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Status of Treated Slaughter-House Efluent and its Effects on the Physico-Chemical Characteristics of Surface Water in Kavuthi Stream, Dagoretti-Kenya

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Abstract: The aim of the study was to assess the status of treated slaughter-house effluent from Dagoretti slaughter-houses and its effect on the physico-chemical characteristics of Kavuthi stream. Samples of both treated slaughter-house effluent and water along a 5 km stretch of the stream were taken and subjected to standard procedures to determine the levels of pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Total Suspended Solids (TSS), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) between January and April 2010. The first two months corresponded with the dry season while March and April with wet season. A mean of 2520±7.66 μS/cm for EC, 2.3±0.13 mg/L for DO, 189.66±3.65 mg/L for TSS, 80.90±5.27 mg/L for BOD and 609.3±81.87mg/L for COD were recorded for slaughter-house effluent. The corresponding measurements for the stream water samples were: 5.41± 0.13 mg/L for DO, 736±5.69 μS/cm for EC, 89.74±2.51 mg/L for TSS, 27.15±2.9 mg/L for BOD and 190.82±43.29 mg/L for COD. While the downstream sites from the point of effluent discharge showed much higher concentrations of the parameters under investigation than the head waters, it was evident that as the stream progressed it was able to recover through self purification. Although the slaughter-house effluent were treated, it did not meet the National Environment Management Authority (NEMA) standard for effluent discharge into the environment leading to cross pollution of the receiving water based on the parameters under investigation. This therefore, calls for the need to upscale the existing wastewater treatment system and to enforce existing legislations to curb water pollution to safeguard both the environment and human health.

Keywords: Dagoretti, effluent, Kavuthi, Kenya, parameters, slaughter-house, surface water

INTRODUCTION

Although slaughter-houses are an important economic activity to the operators as well as livestock producers they however represents a major environmental challenge particularly water, soil and land pollution. The major waste associated with slaughter-house operations are blood, dung and slurry slurry which are washed into waterways or disposed off on land leading to pollution of the respective components of the environment. While Adelegan (2002) acknowledges direct and indirect contribution of environmental pollution by slaughter-houses, Sayed (1987) estimates the pollution potential of slaughter-house plants at over one million population equivalent in the Netherlands.

When discharged into aquatic ecosystems, slaughter-house effluents can cause significant increase in the levels of Biochemical Oxygen Demand (BOD) and nutrients mainly , nitrogen and phosphorus. and other nutrients. This will result in the alteration of the physical and chemical aspects which eventually affect the biological characteristics of waters body. According to Quinn and McFarlane (1989) and Sangodoyin and Agbawhe (1992), effluent discharge from slaughter-houses creates high demand for oxygen in rivers and contamination of ground water and has the potential to create high competition for oxygen within aquatic ecosystems leading to oxygen depletion decreasing the aesthetic value of aquatic ecosystems. The situation is worsen if the operations and location of slaughter-houses are unregulated and in close proximity to the wastewater receptacles. This does not only result in the alteration of the physical and chemical aspects which will not only compromise the quality of water for the various uses, but also the biological composition of the system. This does not only have adverse effect on aquatic organisms, but also on humans who dependent on this water for domestic purposes, (UNESCO, 2006; Krantz and Kifferstein, 2005).

In the recent past, the speed at which urbanization is taking place in Kenya represents a major challenge to water resource management particularly the delivery of essential water, sanitation services and environmental protection. Given the increasing trend in human population in urban centers within Nairobi and its environs, the demand for meat has equally shot up exerting more pressure on the existing slaughter-houses

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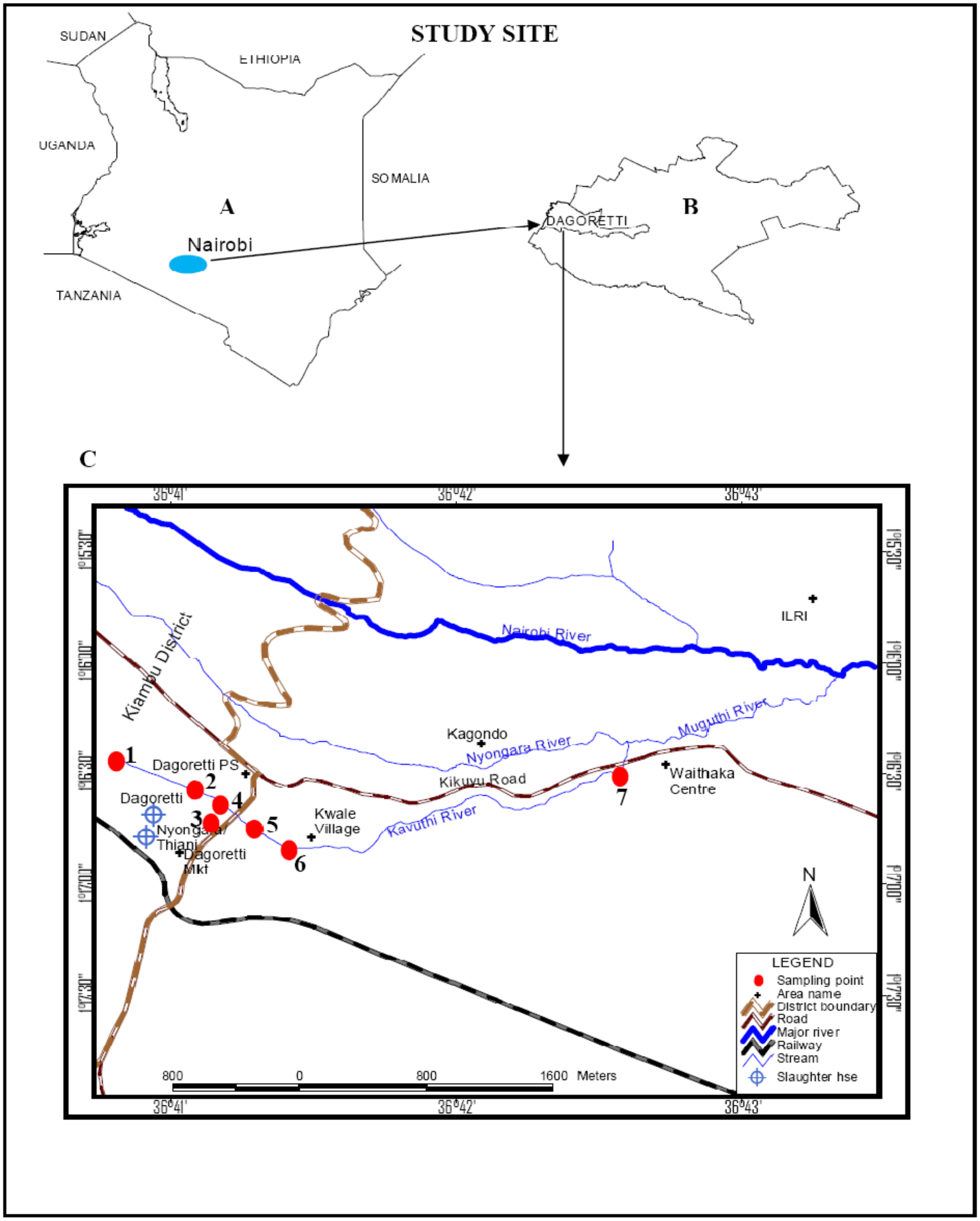

Fig. 1: The study area showing the location of the Kavuthi stream in, (A) Kenya, Kavuthi stream catchment, (B) Dagoretti/ Kikuyu catchment and, (C) Sampling sites

to supply more. Adjusting to the increasing demand, Dagoretti slaughter-houses have witnessed an increase in the number of animals slaughtered per day attributed to an increasing demand for animal product particularly meat. This is expected to create an equal increase in the amount of wastewater generated from the slaughter-house operations. Because of the obvious reasons of large volume of water required in carcass processing and the nature of waste generated, more wastewater will be generated. This surpasses the existing wastewater treatment capacity leading to discharge of untreated or partially treated or untreated wastewater into waste receptacles which are normally aquatic ecosystem (streams and rivers). It is from this background that the study was undertaken with the aim of assessing the status of treated slaughter-house effluent generated from Dagoretti slaughter-houses before discharge into Kavuthi stream and its effect on the physico-chemical characteristics of the stream water. This study was carried out on the stretch of Kavuthi stream, a tributary of Nairobi River, immediately downstream and upstream from Dagoretti slaughter-house effluent discharge into the stream.

MATERIALS AND METHODS

The study area description: Kavuthi stream is one of the tributaries of Nairobi River and it stretch for about 5 km before joining with Nyongara stream next to Waithaka Market Centre (Fig. 1). the stream originates from Gitwe catchment (00º4′7″S, 109º11′41″ E) with an altitude of about 1893 m above sea level in Kikuyu escarpment of Kiambu county and runs across Dagoretti town where a number of the slaughter houses; Nyongara, Mumu, Thiani, Dagoretti and Njonjoro are located. The siting of slaughter-houses is in such a way that the effluent from their operations is collected through a common channel which drains into a primary settlement (solids removal) pond before being discharged into Kavuthi stream. Subsequently, along the riparian zone of the Kavuthi stream, are small-scale farms of vegetables, arrowroots and napier grass and dense informal settlements at some section of the stream.

The lithology of the area is predominantly weathered volcanic rocks with red soils that reach more than 50 feet (15 m) in thickness (Saggerson, 1991). The area has a cool tropical climate with 2 rainy seasons. Highest rainfall is received between March and April and the short rainy season is between November and December. The mean annual rainfall ranges between 850-1050 mm while mean daily temperature ranges between 12 and 26°C. It is usually dry and cold between July and August, but hot and dry in January and February (CBS, 2003). Nairobi's main drainage follows the regional slope of the volcanic rocks towards the east, while subsidiary internal drainage into the Rift region is confined to the western part.

Field sampling and quality assurance: Effluent samples were taken from the drainage channel immediately after Dagoretti slaughter-house effluent treatment system but before discharge into Kavuthi stream at the point designated as (S_3 (Fig. 1). On the other hand the) water samples were taken from 6 sites along the stream and were designated as follows: S_1 and S_2 are located upstream from the point of effluent discharge (S_4) while S_5, S_6 and S_7 are located downstream from the point of effluent discharge. GPS readings for the sampling sites were taken and used to geo-reference the location of the sampling sites on the map of the catchment as illustrated in (Fig. 1). The study was carried out between 29th January 2010 and 7th May 2010 with January and February corresponding with the dry period while March and April corresponded with the wet period following the commencement of rainy season in late March. A total number of 24 effluent samples and 144 water samples were collected from the effluent channel and the stream, respectively for the determination of the following important parameters: temperature, pH, Conductivity, DO, TSS, BOD and COD. Samples were collected in plastic bottles, pre-cleaned by washing with non-ionic detergents, rinsed with deionized water prior to usage. Before the final water samplings were taken, the bottles were rinsed with effluent and stream water and then filled with the respective samples. Water samples for BOD and COD tests were collected in BOD bottles and plastic bottles and covered with aluminum foil. The sample bottles were labelled according to sampling sites. All samples were preserved at 4°C and transported to Egerton University Biological Sciences laboratory for analyses within 24 h. Unstable parameters such as temperature, pH, dissolved oxygen and electrical conductivity were determined in the field using Hydro-lab Quanta Model No. QD 02233. Physico-chemical analyses of the selected effluent and water parameter were conducted following standard analytical methods (APHA, 1998).

Data management and analysis: Field and laboratory data were entered into Microsoft excel spread sheets before transferring to SPSS version 17.0 for further analysis. Prior to statistical analyses, data were tested for normality and homogeneity of variance using Kolmogorov-Smirnov normality test and Levene's Test and where there were violations of these assumptions, appropriate transformations were done. Statistical significance was determined using independent sample T-tests and one-way ANOVA with Least Significance Difference (LSD) for separation of means. Significant relationships between variables were also determined using Pearson's correlation analysis.

RESULTS AND DISCUSSION

Status of treated slaughter-house effluent and Kavuthi stream surface water:

Seasonal and spatial variation: Water quality assessment remains a useful tool for pollution control and assessment and planning of water resource control and management as well as control of disease vectors. Observations on the spatial and temporal variations of

Table1: Seasonal variation of physico-chemical characteristics of slaughter-house effluent

	Dry season		Wet season				
Parameter	Mean	S.E.	Mean	S.E.	df	t-test	p-value
Temperature (°C)	20.69	0.46	20.25	0.57	22	0.597	0.557
PH	8.56	0.02	8.72	0.05	22	-2.959	0.007
EC (µSCm)	2140.00	8.11	2829.83	15.81	22	-4.040	0.001
DO (mgL)	1.81	0.11	2.73	0.15	22	-5.021	0.000
TSS (mgL)	201.17	4.23	186.67	5.25	22	0.551	0.587
BOD (mgL)	104.16	1.56	57.75	4.00	22	10.809	0.000
COD (mgL)	894.57	5.16	324.04	5.08	14	7.708	0.000

Table 2: Seasonal variation of the physico-chemical characteristics of Kavuthi stream water quality

	Dry season		Wet season				
Parameter	Mean	S.E.	Mean	S.E.	df	t-test	p-value
Temperature (°C)	21.36	0.17	19.97	0.21	142	5.172	0.000
PH	8.00	0.07	8.16	0.03	142	-2.134	0.035
EC (µSCm)	704.19	5.21	764.18	5.13	142	-0.820	0.410
DO (mgL)	5.17	0.18	5.61	0.13	142	-1.965	0.051
TSS (mgL)	75.21	6.41	107.89	5.39	142	-3.903	0.000
BOD (mgL)	33.52	3.39	21.32	1.73	142	3.206	0.002
COD (mgL)	288.90	6.18	97.21	6.53	94	3.960	0.000

some physical and chemical characteristics in Kavuthi stream water and slaughter-house effluent are presented in Table 1 and 2. Temperature range between 17.88 and 23.83°C was observed throughout the entire sampling period. Though, there were fluctuations between both sites and times, no significant difference (p>0.05) was observed between sites but significantly differed between times (p<0.05). The low temperature variation observed was considered normal with reference to the location of the study site which is described as cool tropical climate with daily temperatures ranging between 12 and 26°C and temperature of water in rivers is normally between 17.1 and 22.1ºC (Ngecu and Gaciri, 1999). High temperatures recorded in January and February coincided with dry season were expected since heat from sunlight increases the ambient air temperature which subsequently leads to an increase of surface water temperature. Similarly the drop in water temperature in the wet months was attributable to low ambient temperature and dominance of cloudy conditions experienced during the period. The pH for the effluent varied between 8.33 and 8.96 with an average of 8.56 for the 4 months of survey. Although the difference between the dry and the wet season was significant (t = -2.959); p<0.05) (Table 1), the pH range was found to be within the National Environment Management Authority (NEMA) stipulated pH range of 6.0 to 9.0 for effluent discharge into the environment. The same scenario was observed for Kavuthi stream water quality where the pH ranged from circum-neutral to slightly alkaline (6.66 and 9.14 (t = -2.134; p = 0.035) (Table 2). The differences in pH values between the two seasons may have resulted from increased run-off occasioned by rainfall which started in the month of March. Furthermore, the observed spatial variation may be attributed to the onset of rainfall which led to increased run-off carrying domestic and slaughter-house waste containing detergents compounded by laundry and car washing activities along the flow path of the stream contributed to the significant difference in spatial variation (Fig. 1a). Despite the significant spatial differences, the stream pH was within the WHO (2004) tolerance level for drinking water quality standards (6.5-8.5) and (NEMA) limit for irrigation water standards GoK (2006). Electrical Conductivity (EC) values for the slaughter-house effluent on average varied between 2140.00±8.11 µS/cm during the dry season and 2829.83±15.81 µS/cm in the wet season while that of the stream varied between 704.19±5.21 and 764.18±5.13 µS/cm for dry and wet season, respectively. Independent sample t-test revealed a statistically significant difference between the two sampling seasons (t = -4.040; p<0.05) (Table 1) for the slaughter-house effluent and non- significant difference (t = -0.820; p = 0.41) (Table 2) for Kavuthi stream water. Rain water may have led to dissolution and washing of salts used to preserve the hides of the slaughter animals leading to an increase of ions in effluent hence an increase of electrical conductivity. As the effluent was discharged into Kavuthi stream, the concentrations of ions was reduced because of the dilution effects of the stream leading low concentrations of ions in the stream water. Spatially, it was observed that there was significant variation in terms of between EC between the various sampling sites (Fig. 1b). It became apparent that those sites located at the head waters of the stream had much lower levels of EC as compared to the point of effluent discharge (S_4) and the subsequent two downstream sites (S_5 and S_6) save for S_7 which had much lower values comparable to the upstream sites (Fig. 1b). The high values recorded at the point of effluent discharge and the subsequent sites downstream could be attributed to mineralization of organic materials emanating from the slaughter-houses and residential areas along the flow path of the stream. However as the stream progressed downstream, the levels of EC gradually decreased to its lowest minimum at S_7 indicating the healing capacity of the stream. It is also important to note that other land use activities around the head waters e.g., agriculture in the catchment influenced water quality through inflow of nutrients, organic and inorganic contaminants and siltation may plausibly explain the disparities in EC. A gradient in the dissolved oxygen values along the stream profile was observed, with a high DO concentration (6.8±0.14 mg/L) at S_1 and low concentration (3.7±0.14 mg/L) at S_4 (Fig. 1c).There was a slight drop of DO between S_1 and S_2. Because of the organic load from impact of slaughter-house effluent at the point of discharge (S_4), the DO level dropped to its lowest (Fig. 2c) before gradually increasing in the subsequent sites downstream. In addition to high organic load from slaughter-houses, the low dissolved oxygen level could also be attributed to the input other organic loads from domestic waste and organic materials of highly organic wastes from slaughter-houses and sewage discharge, laundry and car washing activities sited along the banks of the stream, leached domestic wastes from the several waste dumps, erosion and surface run-offs and other human activities along the flow path with progress downstream of the stream. The excessive input of organic matter leads to the

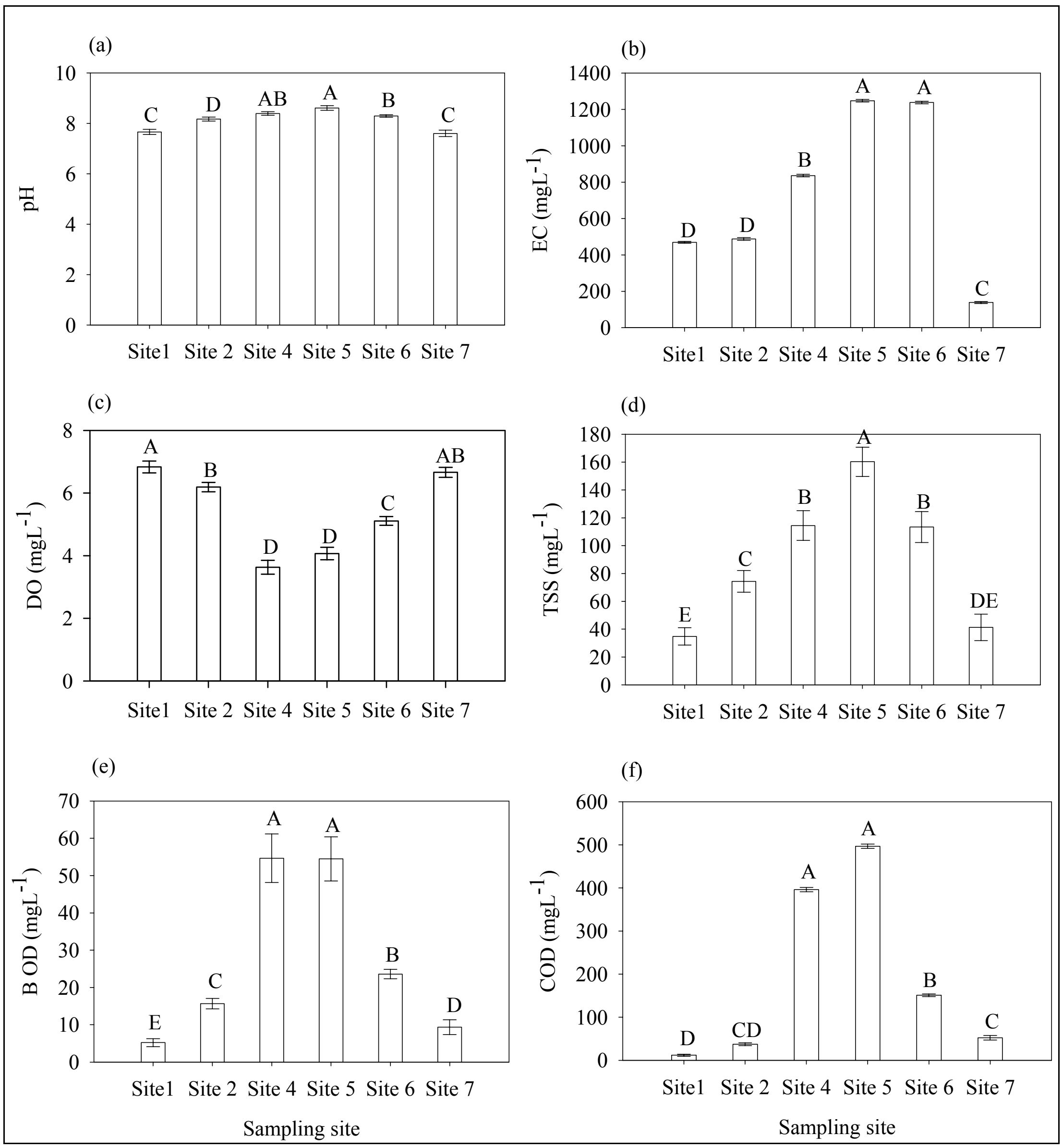

Fig. 2: Spatial variation of (a) pH, (b) EC, (c) DO, (d) TSS, (e) BOD and (f) COD. During the study period Vertical bars sharing the same letters are not significantly different from each other at α = 0.05

build-up of "sludge" and the mineralization process which consumes dissolved oxygen from a water column (Raheem and Morenikeji, 2008).This provides a possible explanation to the difference in DO levels observed concentration recorded at point of effluent discharge (S_4) and other sampling sites and could have led to the significant spatial differences ($p<0.05$) (Fig. 1c) in the DO values observed. Though dissolved oxygen was drastically reduced at the point of discharge site 4 (S_4), the gradual increase to above 5.0 mg/L at site 7 just before the stream confluence with Nyongara stream indicated stream capacity for self purification and lack of input of high oxygen demanding waste along the flow path of the stream. Which according to Alabaster and Lloyd (1980) and Moss (1980) are favourable conditions for aquatic life and domestic purposes. Total Suspended Solids (TSS) concentration showed no significant seasonal variation ($t = 0.551$; $p = 0.587$) (Table 1) for the slaughter-house effluent. However, a significant variation ($t = -3.903$; $p<0.05$) (Table 2) was observed for the Kavuthi stream water quality. On the spatial scale, TSS values averaged between 38.31±4.93 and 156.23±6.39 mg/L and statistically differed significantly between the sampling sites (One way ANOVA $F_{5,\ 138} = 56.54$, $p<0.05$) (Fig. 1d). However, post-hoc analysis indicated that S_1 and S_7 and also S_4 and S_6 were similar (LSD test; p = 0.73 and 0.62), respectively. The high TSS measurements concentration observed at the point of effluent discharge (S_4) and 100 m downstream (S_5) than those observed for the other sites impacted by the slaughter-house effluent could be attributed to the effluent discharged from slaughter-houses and wastewater discharge from residential area adjacent S_5. This was further escalated by the increase in run off with the commencement of rain in March. The low TSS concentration observed in the dry season (January and February) coincided with low flow rate of the stream and high values for wet season (March and April). Fast running water have enough energy to carry more particles and larger-sized sediment and can cause re-suspension of sand, silt, clay and other organic particles (such as leaves and soil particles) in water leading to increase suspension of particles hence an increase in TSS concentration. In general, the TSS value observed for the slaughter-house effluent and stream water quality were as far much above NEMA recommended value of 30 mg/L for effluent discharge into the environment and for sources of water for domestic purposes. Biological Oxygen Demand is one of the most important water quality indicators representing the amount of dissolved oxygen consumed by the decomposition of carbonaceous and nitrogenous matter in water over a specific period of time (usually 5 days) and temperature (20°C). With respect to the present study, the high BOD levels concentrations ranged between 40.65±1.36 and 112.86±1.81 mg/L with a mean of 80.95±5.27 mg/L for the effluent (Fig. 2-e) is an indication of highly organic nature of the slaughter-house effluent. One way ANOVA showed a statistically significant difference between the sampling occasions ($F_{3,\ 20} = 297.92$, $p<0.05$) (Table 1). However, further analysis using LSD revealed that there was no statistical difference between January and February whereas March and April were significantly different from each other. A similar trend was also observed for COD (Table 1).

Along the stream, T the observed spatial variation ranged between (5.4±0.93 and 54.6±4.54 mg/L) while temporal variation ranged between (21.3±1.22 and 35.2±5.18 mg/L). One way ANOVA showed revealed that there were statistically significant differences ($p<0.05$) between both sites and sampling occasions. The observed significant spatial variation could be attributed to the input of biologically oxidizable carbonaceous and nitrogenous organic matter present into the stream natural water resulting from decaying organic matter for site 1 and to the effluent from residential houses, slaughter-houses and other human activities found along the flow path of the stream for the subsequent sites. An increase in BOD noted at site 4 confirms the effect of slaughter waste on water quality. The temporal variation observed could plausibly be attributed to the storm events where high concentration of BOD coincided with the dry months (January and February) while low concentration coincided with wet months (March and April). When compared to NEMA allowable limit of 0.5 mg/L for drinking water and 30 mg/L for water used for irrigation and WHO (2004), the values for all the sites along the stream could not be used for both drinking and agricultural purposes. As a measure of oxygen equivalent of organic matter in water sample susceptible to oxidation by a strong chemical oxidant, such as dichromate brought about by high organic load, (Chapman, 1996), COD measures concentration in the Kavuthi stream differed significantly among the six sites and occasions. The high values obtained for COD at site 4 (501.89±68.53 mg/L) and site 5 (403.29±79.65 mg/L) in the present

Table 3: Pearson's correlation matrix of analyzed pairs of water quality variables

	pH	EC	TSS	DO	BOD	COD
pH	1					
EC	0.69**	1				
TSS	0.75**	0.76**	1			
DO	-0.68**	-0.62**	-0.63**	1		
BOD	0.61**	0.44**	0.57**	-0.83**	1	
COD	0.62**	0.37**	0.41**	-0.79**	0.90**	1

**: Correlation is significant at 0.01 levels (2 tailed) study could be due to high organic load which corresponded to high TSS values in the two sites (Fig. 2d and f). A gradual reduction in COD levels for subsequent sites after site 4 to 54.24±3.24 mg/L at site 7 before the stream confluence with Nyongara River could be due to net dilution effect as the stream progressed downstream and also decomposition of organic load as they move away from pollution source (s). Dilution effect could also provide a possible explanation for the observed temporal/seasonal variation in COD concentration. High COD concentration observed in the months of January and February coincided with the low flow of the stream and vice versa. The values obtained for the stream were higher than 10 mgL permissible limit for water quality set by WHO (2004) and 30 mgL for water for domestic purposes set by NEMA. Consequently, COD concentration for the slaughter-house effluent averaging 609.31±81.87 mgL was way above the NEMA maximum limit of 50 mgL required for the effluent discharge into the environment.

To establish existence of any relationship between the various parameters, Pearson's linear correlation was obtained for the data sets in Table 3. As the levels of TSS, BOD and COD increased, DO decreased as revealed by t he negative correlation coefficients r = -0.63, r = -0.83 and r = -0.79, respectively. Similarly, an increase in the concentration of BOD and COD corresponded with an increase in TSS measures. These correlations suggest similar sources of organic pollutants into the stream.

CONCLUSION AND RECOMMENDATIONS

This study provided important information on the status of the slaughter-house effluent and its effects on the stream water quality. It established that without proper treatment, the slaughter-house effluent could significantly impair the stream water quality as indicated by key water quality indicators. Kavuthi stream represents a case where local perturbations of the local water resources disturbing influences could not be completely avoided. Apart from slaughter-houses, areas used as waste dump sites, farmlands and other domestic activities like laundry and car washing, are very close to some of the sampling sites and would therefore influence the spatial variations in water quality of the stream. With increasing human population and the corresponding increase in the demand for meat, slaughter waste receptacles will continue to deteriorate unless appropriate steps are taken to upscale the current wastewater treatment systems to be able to handle the increase in waste generated. waste management measures are put in place. There is also the need for government through NEMA to strictly enforce Swift intervention measures by the government and other stakeholders including the appropriate legal tools to those who are not complying with standards stipulated for the effluent discharge into the environment to safeguard both and effluent treatment facilities to treat wastes from slaughter-houses in Kenya as well as adoption of cleaner technologies will go a long way to curbing the environmental and human health risks posed by slaughter-house wastes from slaughter-house wastes.

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