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# Abattoir Effluent and Quality of Water in Nyanchabo Stream, Kisii County, Kenya

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## ABSTRACT

The existence of livestock in the great expanse of the world's ecologies affects biodiversity in both developed and fast developing countries where it is frequently a major cause of water pollution. Dairy farm waste and wash-down from slaughter houses constitutes an enormous challenge leading to the release of raw or inadequately treated effluent into water bodies that leads to quality deterioration in receiving waters. Through water quality monitoring, this study aimed to evaluate the impact of Itibo abattoir wastewater on the physico-chemical and bacteriological quality of Nyanchabo stream waters. It ascertained parameters levels of abattoir effluent and stream water before and after the two interacted and compared with the guidelines provided by the National Environmental Management Authority (NEMA) and World Health Organization (WHO). Field sampling was conducted over a six-weeks period, and water quality parameters of temperature, Potential for Hydrogen (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrite ($NO_2$), Phosphate ($PO_4$) and total coliform, *Escherichia coli* and *Faecal streptococci* load were quantified. Standard methods and instruments were employed at the field and laboratory for sample collection and analysis. Statistical analysis was performed using Graph Pad Prism, version 5.0, with statistical significance level set at P=<0.05. The study findings revealed that, except for pH, Temperature, EC, DO, TDS and $NO_2$ which got elevated, the abattoir effluent also amplified the levels of TSS (1144±360.8)mg/l, BOD (199.8±47.9)mg/l, COD (2194±1344)mg/l, $PO_4$(12.40±2.725)mg/l, Total coliform (68,183±16,715)cfu/100ml, E. coli (29850±13212) cfu/100ml and F. streptococci (122667±33193)cfu/100ml in the stream waters beyond permissible limits consequently impacting negatively on the stream water quality. Nyanchabo stream water was hence found to be unfit for use by humans and animals unless the effluent was adequately treated before discharge. Additionally, upstream pollution control measures which include soil erosion control, proper disposal of human and animal faecal matter and reclaiming of the riparian land was recommended to avert stream pollution from other non-point sources.

**Key words:** Abattoir wastes, Effluent, Stream, Treatment pond, Water Quality.

## 1. INTRODUCTION

Rapid growth of industries in developing nations carries with it negative effects in terms of water quality since any waste discharged affect the ecological functions of a stream, river or surface water by altering one or more of its water parameters levels. In the Sub region of Eastern Africa, release of effluent loaded with high levels of organic matter and nutrients into adjacent surface water bodies is common as treatment facilities for industrial and domestic wastes and effluents are either non-existent or inefficient [1]. The livestock subsector in agriculture is one such area that causes instability to many ecologies and contributes to global environmental harms. Greenhouse gas (GHG) discharges from livestock production and resultant waste in the run-off, and from pasture expansion into plantations are significant contributors to climate variability [2].

In developing countries, Kenya included, abattoirs are sited in close proximity to water bodies for quick and easy accessibility to water for slaughtering activities [3], besides being near residential areas to allow for provision of fresh products. Abattoirs require large quantities of high-quality water but are faced with the problem of treating the wastewater before it is returned to a water body or environment. Abattoir wastes are classified as one of the most detrimental industrial wastewaters to the environment [4] as these wastes are characterized by high BOD content, and when released into the environment, they disrupt the ecological balance of the receiving waters [5] which include river deoxygenation and groundwater pollution [6]. Insufficient treatment before discharge is majorly due to economic constraints that have slowed the adoption and implementation of environmental control technologies. Furthermore, for even those that have adopted, the gap to reach efficiency is still big considering for instance, aspects like the number and size of treatment ponds required to reach efficiency in an abattoir set up. Inappropriate management of wastes from abattoirs leads to their disposal into adjacent surface water bodies. This constitutes contamination of such waters consequently posing serious health and environmental hazards to aquatic life, livestock and human beings [7].

Globally, the regulations and standards governing abattoirs vary significantly, like in numerous countries where animal slaughtering is regulated by tradition, custom or religion (e.g. halal for Muslims) rather than by law. Many articles including those by Cook *et al.,* 2017, and Kirui *et al.,* 2024, have confirmed that in Kenya, abattoirs are regarded as high-risk facilities due to their potential to pollute the environment and impact on the health and livelihoods of the locals. The Government instituted laws and regulations governing the meat industry (e.g. Second schedule of EMCA, 1999 & Water quality regulation, 2006) [8], whereby Environmental Impact Assessment (EIA) and subsequent Environmental Audits (EAs) should be implemented to ensure that abattoirs and environment are safeguarded from unhygienic impurities and possible environmental issues. However, implementation of these laws has been beclouded by challenges like establishment of some abattoirs before respective laws are enacted, making it difficult to have an effective Environmental Management Plan (EMP) for Itibo abattoir for instance.

In Kisii, many abattoirs were sited without carrying out EIAs and consequently, no appropriate mitigation measures, like EMP, are available or easily implementable. Itibo abattoir depicted such a scenario despite being the second largest in Kisii County. While the wastewater from the abattoir (influent) was first channeled through treatment ponds (lagoons), the effluent discharged from the pond outlet into Nyanchabo stream was continuous due to overflow of the ponds that left no room for ample retention time, besides being dark brownish in colour.

In light of the above-mentioned situation, this research work aimed at assessing the quality of water in Nyanchabo stream and find out whether the disposal of the abattoir effluent into it had any impacts on the quality of these waters. Many studies have been carried out on the effects of wastes on the receiving waters; wastes from food industries such as sugarcane, beer manufacturing and soft drinks bottling, coffee processing and dairy industries like that on effects of tea factory effluents and runoff from tea farms on Kipsonoi river and Arroket stream by Lang'at B. 2003. Many more have concentrated on wastes from Abattoirs in many parts of the country, e.g. Environmental Degradation and Health Risks associated with wastes from Thika Municipal Slaughter house, Kiambu, County, Kenya, by Muturi, N. J. (2014) [9] but in Kisii, there was very limited documented information especially on surface waters receiving effluent from abattoirs either directly or indirectly.

**Problem statement:** In the study area, the effluent from Itibo abattoir treatment pond was being discharged into receiving waters of the nearby stream and the possible cumulative harmful effects had not received much consideration except for occasional outcry from locals and reactive response by NEMA. The water quality status of Nyanchabo stream especially at and after the point of effluent discharge was unknown. This stream leads to the main river, River Iyabe that was a source of domestic water for the locals in the Sub County and beyond, which was mostly used in untreated form. The self-cleansing and dilution effects that help in restoration of river water quality is always assured when a river has a wide riparian land and well aerated water [10], aspects that were generally inadequate for this stream. Consequently, there was perceived presence of potential environmental and health hazards to downstream users of this water especially since there was insufficient evidence showing treatment of the effluent before discharge into the stream. This problem possibly exacerbated the concentration of harmful organisms and materials in the effluent that ended up in the stream water. This situation prompted the need for this study that intended to assess the impact of abattoir effluent on the water quality parameters of Nyanchabo stream through evaluating the physico-chemical and bacteriological water parameter status before, at and after the point of effluent discharge.

## 2.0 DATA AND METHODOLOGY

### 2.1 Study area

#### *2.1.1 Location*

Itibo abattoir and the adjacent Nyanchabo stream are located one kilometer from Suneka Township Kisii County. The abattoir and part of the stream lies between latitudes 0° 41' 14"S and 0° 41' 54"S and between longitudes 34° 41' 26"E and 34° 42' 10"E and are 100m off Kisii-Migori highway [11] as shown in Figure 1.

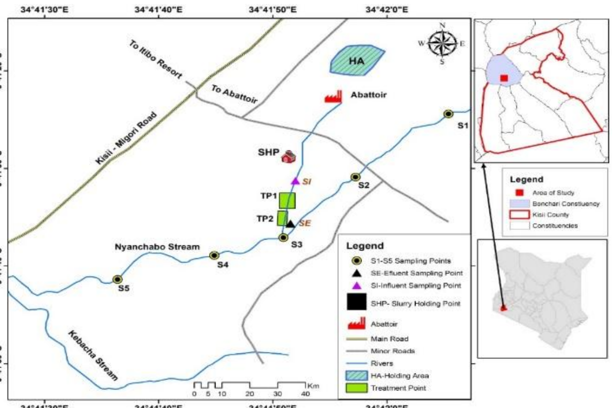



**Figure 1:** Map showing abattoir location in Kisii County and sampling sites.

The abattoir is the second largest in Kisii and does an average of 35 cattle and 20 goats/sheep in two shifts in a day. The wastewater from the abattoir is channeled through two treatment ponds and then discarded as effluent into Nyanchabo stream that passes ten meters from the lower pond. The stream runs for 500 meters before intersecting with another stream, Kebacha to form river Iyabe, a tributary of River Riana that empties its waters in Lake Victoria in Migori County. The surrounding area is characterized by scattered rural dwellings with small scale crop and livestock farming that is done up to the riparian land on both sides of the stream.

### *2.1.2 Climate*

The study area falls within Lower Highland (LH) at 20% and Lower Midland (LM) at 5%. The rainfall pattern is bimodal due to the highland equatorial climate experienced in the region. The annual rainfall is averagely 1500mm with long rains, occurring in March & June whereas short rains are experienced between September & November. July & January are the drier months. Maximum and minimum temperatures vary between 21 & 20ºC and 15 & 20°C respectively [11]

### 2.2 Sampling stations

Seven sampling sites were identified during a reconnaissance trip to the study area (Fig. 1), two abattoir points ($S_I$ & $S_E$) and five (5) along Nyanchabo stream (S1-S5). The sites were selected on the basis of physical appearance of water, presence of point sources of pollution and accessibility. $S_I$ at the influent entry into the treatment ponds, $S_E$ at the effluent exit from the pond before discharge into stream, and S3 on the stream where the effluent joins the stream waters, S1 & S2 at the upstream at a distance of 100 and 50 meters respectively from effluent discharge point into the stream, S4 & S5 were located downstream, 50 and 100 meters respectively from the point of effluent discharge.

### 2.3 Sample collection

The study targeted assessment of thirteen (13) water quality parameters of pH, temperature, electrical conductivity, DO, TSS, TDS, BOD, COD, Nitrite, phosphorus, Total coliforms, *E. coli* and *Faecal Streptococci.* Sampling was done on Wednesdays when peak slaughter occurred, for six (6) weeks in the months of August and September, 2025. Samples were collected in duplicate at the seven (7) sites for field and laboratory analysis between 7.00 and 9.00am when effluent was released into the stream. All sampling followed the APHA (2006) guidelines where; Plastic and glass sampling bottles were pre-cleaned with 1 molar Nitric acid (1M $HNO_3$) rinsed with distilled water and then with sample water before sampling [12]. For onsite measurements, WTW Multiline P4 meter for pH, EC, TDS and DO probe (WTW Oximeter 91) for Temperature and DO, were used where the meters were calibrated using distilled water, probe dipped in sample, allowed to stabilize and reading taken. For laboratory analyses; at abattoir sites ($S_I$ & $S_E$), sampling bottles were held by the bottom and neck held against waste water until full and cap tightened while for stream sites, samples were drawn midstream, at 10cm depth using a water scooper, put into the pre-cleaned bottles and cap tightened. Glass bottles (250ml) were used to collect samples for bacteriological analyses. All the sampling bottles labelled with station, date and time, were then preserved in a cooler box at $4^0$C) and transferred to the Rift Valley Water Services (RVWS) laboratory in Nakuru County for analysis.

### 2.4 Laboratory analysis

Laboratory analyses were conducted on the abattoir and stream samples to determine TSS by Gravimetric method, BOD by 5 -day Respirometry (monometric), COD by Closed reflux then Titrimetric Method, Nitrite by Colorimetric diazotization technique, total phosphorus by Persulphate acid digestion method & photometrically, and Total coliform and E. coli by Serial dilution, Membrane filtration technique, then cultivation using Chromocult culture, and F. Streptococci by Membrane filtration technique. These analyses were conducted in line with the standard operating procedures as per the Standard Methods for Examination of Water and Wastewater [13].

### 2.5 Data Analysis

Statistical analysis was carried out to test whether there were any significant differences between the various sampling stations including S1, which was considered to as the baseline as it was sited where the stream was relatively fresh and less polluted compared to stations at the downstream and abattoir. The mean values of all measured parameters (13) were calculated from the duplicate samples using Microsoft Office Excel, 2010 and then fed onto Graph PAD prism, version 5.0 statistical analysis tool. The data was analyzed at significance level of $p=<0.05$. The minimum and maximum values, means, median, standard deviations, and standard error for each of the parameters were determined using the tool and the results displayed in tables and graphs that were critical for interpretation and presentation of the results.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Physico-chemical properties

#### *3.1.1 Potential for Hydrogen (pH)*

The mean value for pH at study site S1 (7.403 ± 0.2325) was significantly different from values at study sites $S_E$ (8.213 ± 0.06615) *** and S3 (7.963 ± 0.1017) * as shown in Figure 2.

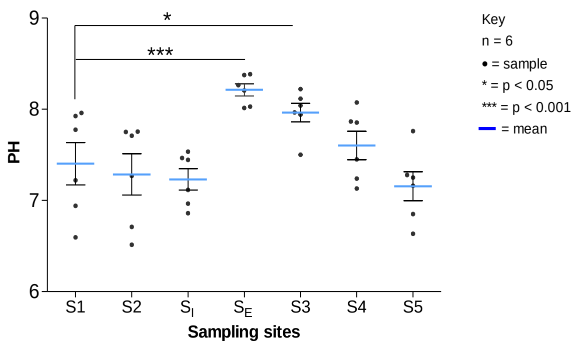



**Figure 2:** Mean values of pH levels for sampling sites.

The pH levels across the sampling sites were generally basic to near neutral, ranging from (7.156 ± 0.1585) to (8.213 ± 0.06615). Sites S1 and S2, at the upstream, had values of (7.403 ±0.2325) and (7.285 ± 0.2267), respectively, consistent with typical unpolluted stream water (6.5-9.0). The pH at $S_I$, was (7.231 ± 0.1176), reflecting minimal change since this originated from the lairage and largely composed of portable water for cleaning carcasses after slaughter. In contrast, the pH at $S_E$ (effluent site) was notably higher (8.213 ± 0.06615), due to biological processes that facilitates protein residues and fat oxidation in the ponds, which release alkaline substances [14]. Site S3, where the effluent interacted with the stream, had a pH of (7.963 ± 0.1017), showing an increase compared to upstream sites. Moving downstream, pH values gradually decreased at S4 (7.603 ± 0.1564) and S5 (7.156 ± 0.1585), due to dilution effect. Despite the effluent discharge at S3, pH values remained within the acceptable range of 6.5 to 8.5, as per NEMA guidelines on permissible limits. This suggested that abattoir effluent did not significantly affect the stream's pH, indicating no adverse effects on aquatic life and on the suitability of the water for domestic use.

#### *3.1.2 Temperature*

The mean value of temperature for study site S1 (20.43±0.4264) was significantly different from value at study site $S_I$ (22.03±0.2707) ** as shown in Figure 3.

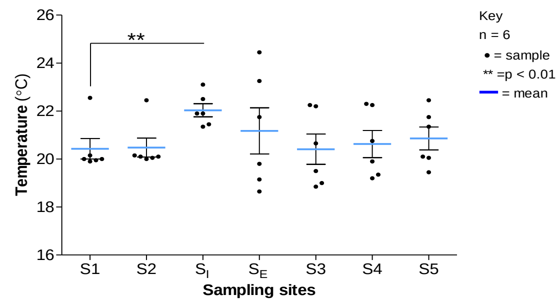



**Figure 3:** Mean values of temperature levels for sampling sites.

Temperature readings across the sampling sites ranged from 20.41°C to 22.03°C, with minimal variation. S1 and S2 had almost similar temperatures of (20.43±0.4264) and (20.48±0.3955)ºC respectively, reflecting ambient stream status. $S_I$ recorded the highest value (22.03±0.2707)ºC, given that this being influent (largely water) from the slaughter process used for washing fresh carcasses at body temperature of 39°C, is initially very warm. The effluent ($S_E$) recorded values of (21.18±0.9614)°C, with large variability, suggesting occasional thermal spikes. It reflected pond conditions, which adjusts to local atmospheric temperatures and tends to remain slightly elevated due to absorption of heat from sunlight by suspended particles. At S3, and downstream sites, S4 and S5, temperatures were lower with slight incremental differences as the stream moves downwards, at (20.41±0.6297) ºC, (20.63±0.5670) ºC and (20.86±0.4755) ºC, respectively. This indicated that the effluent did not significantly impact on the water temperature in Nyanchabo stream after its interaction with the stream at S3. The slight increase in levels downstream was likely due to atmospheric warming rather than the abattoir effluent.

#### *3.1.3 Electrical Conductivity (EC)*

The EC value for site S1 (131.8±5.835) was significantly different from values at sites $S_I$ (2814 ± 134.1) ***, $S_E$ (3658 ± 332.4) ***, and S3 (1352±279.3) *** as shown in Figure 4.

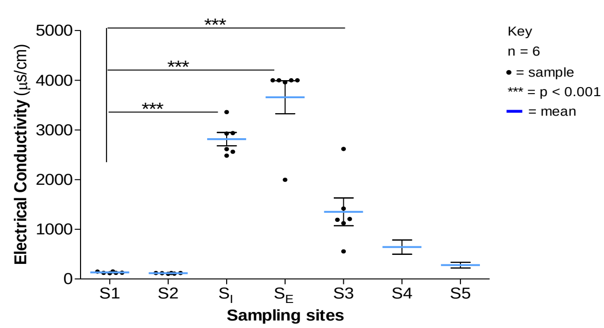



**Figure 4:** Mean values of EC levels for sampling sites.

The study sites at the upstream exhibited low values for EC where S1 was (131.8±5.835) $\mu Scm^{-1}$ and S2 was (116.3±2.851) $\mu Scm^{-1}$. This was consistent with typical EC values for such water (below 1000 $\mu Scm^{-1}$) given that it was still fresh and low in pollution levels. At the abattoir sites $S_I$ and $S_E$, EC levels registered were significantly higher, with values of (2814±134.1) and (3658±332.4) $\mu Scm^{-1}$, respectively. This resulted from the slaughtering process which produced wastewater high in dissolved ions from blood, urine and paunch contents. The effluent from the abattoir's biodegradation ponds contained even higher levels of dissolved ions most likely due to decomposition of organic matter from the abattoir which increased conductivity significantly. There was a significant rise in EC value at site S3 to (1352±279.3) $\mu Scm^{-1}$ owing to stream water interaction with the abattoir effluent which had comparatively high values. This interaction spiked the EC levels that persisted downstream while diminishing gradually at S4 (643.2±142.7) $\mu Scm^{-1}$ and S5 (279.3±58.01) $\mu Scm^{-1}$ due to dispersion and dilution effect of the stream water.

Overally, the results on sites $S_I$, $S_E$, and S3 had elevated levels of EC, signifying pollution potential which could disrupt the ecosystem, reduce organism populations, and result in biodiversity loss, that stem from the abattoir and the inefficiency of the waste treatment system at the ponds. Nevertheless, with NEMA permissible limit for EC being 2000 $\mu Scm^{-1}$ (Table 1), all the sampling sites on the stream displayed values that were well within this limit thereby indicating that the abattoir wastewater had no significant detrimental effect, emanating from EC load, on quality of Nyanchabo stream waters.

### *3.1.4 Total Dissolved Solids (TDS)*

The mean value of total dissolved solids present in study site S1 (65.92±2.934) *** was significantly different from values for solids present in study sites $S_I$ (1407±66.71)***, $S_E$ (1829±166.2)***, and S3 (675.3±139.7)*** as shown in Figure 5.

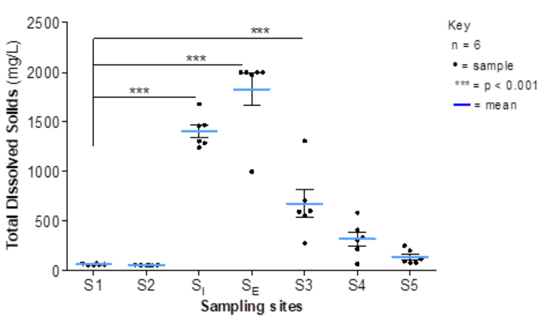



**Figure 5:** Mean values of TDS levels for sampling sites.

TDS values at sites S1 and S2 were lowest with readings of (65.92±2.934) and (58.08±1.325)mg/l, respectively. These sites were located upstream where the waters were relatively fresh and unpolluted with minimal dissolved solid. On the contrary, and following the EC pattern, TDS levels were significantly high at sites $S_I$ and $S_E$, with recordings of (1407±66.71) and (1829±166.2)mg/l, respectively. The influent being the washdown from the slaughtering process at the lairage, introduced a range of dissolved solids likely from blood, fats, inorganic salts (like sulphates and phosphates), nutrients (nitrogen, phosphorus), trace minerals and even heavy metals [15], that could be attributed to the spiked TDS levels at $S_I$. $S_E$ recorded an even higher TDS value than that at $S_I$, indicating that the retention ponds accumulated and made the effluent more concentrated with dissolved solids. The TDS values at S3 of (675.3±139.7) mg/l indicated a significant increase from values at S1 and this reflected the effect of interaction with the abattoir effluent which had higher TDS levels. These levels reduced gradually as the water moved downstream with readings of (321.4±71.37)mg/l and (139.4±29.02)mg/l for S4 and S5, respectively. This was linked to the dilution and dispersion effect of the stream water on the effluent discharged at site S3. The extreme levels of TDS at $S_I$ and $S_E$ portrayed high potential for the abattoir sites to pollute the stream waters, nevertheless, upon interaction with the stream at S3, the TDS values were significantly reduced by dispersion and dilution to levels below the permissible limit set by NEMA of 1200mg/l. It was hence concluded that Itibo abattoir had no significant effect on the TDS values of Nyanchabo stream waters.

### *3.1.5 Dissolved Oxygen (DO)*

The mean value of DO present in study site S1 (6.442 ± 0.6903) was significantly different from values at study sites $S_I$ (3.683 ± 0.9522) ***, and $S_E$ (4.675 ± 1.158) * as shown in figure 6.

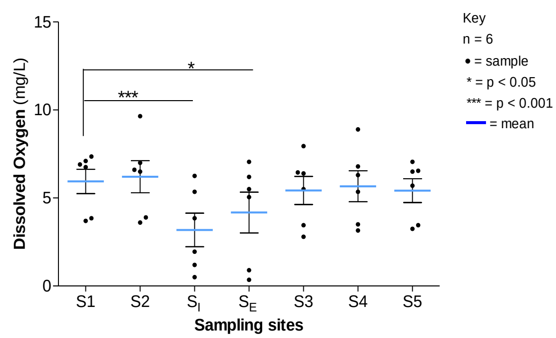
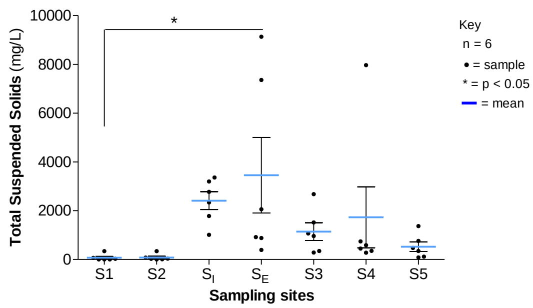



**Figure 6:** Mean values of DO levels for sampling sites.

DO recordings along the stream were fairly constant, however at S3, values were slightly inhibited by interaction with the effluent. At the upstream, readings were (5.942±0.6903)mg/l for S1 and (6.208±0.9100)mg/l for S2. These sites were where the stream waters were relatively fresh, clean and unpolluted though the values indicated presence of oxygen demanding substances. For $S_I$ and $S_E$, DO levels were remarkably low compared S1 and S2, with values of (3.683±0.9522)mg/l and (4.675±1.158)mg/l, respectively. The low values at $S_I$ was attributable to the abattoir wash-down which had high organic matter content (pieces of meat, blood, urine, fats, proteins, fibres, dissolved solids, gut contents and pathogens) that consume oxygen in their decomposition process. This is extended into the biodegradation ponds; however, the organic matter here is exposed to the atmospheric air that avails more oxygen thus the slight increase in DO levels at site $S_E$. At S3, DO of (5.925±0.7995) mg/l indicated a slight reduction in stream water values that is attributed to interaction with effluent from the pond. There occurred to be some slight recovery at S4 with readings of (6.165±0.8803) mg/l and then a slight drop at S5 with readings of (5.917±0.6775)mg/l as the stream water moved downwards, an aspect attributable to the turbulence and aeration effect of the stream water. Despite the fluctuations observed, DO levels fairly remained within the permissible range of 6.5-8.0 mg/l thus no significant impact of the wastewater on the stream's DO quality.

### *3.1.6 Total Suspended Solids (TSS)*

The mean value of TSS present in sampling site S1 (72.83±54.46) mg/l was significantly different from values present in site $S_E$ (3458±1548) mg/l as shown in figure 7.




BOD

**Figure 7:** Mean values of TSS levels for study sites.

Low levels of TSS were recorded in the upstream, with S1 having (72.83±54.46) mg/l and S2, (81.17±52.86) mg/l. This reflected relatively clean water, despite the registered level of suspended materials that comes with run-offs joining the stream as the water moves downstream. On the contrary, the values recorded at the abattoir sites, were comparatively high with $S_I$ registering (2410±366.0) mg/l and $S_E$, (3458±1548) mg/l. This was attributable to abattoir washdown and effluent rich in organic and inorganic matter like condemned meat, undigested ingesta, animal waste, carcasses, etc., known to increase TSS to levels beyond permissible limits [16]. Notably, the treatment process in the biodegradation ponds ironically elevated the TSS level of the influent thus heightening the values at $S_E$, suggesting that there was more accumulation and concentration of TSS materials from other additional sources e.g. run off that carries animal faeces and other materials in the abattoir vicinity into the ponds. TSS value at S3 was (1144±360.8) mg/l indicating an increase from the baseline values at S1, reflecting the effect of effluent discharge after interaction. The downstream recordings depicted a reduction in TSS levels with S4 registering (1730±1249)mg/l and S5, (524.8±196.7)mg/l, a pattern that was attributed to the dilution effect of the stream water on the effluent discharged at point S3. All TSS values recorded at the sampling sites (upstream included) varied widely but remained above the permissible limit of 30 mg/L. The effluent exacerbated the situation at S3 and therefore was found to have significantly elevated TSS in Nyanchabo stream, thus degrading its water quality.

### *3.1.7 Biological Oxygen Demand (BOD)*

The mean value for BOD at study site S1 (9.883± 3.529) was significantly different from values at sites $S_I$ (1206± 291.0) ***, and $S_E$ (541.5± 107.5) * as shown in Figure 8.

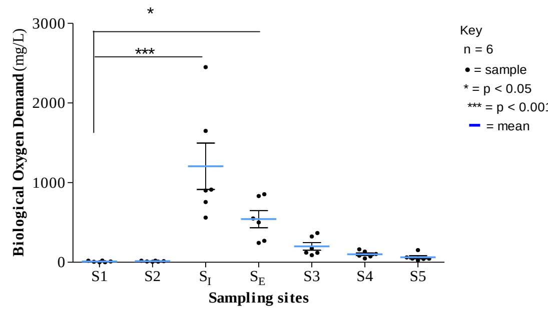



**Figure 8:** Mean values of BOD for study sites.

BOD levels recorded at the upstream sites were very low with values of (9.883±3.529) mg/l at S1 and (13.4±2.19) mg/l at S2. In contrast, extremely high concentrations were observed at site $S_I$ (1206±291.0)mg/l since the influent is a composite of organic matter; animal blood ($BOD_5$ of 156,500mg/l), Paunch manure ($BOD_5$ of 50,200mg/l) [7], animal faeces and other components like fat which demand large amounts of oxygen for degradation thereby elevating the influent BOD levels. Additionally, abattoir wastes have been observed to contain materials having high oxygen demand, notably animal blood [17]. Incomplete treatment of the influent at the ponds made the effluent at $S_E$ to also register high levels of BOD (541.5±107.5)mg/l with the effect of this discharge becoming evident at S3, where the stream BOD was spiked to (199.8±47.9)mg/l. On the downstream, BOD levels gradually decreased, recording (101.0±17.06)mg/l at S4 and (62.5±18.67)mg/l at S5, a reduction attributable to aeration, mixing, turbulence, and dispersion, which enhanced dissolved oxygen availability. The ponds substantially reduced the BOD level in the effluent but considering the NEMA permissible limit of 30 mg/l, only sites S1 and S2 recordings fell within acceptable standards and this therefore implied that the abattoir effluent was the primary source of organic pollution, degrading stream water quality from site S3 onwards and sustained BOD levels well above safe limits.

### *3.1.8 Chemical Oxygen Demand (COD)*

The mean value for COD at study site S1 (12.50±3.212) was significantly different from values at sites $S_I$ (7515±807.0) ***, and $S_E$ (6228±1703) *** as shown in Figure 9.

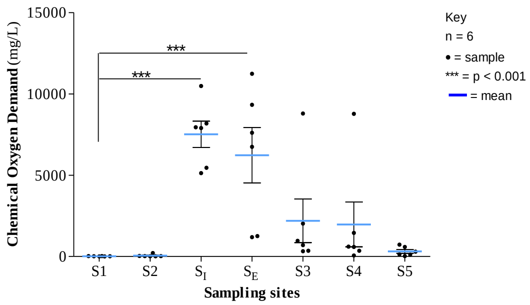



**Figure 9**: Mean values of COD for study sites.

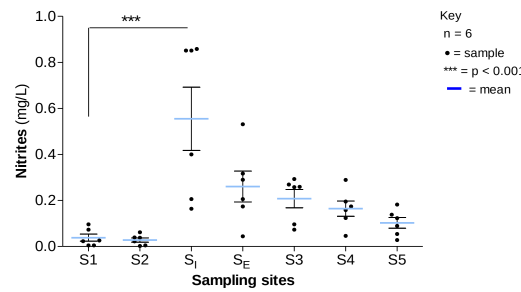



**Figure 10:** Mean values of $NO_2$ for sampling sites.

COD levels at upstream sites S1 (12.5±3.212)mg/l and S2 (53.0±31.03)mg/l were low, depicting relatively fresh and unpolluted water. In contrast, very high COD concentrations were recorded at the abattoir influent $S_I$ (7515±807.0)mg/l and effluent $S_E$ (6228±1703.0)mg/l though for $S_E$, values were slightly lower, indicating the biodegradation ability of the treatment ponds that slightly reduced the COD. These two abattoir sites suggested elevated levels of COD (COD >6,000) and proved that the abattoir wastewater contained substantial organic matter requiring large amounts of oxygen for degradation and therefore posed serious pollution potential. The organic matter from the lairage comprising of blood, meat, fat, and intestines, as well as urine and faeces resulted in high COD, with values of up to 9,000 mg/l as observed by Mabatho *et al.*, 2022 [18], where the COD values for abattoir wastewater or receiving rivers are often high, attributed to the presence of organic matter and various salts [19].

At S3, COD levels of stream water rose to (2194±1344)mg/l attributable to interaction with effluent from the treatment pond which had higher COD level. The COD levels then decreased gradually from point S3 onwards to (1972±1374)mg/l at S4 and drastically to (312.5±1374)mg/l at S5, a trend attributed to aeration, mixing, turbulence, and dispersion that increased oxygen availability. Since the permissible COD limit was 30 mg/l, only the upstream site S1 met the standard. S2 had values above the limit most likely since the site was located near a bridge where runoff from the abattoir vicinity enters the stream and contains higher amount of debris and organic substances typical of surface water runoff. $S_I$ and $S_E$ were hotspots of organic pollutants, which were transmitted to the stream at S3 and persisted downstream, demonstrating that abattoir effluents introduced oxygen-demanding substances and degraded water quality at the stream.

### *3.1.9 Nitrite ($NO_2$)*

The mean value of nitrite present in study site S1 (0.0380±0.01542) was significantly different from values at study site $S_I$ (0.5550±0.1373) *** as shown in figure 10.

Nitrite values for the study sites ranged from 0.0280 to 0.5550 mg/l (table 1). S1 and S2 recorded low means of (0.0380±0.01542)mg/l and (0.0280±0.009342)mg/l, respectively, suggesting low baseline levels of nutrient enrichment that is commensurate with unpolluted stream water. For abattoir sites, $S_I$ and $S_E$ had much higher nitrite levels that indicated localized enrichment. $S_I$ recorded the highest value at (0.5550±0.1373)mg/l indicating that the fresh influent from the washdown of carcasses had high nutrient pollution potential as confirmed by Olugbenga et al., 2019 who mentioned that abattoir wastewater could significantly intensify the amounts of nitrogen, phosphorus, and total solids in the receiving water body. Muhirwa et al., 2010 also reaffirmed that wastewater streams from evisceration processes and slaughter step where the urine and undigested stomach contents are mixed, consist of mixed intestinal contents and blood which are high in nitrate content. Since nitrite levels in wastewater could be treated by biological processes if other inhibiting parameters, such as chloride, are reduced [20], biodegradation in the ponds at the abattoir was observed to affect the level of $NO_2$ downwards since at site $S_E$, its level had reduced to (0.2603±0.06697)mg/l. At S3, $NO_2$ reading was (0.208±0.01542)mg/l and this indicated a rise in the $NO_2$ levels in the stream waters stemming from the interaction of effluent with stream waters. Readings at sites S4 and S5 exhibited reducing levels of $NO_2$ as the water moved downstream from S3. These downstream values, (0.1643±0.03278)mg/l and (0.1023±0.02316)mg/l for S4 and S5 respectively, depicted the dilution and dispersion effect of the stream. The $NO_2$ values in all stations were consistent with expected levels in a typical stream except for that recorded at the influent, $S_I$, that was significantly higher. The $NO_2$ levels did not exceed NEMA and WHO limits of 3 mg/l and therefore the abattoir waste was found not to be of significant threat of causing enrichment by $NO_2$ that could lead to eutrophication at Nyanchabo stream.

### *3.1.10 Total Phosphorous ($PO_4$)*

The mean value for total phosphorous at study site S1 (0.1892 ± 0.02925) was significantly different from values at study sites $S_I$ (28.12±5.562) ***, and $S_E$ (31.96 ± 8.068) *** as shown in Figure 11.

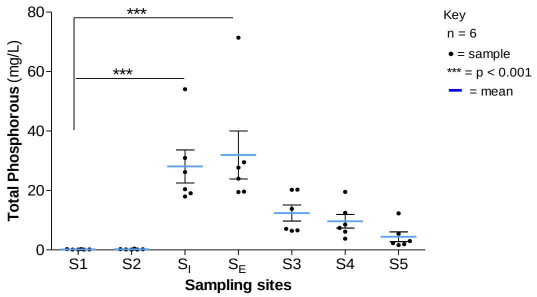



**Figure 11:** Mean values of $PO_4$ for sampling sites.

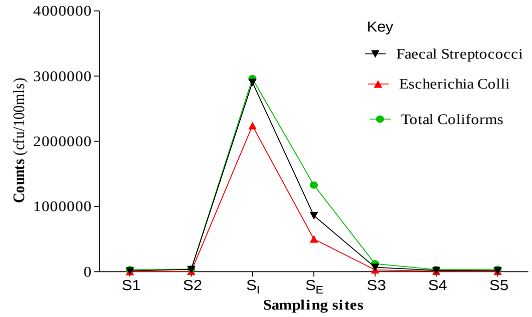



**Figure 12:** Mean values of *Total Coliforms*, *E. coli* and *F. streptococci* for sampling sites.

Total Phosphorous means are illustrated in Figure 11, where the highest means were recorded at abattoir sites $S_I$ (Influent) and $S_E$ (Effluent) with readings of (28.12±5.562) mg/l and (31.96±8.068) mg/l respectively. Abattoir waste generally increases the level of phosphorus in water or soil [16] due to animal feed traces and high composition of organic matter in them. Phosphorus presence in waste water could be also be attributed to the use of detergents in clean-up process in the abattoir after the slaughtering process. This is because phosphorus compounds are present in many detergents and also may come from decomposition of organic matter [21]. Phosphorous is hardly found in high concentrations in freshwater as it is actively taken up by plants [6] and this elucidates the overall low concentrations recorded at the upstream stations with S1 and S2 giving readings of (0.1892±0.02925) mg/l and (0.2228±0.04819) mg/l respectively. However, at S3, elevated levels of (12.40±2.725) mg/l were recorded owing to stream water interaction with the effluent that made the concentrations of phosphorus on the downstream to be higher than the upstream. The levels nevertheless declined gradually to (9.636±2.296) mg/l at S4 and (4.431±1.669) mg/l at S5 owing to dilution and dispersion effects.

Overaly, there was a significant change on the phosphorus level of Nyanchabo stream waters before and after the point of effluent discharge. Points at S3, S4 and S5 depicted phosphorus levels that surpassed the guideline limit (Table 1) for phosphorus of 2mg/l, thus implying that the abattoir wastewater presented significant risk of phosphorus overloading and subsequent chances of eutrophication in Nyanchabo stream.

### 3.2 Bacteriological parameters (Total Coliforms, *E. coli* and *F. streptococci.*)

The mean value for total coliforms at study site S1 (14525± 1885) was significantly different from values at sites $S_I$ (2906000± 520200) ***, and $S_E$ (861500± 261750) *. *E. Coli* mean value at study site S1 (3967± 1142) cfu/100ml was significantly different from value at site $S_I$ (2242000 ± 384148) *** and for *Faecal streptococci*, the value at S1 (32258± 13237), was significantly different from those at $S_I$ (2962000 ± 404297) ***, and $S_E$ (1331000 ± 411392) *** as shown in Figure 12.

In this study, all the sampling sites registered presence of *total coliforms*, *E. coli* and *F. streptococci* though levels varied significantly. Upstream site S1 had relatively low counts of Total coliforms (14,525 ± 1,885), *E. coli* (3967±1142) and *F. Streptococci* (32258±13237) cfu/100ml, though these counts were significantly high for a typical fresh stream. The coliform present here originated from animal and human waste, soil, and surface runoff and represented baseline conditions for the abattoir vicinity. Site S2 registered higher level of (36,667 ± 21,318), (5533±1881) and (39920±14778) cfu/100ml for Total coliforms, *E. coli* and *F. streptococci* respectively. This site hosts the entry point of surface runoff with bigger water volume that comes with more faecal contamination from both human and animal wastes from the abattoir vicinity that includes the unprotected riparian land on both sides of the stream. In contrast, abattoir sites, $S_I$, with high variability between sampling rounds, and $S_E$ recorded extremely high counts of (2,906,000 ± 520,200) and (861,500 ± 261,750) cfu/100ml respectively for total coliforms, (2242000±384148) and (502167±240383) cfu/100ml respectively for *E. coli* and (2962000±404297) and (1331000±411392) cfu/100ml respectively for *F. streptococci*. These stations, $S_I$ and $S_E$ indicated severe contamination (>$10^6$ cfu/100ml) and potential hotspots for faecal pollution. The apparent increase in levels of faecal coliforms in both the influent and effluent was attributed to the wastewater streams of the influent from the evisceration process at the lairage which is largely paunch and intestinal contents [20]. This together with faecal contamination in run-off from the abattoir vicinity created an environment with high coliform bacteria that was observed on the effluent, S2. On entering the treatment ponds, bacteriological values of the influents were evidently suppressed causing a remarkable reduction in the counts at the effluent zone. This depicted some level of treatment potential of the ponds which should have otherwise reduced the counts to zero incase treatment efficiency was flawless. At S3, bacteriological counts of the stream water were spiked sharply to (68,183 ± 16,715), (29850±13212) and (122667±33193) cfu/100ml for total coliforms, *E. coli* and *F. streptococci* respectively, owing to interaction and mixing of the abattoir pond effluent which had extremely high values with the stream waters.

At S4 and S5, the counts declined progressively to (21,100 ± 3,683) then to (16,733 ± 2,941) cfu/100ml for Total coliforms, (6767±1815) cfu/100ml then to (6017±2505) cfu/100ml for *E. Coli* and (33600±6427) then slightly up to (39000±12016) cfu/100ml for *F. streptococci.* This change was attributable to natural mixing, dilution and dispersion of stream water as it flowed downstream.

The mere presence of counts of enteric bacteria such as *E. coli* and *S. faecalis* at the onset on the upstream, points to fecal pollution from human and animal waste. The elevated counts of total coliforms, *E. coli* and *F. streptococci* at site S3 stemming from extremely high levels at sites $S_I$ and $S_E$ served to exacerbate the situation causing gross pollution of the stream directly linked to the discharge of the abattoir waste. Since the permissible limit for all the bacteriological parameters was zero cfu/100ml, all stations, including the upstream ones exceeded safety standards. The levels far exceeded the permissible limit stipulated by NEMA (Table 1), confirming that the abattoir effluent was a key source of bacteriological contamination that is detrimental to stream water quality and generally a hazard the public.

### 3.3 Summary of findings and permissible limits

In this study, the finding and results of each parameter in comparison to the respective permissible limits on effluent release to surface waters established by NEMA were summarized as indicated in table 1.

**Table 1:** Means of parameters values for all study sites and NEMA permissible limits.

| Parameter | NEMA Std | Sampling sites | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Upstream | | Abattoir | | Discharge | Downstream | |
| | | *S1* | *S2* | $S_I$ | $S_E$ | *S3* | *S4* | *S5* |
| **pH**(*pH value*) | *6.5-8.5* | 7.4 | 7.3 | 7.2 | 8.2 | 7.9 | 7.6 | 7.1 |
| **Temp**(*$^OC$*) | *±3* | 20.4 | 20.5 | 22.0 | 21.2 | 20.4 | 20.6 | 20.9 |
| **EC**( *$\mu scm^{-1}$*) | *2000* | 131.8 | 116.3 | **2814** | **3658** | 1352 | 643.2 | 279.3 |
| **TDS**(*mg/l*) | *1200* | 65.9 | 58.1 | **1407** | **1829** | 675.3 | 321.4 | 139.4 |
| **DO**(*mg/l*) | *6-9* | **5.9** | 6.2 | **3.2** | **4.2** | **5.5** | **5.7** | **5.4** |
| **TSS**(*mg/l*) | *30* | **72.83** | **81.17** | **2410** | **3458** | **1144** | **1730** | **524.8** |
| **BOD**(*mg/l*) | *30* | 9.9 | 13.4 | **1206** | **541.5** | **199.8** | **101.0** | **62.5** |
| **COD**(*mg/l*) | *50* | 12.5 | **53.0** | **7515** | **6228** | **2194** | **1972** | **312.5** |
| **Nitrites**(*mg/l*) | *3* | 0.038 | 0.028 | 0.555 | 0.260 | 0.208 | 0.164 | 0.102 |
| **Phosphorus** | *2* | 0.19 | 0.22 | **28.12** | **31.96** | **12.40** | **9.64** | **4.43** |
| **Total Coliforms** *(cfu/100ml)* | *30* | **14525** | **36667** | **$2.906*10^6$** | **861500** | **68183** | **21100** | **16733** |
| **E. Coli** *(cfu/100ml)* | *Nil* | **3967** | **5533** | **$2.242*10^6$** | **502167** | **29850** | **6767** | **6017** |
| **Faecal Streptococci** *(cfu/100ml)* | *Nil* | **32258** | **39920** | **$2.962*10^6$** | **$1.331*10^6$** | **122667** | **33600** | **39000** |

Figures in bold are parameter levels beyond permissible limits as set by NEMA & WHO [22].

- pH, Temperature and NO2 remained below the respective permissible limits at all sampling stations in the upstream, abattoir stations, the outfall and on the downstream.
- EC and TDS were below the permissible limits at the upstream and downstream, however their values went beyond the limits at the abattoir sites; the influent and effluent stations.
- DO, BOD, COD and $PO_4$, were below the permissible limits at the upstream but went beyond the limits at the abattoir sites; influent and effluent and persisted above the limits at the outfall and downstream stations except for DO which went slightly below the required level at the upstream station S1 and COD went slightly above the limits at upstream station S2.
- TSS and bacteriological parameters; Total coliforms, *E. coli* and *F. streptococci* consistently remained above the permissible limits at all sampling stations including the upstream.

## 4. CONCLUSION AND RECOMMENDATIONS

### 4.1 Conclusion

The insights obtained from this study led to the following conclusions:

**(i)** Upstream stations considered as the baseline, had lower, more stable water parameter values. This depicted relatively fresh, less polluted stream, safe for bacteriological and TSS pollution from faecal contamination and farm run-off from the abattoir vicinity that included the animal holding area and the unprotected riparian land on both sides of Nyanchabo stream.

**(ii)** Abattoir sites (influent and effluent) consistently displayed extreme high values and hence qualified as point sources or hotspots for pollution. The existing waste management setup of Itibo abattoir was found to be inefficient since pH, EC, TDS and $NO_2$ parameters of the waste water got elevated by the pond system instead of being reduced. Furthermore, though TSS, $PO_4$, BOD, COD and the bacteriological parameters levels got sequested by the treatment ponds, indicating some level of treatment efficiency, the levels of these parameters remained beyond the permissible limits even after interaction with the stream water.

(iii) At the discharge point where the effluent interacted with the stream water and the downstream stations, the abattoir effluent significantly elevated the pH, EC, TDS and $NO_2$ parameter levels of the stream water and further aggrevated the levels of TSS, BOD, COD, $PO_4$ and bacteriological parameters to remain beyond permissible limits while also inhibiting DO in the process. The effluent from Itibo abattoir though apparently channeled through the biodegradation ponds for treatment, detrimentally affected Nyanchabo stream water quality and the polluted water posed serious environmental and health hazards, rendering it unfit for domestic or industrial use.

### 4.2 Recommendations

It was undeniable that the effluent from Itibo abattoir polluted the waters of the adjacent Nyanchabo stream and as such this paper recommended that:

- Erosion control measures be instituted at the upstream to reduce sediments and suspended materials, community sanitation like establishment of latrines to avert open defecation and cleaning and creation of vegetative buffers to reclaim riparian land to reduce stream pollution stemming from the abattoir vicinity.

- Infrastructural adjustment to existing waste management system of Itibo abattoir; Introduction of a septic tank to precede the treatment ponds to allow for separation or segregation of solid from the liquid abattoir waste, pond addition or expansion of the existing ponds to match the volume of influent from the lairage and provide ample retention period thus effective treatment. Additionally, a natural wetland establishment after biodegradation ponds could be added that could further clean the effluent.

- NEMA, NGOs and other stakeholders within the abattoir operations and waste management space should educate abattoir operators on environmental and public health impacts and the merits of compliance with standards to limit disposal of untreated or partially treated waste water into adjacent surface waters.

- There is great need to strengthen policy implementation and enforcement of wastewater disposal laws and penalization of polluters where necessary.

***Recommendation for further research***

Future research work should consider undertaking studies in areas of;

✓ Impact of solid abattoir wastes on air, soil and biodiversity within the locale of Itibo abattoir.

✓ Effects of abattoir facility size, type and number of livestock slaughtered, vis-a-vis volume of waste generated and waste management capacity for appraisal consideration.

✓ Epidemiological effect of Nyanchabo stream water on the health of locals living in the vicinity of Itibo abattoir.

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