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Seasonal Changes Associated with Effluent Discharge from Abattoir Located along the Bank on Aba River, Abia State, Nigeria

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Abstract
The seasonal changes associated with the extent of pollution on Aba river by effluent from abattoir located along its bank was evaluated. This was done by collecting triplicate samples from the five (5) point sources including the point of contact between effluent from abattoir and the river during dry and rainy seasons for physicochemical and bacteriological qualities. The total heterotrophic count and presence of indicator organisms of feacal contaminants were determined using most probable number techniques (MPN) and culturing of samples in appropriate growth media. The mean physicochemical values for both dry and rainy seasons ranges from 25.00±0.04-29.20±0.11/ 23.50±0.16-27.4±0.40 ^{o}C, total solids 0.66±0.23-2.06±0.37/ 0.78±0.09-2.18±0.14 %, biochemical oxygen demand (BOD) 4.00±0.21-7.20±0.78/ 4.01±0.45-8.80±0.34 mg/L, SO_4^{2+} 246.3±0.16-415.2±0.34/ 265.40±0.12-420.5±0.98 mg/L, NO_3^- 264.4±0.04-574.7±0.09/ 280.3±0.09-585.2±0.74 mg/L, PO_4^- 16.42±0.08-35.60±0.06/ 18.00±0.02-37.10±0.18 mg/L, Zn^{2+} 3.64±0.07-4.48±0.66/ 3,80±0.32-6.40±0.34 mg/L and K^+ 22.40±0.07-214.80±0.29/ 46.44±0.23-220.40±0.10 mg/L respectively. The physicochemical values at point of entry of effluent into the river were consistently higher than values obtained from downstream sampling points. The bacterial load for both dry and rainy seasons ranged from 0.58 x 10^6 ±0.14 to 1.01 x 10^6 ±0.31 CFU/mL and 0.66 x 10^6 ±0.03 to 1.03 x 10^6 ±0.18 CFU/mL respectively. The isolation of some bacterial species such as *Salmonella* species. *Bacillus* species, *Escherichia coli, Streptococcus faecalis, Shigella* species and *Vibrio* species from the river indicated constant pollution of the river with feacal materials. The high bacterial loads obtained in the river constitutes a public health concern and the risk associated with the domestic and recreational use of the river calls for the need of an adequate pollution control programme for Aba river.

Keywords Aba river; Effluent; Abattoir; Bacterial load; Physicochemical quality

1. Introduction

Aba river is an important economic river in Southeast of Nigeria. The river which runs through the City of Aba originated from the Northern Ngwa hinterland of Okpu Umuobo and stretches down to Cross River State where it empties through its creeks into the Atlantic Ocean. The river is used for various human activities including fishing, car washing, bathing, and recreation sports. At one of its major points is the location of Enyimba Hotels. The river serves as a major supply of fresh water for the immediate city dwellers and unfortunately also as a sewage disposal medium. It receives wastes from the industries, abattoirs, market, piggery and car wash centres cited along its course.

Such wastes invariably introduce a variety of microorganisms in addition to the autochthonous microflora of the river. Furthermore, most of the communities living near the river course defecate and dump their domestic wastes into the river thereby creating pollution problem. [1] in their work on Aba river observed a remarkable bacterial variations along the river course and isolated ten bacterial genera and the most prevalent in all their sampling points included *Staphylococcus* species, *Pseudomonas* species, *Eschericha coli* and *Micrococcus* species. [2] observed from selected water sources in Calabar that physicochemical parameters like BOD, Silica and pH were positively correlated with indicator bacteria. Investigations carried out on Aba river, the rivers of Niger- Delta and Lagos region by [3; 4; 5] respectively showed that with the exception of iron, the concentrations of most trace metals in surface waters are generally lower than the global average levels for surface waters and the international drinking water standards.

Effluent discharges into the environment has been on the increase in Nigeria since 1960 due to active industrialization, urbanization and the accompanying increase in commercial activities. Copious amounts of wastes are produced due to human activities and the capacity of the environment to absorb these wastes is limited. On the other hand, waste management has remained underdeveloped and very unsatisfactory leading to environmental pollutions, erosion or degradation of natural ecosystems. As a result of this, many potential pollutants have found their way into natural waters, especially in the urban areas upsetting the ecological balance. Surface waters such as Aba river are usually exposed to microbial contamination from run-offs, soils and any waste deliberately or inadvertently dumped into it resulting in pollution, increase in microbial load, eutrophication, visible aesthetic nuisance and loss of recreational amenities. All natural waters contain bacteria. The aerobic Gram negative rods of the genera *Pseudomonas*, *Alcaligens* and *Flavobacterium* as well as others are common in water. All natural waters can also be polluted by transient bacteria. Among them are human pathogens that gain entry into water from feacal contamination. This contaminated water is a potential transmitter of a number of intestinal diseases.

There are two distinct seasons in Nigeria –the dry and the rainy seasons. During the rains, immense volumes of urban run-off water enter the river. The rains soak and saturate the soil and the excess water flows into streams, ponds, lakes, rivers, lagoons and the sea. Life would have been impossible in the freshwater without rains since the water body could dry up [6]. Rainfall affects the variation of microorganisms in freshwater habitat because when rain falls, microorganisms are carried by run offs into the water body and increases the number of microorganisms present. Also availability of rains helps in dissolving of nutrients present and neutralizing the toxic compounds and ions in the water body. This water influx characteristically delivers into the river high fluxes of suspended solids, nutrients and other pollutants washed from the land and refuse dumps which have remained common features in the urban areas. Thus, increasing the microbial load, nitrate, phosphate and lignocellulose content of the river. An urban river such as Aba river is periodically subjected to leaching action from urban wastes and other aforementioned sources of contaminations and it is highly in-use by the populace for various domestic and industrial purposes. As a result of consequent increase in pollution stress, the river represents a potential source of infections to the users and as such the need for the examination of the presence of water borne pathogens becomes inevitable.

However, research has shown that the occurrence of several diseases like gastroenteritis, skin, eye, throat, ear and respiratory infections happened when a given community has got the habit of swimming in contaminated waters [7]. Rivers, lakes and groundwater provide the sources from which most of the human population obtains water for domestic, industrial and agricultural purposes. Rural communities rely on various sources of water for domestic purposes. The microbial quality of drinking water is a cause of concern world-wide as the practice of disposing waste into streams, rivers or on land becomes common [8]. Waterborne diseases such as cholera, bacillary dysentery, typhoid fever and diarrhoea are associated with water contaminated with human and animal excreta and may usually contain *Salmonella, Vibrio and Shigella* species, enterotoxigenic *Eschericha coli* and a number of different types of pathogenic viruses [7; 9]. The use of raw waters from rivers for washing and drinking without any form of purification by surrounding communities in Nigeria has compounded the problem of water-borne diseases [10]. The extent to which contamination has occurred in Nigerian aquatic systems is not thoroughly quantified [11]. While many rural water systems may be protected from the hazard of feacal contamination, open systems like rivers and lakes may not be easily protected and disinfection of the water sources is neither chemically nor technically feasible. [2; 12; 13] reported that little work has been done on bacterial distribution and effects of effluent discharge on few Nigeria rivers despite the increase in industrialization and urbanization in recent times. In this study the seasonal changes associated with effluent discharge from abattoir located along the bank on Aba river, Abia State, Nigeria was investigated.

2. Materials and methods

2.1. Study area, sample size and distribution

The study area is Aba river located in Aba, Abia State, Nigeria. The river originated from the hinter land of Aba and stretches down to Cross-River State where it empties its creeks into Atlantic Ocean. It is an important economic river used for various human activities including fishing, car washing and industrial uses. Aba is a major city in Nigeria and the commercial nerve center of Abia State. It is a densely populated city whose impact is felt throughout Nigeria. Dry and rainy seasons are distinct in the area with dry season stretching from November to February while rainy season stretches from March to October.

2.2. Sample collection and processing

Five (5) different water samples were collected from different sampling locations along the river with one (1) litre sterile polyvinyl chloride (PVC) plastic water bottles. At each sampling point, three water samples were drawn at random from three points and pooled. Dry season samples were collected in January while rainy season samples were collected in July. The time for the collection of the two seasons samples were between 10.00 am and 11.00 am. Temperatures were determined in situ at four different sampling points. The collected samples were subsequently placed on ice bags and taken directly to the laboratory for analysis.

2.3. Microbiological studies

Ten fold serial dilutions of samples were done using sterile peptone water as the diluent. Spread plate and streaking techniques were used to enumerate and isolate bacteria in the samples [14]. Sample dilutions were prepared by adding 1.0 mL of stock sample to 9.0 mL of the sterile peptone water with vigorous agitation in ensuring adequate disengagement of microorganisms to obtain 10^{-1} dilution. Serial dilutions of the homogenates were continued aseptically and made step-wisely till the sixth (6th) tube, to obtain dilutions of 10^{-3} to 10^{-6} dilutions and appropriate dilutions were plated in replicates using plate count agar for mean viable enumeration and isolation, and tergitol agar for feacal coliform enumeration and isolation. Pure bacterial isolates were identified using cultural, morphological and biochemical characterization. Identification of bacteria to genera level was based on the schemes of [14]. The plates were incubated at 35 ±2 °C for 72 hours and 24 hours for mean viable and coliform counts respectively.

2.4. Physicochemical studies

All the physicochemical parameters namely: temperature ^{o}C *(in situ)*, pH, total solid (%), dissolved solid (%), biochemical oxygen demand (BOD_5) mg/L, hardness ($CaCO_3$) mg/L, ions mg/L (sulphate - SO_4^{2-}, nitrate -NO_3^- and phosphate - PO_4^{2-}), heavy metals mg/L (lead –Pb, iron -Fe, zinc -Zn, copper –Cu, Arsenic –As, manganese –Mn, chromium –Cr, mercury –Hg) and minerals mg/L (calcium –Ca, magnesium –Mg, potassium –K, and sodium –Na) were determined using methods in [15] as described by [16].

2.5. Data analysis

Analysis of variance (ANOVA) was employed in this work and used to analyze all data obtained from the determinations. Descriptive statistics in form of mean and standard deviation and Duncan post hoc were also used to assess the data. The analyses were done using (Statistical Product and Service Solutions) SPSS 20.

3. Results

Tables 1and 2 showed the mean physiochemical parameters of dry and rainy season water samples from Aba river as were investigated. Temperature variations for both seasons ranged between 23.0±0.15 - 27.2±0.11 as presented in (Tables 1 and 2) and were not significant ($p \geq 0.05$) except at the principal test site (point 1, abattoir). The mean pH values for both seasons ranged between 5.10±0.22 - 6.54 ±0.33. A general tendency in pH towards neutrality was observed in all the samples for the seasons, all of which were below 7. No significant difference ($p \geq 0.05$) in total pH variations among same sampling groups in both seasons (upstream and downstream), but significant difference existed between the various groups (upstream and downstream) and point 1 (abattoir) of both seasons when compared ($p \leq 0.05$). Total solids, dissolved solids and biochemical oxygen demand (BOD) showed significant ($p \leq 0.05$) decline in dry season (2.06±0.37, 0.11±0.45, 7.20±0.78) than in rainy season (2.18±0.14, 0.14±0.50, 8.80±0.34) respectively. Point 1 of rainy season (abattoir) recorded the highest mean value of 2.18±0.14% and 8.80±0.34 mg/L for total solids and BOD respectively; while point 4 of rainy season (upstream) recorded the highest mean value of 0.15±0.76% for dissolved solids.

Hardness (mg/L), dissolved ions (mg/L), heavy metals (mg/L) and minerals (mg/L) followed the same pattern of significant ($p \leq 0.05$) decline with dry season over rainy season for total solids, dissolved solids and biochemical oxygen demand (BOD) above, with higher values recorded in rainy season than in dry season. Hardness (mg/L) had its highest value of 28.42±0.65 in point 1 (abattoir) sample of rainy season. In dissolved ions, sulphate and phosphate ions (mg/L) had higher values of 420±0.98 and 37.10.±0.18 in point 1 (abattoir) sample of rainy season, while highest value of 585.±0.74 was with nitrate (mg/L) of point 1 (abattoir) sample of rainy season. Also, heavy metals (mg/L) recorded highest values in point 4 (upstream) of rainy season. In the same vein, mineral content values (mg/L) were highest in point 1 (abattoir) samples of rainy season (Ca- 46.60±0.22, Mg- 2.42±0.55, K- 220.40±0.10, Na- 208.2±0.13).

Table 1: Mean physicochemical results of Aba river samples during dry season

Test Parameters	Point 5 Upstream	Point 4 Upstream	Point 1 Abattoir	Point 2 Downstream	Point 3 Downstream	EPA Limits
Temp °C	$25.0±0.04^b$	$25.2±0.56^b$	$27.2±0.11^a$	$25.9±0.90^b$	$25.5±0.64^b$	
pH	$6.42 ±0.12^{ab}$	$6.54 ±0.33^a$	$5.10±0.22^e$	$6.18±0.33^c$	$6.26±0.69^{cd}$	6.0-8.0
Total Solids %	$0.66±0.23^c$	$0.84±0.13^b$	$2.06±0.37^a$	$0.94±0.22^b$	$0.48±0.70^d$	
Dissolved solids %	$0.07±0.11^a$	$0.12±0.01^e$	$0.11±0.45^{ab}$	$0.10±0.21^{bc}$	$0.09±0.31^{cd}$	50mg/L
Biochemical Oxygen Demand (BOD) mg/L	$4.00±0.21^d$	$4.00±0.44^d$	$7.20±0.78^a$	$5.40±0.78^b$	$4.20±0.60^c$	≤ 3mg/L
Hardness ($CaCo_3$) mg/L	$20.40 ±0.56^b$	$22.46 ±0.23^c$	$28.22±0.33^a$	$18.20±0.23^d$	$14.60±0.33^e$	50mgL
IONS mg/l						
$SO4^{2-}$	$246.3±0.16^e$	$404.6±0.55^b$	$415.2±0.34^a$	$399.2±0.32^c$	$308.3±0.89^d$	200mg/L
NO^{3-}	$264.4±0.04^e$	$286.2±0.66^d$	$574.7±0.09^a$	$411.6±0.41^b$	$306.4±0.44^c$	45mg/L
$PO4^{2-}$	$16.42±0.08^e$	$32.48±0.11^b$	$35.6±0.06^a$	$30.2±0.47^c$	$27.00±0.55^d$	
HEAVY METALS mg/L						
Pb	$0.04±0.12^c$	$0.08±0.67^a$	$0.04±0.45^c$	$0.06±0.54^b$	$0.04±0.05^c$	0.05mg/L
Fe	$0.68 ±0.06^c$	$0.84 ±0.08^{ab}$	$0.68±0.23^c$	$0.88±0.75^a$	$0.64±0.08^{cd}$	0.1mg/L
Zn	$3.64 ±0.07^{de}$	$4.62 ±0.45^a$	$4.48±0.66^{ab}$	$4.20±0.65^{bc}$	$3.80±0.45^d$	5.0mg/L
Cu	$0.20 ±0.14^a$	$0.08 ±0.56^e$	$0.18±0.55^b$	$0.14±0.43^c$	$0.12±0.32^d$	1.0mg/L
As	ND	$0.04±0.11^a$	$0.04±0.46^a$	$0.02±0.32^b$	$0.02±0.03^b$	0.05mg/L
Mn	ND	$0.02±0.06^{bc}$	$0.04±0.34^a$	$0.03±0.67^{ab}$	$0.02±0.02^{bc}$	0.05mg/L
Cr	ND	$0.02±0.03^a$	ND	ND	ND	0.05mg/L
Hg	ND	ND	ND	$0.02±0.03^a$	$0.02±0.04^a$	0.002mg/L
MINERALS mg/L						
Ca	$18.46 ±0.54^c$	$28.66±0.14^b$	$46.20±0.11^a$	$18.82±0.09^c$	$10.64±0.32^d$	75mg/L
Mg	$0.58±0.37^e$	$1.16±0.20^{cd}$	$2.18±0.25^b$	$2.48±0.17^a$	$1.84±0.60^c$	50mg/L
K	$22.40±0.07^d$	$42.12±0.23^c$	$214.80±0.29^a$	$118.6±0.65^b$	$48.20±0.40^c$	
Na	$182.60±0.60^d$	$210.00±0.67^a$	$198.80±0.31^c$	$202.4±0.55^b$	$164.4±0.56^e$	

Values are given as mean ± SD. Within rows, values followed by the same alphabets are not significantly different but those followed by different alphabets are significantly different $p \leq 0.05$.

Table 2: Mean physicochemical results of Aba river samples during rainy season.

Test Parameters	Point 5 Upstream	Point 4 Upstream	Point 1 Abattoir	Point 2 Downstream	Point 3 Downstream	EPA Limits
Temp °C	23.5±0.16[b]	23.2±0.29[b]	25.4±0.40[a]	23.8±0.15[b]	23.5±0.22[b]	
pH	6.28 ±0.10[ab]	6.42 ±0.22[a]	5.60±0.11[e]	6.19 ±0.34[c]	6.15±0.08[cd]	6.0-8.0
Total Solids %	0.78 ±0.09[d]	0.92 ±0.77[c]	2.18±0.14[a]	1.24±0.22[b]	0.50±0.04[e]	
Dissolved solids %	0.10 ±0.11[c]	0.15 ±0.76[a]	0.15±0.50[a]	0.12±0.41[b]	0.10±0.05[c]	50mg/L
Biochemical Oxygen Demand (BOD)) mg/L	4.01 ±0.45[e]	4.20 ±0.65[d]	8.80±0.34[a]	6.80±0.33[b]	6.40±0.15[c]	≤ 3mg/L
Hardness ($CaCO_3$) mg/L	24.20±0.75[bc]	24.80 ±0.08[b]	28.42±0.65[a]	18.80±0.11[d]	14.60±0.14[e]	50mg/L
IONS mg/L						
$SO4^{2-}$	265.4±0.12[e]	438.8 ±0.98[a]	420.5±0.98[b]	403,6±0.34[c]	322.8±0.23[d]	200mg/L
NO^{3-}	280.3±0.09[e]	310.4±0.12[cd]	585.2±0.74[a]	420.5±0.21[b]	315.6±0.12[c]	45mg/L
$PO4^{2-}$	18.0 ±0.02[e]	36.2 ±0.10[ab]	37.10±0.18[a]	34.2±0.21[c]	30.2±0.44[d]	
HEAVY METALS mg/L						
Pb	0.04 ±0.06[d]	0.12 ±0.18[a]	0.08±0.13[b]	0.08±0.33[b]	0.06±0.34[c]	0.05mg/L
Fe	0.82 ±0.62[d]	0.96±0.65[a]	0.88±0.14[b]	0.84±0.19[bc]	0.84±0.07[bc]	0.1mg/L
Zn	3.80 ±0.32[d]	6.80±0.60[a]	6.40±0.34[b]	4.20±0.22[c]	4.20±0.05[c]	5.0mg/L
Cu	0.18 ±0.55[c]	0.24±0.17[a]	0.24±0.26[a]	0.20±0.15[b]	0.18±0.01[c]	1.0mg/L
As	ND	0.12±0.05[a]	0.06±0.32[b]	0.06±0.08[b]	0.04±0.06[c]	0.05mg/L
Mn	0	0	0.04±0.44[a]	0.04±0.06[a]	0	0.05mg/L
Cr	ND	0.04±0.02[a]	ND	ND	ND	0.05mg/L
Hg	ND	0.01±0.90[b]	ND	0.02±0.04[a]	0.02±0.07[a]	0.002mg/L
MINERALS mg/L						
Ca	15.80 ±0.15[d]	22.42 ±0.80[bc]	46.60±0.22[a]	22.68±0.41[b]	13.42±0.44[e]	75mg/L
Mg	2.42 ±0.04[b]	0.66 ±0.20d	2.42±0.55[b]	2.56±0.16[a]	1.82±0.49[c]	50mg/L
K	46.44 ±0.23[c]	18.66 ±0.32[d]	220.40±0.10[a]	115.80±0.34[b]	46.24±0.09[c]	
Na	206.80 ±0.99[a]	208.20 ±0.20[a]	208.20±0.13[a]	182.60±0.67[b]	160.40±0.66[c]	

Values are given as mean ± SD. Within rows, values followed by the same alphabets are not significantly different but those followed by different alphabets are significantly different $p \leq 0.05$.

In rainy season, mean viable count recorded minimum count of 0.62 x 10^6±0.02 CFU/mL at point 4 upstream and maximum value of 1.03 x 10^6±0.18 CFU/mL at point 1 abattoir, while mean faecal coliform count recorded minimum count of 0.7 x 10^5±0.20 CFU/mL at point 3 downstream and maximum count of 1.1 x 10^5±0.05 CFU/mL at point 1 abattoir (Table 3). Whereas in dry season, mean viable count recorded lowest count of 0.56 x10^6±0.22 CFU/mL at point 4 upstream and highest value of 1.01 x 10^6±0.31 CFU/mL at point 1 abattoir, while mean faecal coliform count recorded lowest count of 0.7 x 10^5±0.41 CFU/mL at point 3 downstream and highest value of 1.0 x 10^5±0.17 CFU/mL at point 1 abattoir (Table 4). All obtained values when compared across sampling points were statistically significant ($p \leq 0.05$).

The occurrences and seasonal distribution of bacteria isolates are shown in Table 5. The prevalence of the isolates is in the following descending order: *Clostridium* species, *Salmonella* species, *Bacillus* species, *Escherichia coli*, *Staphylococcus* species, *Streptococcus faecalis*, *Shigella* species and *Vibrio* species. The most prevalent isolates were *Clostridium* species and *Salmonella* species, as they were only absent in point 2 downstream sample of dry season. *Vibrio* species were the least prevalent and were not isolated at both dry and rainy seasons of points 5 (upstream), point 2 and 3 of downstreams. *Shigella* species were found absent in all the dry season samples, except that of point 1 (abattoir).

Of all the sampling points, abattoir recorded all the organisms isolated. A total of eight organisms were isolated which include: *Staphylococcus* species, *Streptococcus faecalis*, *Vibrio* species, *Escherichia coli*, *Shigella* species, *Salmonella* species, *Bacillus* species and *Clostridium* species. Generally, greater numbers of organisms were isolated in rainy season than in dry season (Table 5). Microscopic examinations revealed *Bacillus* and *Clostridium* species were the only spore formers amongst the eight isolates. *Escherichia coli*, *Salmonella* species, *Bacillus* species and *Vibrio* species were motile, where as gram-positive bacteria isolates were *Streptococcus faecalis*, *Staphylococcus* species, *Clostridium* species and *Bacillus* species. All the isolates were coagulase positive except *Clostridium* species.

Table 3: Mean bacterial count of Aba river sample during dry season

Plates	Point 5 Upstream	Point 4 Upstream	Point 1 Abattoir	Point 2 Downstream	Point 3 Downstream
MVC (CFU/mL)	0.58×0^6 $\pm0.14^d$	0.56×0^6 $\pm0.22^e$	1.01×0^6 $\pm0.31^a$	0.73×0^6 $\pm0.24^b$	0.62×0^6 $\pm0.15^c$
MFC (CFU/mL)	0.9×10^5 $\pm0.18^b$	0.9×10^5 $\pm0.03^b$	1.0×10^5 $\pm0.17^a$	0.8×10^5 $\pm0.22^c$	0.7×10^5 $\pm0.41^d$

Legend: MVC – Mean viable count, MFC – Mean faecal count. Values are given as mean ± SD. Within rows, values followed by the same alphabets are not significantly different but those followed by different alphabets are significantly different $p \leq 0.05$.

Table 4: Mean bacterial count of Aba river sample during rainy season

Plates	Point 5 Upstream	Point 4 Upstream	Point 1 Abattoir	Point 2 Downstream	Point 3 Downstream
MVC (CFU/mL)	0.66×10^6 $\pm0.03^{cd}$	0.62×10^6 $\pm0.02^e$	1.03×10^6 $\pm0.18^a$	0.86×10^6 $\pm0.05^b$	0.67×10^6 $\pm0.04^c$
MFC (CFU/mL)	1.0×10^5 $\pm0.12^b$	1.0×10^5 $\pm0.23^b$	1.1×10^5 $\pm0.05^a$	0.9×10^5 $\pm0.10^c$	0.7×10^5 $\pm0.20^d$

Legend: MVC – Mean viable count, MFC – Mean faecal count. Values are given as mean ± SD. Within rows, values followed by the same alphabets are not significantly different but those followed by different alphabets are significantly different $p \leq 0.05$.

Table 5: Occurrence and seasonal distribution of bacterial isolates in Aba river samples

Bacterial Isolates	Point 5 upstream		Point 4 upstream		Point 1 abatoir		Point 2 downstream		Point 3 downstream	
	ds	rs	ds	rs	ds	rs	ds	rs	ds	rs
Staphylococcus species	+	+	+	+	+	+	-	+	-	-
Streptococcus faecalis	+	+	+	+	+	+	-	-	-	-
Vibro species	-	-	-	+	+	+	-	-	-	-
Escherichia coli	+	+	+	+	+	+	-	+	-	-
Shigella species	-	+	-	+	+	+	-	+	-	+
Salmonella species	+	+	+	+	+	+	-	+	+	+
Bacillus species	+	+	+	+	+	+	-	+	+	-
Clostridium species	+	+	+	+	+	+	-	+	+	+

Key: + = Positive, - = Negative, ds = dry season, rs = rainy season,

4. Discussion

Levels of the physicochemical parameters and the extent of pollution in the river samples were determined for both dry and rainy seasons. The mean values of dissolved solids, pH, calcium carbonate ($CaCO_3$), magnesium, calcium, zinc, copper and manganese were below world health organization standards [17] and United States Environmental Protection Agency limits [18] but were comparable to those obtained in Aba river [19] while those of biochemical oxygen demand (BOD), sulphate, nitrate, lead, iron and arsenic were above limits. The implication is that the waste assimilation capacity of the river could be regarded as been high, a condition attributed to dilution, continuous water exchange, sedimentation and depuration processes, as most obtained results attests. A cursory look at results reveal that the concentration of all the parameters investigated is always high and most times highest at point 1 (abattoir) for both seasons. This is clear evidence that the abattoir is a major source of pollution of Aba river in both dry and rainy seasons. Although the water flow in Aba river is limnetic in some areas including point 5 upstream and point 1 abattoir, with little or no upwelling during rainy season, although immense volumes of fresh water passes through the river. The Aba river forms major outlet for water draining of vast watershed; hence the influx has a lot of force and short residence time in the river. The short residence time of the influx means that most of the input materials are discharged along with the water.

However, most of the parameters examined in this study such as total solids, dissolved solids, biochemical oxygen demand, hardness, ions, heavy metals, and minerals were high during the rainy season than in the dry season, owing to influx from run offs, sedimentation, and flow conditions of the river. Sedimentation is an important mechanism for stripping heavy metals and other pollutants from the river at low tide and during dry season when the influx of fresh water is very minimal. Thus, the cumulative impact of all these processes is that heavy metals are kept low in spite of high fluxes from industrial and urban wastes, including the immense urban runoff. Weathering of soils, and erosion on topsoil layers, bedrock and sediments determines water mineralization as well as water quality, which occurs more in the rainy season than in the dry season. Hence, concentrations of minerals were higher in the rainy season than in the dry season. Concentrations of mineral constituents (SO_4^{2-}, Ca^{2+}, mg^{2+}, K^+ and Na^+) and water hardness greatly depend on these factors. This assertion is also corroborated by [20; 21].

Results have shown low concentrations of some heavy metals and effects on the inhabiting microorganisms including bacteria. The concentrations of some metals (Pb, Cu, Mn, and Zn) may indicate anthropogenic pollution [21]. These metals may enter the food chain and concentrate at higher trophic levels. The toxicity of heavy metals occurs when present in superabundance. Furthermore, the fundamental problem with heavy metals according to [22] is that although some of them are needed by organisms in trace amounts, but when present in excess they denature enzymes thus inhibiting bacterial metabolism. Microorganisms including bacteria require many nutrients for healthy growth and reproduction. [23] was in support of this assertion by reporting that carbon, oxygen, hydrogen and nitrogen are required in large quantities, while iron, magnesium and potassium are required in smaller amounts. Corroborating the aforementioned parameters, the concentrations of iron, magnesium and potassium in barely significant concentrations may have beneficial effects on the growth and activities of microbes including bacteria in the Aba river.

High lead levels in Aba river could be traced to urban and industrial wastes and high petro-lead used by vehicles in Nigeria [3]. Waste management in urban and industrial cities in Nigeria such as Aba has remained a challenge. Inflow wastewaters to Aba river have been found polluted with untreated industrial wastes which are carelessly discharged directly or indirectly into the river. One other important source of industrial lead pollution is the expired motor batteries which find their way as wastes into the river. The low levels of some metals as was determined in this study could be attributed to dilution, sedimentation and depuration.

Analysis of occurrences and seasonal distribution of bacteria showed a significant difference between the positive and negative seasonal occurrence of *Shigella* species. The implication is that *Shigella* species is positively and significantly associated with rainy season while it is negatively and significantly associated with dry season. But other isolates like *Staphylococus* species, *Streptococcus feacalis*, *Vibrio* species, *Escherichia coli*, *Salmonella* species, *Bacillus* species and *Clostridim* species are not significantly associated with the seasons. The increased number of bacteria facilitated the rate of degradation of organic matter in the river, thus depleting the dissolved oxygen content [16]. The elevation of phosphate level in the river from faecal waste discharged from abattoir may be responsible for the river eutrophication. The increase in sulphate concentrations was attributed to the impact of weathering, overland run off and intrusion of brackish water [21]. The observed high nitrate level may be as a result of agricultural pollution. The bacterial population of aquatic environment may vary both in number and type with the source and component of the water playing critical roles. The results (Tables 3 and 4) indicated some variations in the bacterial population of the stations in the two seasons. These variations suggest the impact of human activities and natural changes. Furthermore, the proximity of cattle-grazing area to the site may have partly explained the increase in bacterial population. The low bacterial count (Table 4) at point 4 upstream when compared to other sites may be due to reduced human and discharged activities, sedimentation and depuration.

The relatively high coliform counts of both dry and rainy season at point 1 (abattoir) may be connected with high rate of cattle defecation habit and evacuation of intestinal contents during slaughtering [24]. The introduction of wastes from the abattoir and the surface run off during the rains are also contributory factors. The presence of *Escherichia coli, Streptococcus faecalis and Shigella* species in this study have contributed to the credence of these findings. In addition, the presence of *Clostridium* species in all the sites further confirms human faecal contamination of these sites [25]. The isolation of *E. coli* in most of the sites (Table 5) is an indication of human contamination. The presence of *Bacillus* species which are mostly soil inhabitants [26] showed contamination from overland runoff. The presence of *Salmonella* and *Shigella* species at most of the sites and *Vibrio* species at the abattoir is indicative of serious public health concern [27]. Results obtained from this study have shown some outstanding variations in both physicochemical and bacterial loads at the different sampling stations in both seasons. This trend reflects the diverse kinds of wastes that enter Aba river. This work was carried out to assess the seasonal changes associated with effluent discharge from abattoir located along the bank on Aba river.

5. Conclusion

In conclusion, analysis of Aba river showed there is a clear evidence of pollution in both seasons. The natural purifying powers of Aba river has been exceeded which is visibly shown by the consequence of eutrophication. Unfortunately some inhabitants of Aba still depend on this river for drinking and domestic purposes in the face of frequent shortage or absence of pipe borne water. Waste discharges into the river therefore have to be controlled and monitored. There is an urgent demand for proper, well described, reference values on waste production. Monitoring programmes need to be set up to allow for a more reliable environmental impact assessment of slaughter house activities than is presently the case. There is an urgent need to strengthen pollution control enforcement mechanisms by providing modern equipment, water and electricity in abattoir operations as it provides raw materials for industry and protein source for human. Furthermore, the discharge of waste into water body is a serious public health issue as it devalues the aesthetics of water fronts and initiates disease outbreaks. The waste water should be treated before discharge into water bodies and could also be used to generate biogas for useful purposes.

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Disclosure of Conflict of Interest

There is no conflict of interest of any sort.

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