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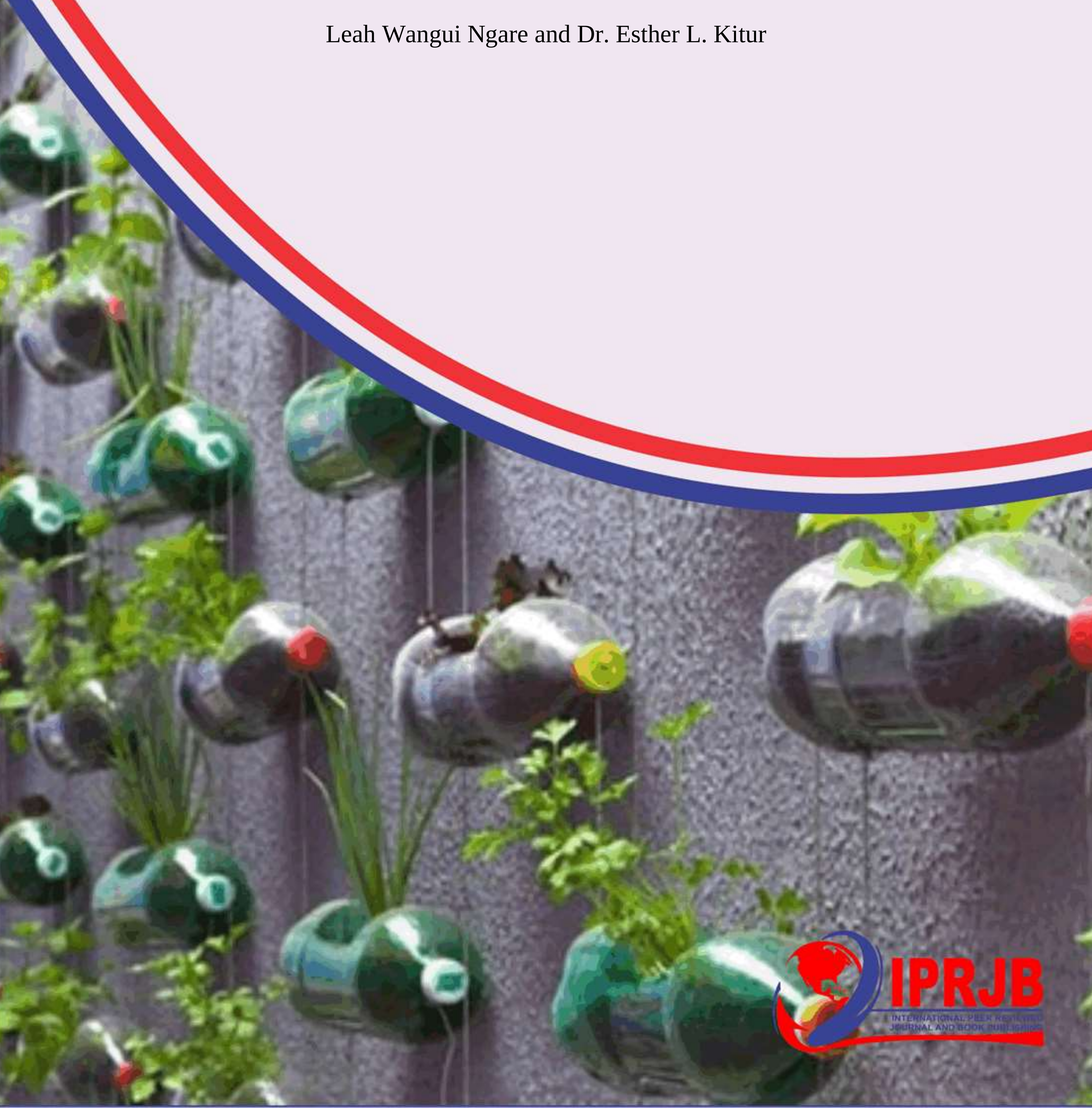

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The Quality of Kiserian Slaughterhouses' Effluent and Its Implication on Kiserian Dam Water in Kajiado County, Kenya

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Abstract

Purpose: Wastewater from abattoirs, municipal, agricultural and industrial effluents is a major source of environmental pollution as they consume large amounts of fresh water for meat processing and hygienic purposes. The main objective of the study was to assess the quality of the effluent from Keekonyokie and Kiserian slaughterhouses and its effect on the quality of water in Kiserian dam.

Methodology: The parameters measured were pH, total suspended solids, total nitrogen, total phosphorous, dissolved oxygen and fecal coliforms (*E. coli)*. Samples were collected from 4 sampling sites three times a week for three months. SPSS (ANOVA) for their significant differences. One-sample t-test used to compare the parameter means with NEMA 2006 standards. Pearson Correlation used for correlation among the parameters.

Findings: The mean fecal coliforms 2215.206 mg/l, Phosphorous 47.379 mg/l, Nitrates 36.71 mg/l, TSS 387.57 mg/l which were above the standards of NEMA 2006 of nil, 2, 2 and 30 mg/l respectively while DO was 8.58 mg/l and pH 6.86-7.0 both of which were below the NEMA 2006 standards of 30 mg/l and 6.5-8.5. The results of all parameters were significantly different among the sites (p=0.00). There was significant difference between the parameters and the NEMA 2006. ANOVA results on parameters showed the all coliforms increased with increase in rainfall with the highest levels in September with a mean 18662.7 mg/l and in July with the lowest of 12962.5 mg/l.

Unique Contribution to Theory, Practice and Policy: The study can be used by slaughterhouses developers and management on slaughterhouse wastewater treatment. To be used by slaughterhouses licensing authorities on SWW requirements before licensing. To be used by Public Health Department for disease surveillances and Water Regulatory Management Authority on domestic water treatment.

Keywords: *Abattoir, Dam, Offals, Zoonotic diseases, Lagoons*

INTRODUCTION

Slaughterhouses, also known as abattoirs, are industries that are involved in the commercially slaughter animals such as cattle, goats and sheep, among others and processing the meat for human consumption (Shukri *et al*, 2017). They are special facilities designed and licensed for receiving, holding, slaughtering and inspecting meat animals and meat products before releasing to the public for consumption (Bandaw and Herago, 2017).

Abattoirs aim at optimizing wholesome meat production for human consumption, however, significant amounts of secondary wastes including organic and inorganic solids and liquids not fit for consumption are generated in the process (Bandaw and Herago, 2017). The major environmental effect of animal products processing and packaging results from the discharge of wastewater and wastewater is not merely a water management issue but it can affect the environment and all living organisms (WWAP,2017). Pollution of environment by slaughterhouse wastewater (SWW) is exacerbated by accelerated human activities such as increased population growth, urbanization, industrialization, rising incomes and high demands for meats as a source of proteins thus posing a serious environmental threat to sustainable development leading to potential environmental pollution (Nwankwo *et al*, 2019).

On a global scale, environmental pollution by food industries such as meat processing plants through discharge of effluent, has become a threat to plants and animals which eventually threaten the quality of human life (Apand *et al*,2019). In some developed countries, meat processing plants are situated away from major towns and coupled with enforcement of laws and regulations on wastewater discharge this has greatly reduced environmental related issues whereas in developing countries, lack of proper infrastructure and regulations has contributed to severe environmental implications (Edokpayi *et al*, 2017). SWW pathogens can also be spread to individuals exposed to water bodies, rendering the water unfit for consumption, swimming or irrigation (Bustillo-Lecompte and Mehrvar, 2017).

Majority of slaughterhouses in the emerging economies have a shortage of SWW treatment plants and the consequently, the discarding of effluent to the land and water bodies that may lead to the spread of pathogens to humans, odor, and excess nutrients which alter the receiving ecosystems (Shukri *et al*, 2017).

Kiserian slaughterhouses which are two in number, namely Keekonyokie and Kiserian slaughterhouses drain their slaughterhouse wastewater (SWW) into Kiserian Dam through an open drain. The Dam is used as a water source for domestic purposes and irrigation by the local residents leaving near the Dam and the larger Kiserian town. The organic carbon accumulation in meat processing plants (MPP) effluent is fairly high, which when combined with the pathogens present in SWW and cleaning products for cleaning purposes, results in polluting effect on the receiving water body (Farooq and Zaki,2017).

With increase in the global population and the rising demand for food, global supply of steak, pig meat and chicken meat has more than doubled in the last decade and expected to continue till 2050. As a result of the increased number of slaughterhouse facilities, high volumes of slaughterhouse wastes are expected to be discharged into the water bodies (Bustillo-Lecompte, *et al*, 2016).

The meat processing sector is one of the leading users of overall fresh water in use in the agriculture and beef industry globally for meat production and cleaning of facilities to maintain hygiene and production of wholesome meat (Bustillo-Lecompte and Mehrvar, 2017). Consequently, abattoirs produce a lot of wastewater holding huge amount of soluble and insoluble matter such as blood, pathogens, salts, fats, pathogens, gut grass, salts and processing chemicals (Hawumba *et al*, 2017). Another source of contamination from abattoirs is the surfactants used in the cleaning. Surfactants are important elements in detergents and may penetrate into the aquatic environment as a result of insufficient SWW treatment inducing short-term and long-term variations in the system that affects individuals, fish and plants (Bustillo-Lecompte and Mehrvar, 2017).

The effluents of abattoirs are composed of serious causes of environmental pollution, odor and health hazards if not properly handled. Due to the extraordinary content of organic and minerals, wastewater from abattoirs need special care and disposal to the environment (Husam and Nassar, 2019). Raw or partially treated SWW contain nutrients for algae, non-biodegradable organic matter, heavy metals and other toxic substances that would accelerate the deterioration of receiving water bodies (Apand *et al*, 2019).

Epidemiology research illustrates the connection between the pathogenic bacteria, *E. coli* and the occurrence of intestinal ailment as a result of contacting or the consumption of polluted water and serves the basis for water quality regulation (Shukri *et al*, 2017). The composition and the volume of slaughterhouse wastewater varies according to the type and number of animals slaughtered and the amount of water requirements for the process (Bustillo-Lecompte *et al*, 2016).

Statement of the Problem and Justification

There is no documented information on the quality of the effluent from the Keekonyokie and Kiserian slaughterhouses that drains into Kiserian dam yet the dam water is used for domestic purposes, recreation, swimming and irrigation by residents of Kiserian town and its outskirts. Residents living near the Dam consume this water without any pretreatment which may cause waterborne diseases and other related public health conditions. If the effluent has high nutrients, it may affect plants grown under irrigation using the dam water or the effluent. Therefore, it is important to monitor the quality of effluent from the slaughterhouses before getting into Kiserian Dam and its effect on dam water. Therefore, the aim of the study is to determine the level of physico-chemical parameters and the total coliforms in the effluent and in the dam water.

Research Questions

1. What are the levels of pH, total suspended solids, total nitrogen, total phosphorous, dissolved oxygen and fecal coliforms (*E. coli*) in the slaughterhouse effluent and Kiserian dam water?
2. How do the physico–chemical and biological parameters of slaughterhouse effluent and Kiserian dam water compare with EMCA recommended standards of effluent discharge into the environment and drinking water respectively?
3. Do the physico–chemical and biological parameters of the effluent and dam vary with season?

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Research Hypotheses

1. There is significant difference in levels of the physico–chemical and biological parameters of the effluent and that of Kiserian dam water.

2. The physico–chemical and biological parameters of effluent from the slaughter house and Kiserian dam water is significantly different from EMCA recommended standards of effluent discharge into the environment and drinking water respectively.

3. The physico–chemical and biological parameters of the effluent and dam vary significantly with season.

Research Objectives

The main objective of the study was to assess the quality of the effluents from Keekonyokie and Kiserian slaughterhouses and its implication on water quality of Kiserian Dam and whether the effluent quality varies with seasonal variations.

Conceptual Framework

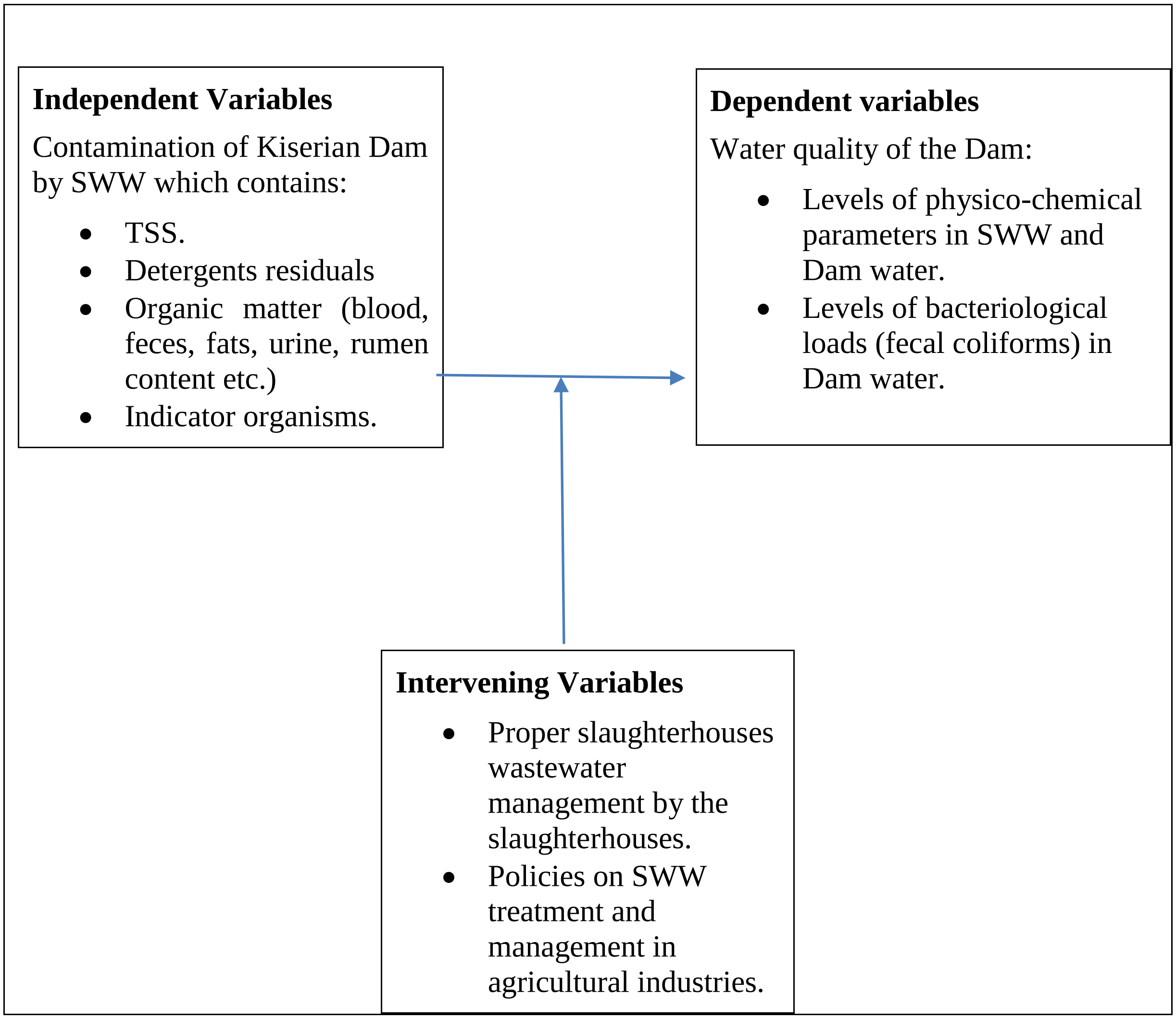

Figure 1: Conceptual Framework (Modified from Bas Swaen, 2021)

LITERATURE REVIEW

Water Pollution due to Slaughterhouse Activities

Water quality caused by insufficient or non-existent wastewater management regulations and practices endanger human health, well-being and wealth creation of a community. Attempts to ensure access to clean drinking water and proper sanitation, as guided by the Millennium Development Goals (MDG) Target 7C on drinking water and basic sanitation has been challenged by poor wastewater management (UN-Water, 2017).

Wastewater management involves the practice of taking wastewater and treating/managing it in order to minimize the contaminants to reasonable standards so as to safe for discharge into the terrestrial or aquatic environments (UN-Water, 2017). Inadequate treatment of slaughterhouse wastewater is one of the sources for surface water deoxygenation and groundwater contamination, and as a result, the United States Environmental Protection Agency (USEPA) classifies it as one of the most hazardous agricultural wastewaters (Bustillo-Lecompte and Mehrvar, 2017).

Furthermore, Edokpayi *et al* (2017), claim that abattoir waste has been known to pollute land, air as well as sources of water around it and water borne diseases such as typhoid fever and dysentery have been associated with it. If left untreated the high organic load wastewater discharge from food industries is one of the most important causes of environmental pollution in the world and a major contributing factor on aquatic ecosystem change (Hajjar and Saghir, 2018).

Slaughterhouses generate considerable quantities of wastewater due to the large amounts blood, stomach contents, cleaning of the facility and equipment used in the slaughtering process and the need for cleaning and hygiene of meat (Husam and Nassar, 2019). In an inefficient Slaughterhouse wastewater treatment procedure, the SWW contains a high concentration of slaughtered animals' blood, high particulate matter from rumen and stomach fats, undigested food, flesh parts and bone fragments (Nwankwo, *et al*, 2019). Pre-treatment of the wastewater is the starting point of the SWW treatment in lagoons and it consists of the removal of solids such as fat, grease, bones, fiber and pieces of meat from the wastewater using screens, grease and grit traps. Slaughterhouse wastewater contaminate ground and surface water due to the high content of blood, fat, manure, urine and meat tissues (Husam and Nassar, 2019).

Lagoons, also referred to as Water Stabilization Ponds (WSPs), according to Meat Control Act (356) of the Laws of Kenya are the recommended way of treating organic wastewater in all slaughterhouses as they are among the cost effective and efficient where raw wastewater is entirely treated by natural processes involving bacteria and algae. These ponds are large, shallow and are designed in a series of anaerobic, facultative and aerobic ponds depending with the activity occurring in each lagoon. Solids and BOD are removed by sedimentation and through subsequent anaerobic digestion inside the accumulated sludge. Anaerobic bacteria convert organic carbon into methane and through this process, remove sixty percent of the BOD and in subsequent lagoons, aerobic bacteria are active (EAWAG and Suphler, 2019). Abattoir wastewater is ideally suited for anaerobic treatment due to its increased concentration of biodegradable organic, alkalinity and ample phosphorous (Nwankwo *et al*, 2019).

Considering the importance of preserving the natural quality of the environment, as well as completely preventing the draining of untreated or partially treated effluents into natural bodies, it's paramount to treat SWW before pouring into recipients (Aleksandar, *et al,*2020)

MATERIALS AND METHODS

pH

The pH measurement was done using the pH probe with a temperature compensation of 25 °C. The pH probe was inserted in water and the readings allowed to stabilize before the reading was recorded in all the sampling sites.

Total Suspended Solids

The filterable solids or the Total Suspended Solids (TSS), were calculated by filtering 20 ml of the samples in triplicate through a microfiber glass filter and calculating the amount of TSS in mg/l after drying in the oven at 103-105°C (Shukri *et al,* 2017).

Total Nitrogen

Organic and inorganic nitrogen, which include nitrate, nitrite and ammonia are the most common sources of nitrogen in wastewater. The direct Nesslerization method was employed to calculate ammonium nitrogen. In a test-tube 0.2ml Nessler reagent was added to 5ml of diluted samples and thoroughly mixed. After 15 minutes, the absorbance of the sample was measured using spectrophotometer at 425 nm against total sample.

To assess nitrite nitrogen, 5 ml of the sample was mixed with 0.2 ml of color reagent. After 10 minutes, the nitrite concentration was measured spectrophotometrically against the total reagent at 543nm. The cadmium reduction approach was used to calculate nitrate. 75ml ammonium chloride was thoroughly mixed with 25ml filtered sample before being poured through a column of granule copper-cadmium. The reduced sample was obtained at a rate of 7-10ml per minute after which the first 25ml was discarded. After 10 minutes of color growth, the nitrate concentration was determined spectrophotometrically by measuring the absorbance at 543nm against a reagent blank using aliquots of 0.2ml color reagent applied to a mixture of 5ml of the reduced sample, and after 10 minutes of color development, the nitrate concentration was determined spectrophotometrically by measuring the absorbance at 543nm.

Organic nitrogen was calculated from the difference between total Kjeldahl nitrogen (TKN) and ammonium nitrogen after first estimating the Kjeldahl nitrogen (TKN). Total nitrogen was used to calculate the Kjeldahl apparatus (Shukri *et al*, 2017).

Total Phosphorus

The persulfate digestion method was used to calculate the total phosphorous. In a 50ml sample, a drop of phenolphthalein indicator was applied and thoroughly mixed. When red color appeared, sulfuric acid solution was added drop by drop to remove it. Then 1ml $1N\ H_2So_4$solution and 0.5g solid $H_2S_2O_8$ was applied. This mixture was heated for 30 minutes in an autoclave to convert organic phosphates to orthophosphate and then cooled at room temperature. A drop of phenolphthalein indicator solution was added, and the color was neutralized with NaOH to pale pink color, before being made up to 100ml with distilled water. The concentration of

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orthophosphates was calculated using the ascorbic acid process which involved pipetting 2.5ml aliquots from the 100ml into clean dry test tubes, then adding 0.4ml of combined reagent and thoroughly mixing them together. The sample absorbance was determined spectrophotometrically at 880nm after 10 minutes but not longer than 30 minutes, using reagent blank as the reference solution (Shukri *et al,* 2017).

Dissolved Oxygen

Dissolved oxygen (DO) is the measure of the oxygen dissolved in wastewater that can be able to sustain life of organisms. Azide-Winkler method was used to measure the DO. The most important was to avoid bubbles into the sample, fill the sample to overflow then stopper the bottle. A 2ml of manganese sulfate was added through a calibrated pipette just below the sample surface in a 300ml glass stoppered bottle filled with the sample. 2ml of alkali iodide Azide reagent was added in the same manner. Inverting of the sample was done severally. A brownish-orange cloud of precipitate appeared showing the presence of oxygen. Mixing was done again by turning the bottle upside down and then letting it to settle.

201ml of the sample was titrated with sodium thiosulfate to a pale straw color in a glass flask. 2ml of starch solution was applied at a time before a blue color appears. The sample was titrated slowly until the sample turned clear (Macdonald, 2019).

Fecal Coliforms (E. coli)

The presence of *E. coli* as an indicator for fecal coliforms contamination in Kiserian Dam was determined by use of Membrane filtration technique on a Chromocult Coliform Agar (CCA) enriched with cefsulodin at 5mg/l. Servings of 100ml of each sample dilution were filtered through cellulose nitrate membrane filters, and the membranes were incubated on CCA plates for 24 hours at 44.5°C. The non-fecal bacteria are heat shocked and their growth suppressed as a result of elevated temperature. The fecal coliform colonies develop and acid that reacts with the X-glucuronide to give the colonies their blue color. The colonies were counted and the resulting microbial destiny measured (Shukri *et al,* 2017).

RESULTS

The results of the study were analyzed and discussed according to individual objectives of the study.

Levels of Physio-Chemical and Bacteriological Parameters in the Slaughterhouse Effluent and Kiserian Dam Water

The level of physio-chemical and bacteriological parameters of the effluent from the slaughterhouse and in the dam showed variations during the study period (Table 1).

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Table 1: Levels of Physio-Chemical Parameters in the Slaughterhouse Effluent and Kiserian Dam Water during the Study Period

Sites/Parameters	pH	Do	TSS	Nitrates	Phosphorous	Coliforms
Site 1	6.35	19.3	725.70	37.22	100.44	1193.28
Site 2	7.2	7.40	339.85	21.61	54.39	3633.33
Site 3	7.16	4.37	459.00	67.74	33.39	4014.22
Site 4	6.85	3.26	25.73	19.28	1.3	20
Means of Sites	6.89	8.58	387.57	31.64	47.38	2215.21

pH

The pH recorded during the study period varied. It ranged from 6.35 at the slaughterhouses outlet (S1) to 7.2 at Site 2 (Table 1). The pH of 6.85 was recorded at site 4 (dam). The mean pH recorded at the dam was 6.89 (Table 1). Using the ANOVA, there was significant difference among the sites (p=0.10).

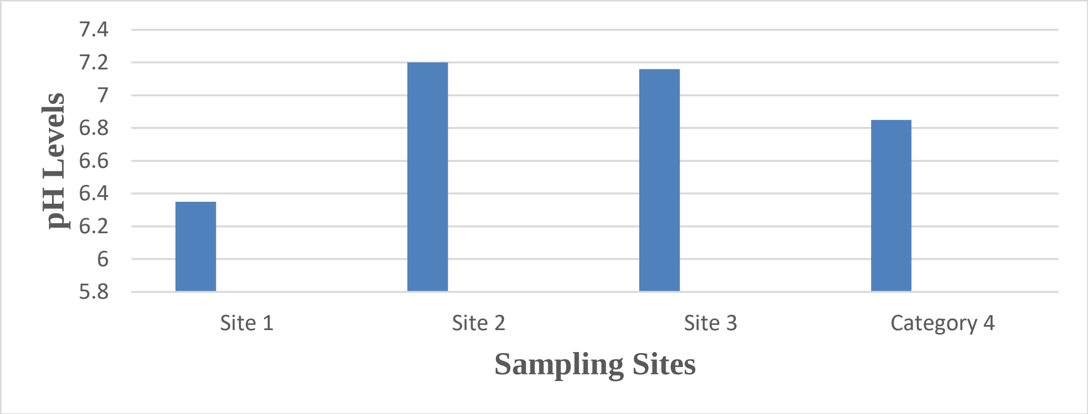

Figure 1: Means of pH Levels at Sampling Sites during Study Period (July to September 2021)

pH in water is influenced by presence of high organic matter (Jannat *et al*, 2019). And number of dissolved solids. According to (Bibi *et al*,2018), presence of sulphate contents in water affects the level of pH of water bodies. The pH of water also varies due to the number and variation of microorganisms in water and their activities (Ajayi *et al*, 2019).

The high level of pH (7.2) at Site 2 (Table 1 and Fig. 1) could be attributed to the high phosphorous from slaughterhouses' cleaning detergents and high dissolved solids before the solids start to settle as the water is moved down the river towards the dam, while the low pH (6.85) at Site 4 (Table 1 and Fig.1) could be due dilution and settling of some of the dissolved solids as the water movement in the dam is reduced and this is because the dam receive water from several streams.

The range levels of pH (6.35-7.2) are lower than those of meat processing plant in Johor which had levels of 6.5-8.0 (Apand *et al*, 2019). In Serbia, SWW showed a range 6.5-8.0 which is higher than those of Kiserian Slaughterhouses (Akrout *et al*, 2021). In India, an overview of a beef-based slaughterhouse showed a range of 6.26-6.65 levels of pH (Dhenkula *et al*, 2022).

Total Suspended Solids (TSS)

The study showed the level of Total suspended solids varied during the study period (Table 1 and Figure 2). The highest concentration was recorded in Site 1 (727.70 mg/l) while the lowest (7.33 mg/l) was recorded at the dam (S4) (Table 3.1 and Fig. 3.2). Using ANOVA there was significant difference in total suspended solids between sites (p=0.10).

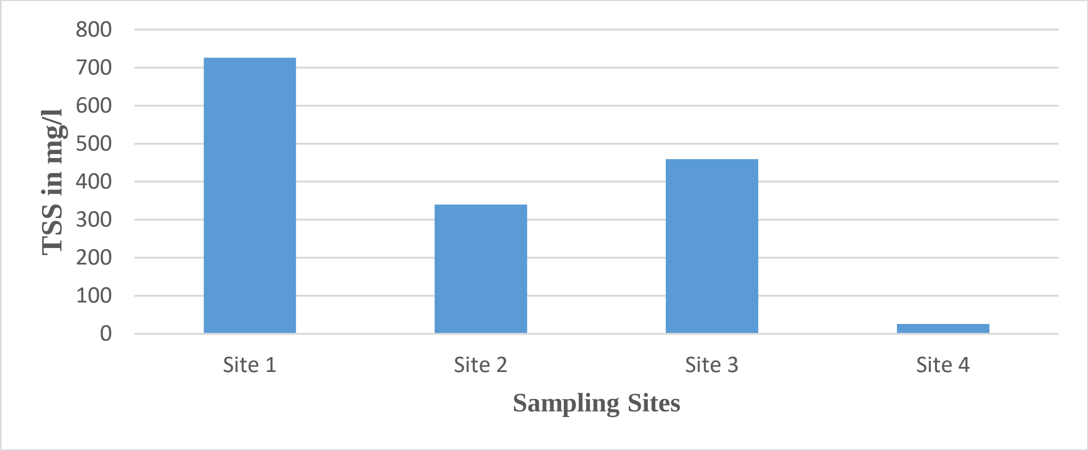

Figure 2: Means of TSS Levels in Sampling Sites in mg/l during Study Period (July to September 2021)

The variations in total suspended solids in water bodies is influenced by run-off, storms, from urban waste discharges and disposal of municipal waste into the water body (Barakat *et al,*2016). During rainy seasons movement of riverbed materials and eroded river banks increases TSS levels in the runoff. Organic impurities, insoluble inorganics, micro-planktons result in increased in TSS (Anh *et al,*2020). Fast-moving water bares large particles and causes sediments re-suspend in case of change of speed (Chen *et al*, 2019).

The high TSS in Site 1 could be attributed to the wastewater from the slaughterhouses which has very high content of fats from stomach contents from slaughtered animals and other solid wastes generated in the slaughterhouses. The low levels of TSS in the dam could be due to the fact that most of suspended solids have settled as the movement of the effluent trench has decreased before it reaches Site 4. The low TSS at site 4 is attributed to dilution and possible settlement of materials at the bottom of the dam. The increase again in site 3 could be attributed to deposition of waste as water moves along the trench.

The study findings when compared with other studies, Kiserian slaughterhouses effluent mean of 508.18 mg/l is higher than that reported for slaughterhouses wastewater in Serbia with a mean of

364.96 mg/l (Akrout *et al*,2021) but lower than in Johor Malaysia, local medium meat processing plants effluent with a mean of 1400 mg/l (Apand *et al*,2019).

Dissolved Oxygen (DO)

The study showed variations in the levels of dissolved oxygen in both the effluent and dam water (Table 1 and Figure 3). The highest level of dissolved oxygen was recorded at site at Site 1 (19.3 mg/l), and the lowest was at site 3 with 4.367 mg/l). The level of 3.256 mg/l, was found at Site 4 which is the dam (Table 1.Fig. 3). Using ANOVA there was significance difference between the sites (p=0.000).

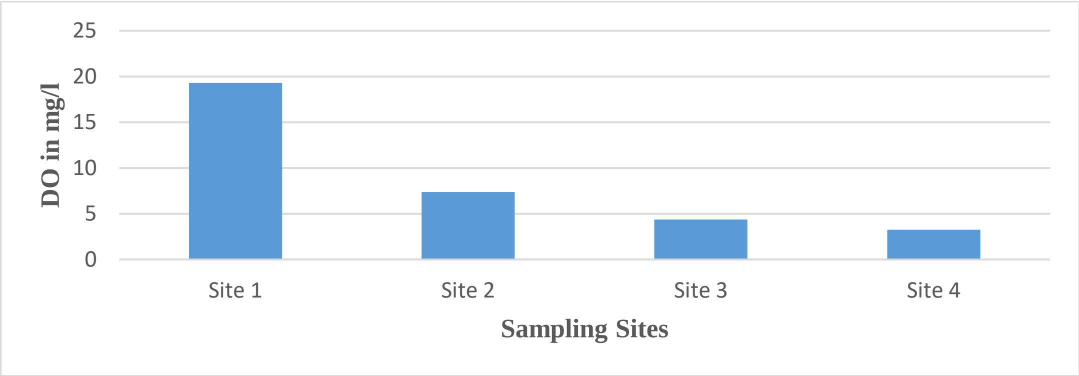

Figure 3: Means of DO levels in Sampling Sites in mg/l from July to September 2021

Temperature influences the rate of chemical and biological reactions of organisms present in water bodies which may lead to variations in DO levels (Bustillo-Lecompte and Mehrvar, 2017). Lower temperatures increase solubility of oxygen thus contributing to the increased levels of oxygen in various water bodies (Sajitha and Vijay Amma, 2016).

The high levels of dissolved oxygen recorded at Site 1 (19.3 mg/l) (Table 1 and Figure 3) could be attributed to agitation of waste water as it rushes out of the slaughter house into the trench. As the waste water moves down the trench dissolved oxygen is used up by microorganism (Sites 2 and 3) 7.40 mg/l,4.367 mg/l respectively as shown in Table1 and Figure 3. The dam recorded the lowest dissolved oxygen 3.256 mg/l (Table 1 and Figure 3) and this could be attributed to no agitation and also most dissolved oxygen has been used up by microorganisms.

Results from studies on Johor local slaughterhouse showed a mean of 6.1 mg/l (Apand *et al*, 2019) as compared to that of Keekonyokie and Kiserian slaughterhouses' discharge point, Site 1, of 19.3 mg/l. Another study done in Delta State showed abattoir wastewater had means of 8.55 mg/l (Amaku *et al*, 2020). Which is lower than the mean of 10.35 mg/l for Keekonyokie and Kiserian slaughterhouses' effluents.

Nitrates

The study revealed the levels of nitrates in mg/l varied among the sites (Table 1 and Figure 4). The highest concentration of 67.744 mg/l was recorded in Site 3 which is found at the point where the effluent enters the Dam while the lowest concentration of 21.61mg/l was recorded in Site 2 (Table 1 and Figure 4). Using ANOVA, it showed there was significant difference among sites (p=0.05).

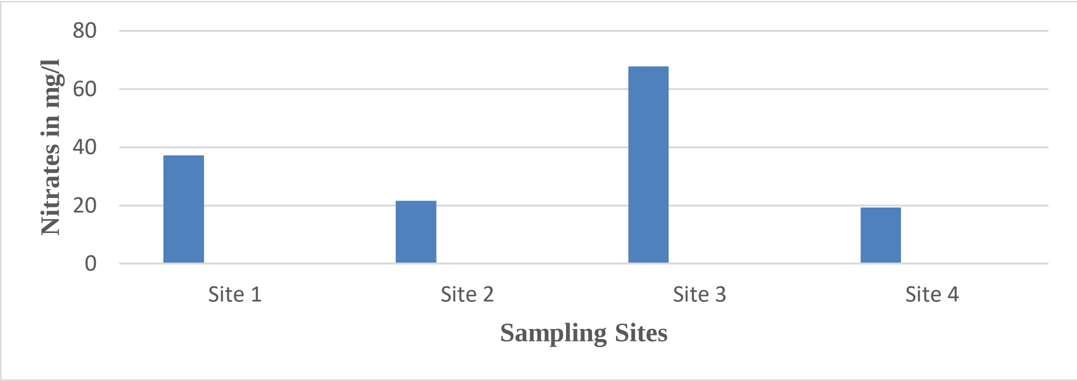

Figure 4: Means of Nitrates in Sampling Sites in mg/l from July to September 2021

Variations in levels of nitrate in water bodies may be attributed to discharge of human faecal material and run-off from zero grazing units near these water bodies (Koech *et al*,2018). Farming activities near dams or streams are other reasons why variations in nitrate levels occur when nitrates in agrochemicals is washed into the water bodies (Kitulu *et al*, 2020). Erosion from natural deposits and possible leakage from sewerage can cause significant variations in nitrate levels in water bodies (Brindha *et al*, 2017).

The variations in mean levels in this study could possibly be due to run-offs, leakage of domestic sewerage and animal waste into the drain carrying SWW as it passes through residential areas. Site 3, which has the highest mean levels of nitrates, is at the end point of the drain as it enters the dam where locals practice some farming hence the likelihood of addition from artificial fertilizers.

Reports from studies done on local slaughterhouse in Malaysia (Apand *et al*, 2019), showed mean of 317.22 mg/l. Also, a study done on an Indian slaughterhouse wastewater by Dhenuka *et al*, (2022) got means174 mg/l compared to this study's mean of 31.644 mg/l.

Phosphorous

The study revealed the concentration of phosphorous varied among sites during the study period. The concentration ranged from 1.2961 mg/l at Site 4 to the highest of 100.44 mg/l at Site 1 and a mean of 47.379 mg/l (Table 3.1). Using ANOVA, there was significant difference in phosphorous levels among sites (p=0.005).

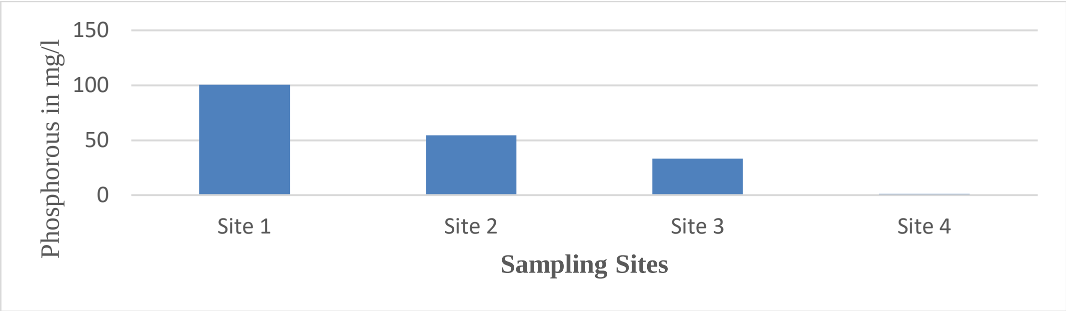

Figure 5: Means of Phosphorous Levels in Sampling Sites in mg/l during the Study Period (July to September 2021)

Variations of phosphorous levels in water quality analysis are attributed to the discharge of partial treated municipal sewerage (Koech *et al*, 2018). Discharges from slaughterhouses effluents with high phosphate content might also increase levels of phosphorous in water bodies (Amaku *et al*, 2018). Agrochemicals used in farms and washed into the water bodies can also contributed to increase in phosphorous in such bodies (Kitulu *et al*, 2020). Intensive usage of phosphate rich washing detergents to clean floors of slaughterhouses as well as intestinal contents are plausible reasons for high phosphorous in SWW (Koech *et al*,2018).

The study shows a higher concentration of phosphorous in Site 1, where the SWW leaves the slaughterhouses. This is an indication that the effluent from these slaughterhouses has a high concentration of phosphorous possibly from intestinal contents, i.e., urine and dung as well as phosphate rich cleaning detergents. The level reduces as the effluent flows to the dam with the least recorded at the consumption water drawing point (Site 4).

Concentration of phosphorous mean of 62.86 mg/l was found in study of SWW in Johor Malaysia (Apand *et al*, 2019) was higher than the mean in this study. In India, an overview study of a slaughterhouse wastewater characterization (Dhenkula *et al*,2022) showed a low mean of 8.7 mg/l compared to this study' mean of 47.379 mg/l.

Fecal Coliforms *(E. coli)*

The study revealed that the concentration of faecal coliforms varied among sites with the highest levels of 4014.22 mg/l at Site 3 and the lowest at Site 4 (Table 1 and Figure 6). Using ANOVA there was significant differences in coliform concentration between the sites (P< 0.05).

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Figure 6: Means of Faecal Coliforms in Sampling Sites in mg/l during the study period (July to September 2021)

The variations of coliform concentrations in water bodies is influenced by the source of runoff into the water (Kitulu *et al*, 2020). The presences of coliforms in water bodies is attributed to wastewater discharge and livestock farming activities in the area which increases the coliforms concentration in these bodies (Carmen *et al*,2019). Fecal coliform bacteria prefer to live near the earth surface area and their survival is conditioned by temperature, nutrients, water microbiota and biotic interactions (Carmen *et al*, 2019).

The high concentration of coliforms recorded at Site 3 (4014.22 mg/l) (Table 1 and Figure 6) could be attributed to bio-magnification of the bacteria because they have been present in the previous sites at an increasing trend. Another probability that could have caused the high levels of the coliforms at Site 3 is that the trench passes through a residential area and there is some likelihood of raw municipal wastewater entering the open trench. The low concentration of 20mg/l at Site 4 could probably be attributed to dilution in the dam has large volume of water as the dam receives water from many tributaries.

Work to identify and assess different sources of contamination to drinking water gave 56 mg/l of coliforms in water before treatment and 54 mg/l in raw water from Ain Zada Dam of Bordj Bou Arreridj, Algeria (Aidoud *et al*, 2019). In another report on microbial analysis in wells in a study to assess the impact of abattoir effluent on the quality of ground water in Omu-Aran, Nigeria showed a concentration mean of 23100 mg/l way above this study's levels of 2215.21 mg/l (Elemile *et al*, 2019).

Comparison of Parameters' Means with NEMA 2006 Standards

NEMA is in charge of environmental management in Kenya and it has a clear set of standards that regulate effluent discharges into the environment. Using the collected data, a t-test analysis was performed to establish if these parameters recorded from the sites were significantly different from the NEMA 2006 Standards for effluent discharge. (Table 3.2) gives the test results of each of these parameters and how they compare with NEMA 2006.

Table 2: One-sample t-test of site parameters' means against NEMA 2006 (α=0.05)

Parameters	Means of Sites	NEMA 2006	t-statistics	p-value
pH	6.89	6.86-7	-1.71	0.019
DO	8.58	30	-49.471	0.000
TSS	387.57	30	11.057	0.000
Nitrates	36.71	2	14.057	0.000
Phosphorous	47.38	2	9.89	0.000
Fecal coliforms	2215.21	Nil	11.19	0.000

pH

The mean pH of the study site recorded was 6.89 and the NEMA standards is 6.86. A single-sample t-test was performed to find out whether pH of the sites significantly differed from that allowed by NEMA 2006 standards for effluent discharge. Based on the results, was found that there is no statistical difference between the pH of the site and the one allowed by NEMA, t (71**)** = -1.71, p = 0.091 (Table 2). This means that the effluent in the sites meets the pH standard set by NEMA Standards for effluent discharges into the environment (Figure 7)

Dissolved Oxygen (DO)

The mean dissolved oxygen recorded at the site during the study period was 8.58 mg/l and the NEMA 2006 standards for effluent discharge is 30 mg/l. Using a single-sample t-test, results showed that there was a statistically significant difference between the mean DO level of the site and the NEMA standard for effluents discharge t (71) = -49.47, p<0.05 (Table 3.2). The levels of DO on the site were significantly lower than NEMA 2006 standards for effluent discharge (Figure 7).

Total Dissolved Solids (TSS)

The mean total dissolved solids of the site recorded was 387.57 mg/l, while the standard set by NEMA for effluent discharge into the environment is 30 mg/l. Using the single sample t-test, the results showed that the mean TSS level of the sites was significantly different from the standard set by NEMA, t (71) = 11.06, p<0.05 (Table 3.2, Figure 3.7). The TSS level in the effluent was significantly above the NEMA set standards for effluent discharge into the environment.

Nitrates

The mean nitrates amount of the site was 36.71 mg/l (Table 2). The single sample t-test showed significant difference from the standard set by NEMA 2006 standards for effluent discharge, t (71) = 14.05, p<0.05, Table 2, Figure 7). Showing the nitrates levels at the sites were higher than NEMA 2006 standards for effluent discharge.

Phosphorus

According to NEMA 2006 standards for effluent discharge, effluent should have a Phosphorus content of 2 mg/l and the mean levels of SWW in this study was 47.38 mg/l. Using the t-test it was found that the sites contained significant high mean amounts of phosphorus than NEMA 2006 standards for effluent discharge $t(71) = 9.89$, $p<0.05$ The mean of the phosphorus on the sites was significantly higher than the amount required by NEMA 2006 standards for effluent discharge, (Figure 7)

Fecal Coliforms *(E. coli)*

The mean Fecal Coliforms recorded at the sites was 2215 mg/l while the NEMA standards for effluent discharge is Nil (Table 2, Figure 7). A t-test showed the mean fecal coliforms on-site was significantly difference from the set standard by NEMA 2006 standards for effluent discharge (Table 2), $t(71) = 11.19$, $p <0.05$. The fecal coliforms on the sites were significantly higher than the NEMA set standard. (Figure 7).

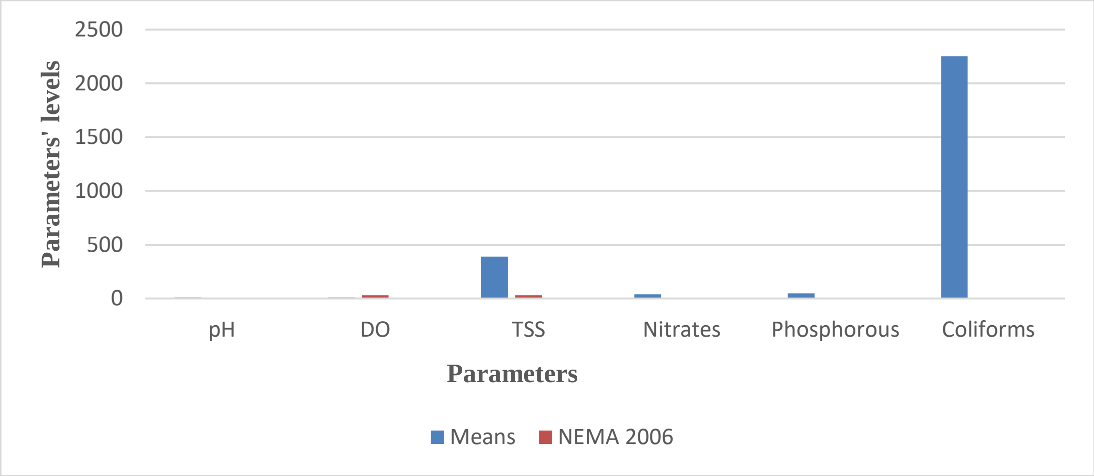

Figure 7: Parameters' Means Comparison to NEMA 2006

Relationship between the Parameters and Rainfall (Months)

The study sought to find out if there was any relationship between the levels of the biological and physico-chemical parameters of the effluent and rainfall.

Table 3: Amount of Rainfall Received during the Study Period

Months	Rainfall in mm
July	9.9
August	10.0
September	11.7

(Source: KMD, Ngong Station)

Fecal Coliforms in Mg/L at the Study Site

The highest amount of coliform was recorded in September in all the sites when the highest amount of rain was recorded (11.7mm) while the lowest number of Fecal coliforms was recorded in July, the month the lowest rainfall was recorded (9.9mm) (Table 4) the high number of fecal coliforms in all sites in September could be attributed to rainfall received then which increased run-offs and possible discharges of municipal effluents.

Table 4: Fecal Coliforms Levels Mg /L in Sites per Month

Sites/Months	July	August	September
Site 1	6948	7153	8579
Site 2	21403	21656	22301
Site 3	23410	23912	24964
Site 4 (Dam)	88	120	152

pH at the Study Sites and Rainfall

The study revealed there was a relationship between pH recorded in all the sites and rainfall. The study found out that the pH at all the sites increased with increase in the amount of rainfall. A high pH was recorded in all the sites in September when the highest rainfall of 11.7mm was recorded while the lowest pH was recorded in July with recorded rainfall of 9.9mm received during the study period. The high levels of pH in September could be attributed to high levels of organic matter from run-offs (Table 5).

Table 5: Ph Levels in Sites per Month

Months/Sites	July	August	September
Site 1	6.82	6.57	6.19
Site 2	7.025	7.08	7.49
Site 3	6.56	7.31	7.24
Site 4	6.48	7.0	7.07

Phosphorous in Mg/L at the Study Sites

The study showed there is a relationship between the amount of rainfall received and the phosphorus recorded at the site during the study period. The highest levels /concentration of phosphorus were recorded in all the sites in September when the area recorded the highest amount of rainfall 11.7mm except in the dam where the lowest concentration was recorded in September even when rainfall received was high. The high concentration of phosphorus in all sites during the time of high rainfall could be attributed to run off from the human activities around the area and in the dam the low concentration could be due to dilution (Table 6).

Table 6: Phosphorous Levels in Sites per Month

Months/Sites	July	August	September
Site1	512	578	718
Site2	214	366	399
Site3	171	195	235
Site 4 (Dam)	9.41	11.89	1.4

Nitrates in Mg/L at Study Sites

The levels of nitrates showed a relationship with the amount of rainfall received during the study months (Table 6). in all the sites the high level of nitrates were recorded in September, the month where the highest rainfall was recorded. The amount of rain recorded in September was 11.7mm the highest recorded in the three months of the study while the lowest was in July with 9.9mm of rainfall. The high levels of nitrates in all the sites could be attributed to run-off from the human activities along the effluent trench and livestock production units waste discharges (Table 7).

Table 7: Nitrates Levels in Sites per Month

Months/Sites	July	August	September
Site1	35	36.16	40.37
Site2	14.33	19.6	30.8
Site3	63.66	68.5	71.06
Dam	16.23	20.6	24

TSS in Mg/L at Study Sites

The mean TSS recorded during the study period showed relationship with the amount of rainfall received in that month. The highest rainfall of 11.7 was recorded in the month of September and it is also the month where the levels of total dissolved solids were the highest in all the sites during the study period. The high level of TSS during the period of high rainfall could be attributed to run-off from human activities along the sewage trench (Table 8).

Table 8: TSS Levels in Sites per Month

Months/Sites	July	August	September
Site1	581.6	745.3	850.1
Site2	272.23	381.33	366
Site3	444.83	450	502.17
Dam (Site 4)	25.053	28	27.5

DO in Mg/L at Study Sites

A relationship between dissolved oxygen in the study area and the rainfall was studied and it was found that the mean DO was had a relationship with the amount of rainfall received, high level of dissolved oxygen was recorded in all the sites in the month of September, the month which recorded the highest rainfall of 11.7 mm. The high level of dissolved oxygen could be attributed to low temperatures during the rainy season and agitation which improves the solubility of atmospheric oxygen into the water (Table 9).

Table 9: DO Levels in Sites per Month

Months/Sites	July	August	September
Site1	11.45	13	14.6
Site2	5.9	7.9	8.3
Site3	2.8	5.06	9.9
Dam	2.35	3.26	4.15

Conclusion

The following conclusion were made according to the objectives of the study. On the levels of parameters in the slaughterhouses' effluent and Kiserian dam, the results showed that pH was high in Site 4 (Dam) than in Site 1 (point of effluent discharge from the abattoirs). All other parameters concentrations were significantly higher in Sites 1,2 and 3 than in the Dam. The second objective was on the comparison of the parameters' means concentrations with the recommended standards by NEMA 2006 on effluents, discharge into environment. The pH levels were within the recommended standards of effluents' discharge into the environment. DO levels were lower than NEMA 2006 standards while those of TSS, Nitrates, Phosphorous and Fecal coliforms were way above the recommended levels. The results compared negatively with NEMA 2006 hence the abattoirs effluents had effects on Dam water quality. The third objective was to determine whether these parameter levels varied due to weather. The results of Fecal Coliforms increased in the month of September when 11.7 mm of rainfall was experienced. pH levels were lower in July which received the lowest rainfall during the study period (July to September 2021). There were no variations in levels of the other parameters, DO, TSS, Nitrates and Phosphorous, during the study period. The increased fecal coliforms concentration maybe due to biomagnification of the bacteria.

Recommendations

The effluents from the slaughterhouses, Keekonyokie and Kiserian have a negative on the water quality of Kiserian Dam according to the study as the levels of parameters are higher in the effluent than in Dam water. Therefore, pre-treatment of slaughterhouses' effluent is recommended to reduce the concentration levels. SWW treatment is a form of resource recovery where the safe effluents can be used for irrigation and also reduce contamination of the receiving water bodies thus improved water quality.

The concentration levels of the parameters' in both the abattoir effluent and dam water varied significantly with recommended levels of effluent discharges to the environment by NEMA 2006. Treatment of effluents from slaughterhouses need to treated before being discharged to the environment. SWW management must be a requirement in licensing and permitting slaughterhouses establishment and operations in aid of environmental conservation and preservation.

The parameters' levels showed no major significance difference during the study period other than the Fecal Coliforms that was high in the last month of the study. This increase in Fecal Coliforms in the month of September was probably due to biomagnification. Slaughterhouses' effluent need to be treated before being discharged into the environment to avoid contamination of receiving water bodies and also crops that are irrigated with such effluents.

DECLARATIONS

Limitations

No limitations

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Competing Interest

I have no competing interest

Warning Hazards

No hazards to be warned of.

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