A Spatial Assessment of the Microbiological and Physicochemical Quality of a Stream Receiving Raw Abattoir Waste

O.K. Agwa, E. Sito and C.J. Ogugbue

Department of Microbiology, University of Port Harcourt, Port Harcourt, Nigeria

Abstract: The discharge of untreated abattoir waste into rivers and streams can have adverse environmental consequences on water quality. This study was carried out to determine the spatial trends in the physicochemical and microbiological quality of the Ogbogoro stream receiving raw abattoir waste. Water samples were collected over a period of 12 weeks from four sites (upstream, effluent discharge point, mid stream and downstream) in the stream to reflect the spatial variations in concentrations of water quality parameters. Parameters such as microbial counts, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), pH, temperature, total suspended solid (TSS), turbidity, total alkalinity, nitrate, sulphate, phosphate and odour were analyzed using standard procedures. Results obtained showed that the stream was characterized by high coli form counts due to the discharge of abattoir waste into the stream especially downstream of effluent discharge point. Water samples from downstream stations also showed higher concentrations of TSS, turbidity, odour, nitrate, sulphate and phosphate when compared to the upstream station while, BOD and COD values were lower at these stations than in the upstream station. Decrease in pH and total alkalinity was obtained downstream after the effluent discharge point and this was attributed to production of organic acids during breakdown of organic matter from the abattoir waste. BOD and faecal coli forms showed a positive correlation $r = 0.780774$ significant at $p < 0.05$ at the effluent discharge point, suggesting microbial contamination as a result of organic matter input. The mean value ranges of most of the parameters analysed such as: BOD (8.20-13.30); COD (32.0-49.0); nitrate (0.10-2.60); sulphate (0.39-1.84) and phosphate (0.01-0.26) were lower than FEPA and WHO maximum permissible limits for rivers and streams. Nevertheless, the current microbiological quality status of the Ogbogoro stream as a result of abattoir waste discharge poses an environmental and health hazard to those who use it for recreational and domestic purposes. Based on above mentioned results, it could be recommended that adequate treatment of the stream water be carried out before its usage for domestic or agricultural purposes in addition to strict monitoring of abattoir waste disposal into water bodies by relevant agencies.

Key words: Abattoir · Wastewater · Ogbogoro Stream · Water Quality · Pollution

INTRODUCTION

The demand for fresh water is fast increasing at a rate greater than the world’s population growth and access to safe water supply has become a serious issue across the globe. In many developing countries like Nigeria, more than half of the population suffer from lack of safe water supply and secure sanitation as available reports site gross contamination of most major fresh water bodies across the nation as a result of the discharge of industrial effluents, sewage and agricultural waste among others [1]. These fresh water bodies (lakes, wells, streams, rivers, wetlands, etc.) represent the main sources of safe water for household, agricultural and even industrial applications and are required for drinking, cooking, recreational activities, farming, fishing, etc, making them unavoidable for the evolution of society and civilisation [2, 3]. Hence, the water quality situation of fresh water bodies has become very critical especially in Nigeria and currently attracts great environmental and public health concerns [4, 5].

Corresponding Author: Ogugbue, Chimezie Jason, Department of Microbiology, University of Port Harcourt, P.M.B. 5323, Port Harcourt, 500004, Rivers State, Nigeria. Tel: +2348108643429.
Of recent, attention has been drawn to the possible debilitating effect of abattoir waste on the quality of receiving water bodies. Improper management of abattoir wastes and subsequent disposal either directly or indirectly into river bodies portends serious environmental and health hazards both to aquatic life and humans [6]. In Nigeria, abattoirs are usually located near water bodies where access to water for processing is guaranteed and the location and operation of these abattoirs are generally unregulated by the controlling authorities [6]. During processing of slaughtered animals, the animal blood is released untreated into the flowing stream while the consumable parts of the slaughtered animal are washed directly into the flowing water [7]. Other unwanted animal parts such as fat, grease, hair, feathers, grit, undigested feed, condensed meat, aborted foetuses and bones which are characterized by their high organic level [8-10] may also be discharged into the water bodies.

By virtue of these activities, the abattoirs generate large quantities of biodegradable wastewater with high strength and complex composition which may elevate the pollution status of the receiving surface waters. Apart from being unpleasant and aesthetically unacceptable, the liquid waste usually contains high levels of ammonia, high biochemical oxygen demand and microorganisms [11]. Significant increases in the levels of biological oxygen demand (BOD) and other nutrients in the fresh water bodies could trigger eutrophication [12]. Once a water body undergoes eutrophication, it will lose its primary functions and subsequently lead to a faster rate of succession from existence to higher serial stage due to nutrient enrichment [13]. This decline in water quality and environmental degradation could result in sharp decline of fish population thus, diminishing the nutritional in-take of communities bordering such water bodies [14]. More so, there is a danger of pathogens from cattle waste being transmitted to humans recreating in such water bodies which could result in zoonotic diseases such as coli bacillosis, salmonellosis, brucellosis and helminthes [15]. Consequently, it has become pertinent to assess the physicochemical and microbiological status of these surface water bodies in order to determine the impact of the activities of the abattoir operations on them. This will help determine the quality of these water bodies and the inherent risk factors associated with the use of the water from these contaminated aquatic environments for various purposes such as drinking, recreation, aquaculture, industrial processes, etc.

Hence, this study was carried out to determine the spatial trends in the microbiological and physico-chemical quality of Ogbogoro Stream in Port Harcourt, Nigeria. Ogbogoro Stream receives untreated solid and liquid waste from the Ogbogoro Abattoir and the stream is utilized for various domestic purposes downstream. The data from this study could be of help in formulating future waste management protocols in Nigeria in terms of quality and quantity of abattoir waste to be discharged into water bodies.

MATERIALS AND METHODS

Description of the Study Area: The Ogbogoro abattoir is situated at Ogbogoro town (Latitude. 4.8466667°, Longitude. 6.9305567°), a suburb in Port Harcourt City, Nigeria. Fig. 1 shows the map of the study area. The abattoir is located beside the Ogbogoro Stream and discharges effluent into the water body. Downstream of the river is a densely populated residential zone that utilizes the river water for various domestic purposes. Besides the non point source pollution from the population, the main point source of pollution of the stream is the abattoir. The abattoir is used for the processing of cattle, goats, pigs and sheep and is open for operation seven days per week. Normal activities commence early in the morning and end around 5pm daily. The abattoir uses the stream water and different kinds of detergents for cleaning purpose.

Sample Collection: Water samples were collected with sterile hermetically sealed polyvinyl chloride (PVC) plastic water bottles (1L) at a depth of 1 meter below the water surface from Ogbogoro stream at four different locations. The sampling was done weekly for seven weeks between August and September 2009 and was carried out from 10.00–11.00 hrs. At each sampling point, three water samples were withdrawn at random from three points and pooled to get a representative sample. The sampling points which were established after a reconnaissance visit include: upstream (US, 60m before the effluent discharge point); point of effluent discharge (ED); mid stream (MS, 30m from discharge point) and down stream (DS, 60m away from the discharge point). The need for comparative studies was the criterion for the choice of the sampling stations at the upstream, effluent discharge and downstream points. Samples collected upstream of waste discharge point were for purposes of ascertaining the natural, non polluted status of the stream.
All sample bottles were previously washed with non-ionic detergents and rinsed severally with de-mineralized water before use. At the collection points, the bottles were rinsed thrice with the stream water before samples for analysis were collected. After collection, samples were labelled appropriately, kept in an ice box and subsequently transported to the laboratory for analysis within 4 hours.

**Microbiological Analyses:** The microbial counts of water samples were determined using the spread plate inoculation technique. An aliquot (0.1 mL) of ten-fold serial dilutions ($10^{-1}$–$10^{5}$) of each water sample was inoculated on various media using a sterile spreader. Inoculation on plate count agar (Lab M) was for the enumeration of total culturable aerobic heterotrophic bacterial (TCAHB) count whereas; MacConkey agar and Potato dextrose agar (PDA) were used for the enumeration of total coli forms (TC) and total fungi (TF) respectively. Plates for bacterial enumeration were incubated at 35°C for 48 h while, PDA plates were incubated at 25°C for 5 days. After incubation, distinct colonies that developed were counted and expressed as colony-forming units per millilitre (CFU/ml). Bacterial and fungal colonies were picked at random from plates containing the highest countable dilution and purified by sub-culturing. The bacterial isolates were screened and identified based on their morphological, physiological and biochemical characteristics as described by Vanderzannt and Splittstoesser [16] and with reference to the Bergey’s
Manual of Determinative Bacteriology [17]. The fungal isolates were identified according to the protocol of Samson and Reenen-Hoekstra [18] which was based on microscopic examination of their conidial heads, philiades, conidiophores and presence or absence of rhizoids.

Enumeration of faecal coli form count of water samples was by a one step 5-tube most probable number (MPN) technique using MacConkey’s broth (Lab M) with the growth medium with tubes incubated at 44.5°C for 24 h. Aliquots (10, 1 or 0.1 mL) of each water sample were added to double or single strength medium as appropriate. Tubes showing growth and gas production after 24 h incubation were scored fecal coli form positive and their estimated numbers were determined from the standard MPN tables.

Physicochemical Analyses: In situ measurements of pH and temperature were taken at the sampling points with a portable pH meter (Deluxe pH Meter, model ME963–P, Unicom, India) and mercury-in-glass thermometer respectively. Odour and levels of biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), turbidity, total suspended solids (TSS), total alkalinity, nitrate, phosphate and sulphate ions in water samples were determined using Standard Methods recommended by American Public Health Association [19]. Results of laboratory analysis were compared with WHO and various water quality guidelines in Nigeria [20-23].

Analysis of data: Data obtained after analyses from all sampling points were subjected to data evaluation using standard statistical methods of analyses such as mean, two-way analysis of variance (ANOVA) and standard deviations [24] to ascertain the spatial variations and significant difference between the stations. The relationship among the physicochemical and biological parameters was also determined using the correlation analysis toolkit.

RESULTS AND DISCUSSION

The results of the spatial variation in microbiological parameters of water samples obtained from Ogbogoro stream are presented in Fig. 2. The mean TCAHB count of the samples ranged between $5.4 \times 10^4$ and $1.87 \times 10^7$ CFU/mL while, the mean total coli form count ranged between $5.0 \times 10^3$ and $8.0 \times 10^7$ CFU/mL. Spatial differences in bacterial numbers at the various sampling points were evident as higher counts for mean TCAHB and TC were observed at the ED point and downstream sampling locations indicating higher contamination levels of the down stream points. Estimation of faecal coli form counts at the different stations using the MPN method indicated mean counts ranging from 5.50 to 130 MPN/100 mL with the ED station showing the highest mean faecal coli form MPN count of 63.38 MPN/100 mL. The mean TF counts ranged from $3.9 \times 10^2$ to $1.12 \times 10^3$ CFU/mL (Fig. 3) with ED point and downstream sampling location showing higher counts for TF. At the DS point, mean TF count of $3.21 \times 10^3$ CFU/mL was obtained while the US point showed a mean TF count of $1.83 \times 10^4$ CFU/mL. The US sampling point showed the least mean counts for all microbial parameters (Figs. 2-5). The bacterial isolates from the water samples were identified as belonging to the following genera; Staphylococcus, Escherichia, Pseudomonas, Enterobacter, Bacillus, Proteus, Klebsiella, Flavobacterium, Acinetobacter and Salmonella. The fungal genera isolated include Aspergillus, Penicillum, Fusarium, Saccharomyces and Mucor. The ED site recorded the highest diversity of microbial strains isolated from water samples followed by MS and DS sampling points in that order. Some of the bacteria isolated from the water samples have been reported as causative agents of various diseases [25]. Such diseases include acute enteritis in infants and adult caused by Escherichia. coli [26] and typhoid fever caused by Salmonella typhi [27]. Except for Aspergillus, most of the fungi isolated from the water sample are common soil saprophyte and are usually not considered to be medically important [28]. However, these saprophytic fungi may become opportunistic pathogens for individuals with compromised immune systems when exposed to these microorganisms [29].

The relatively higher microbial numbers detected at ED and downstream locations when compared to the US sampling location can be attributed mainly to the large amount of raw or improperly treated abattoir waste discharged into the stream. The discharge of waste water from the abattoir into streams and rivers has previously been shown to raise the level of contaminants making the water bodies unsafe for usage by residents along the river and for farming activities [30]. Bacteria and viruses from animal wastes carried to streams can cause diseases. High coli form counts in water bodies indicate that there is a greater chance that pathogenic organisms are also present. Persons swimming in such waters have a greater chance of getting sick from swallowing disease-causing
Table 1: Spatial variations of the mean of measured physicochemical parameters of the Ogbogoro stream

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Upstream station (US) n=12</th>
<th>Effluent discharge point (ED) n=12</th>
<th>Mid stream station (MS) n=12</th>
<th>Down stream station (DS) n=12</th>
<th>Range</th>
<th>FEPA* limits</th>
<th>WHO** limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD (mg/L)</td>
<td>Mean±SD 10.34±1.28</td>
<td>10.28±1.04</td>
<td>10.29±0.53</td>
<td>9.87±0.83</td>
<td>8.20-13.30</td>
<td>30</td>
<td>50</td>
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<tr>
<td>COD (mg/L)</td>
<td>Mean±SD 42.87±2.73</td>
<td>42.08±3.09</td>
<td>42.57±1.42</td>
<td>42.63±2.90</td>
<td>32.0-49.0</td>
<td>80</td>
<td>1000</td>
</tr>
<tr>
<td>DO (mg/L)</td>
<td>Mean±SD 6.50±0.48</td>
<td>6.84±0.50</td>
<td>6.65±0.32</td>
<td>6.82±1.16</td>
<td>5.0-9.68</td>
<td>Not &lt;2</td>
<td>6</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>Mean±SD 28.17±1.91</td>
<td>27.78±1.13</td>
<td>28.37±1.29</td>
<td>27.61±1.39</td>
<td>25.78-32.0</td>
<td>35-40</td>
<td>29</td>
</tr>
<tr>
<td>pH</td>
<td>Mean±SD 6.91±0.71</td>
<td>7.23±0.99</td>
<td>7.19±0.79</td>
<td>7.02±0.74</td>
<td>6.13-8.90</td>
<td>6-9</td>
<td>6.5-8.5</td>
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<tr>
<td>TSS (mg/L)</td>
<td>Mean±SD 31.58±9.05</td>
<td>32.44±8.78</td>
<td>32.67±8.42</td>
<td>31.46±8.99</td>
<td>20.0-44.0</td>
<td>30</td>
<td>NA</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>Mean±SD 0.46±0.25</td>
<td>0.77±0.44</td>
<td>0.64±0.32</td>
<td>0.56±0.24</td>
<td>0.12-1.83</td>
<td>&lt;10</td>
<td>5</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>alkalinity (mg/L)</td>
<td>Mean±SD 2.55±1.79</td>
<td>2.37±1.80</td>
<td>2.30±2.07</td>
<td>2.25±1.94</td>
<td>0.64-6.90</td>
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<td>NA</td>
</tr>
<tr>
<td>Nitrate (mg/L)</td>
<td>Mean±SD 0.39±0.44</td>
<td>0.83±0.79</td>
<td>0.63±0.57</td>
<td>0.62±0.80</td>
<td>0.10-2.60</td>
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<tr>
<td>Sulphate (mg/L)</td>
<td>Mean±SD 0.69±0.16</td>
<td>0.91±0.32</td>
<td>0.91±0.32</td>
<td>0.92±0.29</td>
<td>0.39-1.84</td>
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<td>250</td>
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<tr>
<td>Phosphate (mg/L)</td>
<td>Mean±SD 0.05±0.08</td>
<td>0.07±0.09</td>
<td>0.06±0.08</td>
<td>0.07±0.09</td>
<td>0.01-0.26</td>
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<tr>
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<td>offensive</td>
<td>Slight odour</td>
<td>NA</td>
<td>inoffensive</td>
<td></td>
</tr>
</tbody>
</table>

*Maximum Allowable Level (FEPA, 1991); **Maximum Allowable Level (WHO, 2004); NA-Not Available

organisms, or from pathogens entering the body through cuts in the skin, the nose, mouth, or the ears. This can limit the uses of such water bodies for swimming or contaminate drinking water in groundwater wells. Increased microbial population could also lead to a disruption in microbial community structure that can create shifts in ecosystem-level carbon, energy and nutrient flows [31]. Hence, stricter laws and regulations on effluent discharge from slaughterhouse facilities would give incentive to this sector to reduce effluent volumes and organic loads.

Table 1 presents the spatial variations in the measured physicochemical parameters of the water samples from the various sampling locations. The mean BOD values of samples ranged between 8.20 and 13.30 mg/L across all stations. However, contrary to expectations, relatively higher BOD levels were obtained at the US sampling location when compared to other locations. Though the reason for this trend could not be ascertained, it may be attributed to the effect of non point pollution upstream emanating from anthropogenic activities upstream. The origin of organic pollution in an ecosystem has been attributed to organic manure, fertilizers, high stocking density, feed waste, faecal matter, algal bloom and human interference [32, 33]. Mean BOD level at the ED sampling point (10.28±1.04 mg/L) was higher than the DS location and also showed a higher microbial diversity than all other sampling locations which correspond to the discharge of abattoir waste at that point. The mean BOD levels of the stream at the US, ED and MS sampling locations were slightly above the FEPA limits of 10 mg/L. On the other hand, COD levels at the different stations were not significantly different (p > 0.05) indicating the discharge of abattoir waste into the stream did not significantly alter the COD level of the stream. The mean COD levels ranged from 32.0 to 49.0 mg/L and were below the FEPA and WHO standards for surface waters. Both the COD and BOD are important water quality parameters that indicate the level of organic pollution in water quality assessment. The moderate levels of these parameters in the water samples from Ogbogoro stream suggest that the pollution index of the stream was not significantly elevated as a result of the discharge of abattoir waste into the water. The self purification mechanism of the stream and timing of sample collection may also have contributed to the levels of BOD and COD obtained.

The data on dissolved oxygen (DO) levels of the stream indicate that BOD and COD were the primary factors affecting DO concentrations in the water samples as negative correlations between DO concentration and BOD3 (r= -0.60242) and between DO concentration and COD (r= -0.76812) were obtained especially at the ED station. Mean DO values ranged from 5.0 to 9.68 mg/L with no significant differences (p > 0.05) obtained between values obtained at the various sampling locations. The DO of a water body is a measure of its degree of pollution by organic matter, the destruction of organic substances as well as its self purification capacity. A standard DO concentration of 5 mg/L DO has been recommended as adequate for sustaining aquatic life while, a concentration below 2 mg/L may adversely affect aquatic biological life [24]. Dissolved oxygen concentrations in unpolluted water normally range...
between 8 and 10 mg/L [34, 35]. In this study, the DO levels at the various stations were above 5 mg/L indicating that the discharge of abattoir waste into the stream had no deleterious effect on DO concentrations of the Ogbogoro stream. The amount of dissolved oxygen in streams is dependent on the water temperature, the quantity of sediment in the stream, the amount of oxygen taken out of the system by respiring and decaying organisms and the amount of oxygen put back into the system by photosynthesizing plants, stream flow and aeration. A complex interplay of these factors may have cushioned the anticipated impact of the abattoir waste discharge on DO concentrations of the stream. Interestingly, the mean DO of the ED point was higher than that of the MS and DS sampling points and this could be enunciated in the fact that decrease in oxygen demand on the stream as a result of the organic matter input at the ED point may not be immediate due to stream flow dynamics and the time lapse between the introduction of organic waste and its actual degradation by microorganisms. High BOD levels in water bodies accelerate bacterial growth and consume the oxygen levels in a river. The oxygen may diminish to levels that are lethal for most fish and many aquatic insects. As the river re-aerates due to atmospheric mixing and as algal photosynthesis adds oxygen to the water, the oxygen levels will slowly increase downstream. This may explain the DO sag curve (drop and rise in DO levels downstream from a source of BOD) observed in the data presented (Table 1).

Total alkalinity was higher at the US sampling station and decreased downstream after the ED point. This decrease may be attributed to the increased acidity of the aquatic system downstream due to generation of organic acids from organic matter decomposition. Mean temperatures of sampling stations ranged from 25.78 to 32.0°C while, mean pH values ranged from 6.13 to 8.90. The temperature and pH ranges were within FEPA limits of 35–40°C and 6–9 respectively for rivers and streams. Temperature values showed little variations in all the sampling stations suggesting that the discharge of abattoir waste did not significantly influence its spatial distribution particularly at the ED point while, decrease in pH was obtained progressively downstream after the ED point. Analysis of variance (ANOVA) did not reveal significant spatial variations (p>0.05) in the levels of temperature or pH of the stream water. The slight variation in temperature obtained however, may be attributed to the influence of stream flow, streamside vegetation and groundwater inputs. The fairly uniform temperature values obtained also suggests that there is no discernible thermal pollution from the pollution sources responsible for the other pollutants. The fairly high temperature of water in the stream is conducive to vigorous microbial activities that degrade organics, with consequent purification of the stream. Most natural waters are buffered by a carbon-dioxide-bicarbonate system which tends to keep pH of most waters around 7 –7.5, unless large amounts of acid or base are added to the water. Hence, the decreasing pH (7.23-7.02) obtained from the ED to the DS sampling points may be ascribed to the organic acids produced by the decaying organic matter released into the stream during discharge of abattoir waste. Other authors have reported similar pH ranges (6.13-8.90) obtained in this study. The Krka River in Slovenia exhibited a mean pH of 8 [36], while the Ankara stream in Turkey was reported to exhibit a pH of 7.6–8.11 [37]. Emanation of offensive odour was observed in water samples obtained from ED and MS sampling points. The DS water samples had a slight odour where as, the US water samples were odourless. The putrefaction of organic compounds especially proteins in the abattoir waste may have been responsible for the offensive odour perceived in ED and MS samples. The dilution effect of the stream flow downstream probably dissipated the odour strength in water samples at the DS sampling point when compared to ED and MS points.

Data on turbidity, nitrogen and sulphate levels of the stream indicate that these parameters were highest at the discharge point (ED) of the abattoir waste when compared with the upstream and downstream sampling locations. Levels of these parameters were also higher at MS and DS points than at the US sampling location. The unidirectional downstream flow path of the stream may be responsible for this distribution pattern. Mean turbidity levels at all stations ranged from 0.12 to 1.83 NTU and were lower than the FEPA limits of 10 NTU for drinking water. Nitrate level of the samples ranged from 0.10 to 2.60 mg/L while the sulphate levels ranged from 0.39 to 1.84 mg/L. The mean values of nitrate and sulphate concentration obtained were lower than the FEPA limits of 10 mg/L and 500 mg/L respectively for rivers and streams. The low levels of nitrogen and sulphate obtained were contrary to our expectations and indicate the good health status and self purification capacity of the stream despite the discharge of abattoir waste into it. This is because excessive concentrations of nutrients can over stimulate aquatic plant and algae growth and cause oxygen depletion which may deprive fish and
invertebrates of available oxygen in the water (eutrophication). Moreover, an increased level of nitrate in drinking water sources has also been linked to the blue-baby syndrome in infants. The TSS levels ranged from 20.0 to 44.0 mg/L with no significant differences (p<0.05) obtained between mean values at the different sampling locations. TSS levels obtained at the various stations exceeded the recommended FEPA limits of 30 mg/L. A high TSS can reduce light penetration thus, decreasing algal growth; and low algal productivity can reduce the productivity of aquatic invertebrates, a food source of many fishes. Mean phosphate levels were within the maximum allowable phosphate level of 5 mg/L [20] and values ranged from 0.01 to 0.26 mg/L. No distinct pattern in spatial distribution of phosphate levels of water samples was obtained and there were no significant differences (p>0.05) between the values obtained.

CONCLUSION

This study has shown that the discharge of abattoir waste into Ogbogoro stream negatively imparts on the microbiological quality of the stream especially at stations downstream of the discharge point. The spatial distribution of microbial parameters indicated high counts at the discharge point and tended towards gradual abatement downstream. The spatial distribution of the physico-chemical parameters along the stream showed relatively higher values at the ED point with increased attenuation in the levels of the parameters downstream indicating the capacity of the stream for self-purification. Nevertheless, adequate treatment of waste before discharge and waste management practices that ensure waste reduction, re-use and recycling, should be encouraged by environmental regulatory bodies in order to protect the water resources from negative impacts of abattoir wastes.

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REFERENCES


