97 per cent of plant and animal weight and 70 per cent of human body (Goel, 2006; Hogan, 2010; WHO, 2011). Most water resources are polluted by non point source pollution where pollutants gradually diffuse or leach into rivers unlike point source pollution where pollutants are directly discharged from a single discrete source (Goel, 2006; Hogan, 2010). Ultimately water pollution exacerbates water scarcity as it limits the use by, and or imposes a higher cost for treatment on downstream users. Hence deteriorating water quality has become one of the most critical issues affecting both the developed and developing countries alike (WHO, 2007).

2. Materials and methods

This study was conducted along Sosiani River which traverses Eldoret town in Uasin Gishu County of Kenya. 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 discharges into Kipkaren River in Turbo which subsequently drains into Nzoia River a catchment of Lake Victoria the second largest freshwater Lake in the world (RoK, 2013). Eldoret town is located on a highland plateau rising upto 2080m above sea level which is then dissected by Sosiani River. The 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). Hence Eldoret town can be described as a river valley town. Sampling sites were selected at specific effluent discharge points at Zena flower farm, Sukunanga car wash, Municipal effluent discharge point at Kapsabet Bridge, effluent discharge point from Huruma dumpsite, Huruma sewage treatment plant and finally downstream in Turbo.

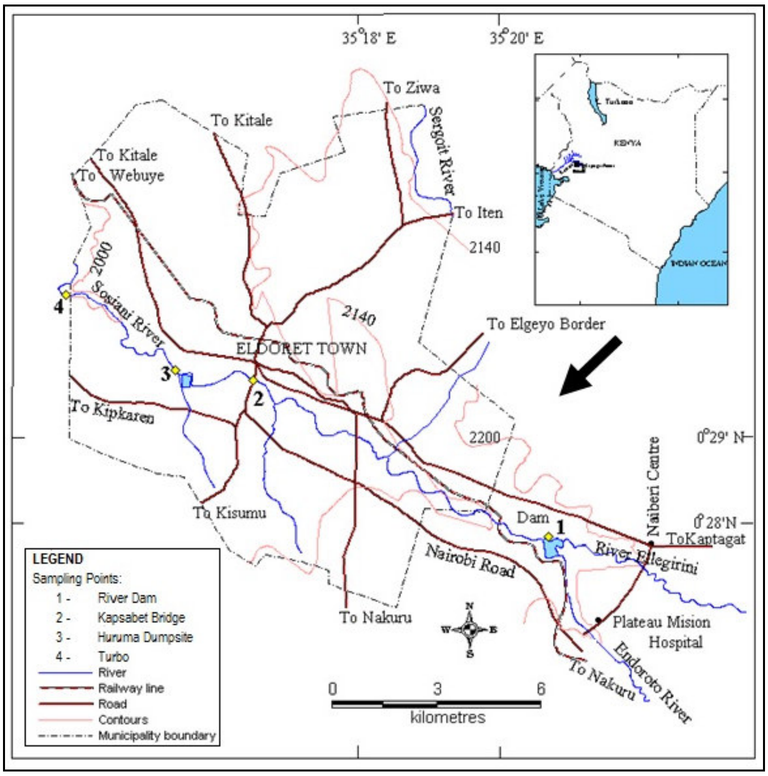

Figure1: Map showing flow of Sosiani River
Source: Survey Data, 2016

Composite water samples were collected every month from 13 effluent discharge points, upstream, midstream and downstream for a period of one year. Water samples were collected for TSS and TDS 1Litre, BOD 1Litre. They were refrigerated to minimize potential for volatilization or biodegradation. On the other hand in situ measurements were taken for pH and temperature using Wagtech international portable meter and turbidity using Hach 2100A Turbidimeter. Turbidity was measured 1m below the water surface to avoid ambient light. All sampling equipment were checked for any faults and calibrated with standard reference solutions to ensure accuracy. All parameters were analysed using APHA 2012 standard sampling procedures. Results were captured in excel spreadsheet and analysed for ANOVA and correlation analysis using SPSS software version 20.

3. Results and Discussion

Table 1: Means of physicochemical parameters along Sosiani River

Sampling points	Temp (°C)	pH	DO (mg/L)	Turb (NTU)	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	TDS (mg/L)
Two River Dam	20±0.5f	7.1±0ef	7.7±0.3bc	17.4±3.5b	39.6±5.9c	62.7±8.3de	5±0.8b	26.3±2.3e
Zena Flowers	19.9±0.4f	6.9±0.1f	2.5±0.1d	97.9±18b	47.6±7.3c	326±39.1cd	98.3±11.4b	89.4±7.9cde
Sukunanga Car Wash	22.6±0.3de	7.2±0.1de	8.1±0.3bc	12.2±2b	15.2±2.2c	24.1±3.2e	16.2±2.1b	33±4.2e
Munyaka Stream	23±0.3de	7.3±0.1cd	8.5±0.5bc	14.1±2.4b	14.1±1.1c	16.4±1.6e	53±7.1b	118.3±12.6c
Car wash at Naivash	27.2±0.2ab	6.9±0.1f	8.2±0.5bc	1686.4±289.4a	9±1.6c	484.6±51.8c	1261.9±180.7a	201.5±22.1b
Kapsabet bridge	19.6±0.1f	7.2±0de	8.9±0.3bc	15.3±2.8b	7.1±1.3c	22.4±3.7e	15.7±2.3b	42.6±4.7de
Oldonyo dairies	22.1±0.3e	6.6±0.1g	9±0.4bc	26.5±5.5b	8.2±1.1c	15.8±1.9e	53.2±6.6b	58±5.1cde
Kipkaren bridge	27.7±0.1a	7.5±0bc	9.7±0.6b	5.1±0.7b	6.4±1c	17.3±3e	26.3±3.8b	49.6±5.6cde
Raiply effluent	22.7±0.1de	7.2±0de	7.4±0.3bc	81.9±14b	474.1±50.8b	1619.1±161a	100±11.2b	318.1±26.2a
Bondeni Estate	25.5±0.2c	5.5±0h	8.3±0.8bc	98.3±13.5b	639.2±64.9a	1026.3±104.3b	39.4±6.2b	362.9±30.1a
Huruma sewage	26.3±0.2bc	8.2±0a	13.7±1.3a	11.7±2.1b	50.3±5.6c	63.2±7.4de	49.3±6.3b	319.8±25.1a
Huruma dumpsite	23.8±0.3de	7.6±0bc	7.4±0.4bc	34.4±6b	10.2±1.3c	43.6±5.3e	21.7±2.3b	108.4±10.9cd
Turbo	19±0.2f	7.1±0def	6.7±0.1c	8.2±1.6b	7.1±1.2c	15.6±2.1e	16.2±2.3b	73.4±7.3cde
F value	185.52	159.8511	18.94	32.41745	78.95591	77.64921	45.34272	59.0129
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means sharing the same letter are not significantly different

Source: Survey Data, 2016

The results of the physicochemical properties are presented (Table1).There was significant variation in physico-chemical water parameters along the river as more sediment is discharged. Further downstream the concentrations decreased which could be attributed to self cleansing ability of the river. Similarly there was significant variation in the physico-chemical properties during rainy seasons which can be attributed to increased surface runoff.

3.1 Total Suspended Solids

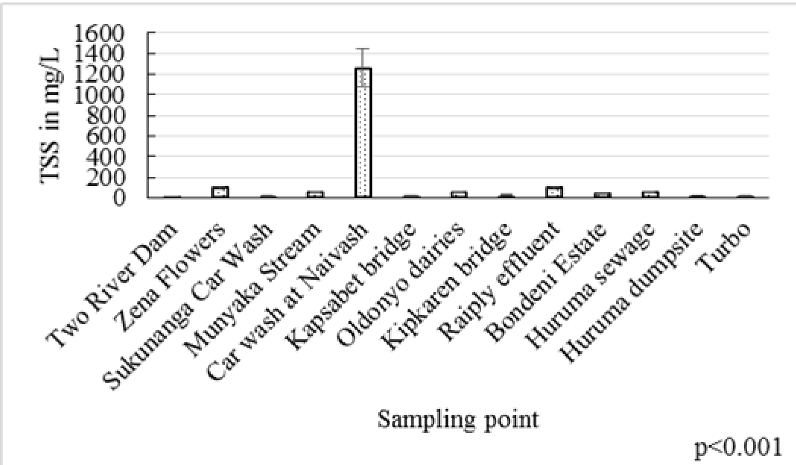

Figure 2: Variations in TSS along Sosiani River
Source: Survey Data, 2016

The River exhibited spatial temporal variations in total suspended solids along the river and with changing seasons (Figure 2). The mean concentration of TSS in Sosiani River was 135mg/L lower than the recommended WHO levels of 600mg/L. However the highest level of TSS was recorded at Naivash Carwash (1261.9±180.7mg/L) which is double the maximum recommended levels by WHO. In general TSS varied significantly across the river at F= 185.52 $P < 0.001$. The mean TSS for the wet season for the entire river was 194mg/L while the dry season had a mean TSS of 76.1mg/L which varied significantly at $P< 0.045$. TSS clogs respiratory surfaces and interferes with the feeding appendages of macro-invertebrates hence they suffocate and die (Obasohan *et al.*, 2010). These findings are consistent with findings of Yillia *et al.*, (2009) who found that found that rains in River Njoro catchment led to notable increase in surface runoff and corresponding rise in suspended solids in river water. A significant positive correlation (r= 0.5-0.835; $P< 0.05$) for TSS and bacteria density in the Njoro River was reported (Yillia *et al.*, 2009). In a recent study suspended solids and turbidity were reported to increase 2 – 3 times during wet season at most stream sites at the upper and middle reaches and 10 times more at the lower reaches downstream of Njoro town (Yillia *et al.*, 2009).

Total Dissolved Substances

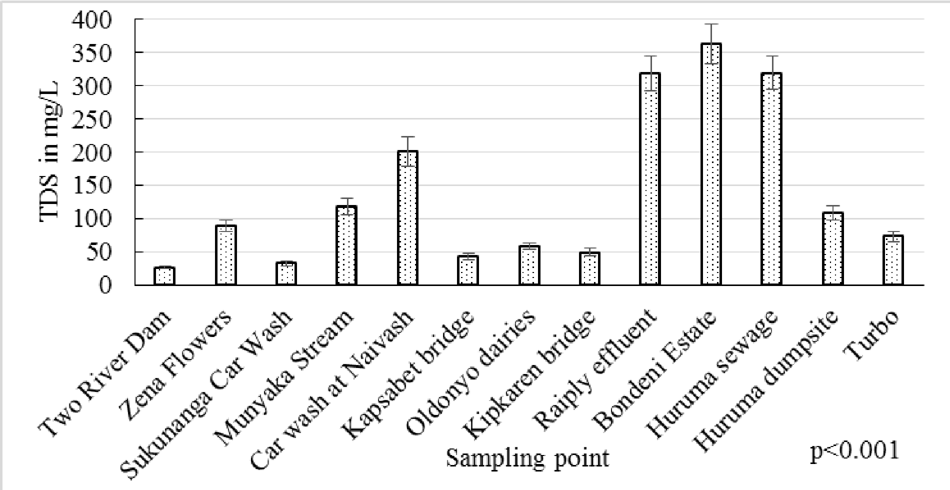

Figure 3: Variations in TDS along Sosiani River
Source: Survey Data, 2016

The total dissolved substances increased downstream and varied significantly with the rain season (Figure 3). The mean TDS of Sosiani River was 138.56 mg/L which is below the NEMA standard (1200mg/L). The WHO guideline standards are silent on TDS levels in drinking water. TDS varied significantly along the river ($F= 59.0129$ at $p<0.001$). The highest mean concentration of TDS was recorded at Bondeni estate 362.9±30.1mg/L. The TDS increased significantly with the onset of rain season. The mean TDS in the dry season was 98.2mg/L and during wet season 178.9mg/L with a significant positive correlation at $P< 0.001$. Sediments and dissolved substances impair organoleptic and aesthetic properties of water giving it a musty taste and changed water colour (Hogan, 2010). Dissolved substances increase electrical conductivity, BOD and turbidity of water which influences animal and plant species or forms of life a river can support (Forrow & Maltby, 2000; Mosley *et al.*, 2004). Though no health based guidelines have been proposed for TDS by WHO, palatability of water with TDS less than 600mg/L is considered good (WHO, 2011).

3.2 Turbidity

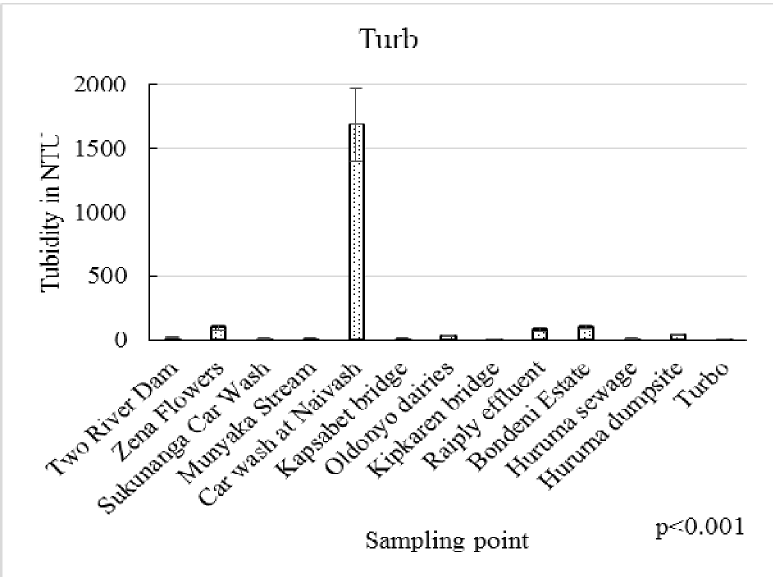

Figure 4: Variations in Turbidity levels along Sosiani River
Source: Survey Data, 2016

The average turbidity of Sosiani River is 162NTU which is above the NEMA standard for recreation waters 50mg/L (Figure 4). The NEMA and WHO guidelines are silent on standards of turbidity for drinking water and irrigation. There was significant variation in turbidity levels along the sampling points $F= 32.41$ P<

0,001. Hence Sosiani River can be described as cloudy since turbidity is in excess of 50NTU. Turbidity increased during the rainy season as a result of surface runoff with a significant positive correlation p<0.028. Increased runoff washes sediments into the river which increases suspended matter. Rainstorms also increase turbulence which takes bed sediments into suspension leading to relatively high concentrations of suspended mater in the river (Correll et al., 2001). High turbidity reduces the efficacy of water disinfection. Turbidity decreases downstream an indicator of self cleansing property of the river.

This findings are in agreement with those of Long & Plummer, (2004) who found turbidity levels in a small stream to vary with changes in precipitation and Volk et al., (2002) found that turbidity levels in a stream could increase by as much as 300 fold following precipitation events. Muchukuri et al., (2014) also found that the mean turbidity range for River Subukia was from 32.9±3.48 s.e. mean NTU recorded in March to 201.7±50.06NTU (Mean±se) recorded in May while that of River Momoi ranged from 19.0±3.05 NTU in March to 2003 NTU in May. There was significant variation in turbidity levels (F[2, 17] =7.8, p=0.004). Further, Yillia et al., (2009) found out that Suspended solids and turbidity increased 2 – 3 times during wet season at most stream sites on River Njoro at the upper and middle reaches and 10 times more at the lower reaches downstream of Njoro town.

3.4 Biological and Chemical Oxygen Demand

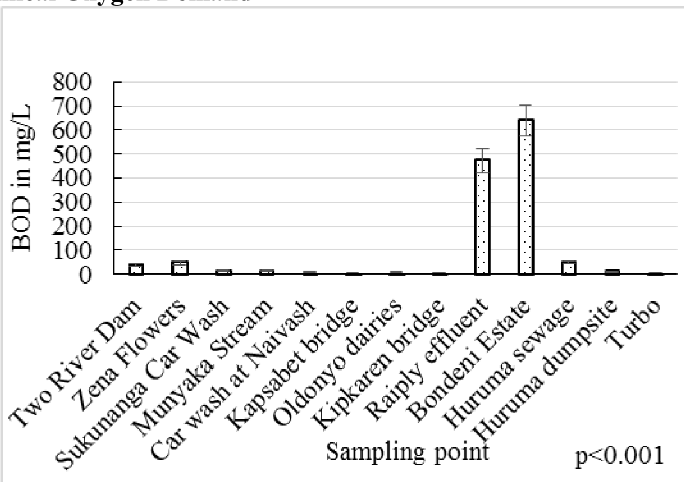

Figure 5: Variations in BOD along Sosiani River
Source: Survey Data, 2016

The Biological Oxygen demand of Sosiani River was found to be very high (mean BOD 145.54mg/L) hence cannot support aquatic life which require a maximum BOD 4mg/L (Figure 5). There was significant variation in BOD levels along the river (F= 78.95 & P < 0.001). The BOD also increased with the onset of rainy season with a significant positive correlation of P<0.038. High BOD stresses aquatic organisms and in extreme cases they suffocate and die and also interfere with reproductive function of fish and other aquatic organisms (Clescerl, 2008). Equally, the mean COD at all sampling sites in Sosiani River was very high 287.47mg/L. There was significant variation in COD levels along the river (F=77.64 & P<0.001). It was also observed that COD at each sampling point was higher than BOD. When the ratio of BOD to COD is greater than 0.8, the river is considered highly polluted. Findings of this study are consistent with those of Alavi *et al.*, 2007; Bukhalama, 2007; Maina *et al.*, 2010 who observed that COD and BOD increased downstream as more effluent was discharged with the onset of rainy season.

3.3 Water pH

Sosiani River had an average water pH of 7.1(Figure 6). There was significant variation in pH levels along the sampling points (F= 159.85 & P <0.001). Water pH was highest at Huruma sewage 8.2±0.02 and was significantly higher than at any other point along the river (p<0.001). This was however, within the NEMA recommended pH range of 6.5 to 8.5. It was also observed that the water pH did not significantly vary during the rainy season P<0.616. However, the WHO guidelines are silent on permissible levels of water pH. This findings are consistent with those of Muchukuri *et al.*, 2014 whose study on Subukia and Momoi Rivers in Subukia town established that pH values do not vary significantly (F(2,17 =2.93 p=0.081).

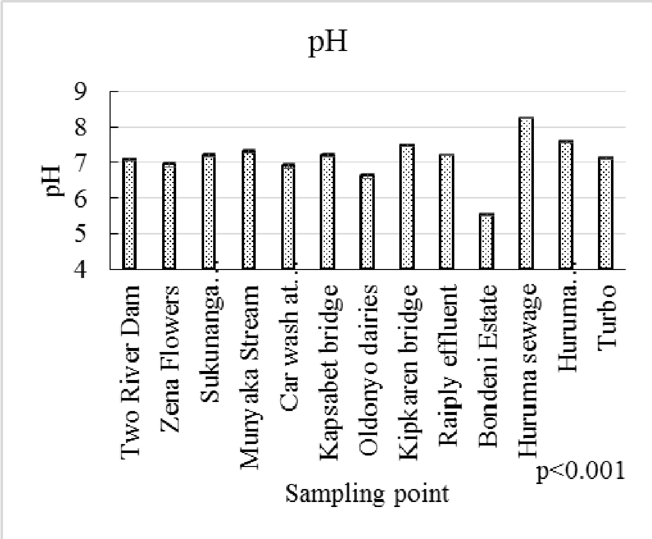

Figure 6: Variations in pH along Sosiani River
Source: Survey Data, 2016

3.6 Water temperature

The average water temperature in Sosiani River was 23^0C (Figure 7). There was significant variation in water temperature at different sampling points along the river at F=185.52, p<0.001. Water was warmest at the Kipkaren Bridge 27.7 ± 0.1^0C and coolest at two river dam and downstream in Turbo which is attributed to forest cover. Tree canopy protects the river from solar radiation hence ameliorating the water temperatures (Medema *et al.*, 2003). The water temperature also varied significantly with the onset of the rainy season P<0.013.

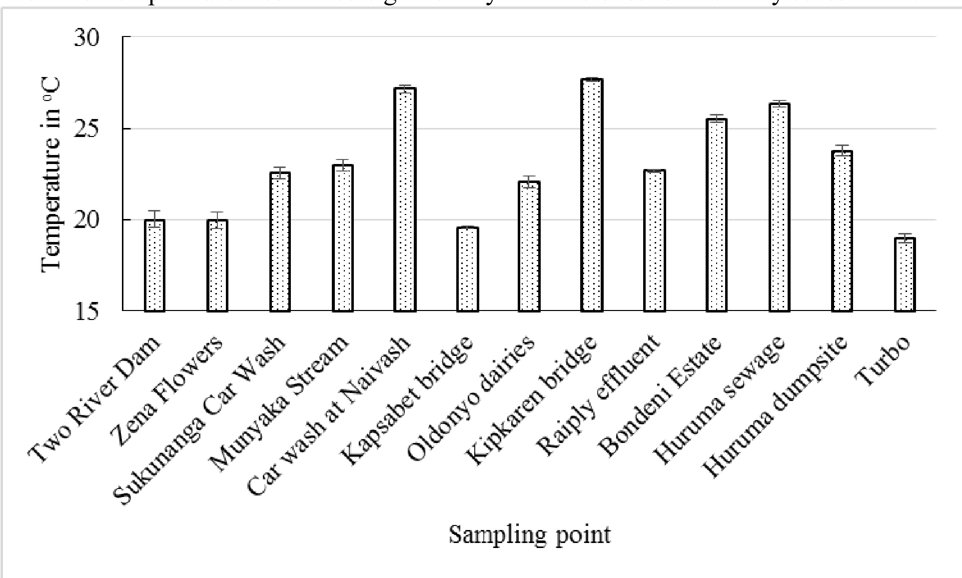

Figure 7: Variations in water temperature along Sosiani River
Source: Survey Data, 2016

These results are in agreement with Muchukuri, (2014) whose study on Subukia River found out that the reduction in temperature from March to May was attributed to change in season as rains began in mid- April to May after a hot and dry period in March. The results are also consistent with those of GLOWS, (2007) who found that water temperature was affected by season and time of the day along Mara River basin.

Plate 1: Pollution in Sosiani River
Source: Survey Data, 2016

4. Conclusion

Sosiani River exhibited Spatio-temporal variations in physicochemical properties of water quality. This is attributed to the many facilities along the riparian which discharge effluent into this river (Plate 1). The water quality parameters varied significantly along the river and with the onset of rain season due to increased surface runoff. Sosiani is a turbid river. The low dissolved oxygen, high BOD and turbidity is a threat to aquatic life and probably this explains why Sosiani River is not an important source of fish for residents of Eldoret town. However the water quality in Sosiani River improves further downstream in Turbo perhaps due to self cleansing ability of the river. Hence the study concludes that water in Sosiani River is polluted and not suitable for human consumption and or recreation purposes. If this pollution continues unabated, the health of residents of Eldoret municipality who rely on Sosiani River for drinking water is at risk.

5. Recommendations

This study recommends that drinking water sourced from Sosiani River should be treated while Eldoret Water and Sanitation Company (ELDOWAS) should channel urban surface run-off and municipal effluent into effluent treatment works for pre-treatment. Water Resource Management Authority (WRMA) and National Environment Management Authority (NEMA) should enhance enforcement of waste water regulations which require all facilities discharging effluent to construct wetlands if not connected to the sewer line and frequently monitor this discharge. Last but not least the County government of Uasin Gishu should relocate Huruma dumpsite away from the banks of Sosiani River and develop a sanitary landfill. Finally Kenya Forest Services (KFS) and all stakeholders should step up efforts to reafforest Kaptagat forest and plant trees along the riparian corridor of Sosiani River to reduce soil erosion.

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