Available online at www.elixirpublishers.com (Elixir International Journal)

Pollution

Elixir Pollution 117 (2018) 50489-50492

ISSN: 2229-712X

Effects of Slaughter-House Effluent on Eutrophication Parameters in Kavuthi Stream, Dagoreti- Kenya

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ARTICLE INFO

Article history:

Received: 01 March 2018;

Received in revised form: 02 April 2018;

Accepted: 12 April 2018;

Keywords

Eutrophication,
Effluents,
Slaughter-House,
Stream, Kavuthi,
Kenya.

ABSTRACT

Eutrophication is a worldwide environmental problem attributed to direct or indirect discharge of untreated or partially treated effluents from a variety of industries including slaughter-houses. Nutrient-rich water compromises its suitability for various uses and threatens human and environmental health. A study was carried out to assess the impact of effluents from Dagoreti slaughter-houses on the water quality of Kavuthi stream, one of the tributaries of Nairobi River. Samples of effluent effluents from the slaughter-houses and water from Kavuthi stream were collected in 2010 for the determination of both temporal and spatial variation of various eutrophication parameters: total phosphates (TP), soluble reactive phosphates (SRP), ammonium (NH_4), nitrate (NO_3) and nitrite (NO_2). A mean concentration of 5.14± 0.30 mgL^{-1} for TP, 2.80±0.37mgL^{-1} for SRP, 18.27± 0.93 mgL^{-1} for NH_4-N, 8.88±0.25 mgL^{-1} for NO_3-N and 1.63±0.22 mgL^{-1} for NO_2-N were recorded for the effluent from the slaughter-house. Significant differences were observed between sampling occasions and sites ($p<0.05$) along the stream. On average, 1.52±0.08 mgL^{-1} for TP, 0.68±0.05 mgL^{-1} for SRP, 5.34± 0.41 mgL^{-1} for NH_4-N, 4.36±0.20 mgL^{-1} for NO_3-N and 0.46±0.05 mgL^{-1} for NO_2-N for the water samples along Kavuthi stream were recorded. Despite the significantly high concentrations of these nutrients in sites downstream of the effluent discharge point as compared to upstream sites, their levels were within the limits stipulated by National Environment Management Authority (NEMA) - Water Quality Regulation for effluent discharge into the environment and source of water for domestic purpose. The study recommends that the slaughter-house operators adopt appropriate effluents treatment interventions and effluent discharge guidelines in order to safeguard human and environmental health.

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Introduction

Slaughter-houses are an important economic activity to the operators as well as livestock producers. However, slaughter-houses represents a major environmental challenge particularly water, soil and land pollution. The major waste associated with slaughter-house operations are blood, dung and 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 slaughterhouse 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 nutrients; mainly, nitrogen and phosphorus which result in alteration in the biological characteristics of surface waters. The pollution of surface water not only affect the integrity of the aquatic ecosystems, but also human health (Krantz and Kifferstein, 2005; UNESCO, 2006). Numerous studies have demonstrated that infants less than six months of age exposed to high level of nitrate in drinking water supplies are particularly vulnerable to methemoglobinemia also known as “blue-baby syndrome” (McDonald and Kay 1988).

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 to supply more. To keep pace with the increasing meat demand, slaughter-houses in Dagoretti have witnessed an increase in the number of animals slaughtered per day. This creates an increase in water demand which equally result in increased volume of wastewater generated from the slaughterhouse operations. Without corresponding upscaling of effluent treatment facilities, existing wastewater treatment capacity is overstretched leading to discharge of untreated or partially treated or untreated wastewater into waste receptacles which are in most cases aquatic ecosystem (streams and rivers). It is from this background that this study was undertaken with the aim of assessing the effects of slaughter-house effluents on eutrophication parameters in Kavuthi stream.

Materials and Method

Description of study area

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 (Figure 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

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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 (S3 (Figure 1). In addition, water samples were taken from 6 sites along the stream designated as: S1 and S2 located upstream from the point of effluent discharge S4 while S5, S6 and S7 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 the map.

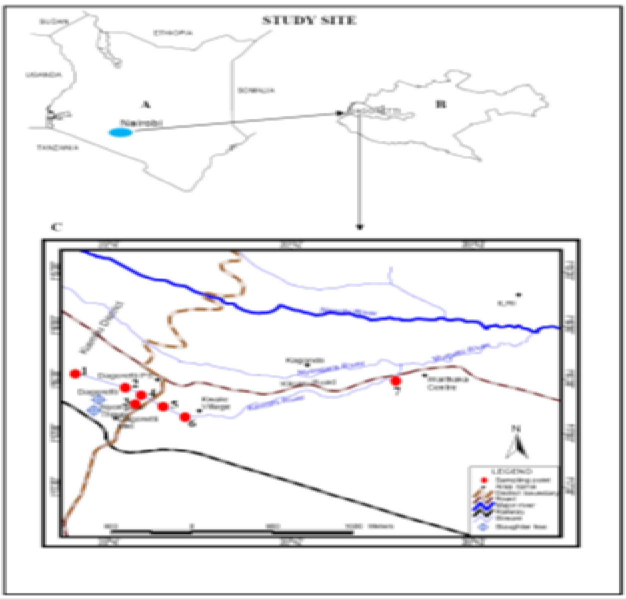

Figure 1. Geographical location of Kavuthi stream within Dagoretti/Kikuyu catchment.

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 total phosphates (TP), soluble reactive phosphates (SRP), ammonium (NH_4), nitrate (NO_3) and nitrite (NO_2). 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. 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 hours. Nutrient analyses were conducted following standard analytical methods (APHA, 1998).

Data 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

Water quality assessment remains a useful tool for pollution control, planning and management of water resource.

Spatio-temporal variation in eutrophication parameters

Soluble Reactive Phosphate and Total Phosphate

Soluble Reactive Phosphate (SRP) averaged between 0.23±0.06 mgL^{-1} and 1.15±0.10 mgL^{-1} and 2.80±0.37 mgL^{-1} measured for water samples from Kavuthi stream and the effluent respectively. One way ANOVA revealed that there was a statistically significant difference between the sampling sites and occasions for the sites along the stream ($F_{5, 138}=18.98$; $p<0.05$ and $F_{3,,140}=29.76$; $p<0.05$), respectively (Figure 2 & Table 1). The separation of means showed that Sites 2 and 7, 4 and 6 and 5 and 6 were not significantly different from each other (LSD test, p=0.42, 0.12 and 0.41), respectively.

Equally, there was statistically significant differences in the levels of TP concentration amongst the sampling sites and occasions for the stream ($F_{5, 138}=107.52$; $p<0.05$ and $F_{3, 140}=3.42$; $p=0.02$), respectively (Figure 3 & Table 1).Post-hoc test indicated that sites 4 and 5 and sites 6 and 7 were similar (LSD test; p=0.092 and 0.059), respectively. One way ANOVA

Low levels of phosphates i.e. SRP and TP recorded just before the point of slaughter-house effluent discharge by virtue of their location with respect to the point effluent discharge. However, the difference in phosphate concentrations observed between the two sites maybe attributable to discharge of partially treated sewage from residential apartment at S2. In addition, phosphates can enter aquatic environments from the natural weathering of minerals in the drainage basin, from biological decomposition, and as runoff from human activities in urban and agricultural areas (Geneviève *et al*., 2006). Koning, *et al* (2000) also points out that run-off from riparian settlements, cultivated pastures and industrial activities are potential sources of nutrient load in the receiving stream and rivers. Intensive use of phosphate rich detergents in cleaning the floors of the slaughter-houses and the intestinal contents .i.e. urine and dung as well as wastewater form car washing laundry, saloon, bathrooms and kitchen activities are plausible reasons for high concentration of phosphates observed in S4 and S5. Goldman and Horne (1983) observed that the major sources of soluble phosphates, among others, are phosphate-containing detergents, which contribute half the phosphate contained in domestic sewage.

Low concentrations of phosphates observed in dry months of January and February coincided with low flow of the stream as opposed to high concentrations which coincided with high flow during the rainy months of March and April. However, other studies have demonstrated that if nutrient influxes in a river are dominated by point sources, water phosphates concentrations are often higher during low-flow periods when the dilution effect is at its lowest (Neal *et al*, 2008). Dorioz *et al* (1998) havers that the amount of diffuse phosphorous entering rivers is dependent on rainfall, hydrological conditions and land use in the watershed

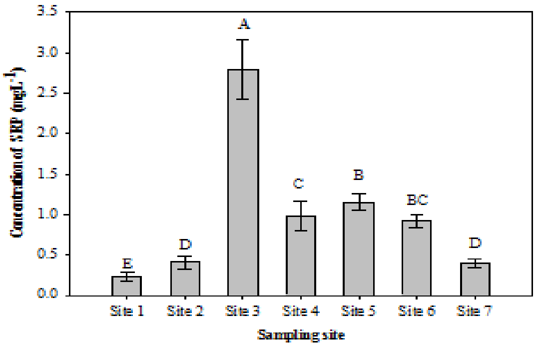

Figure 2. Spatial variation of soluble reactive phosphate.

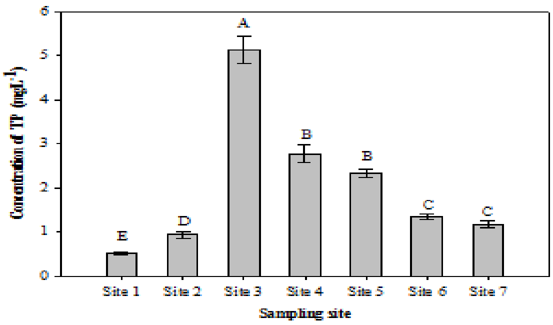

Figure 3. Spatial variation of total phosphate.

Table 1. Temporal variation of nutrient concentration in Kavuthi stream.

Month	SRP	TP
January	$0.42±0.07^{a}$	$1.32±0.10^{a}$
February	$0.25±0.03^{a}$	$1.42±0.14^{a}$
March	$0.88±0.10^{b}$	$2.00±0.21^{b}$
April	$1.16±0.10^{c}$	$1.33±0.13^{a}$

Figures are means ± standard error of measurements of nutrients taken between January and April 2010 with n=24. Means sharing the same superscript letter notations are not significantly different from each other at α=0.05.

Ammonium, nitrate and nitrite

A significant spatial differences in the concentrations of NH_4-N ($F_{5, 138}$=94.61; p<0.05), NO_3-N ($F_{5, 138}$=97.26; p<0.05) and NO_2-N ($F_{5, 138}$=18.94; p<0.05) for sites along the stream (Figure 4,Figure **5**Figure 6; Table 2). However, post-hoc test revealed that the concentration of NH_4-N in S4, S5, and S6 were similar (LSD test, p< 0.05). There were also similarities in the concentration of NO_3-N between S2 andS7, (LSD test, p= 0.36) while S1 and S2 showed no statistical difference in terms of NO_2-N concentrations (LSD test; p<0.05). The concentrations of NH_4-N, NO_3-N and NO_2-N for the effluent (S7) averaged18.27±0.94 mgL^{-1}, 8.88±0.26 mgL^{-1} and 1.63±0.22 mgL^{-1} respectively with one way ANOVA revealing statistically significant differences between sampling occasions (p<0.05), (Table 2). Post hoc analysis using LSD confirmed that January and February (p=0.39) and February and April (p=0.17) were similar in terms of nitrate concentration.

Unlike other forms of nitrogen, the fairly uniform concentration of ammonium-nitrogen at S4, S5 and S6 may be attributed to the enhancement of discharge of human faecal materials from shallow latrines and run-off from zero grazing units along the stream. S1 and S2 were significantly different from each other despite the fact that both were located upstream from the point of slaughter-house effluent discharge. Like phosphate concentration, the high concentration of ammonium-nitrogen observed in S2 could be as a result of sewage discharge and wastewater from the residential apartment adjacent to Kavuthi stream at this section of the stream. In addition, run off from farming activities and the use of mineral fertilizers and manure used could also explain the observed results.

Unlike ammonium, the concentration of nitrates gradually decreased gradually as the stream progressed downstream from the point of slaughter-house effluent discharge reaching its lowest at S7 (3.33±0.23mgL^{-1}) which was not significantly different from S1and S2. The decrease in nitrate concentration could be attributed to dilution due to increased water flow in the stream later in the study. This agrees with the assertion by Allan (1995) that high flows dilute and concentrate nutrient materials.

Compared with NEMA allowable limit for source of domestic water (i.e. drinking and cleaning) (GoK, 2006). In general all the six sites studied in the Kavuthi stream had low water quality based on the standards in Thokoa, (1996) and were variously stressed by nutrients from the activities within its catchment. The results indicated that the concentrations of nutrients increased from S1 downstream reaching its peak at the point of effluent discharge (S4) before decreasing gradually downstream. It can be inferred that the whole stretch of the stream under study was equally polluted, regardless of the source of pollution.

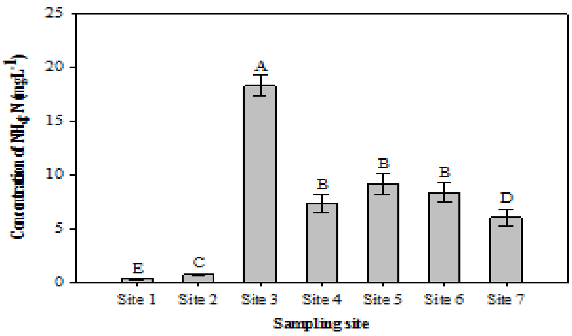

Figure 4. Spatial variation of NH_4-N concentration.

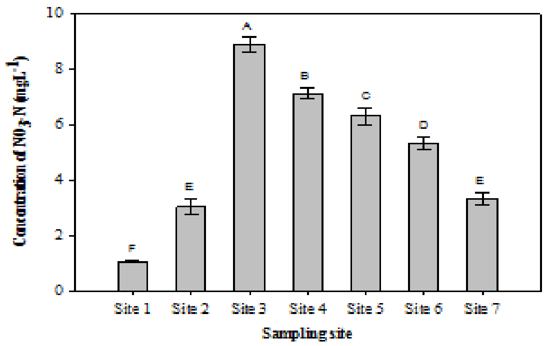

Figure 5. Spatial variation of NO_3-N concentration.

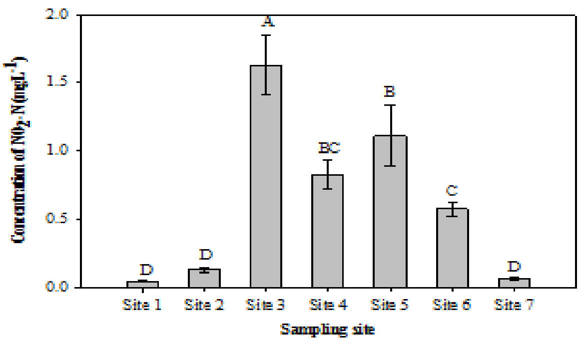

Figure 6. Spatial variation of NO2-N concentration.

Table 2. Temporal variation in NH_4, NO_3 and NO_2.

Month	NH^+_4-N	NO_3-N	NO_2-N
January	3.50±0.43 a	3.75±0.37 a	0.31±0.1 a
February	4.70±0.54 a	3.92±0.42 a	0.23±0.1 a
March	10.06±1.11 b	5.13±0.45 b	0.85±0.2 b
April	3.09±0.42 a	4.65±0.29 a b	0.46±0.1 a

Conclusion

The effects of slaughter-house effluent discharge into Kavuthi stream were assessed through water quality monitoring. The findings of this research indicated that livestock processing and marketing activities at Dagoreti slaughter-houses were negatively impacting Kavuthi stream water quality. Concentrations of soluble reactive phosphate, total phosphorus, ammonium-nitrogen, nitrate-nitrogen and nitrite-nitrogen were in excess of normal levels for river water. The downstream levels of these parameters were higher than their corresponding upstream values, indicating that the discharge of the slaughter-house effluent into the stream have negatively impacted the stream. The dilution of the highly organic and nutrient rich slaughter-effluent in the stream was not enough to reduce them to acceptable levels. Although there is a potential that an improvement of the water quality may have been observed further downstream due to self-purification and further dilution effects, the high levels of these parameters is a worrying issue. The findings of this research is useful in identifying water quality problem areas and planning of interventions including engineering as well as legislative measures to curb water pollution from slaughter-houses or similar facilities.

Acknowledgment

The authors are grateful to Egerton University for providing the facilities for this work. We are also grateful to Ms. Rachel Njoroge of Department of Biological Sciences laboratory.

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