MICROBIOLOGICAL AND PHYSICOCHEMICAL ASSESSMENT OF SURFACE WATER IMPACTED BY RAW ABATTOIR WASTES

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Abstract: The microbiological and physicochemical qualities of surface water collected from Ikpobariver at different points were evaluated using standard procedures. The samples were collected into sterile 4 liter plastic containers once monthly from May 2015 to February, 2016. The mean heterotrophic bacterial and fungal counts for the surface water samples varied from 6.5×10^2 cfu/ml ± 150 to 6.3×10^4 cfu/ml ± 49200 and 3.0×10^2 ± 195 to 7.0×10^3 cfu/ml ± 3950, respectively. The differences in the respective mean heterotrophic bacterial and fungal counts was significant ($P<0.05$) with microbial counts obtained from the point of discharge being responsible for the difference. Eleven (11) bacterial and nine (9) fungal isolates were tentatively identified and included; *Bacillus subtilis*, *Micrococcus* sp., *Staphylococcus aureus*, *Micrococcus luteus*, *Citrobacter* sp., *Pseudomonas aeruginosa*, *Escherichia coli*, *Aspergillus versicolor* and *Rhizopus* sp. *B. subtilis*, *Micrococcus* sp., *S. aureus* and *M. leutus* exhibited resistance towards ampiclox and septrin and were sensitive to ciprofloxacin, rocephin, erythromycin and gentamicin. The mean pH and dissolved oxygen (DO) values varied from 5.7 ± 0.4 to 6.05 ± 0.4 and 1.105 mg/L ± 0.2 to 4.7 mg/L ± 0.8, respectively. The microbiological index of the water samples was very poor as *E. coli* was detected in all the surface water samples. This trend indicated that the water samples were unfit for direct consumption.

Keywords: Abattoir, antibiogram, fecal coliform, Ikpobariver, surface water

Introduction

The Nigerian slaughter house industry has been documented as a critical component of the livestock sector which has and is still serving as a primary source of raw meat to over 150 million people and also creating employment opportunities for several demographic fractions such as young men and women across the nation (Nafarnda *et al*., 2012). Neboh *et al*. (2013) described abattoir or slaughter house as any premise utilized or designated specifically for the commercial slaughter of animals whose meat is intended for human consumption. The authors also reported that abattoirs are known all over the world to pollute the environment either directly or indirectly from their various processes. Nafarnda *et al*. (2012) opined that the abattoir sector in developing countries like Nigeria was less developed in comparison to those obtainable in the developed climes like Western Europe. Ogbonnaya (2008) reported that facilities for the treatment of abattoir effluents are lacking, unlike in developed countries where these facilities are adequately provided. Abattoir operations are meant to minimally process the edible portions of slaughtered animals for human consumption under appropriate sanitary conditions (Fearon *et al*., 2014). As a direct consequence, varying amounts of waste materials which include; organic solids and liquid waste are generated and discarded through various procedures. The solid waste is known to consist mainly of bones, undigested ingest and occasionally aborted fetuses while the liquids comprise of blood, urine, water, dissolved solids and gut contents (Fearon *et al*., 2014). Odoemelan and Ajunwa (2008) stated that Abattoir activities have been implicated in the anthropogenic pollution of surface and underground waters as well as air quality, therein indirectly affecting the health of residents living within the vicinity of these facilities. There is high density of active slaughter houses clustered around the banks of the Ikopbariver bridged at Oregbeni hill, Benin City. These abattoirs have been known to utilize the river as a receptacle for the daily tonnage of raw solid and liquid wastes emanating from these facilities. Aside from the deliberate discharge of Slaughter house wastes by both owners and workers of these establishments, other activities which include; recreation, fishing, washing of vehicles and clothes are being conducted by individuals residing very close to the river watershed. This study was aimed at the evaluation of the culturable microbiological flora and physico chemical qualities of surface water directly impacted by discharged raw abattoir wastes generated from a slaughter house sited close to the bank of the Ikpobariver, Benin City.

Materials and Methods

Collection of surface water samples

Water samples were collected from three (3) sampling points; upstream; N06°22'27.70" E 5°38'48.826' and downstream; N06°20'36.27" E 5°38'50.388' along the Ikpoba River and a point of discharge (PD); N06°20.938" E 005°38.693'on the river, very close to an open waste drain emanating from an active abattoir sited in close proximity to the river. All the samples were abstracted with the aid of sterile 4 liter plastic containers. The samples were collected monthly from May 2015 to February, 2016. The plastic containers were appropriately labeled and kept in coolers containing ice and immediately transported to the laboratory for microbial and physico-chemical analyses.

Microbial analyses of the samples

The culturable heterotrophic bacterial and fungal counts were evaluated using the pour plate method (Harley and Prescott, 2002). The total and fecal (*Escherichia coli*) coliform profiling of the respective water samples was evaluated using the multiple tube dilution procedure as described by Cheesebrough (2006). The general purpose media employed for the determination of heterotrophic bacterial and fungal counts were Nutrient agar (NA) and Potato Dextrose agar (PDA) while MacConkey broth (MCB) and Eosin Methylene Blue Agar (EMB) was utilized for the multiple tube dilution method. Pure cultures of the heterotrophic bacterial isolates and coliforms were identified and characterized on the basis of cultural, morphological and biochemical characteristics carried out according to procedures described by Cheesebrough (2006) and Sharma (2009). Physiological and

biochemical tests such as Gram staining, methyl red, indole, citrate utilization, VogesProskauer and urease production tests were done to tentatively identify the microbial isolates. The fungal isolates were identified through observation of their cultured colonies. Also, microscopic examination of their respective spores and hyphal appendages using a sterile inoculating needle, distilled water and lacto phenol/cotton blue wet mount preparation was performed as described by Sharma (2009) and the recorded microscopic observations were compared with relevant illustrations as described by Barnett and Hunter (1972) and Alexopolulos and Mims (1996).

Evaluation of the antimicrobial sensitivity profile of the water borne bacterial isolates

The antibiotic sensitivity pattern (antibiogram) of the tentatively identified bacterial isolates was determined using spread plate and multiple disc diffusion methods with Mueller Hinton agar plates as described by Harley and Prescott (2002) and Vandepitte *et al*. (2003). The utilized commercially available antibiotics discs were; Pefloxacin (PEF) (10 µg), Gentamicin (CN) (20 µg), Ampiclox (APX) (30 µg), Zinnacef (Z) (10 µg), Amoxacillin (AM) (10 µg), Rocephin (R) (25 µg), Ciprofloxacin (CPX) (50 µg), Streptomycin (S) (30 µg), Septrin (STX) (10 µg), Erythromycin (E) (30 µg), Sparfloxacin (SP) (30 µg), Augmentin (AU) (30 µg), Amoxacillin (AM) (10 µg), chloramphenicol (CH) (20 µg) and Ofloxacin (OFX) (30 µg) as made by OPTUN Nig. Ltd.The diameter of the resultant inhibitory zones exhibited by the exposed bacterial isolates against the respective antibiotics was then translated into resistance and susceptibility categories as described by CLSI (2007).

Physico chemical analysis of the water samples

The pH, electrical conductivity and dissolved oxygen were determined with the aid of relevant meters. Determination of the total hardness, alkalinity and sulphate were done following the procedure described by APHA (1993). The total solid (TS) of each water sample was derived from the addition of both the TSS and TDS values (Ademoroti, 1996) while nitrate and phosphate parameters were evaluated following the procedure as described by Radojevic and Bashkin (1999). Procedures as described by Ademoroti (1996) was employed to determine the chloride value, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Iron, Cadmium, Copper, Zinc and Lead parameters.

Statistical analysis of the mean heterotrophic microbial counts

Analysis of variance (ANOVA) of the respective mean heterotrophic microbial counts obtained from the respective surface water samples was conducted ($\alpha = 0.05$). Duncan Multiple Range (DMR) tests were conducted to locate the cause of any significant differences in the mean counts.

Results and Discussion

The mean heterotrophic microbial counts recorded for the respective water samples are presented in Fig. 1 and 2. The mean heterotrophic bacterial counts for water samples abstracted at the point of discharge in the sampling period ranged from 3.7×10^4 cfu/ml ± 17700 for January 2016 to 6.3×10^4 cfu/ml ± 49200 for May, 2015. The mean heterotrophic bacterial counts for water samples collected at the downstream point in the sampling period ranged from 2.4×10^3cfu/ml ± 1540 for May, 2015 to 2.2×10^4 cfu/ml ± 14100 for December, 2015. The mean heterotrophic bacterial counts for water samples collected at the upstream point in the sampling period ranged from 6.5×10^2 cfu/ml ± 150 for June, 2015 to $.4\times10^4$ cfu/ ml ± 8950 for December, 2015. The mean heterotrophic fungal counts for water samples sourced at the point of discharge in the sampling period ranged from 6.5×10^2 ± 250 for June, 2015 to 7.0×10^3 cfu/ml ± 3950 for December, 2015. The mean heterotrophic fungal counts for water samples collected at the downstream point in the sampling period ranged from 3.0×10^2 ± 195 for May, 2015 to 6.4×10^3 ± 4600 for December, 2015. The mean heterotrophic fungal counts for samples collected at the upstream point in the sampling period ranged from 4.0×10^2 ± 100 for May, 2015 to 2.4×10^3 ± 1500 for December, 2015. The differences in the respective mean heterotrophic bacterial and fungal counts was significant ($P<0.05$) with microbial counts obtained from the point of discharge being responsible for the difference.

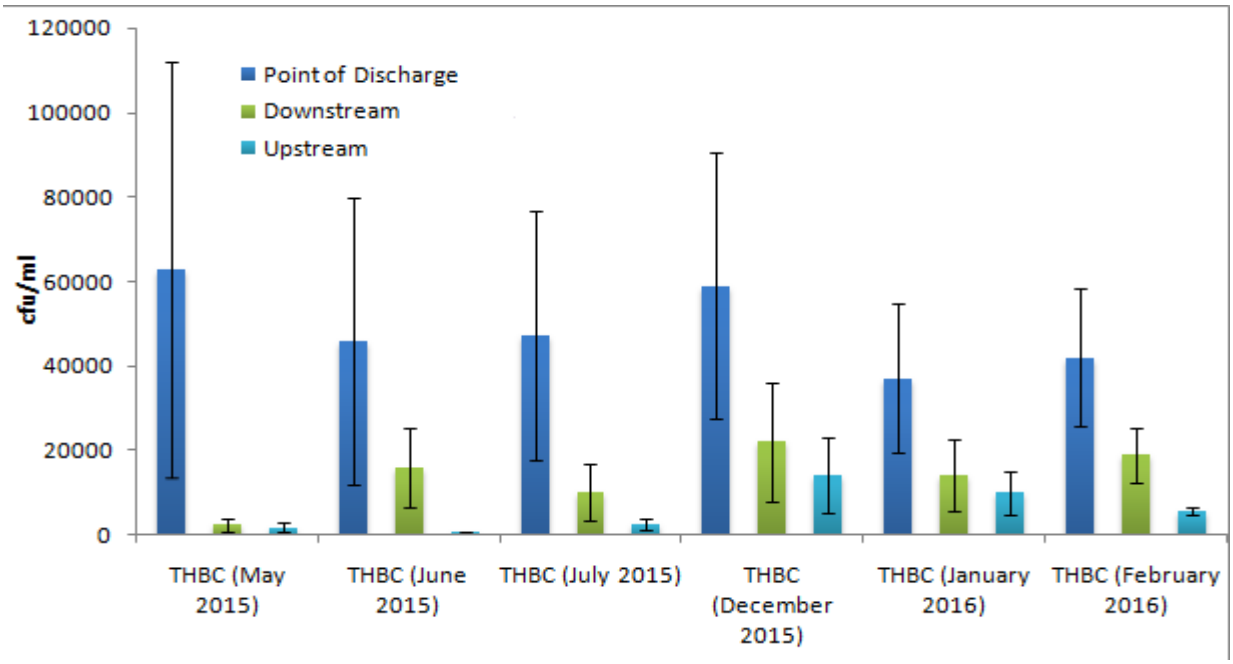

Fig. 1: Total mean heterotrophic bacterial counts of the sampled surface water collected in the sampling period; May, 2015- February, 2016

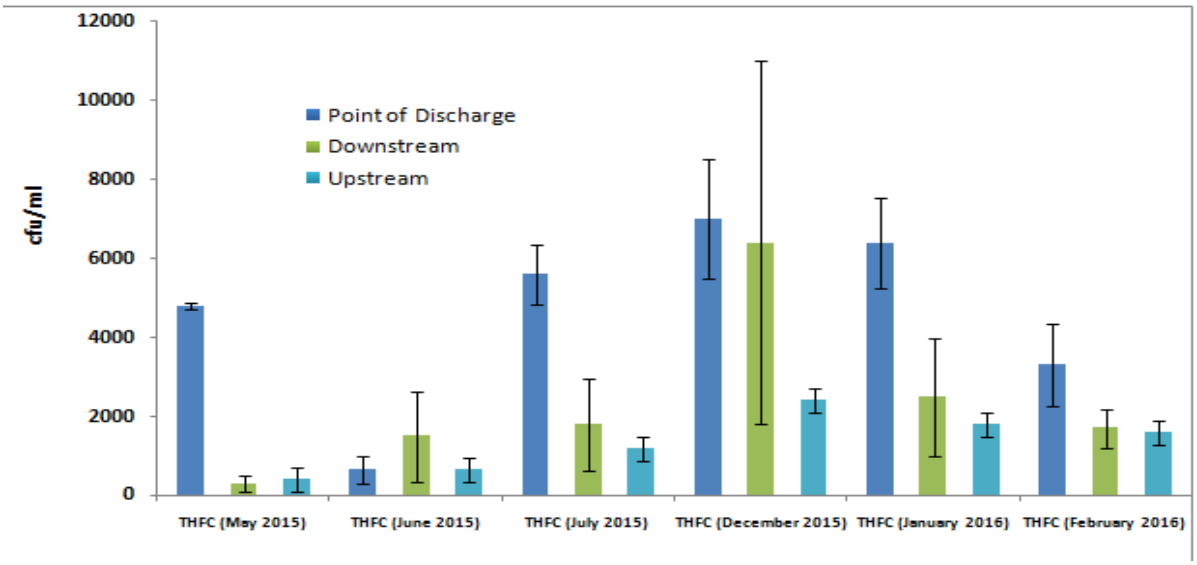

Fig. 2: Total mean heterotrophic fungal counts of the sampled surface water collected in the sampling period; May, 2015 - February, 2016

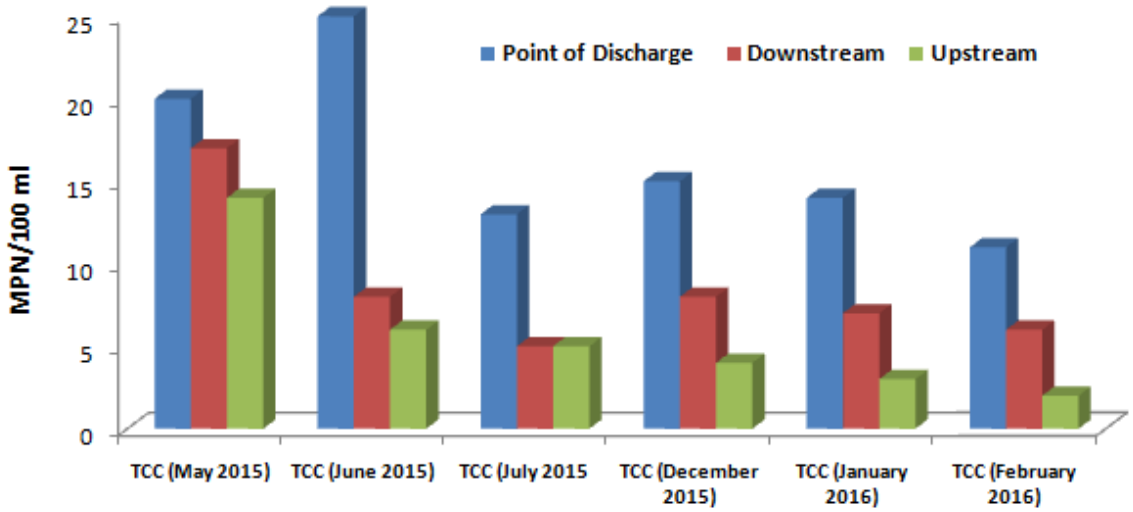

Fig. 3: Total coliform counts of the sampled surface water collected in the sampling period; May, 2015 - February, 2016

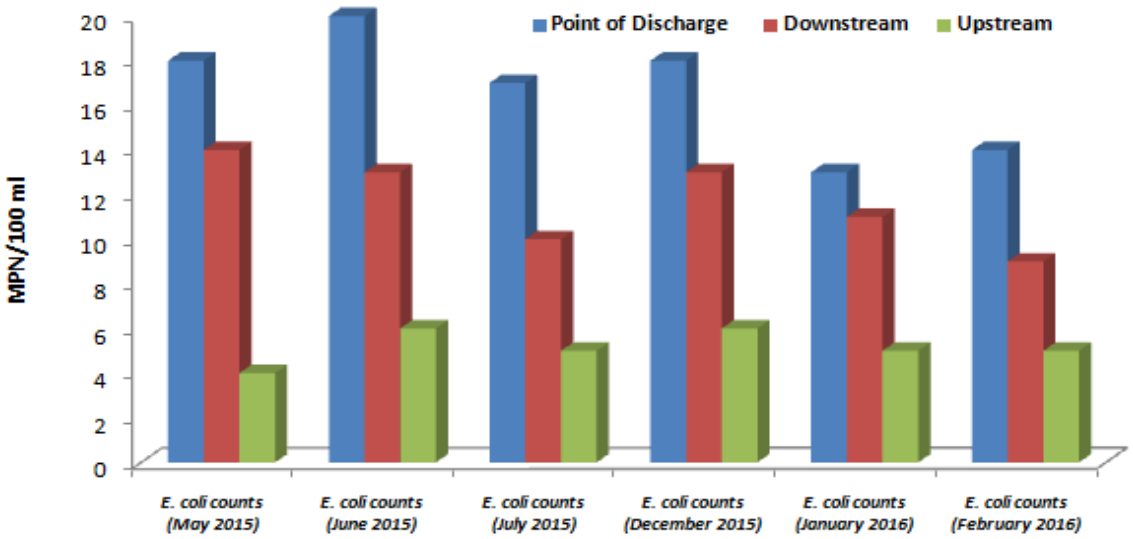

Fig. 4: *E. coli* (fecal coliform) counts of the sampled surface water collected in the sampling period; May, 2015 - February, 2016

The total coliform counts for water samples obtained at the point of discharge in the sampling period ranged from 11 MPN/100 ml for February, 2016 to 24 MPN/100 ml for June, 2015 (Fig. 3). The total coliform counts for water samples collected at the downstream point in the sampling period ranged from 5 MPN/100ml for July, 2015 to 17 MPN/100ml for February, 2016 (Fig. 3). The coliform counts for samples collected at the upstream point in the sampling period ranged from 2 MPN/100ml for February, 2016 to 14 MPN/100ml for May, 2015. The fecal coliform (*E. coli)* counts for water samples abstracted at the point of discharge in the sampling period ranged from 13 MPN/100ml for January, 2016 to 20 MPN/100ml for June, 2015 (Fig. 4). *E. coli* counts for samples collected at the downstream point in the sampling period ranged from 9 MPN/100ml for February, 2016 to 14 MPN/100ml for May, 2015. *E. coli* bio-load for samples collected at the upstream point in the sampling period ranged from 4 MPN/100ml for May, 2015 to 6 MPN/100ml for both June and December 2015. The analyzed water samples harbored a diversity of culturable microorganisms as indicated by the recorded culturable microbial bio-load. The microbial counts recorded for water samples collected at the point of discharge of the raw abattoir wastes were significantly higher than counts observed for samples obtained at both the upstream and downstream points on the Ikpobariver. This trend could be indicative of both the organic and microbial load of the evacuated raw abattoir effluent and its impact on the receptacle (Ikopbariver) at the point of discharge. Atuanya *et al.* (2012) reported a similar phenomenon for the same receptacle and further opined that the effects of these abattoir effluent discharges into Ikpoba River were evident in the downstream water qualities of the river water. Agwa *et al.* (2013) also observed this trend in the course of evaluating the spatial and temporal variations in the microbiological quality of Ogbogoro stream which was polluted by raw slaughter house waste water from a nearby abattoir. Akan *et al.* (2010) opined that the discharge of wastewater from abattoirs into nearby water bodies can raise the level of organic contaminants thereby making the affected surface waters unsafe for activities such as swimming or irrigation by individuals living within the catchment area of the stream, lake or river. In this study, there might have been evidence of self-purification as the observed microbial counts for the downstream sampling point was significantly lower than values recorded at the point of discharge.

Eleven (11) bacterial and nine (9) fungal isolates were characterized and tentatively identified (Figs. 5 and 6). The microbial isolates included; *Bacillus subtilis*, *Micrococcus* sp., *Staphylococcus aureus*, *Micrococcus luteus*, *Citrobacter* sp., *Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiellamobilis*, *Enterobacter* sp., *Acinetobacter* sp., *Flavobacterium* sp., *Aspergillus niger*, *Saccharomyces* sp., *Mucor* sp., *Fusarium* sp., *Penicillium* sp., *Aspergillus flavus*, *Candida* sp., *Aspergillus versicolor* and *Rhizopus* sp. (Figs. 5 and 6). Amongst the bacterial isolates, *E. coli* was the most dominant while *Flavobacterium*sp. was the least isolated (Fig. 5). *A. niger*had maximal percentage frequency of isolation amongst the fungal cultures while *A. versicolor* and *Candida* sp. were the least isolated fungal cultures (Fig. 6). The isolation of *P. aeruginosa*, *E. coli*, *Flavobacterium*sp., *Acinetobacter* sp., *Saccharomyces* sp., *Mucor* sp., *Fusarium* sp., *Penicillium* sp. and *Aspergillus spp*. (Figs. 5 and 6) was in agreement with a report by Agwa *et al*. (2013) which indicated the presence of these micro- organisms in water samples collected from Ogbogoro stream which served as a receptacle for raw abattoir waste emanating from Ogbogoro abattoir located in Port Harcourt, Rivers State. The detection of *S. aureus* (Fig. 5) from the examined samples was similar to a report by Atuanya *et al.* (2012) which stated the presence of this bacterial isolate from upstream and downstream surface water samples abstracted from Ikpoba River.

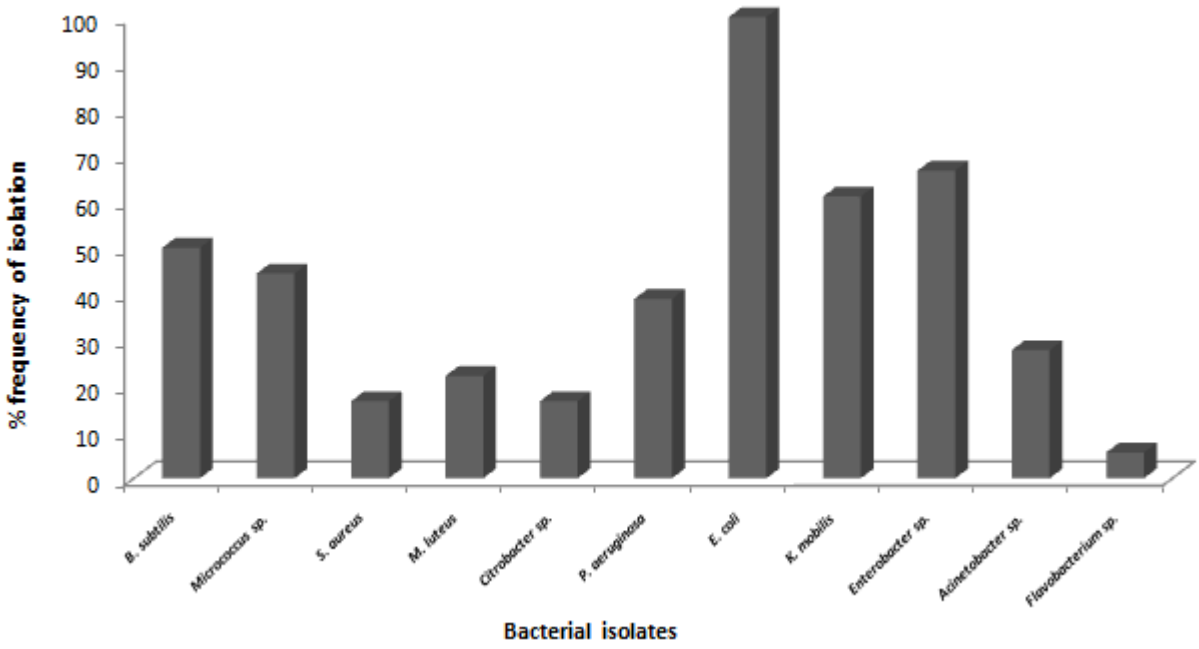

Fig 5: Percentage frequency of isolation values for the identified water borne bacterial isolates

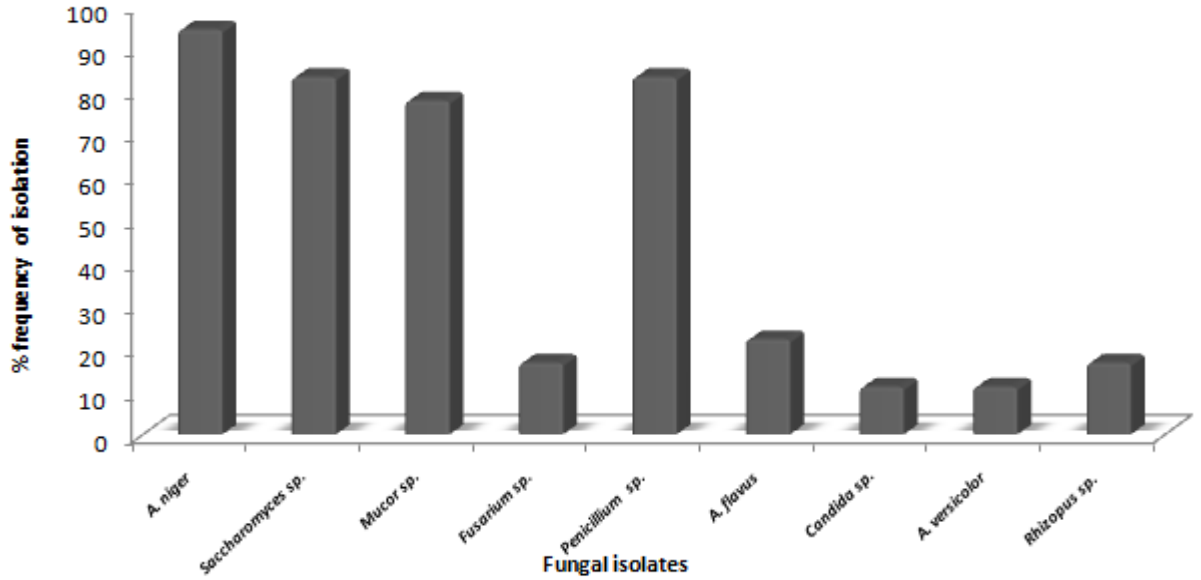

Fig 6: Percentage frequency of isolation values for the identified water borne fungal isolates

Table 1: Antibiotic susceptibility patterns of the bacterial isolates

G+ve cultures	PEF (10 µg)	CN (20 µg)	APX (30 µg)	Z (10 µg)	AM (10 µg)	R (25 µg	CPX (50 µg)	S (30 µg)	SXT (10 µg)	E (30 µg)
B. subtilis	0 (R)	17 (I)	0 (R)	10 (R)	13 (I)	18 (S)	22 (S)	0 (R)	0 (R)	15 (I)
Micrococcus sp.	14 (I)	20 (S)	0 (R)	0 (R)	0 (R)	12 (I)	25 (S)	0 (R)	0 (R)	20 (S)
S.aureus	0 (R)	19 (S)	0 (R)	0 (R)	16 (I)	20 (S)	21 (S)	10 (R)	0 (R)	18 (S)
M. luteus	18 (S)	22 (S)	0 (R)	15 (I)	20 (S)	18 (S)	28 (S)	13 (I)	0 (R)	20 (S)
G-ve cultures	**SXT (10 µg)**	**CH (20 µg)**	**SP (30 µg)**	**CPX (50 µg)**	**AM (10 µg)**	**AU (10 µg)**	**CN (20 µg)**	**PEF (10 µg)**	**OFX (30 µg)**	**S (30 µg)**
Citrobacter sp.	0 (R)	10 (R)	15 (I)	22 (S)	18 (S)	0 (R)	20 (S)	10 (R)	28 (S)	12 (I)
P. aeruginosa	0 (R)	0 (R)	0 (R)	24 (S)	0 (S)	0 (R)	23 (S)	0 (R)	22 (S)	0 (R)
E. coli	0 (R)	0 (R)	0 (R)	20 (S)	0 (R)	14 (I)	19 (S)	08 (R)	25 (S)	05 (R)
K. mobilis	0 (R)	0 (R)	10 (R)	26 (S)	10 (R)	0 (R)	22 (S)	0 (R)	28 (S)	10 (R)
Enterobacter sp.	0 (R)	12 (I)	15 (I)	19 (S)	0 (R)	0 (R)	20 (S)	10 (R)	26 (S)	0 (R)
Acinetobacter sp.	0 (R)	15 (I)	18 (S)	22 (S)	0 (R)	0 (R)	24 (S)	15 (I)	30 (S)	16 (I)
*Flavobacterium*sp.	0 (R)	13 (I)	19 (S)	20 (S)	10 (R)	0 (R)	28 (S)	18 (S)	25 (S)	11(I)

PEF: Pefloxacin, CN: Gentamicin, APX: Ampiclox, Z: Zinnacef, AM: Amoxacillin, R: Rocephin, CPX: Ciprofloxacin, S: Streptomycin, SXT: Septrin, E: Erythromycin, SP: Sparfloxacin, AU: Augmentin, AM: Amoxacillin, OFX: Ofloxacin, CH: Chloramphenicol, R: Resistant, I: Intermediate, S: Sensitive

Table 2: Summary of the physiochemical values for the water samples collected between May 2015 and February, 2016

Parameter	Point of discharge	Downstream	Upstream	FEPA[b]
pH	*6.05 ± 0.4	6.05 ± 0.4	5.7 ± 0.4	6-9
Temperature (^{0}C)	29.33 ± 0.63	29.52 ± 0.45	28.93 ± 0.72	<40
Conductivity (mhos/cm)	31.02 ± 8.57	8.17 ± 1.57	6.83 ± 1.48	1000
Alkalinity (mg/L)	137.64 ± 23.3	68.54 ± 4.72	54.26 ± 2.69	NS
Total solid(mg/L)	1543.50 ± 197.1	946.72 ± 55.5	330.50 ± 16.9	NS
DO(mg/L)	1.1± 0.2	2.6 ± 0.2	4.7 ± 0.8	7.5
BOD(mg/L)	738.97 ± 100.9	357.26 ± 60.7	139.98 ± 23	30
COD(mg/L)	1515.2 ± 188. 9	993.7 ± 69	390.3 ± 23.2	80
Total Hardness(mg/L)	45.2 ± 10. 8	21.3 ± 4.7	6.3 ± 0.9	150
Nitrate(mg/L)	27.77 ± 10. 6	9.8 ± 5.5	0.3 ± 0.2	20
Sulphate(mg/L)	27.1 ± 5. 8	8.5 ± 0.7	4.3 ± 0.5	500
Phosphate(mg/L)	9.5 ± 1. 5	4.9 ± 0.9	0.6 ± 0.1	NS
Chloride(mg/L)	52.3 ± 5.4	29.8 ± 2.5	21.2 ± 3.6	NS
Heavymetal				
Lead(mg/L)	22.2± 3.8	0.8 ± 0.2	0.01 ± 0	0.01
Zinc(mg/L)	38.3 ± 7.3	9.8 ± 3.8	0.07 ± 0.02	NS
Cadmium(mg/L)	0.2 ± 0.1	0.02 ± 0	0.01 ± 0	0.003
Iron (mg/L)	62.9 ± 8.6	6.02 ± 0.7	1.27 ± 0.2	0.3
Copper (mg/L)	9.3 ± 1.5	1.5 ± 0.6	0.2 ± 0.1	1.0

*Overall mean± Std. error, NSDWQ: [b]FEPA limits (Magaji, andChup, 2012), DO: Dissolved oxygen, BOD: Biochemical oxygen demand, COD: Chemical oxygen demand, NS: Not Stated

The mean physicochemical and heavy metal profiles of the respective water samples are shown in Table 2. The mean pH and temperature readings ranged from 5.7 ± 0.4 and 28.93^{o}C ± 0.72 for upstream samples to 6.05 ± 0.4 for point of discharge and 28.52^{o}C ± 0.45 for downstream, respectively. Conductivity and alkalinity mean values ranged from 6.83 mhos/cm ± 1.48 and 54.26 mg/L ± 2.69 for upstream samples to 31.02 mhos/cm ± 8.57 and 137.64 mg/L ± 23.3, respectively for samples collected at the point of discharge. Total solids and dissolved oxygen (DO) mean values ranged from 330.50 mg/L ± 16.9 and 1.105 mg/L ± 0.2 for upstream and point of discharge samples to 1543.50 mg/L ± 197.1 and 4.7 mg/L ± 0.8 respectively for samples collected at the point of discharge and upstream. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) mean values ranged from 139.98 mg/L ± 23 and 390.3 mg/L ± 23.2 for upstream samples to 738.97 mg/L ± 100.9 and 1515.2 mg/L ± 188.9, respectively for samples collected at the point of discharge. Total hardness and nitrate mean values ranged from 6.3 mg/L ± 0.9 and 0.3 mg/L ± 0.2 for upstream samples to 45.2 mg/L ± 10.8 and 27.7 mg/L ± 10.6, respectively for samples collected at the point of discharge. Sulphate and phosphate mean readings ranged from 4.3 mg/L ± 0.5 and 0.6 mg/L ± 0.1 for upstream samples to 27.1 mg/L ± 5.8 and 9.5 mg/L ± 1.5 respectively for samples collected at the point of discharge. Chloride and Pb mean readings ranged from 21.2 mg/L ± 3.6 and 0.01 mg/L ± 0 for upstream samples to 52.3 mg/L ± 5.4 and 22.2 mg/L ± 3.8, respectively for samples collected at the point of discharge. Zn and Cd mean readings ranged from 0.07 mg/L ± 0.02 and 0.01 mg/L ± 0 for upstream samples to 38.3 mg/L ± 7.3 and 0.2 mg/L ± 0.1 respectively for samples collected at the point of discharge. Fe and Cu mean values ranged from 1.27 mg/L ± 0.2 and 0.2 mg/L ± 0.1 for upstream samples to 62.9 mg/L ± 8.6 and 9.3 mg/L ± 1.5, respectively for samples collected at the point of discharge.Aside from temperature and pH, the mean physicochemical values observed for the water samples collected at the point of discharge of the raw effluents into the receptacle (Ikpoba River) was comparatively higher than corresponding values recorded for both upstream and downstream samples. This trend would suggest that the discharge of the raw abattoir effluent into the river impacted negatively on the physicochemical status of the water body. However, there was evidence of the capability of the river to undergo self-purification as there was a corresponding reduction in the mean physicochemical values recorded for samples abstracted downstream from the point of discharge. Agwa *et al*. (2013) reported higher physicochemical readings for surface water obtained at the point of discharge of raw effluents from a nearby slaughter house into Ogbogoro stream, Rivers State. Okoronkwo *et al.* (2013) stated that dissolved oxygen was an important measure of water quality and the recorded mean DO values varied between the sampling points in this study.Emongo*et al.* (2005) ascribed variation in dissolved oxygen value of polluted water body to oxygen consumption by aerobic organisms as a consequence of an increment in oxygen demanding wastes such as raw effluents. Tekenah *et al.* (2014) stated that the availability of oxygen in an aquatic ecosystem was an indicator of the systems health and general quality. The mean BOD and COD values for the respective water samples were much higher than the allowable FEPA limits. This negative trend could be ascribed to the possible high organic load and strength of the disposed Abattoir wastes as the biochemical and chemical oxygen deficit was much higher in for samples abstracted from the discharge point. Biological activities are known to impact on the concentration of dissolved oxygen in addition to the weather and changes in the physical factors such as temperature (Okoronkwo *et al.*, 2013). Chapman (1996) stated that 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. There were fluctuations in the mean nitrate values recorded for the surface water samples, although the values were below the stipulated limit for drinking water (Table 2). Osibanjo and Adie (2007) opined that possible sources of nitrates could be from oxidation of other forms of nitrogen compounds such as ammonia and nitrite into nitrate. The mean concentration of Fe, Pb, Zn and Cu was comparatively higher for surface water collected at the point of discharge of the raw wastes. However, the comparative high mean iron content of the surface water sample collected at the point of discharge could be linked directly to impact of discharged abattoir waste especially blood which contains hemoglobin. However, it is difficult to ascertain or speculate the exact source of the other metals; Pb and Zn detected at high concentrations in samples obtained at the point of discharge. However, the documentation of elevated mean values of these trace metals is disturbing in view of the public health significance of some of these metals especially lead. Oyeku *et al.* (2001) reported that the presence of Fe in substantial levels could render water unsuitable for use by food processing industries.

Conclusion

The microbiological index of the water samples was very poor as *E. coli* was detected in all the waters obtained from the respective sampling point on the river. This trend indicated that the water samples were unfit for direct human consumption. The discharged organic waste also impacted negatively on the oxygen status of the samples. There is an urgent need by abattoir users' to improve on their existing waste management system so as to minimize the risk posed to aquatic organisms, environment and human residents whose life and survival is dependent on a healthy and clean Ikpoba river biome.

Conflict of Interest

Authors declare that there is no conflict of interest related to this study.

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