ORIGINAL RESEARCH ARTICLE

Effects of abattoir activities on the water quality of Oko-Oba river in Agege, Lagos, Nigeria: a seasonal variation assessment

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Abstract
Surface water from the Oko-Oba River in Agege, Lagos Nigeria which runs beside the Oko-Oba Abattoir was assessed for its physicochemical quality in relation to temporary seasonal variation. The samples were collected in May and September 2019 (wet and dry season) and analysed for physicochemical (including some potentially toxic metals (PTMs)) and microbiological parameters using standard protocols of American Public Health Organization (APHA) and American Society for Testing and Materials (ASTM). Many physicochemical and microbiological parameters analysed for the samples did not meet regulatory standards for surface water. Some significant correlations were observed between the seasons, sampling points and parameters. The results of this study showed that seasonal variations affected some the water quality parameters of the Oko-Oba River. Further studies are recommended to provide information on the effect of the Abattoir activities on aquatic life in other to ensure sustainable river bodies.

Key Words: *Abattoir, seasonal variation, physicochemical parameters, microbiological analysis, correlation study*

Introduction

Abattoirs provide meat and other materials required for domestic and export purposes (Nwanta et al., 2008). They also generate employment opportunities for large groups of people directly and indirectly while providing revenue for government (Alhaji and Baiwa, 2015). However, abattoir activities such as, slaughtering of animals, washing of meat, evisceration (removal of content of stomach), removal of bones, storage of blood and fat, hair removal and burning of waste among others lead to the generation of large amounts of liquid and solid wastes. Abatoir liquid wastes include the blood and washwater from the processing of meat and meat parts while abatoir solid wastes include the excrements removed from the intestines and stomach of the animals, wasted meat and fats (Akanni et al., 2019) among others. These wastes adversely impact on the surrounding environments. Pathogens present in animal carcasses or animal wastes may be washed into waste water discharged into surrounding water body(s) leading to occurences of pathogenic organisms in water bodies (Abattoirs are usually situated near water bodies such as rivers, stream or canals in Lagos**)** (Augustyn**,** et al, 2016**).** Thus, causing the degradation of surounding land and lowering of both surface and ground water qualities (Ekpetere et al., 2019). Abattoir activities if not managed may lead to the pollution of the soil and water resources.

Ojekunle and Lateef (2017) assessed the impact of abattoir wastewater discharge on the water qualities of some surface and ground water bodies in Abeokuta Ogun state Nigeria. Out of all the parameters accessed in their study, the values for hardness, lead (Pb), Copper (Cu), Zinc (Zn), Cadmium (Cd), Iron (Fe) and faecal coliform for most their samples exceeded the stipulated permissible values by FEPA for surface water. The impact of abattoir waste water on river Illo Ota in Ogun state, surface and ground water bodies in Oshogbo Osun all in Nigeria, were studied by Omole and Longe (2008) and Akanni et al., (2019) respectievly. They all found that at least one or more water quality parameters did not meet the standard values for surface water. Oluseyi et al, (2019) compared the effects of abatoir waste water from two Abattiors in Lagos Nigeria (Oko-Oba and Itire Abatoir) on their surrounding surface and ground water. They also found that some water quality parameters did not comply with the limits. Barakat et al., (2016) and Pejman et al. (2009) studied seasonal variation on surface water quality of various water bodies but not around Abattoirs. Their findings were different and unique to the water bodies studied however, water quality varied with climatic seasons.

Previous studies on the Oko-Oba River water quality by Oluseyi et al., (2019) and Ojo (2014) in 2011 and 2014 respectively were only base on a season. They did not consider the seasonal climatic variation and its relationship with water quality of the River. The aim of this study is to access the effect of the abattoir activities near the Oko-Oba River in Agege Local Government Area of Lagos, Nigeria on the River with a view of understanding how seasonal variation impacts on the River water quality.

Material and method

Study area

Lagos located in South Western Nigeria, is the commercial nerve centre of the country and is home to over 18 million people which is about 10 % of the country's population (Ojeh, 2016). It is estimated that about 8000 ruminant livestock (valued at 1.6 billion Naira) are eaten daily in Lagos (Agbeze, 2017). To meet the demand, animals (especially cattle) are killed in Abattoirs and distributed across the state.

The study area was Oko-Oba river beside Oko–Oba Abattoir of Agege Local Government Area, Lagos, Nigeria (Figure 1). Oko-Oba abattoir is the largest of the authorized abattoirs in Lagos state, Nigeria. It accounts for over 30 % of the meat processed for consumption in Lagos (Agbeze, 2017). The river was sampled at upstream, midstream and downstream with respect to the abattoir (Figure 1). Three samples each were taken from upstream, midstream and downstream of the river. The sampling points were geo-referenced with the aid of a handheld Global Positioning System (GPS) and recorded as coordinates of the locations (Figure 1).

There are two seasons in Nigeria. They are the dry and wet season. The wet season spans from April to July and September to October while the dry season spans from November to March. Dry season characteristics are found in the month of August (the break between double maxima rainfall) extensions into September is now being observed due to climate change (Adedeji et al., 2018; Salau, 2016; Odekunle, 2004).

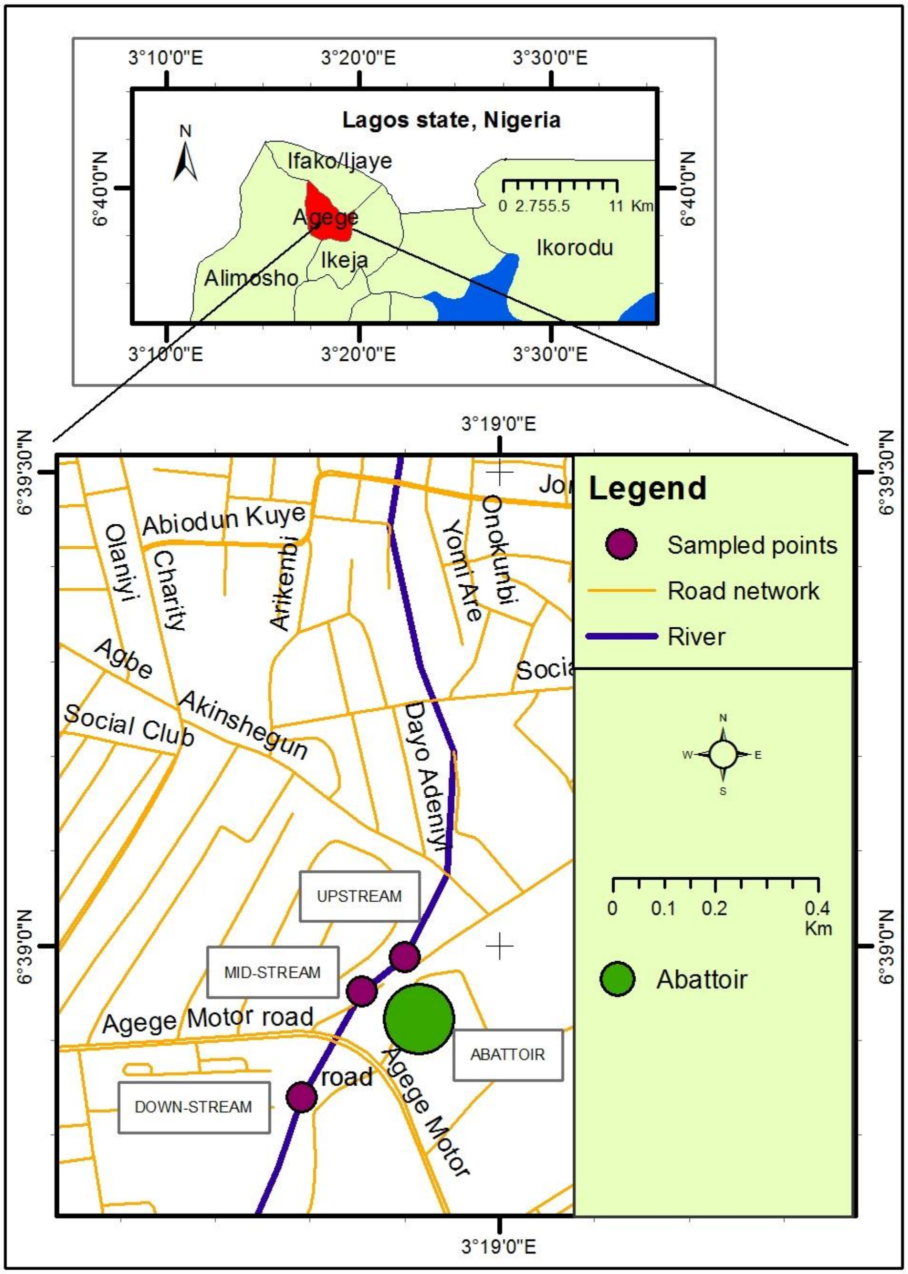

Figure 1: Map of the study area showing sampling points on the Oko-Oba River by the Oko-Oba Abattoir, Agege, Lagos Nigeria (Author, 2020).

Sampling

Surface water samples were collected on the 17th of July 2019 (wet season) and the second batch was collected on the 2nd September 2019 (dry season) (2nd of September was still part of the August break which is a dry season in Nigeria because of observed climate change). Samplings were done in the mornings around 10am to 11am when abattoir activities were at its peak. The water samples were collected and stored in pre-washed plastic bottles that had been soaked in 1% nitric acid solution. Sterile bottles (250 ml capacity) were used to collect samples for the microbial analyses at 20 cm to 30 cm depth from the river. Samples were appropriately labeled and preserved in a cooler with ice packs before being transported to the laboratory for analysis. The samples from the three sampling points at each location (upstream, midstream and downstream) were mixed to generate a composite sample prior to analyses (Oluseyi et al., 2019).

Physico-chemical analyses of Surface water

Sample analyses began immediately on arrival of the samples in the laboratory. Physico-chemical parameters determined for the samples include pH, total suspended solids (TSS), total solids (TS), total dissolved solid (TDS), chloride, (TS), chemical oxygen demand (COD), biological oxygen demand (BOD) and potentially toxic metals (PTMs), such as lead and cadmium (Odour and colour were also observed). Standard protocols of American Public Health Organization (APHA, 2005) and American Society for Testing and Materials (ASTM) were employed for analysis of surface water physicochemical parameters. pH of samples was determined electrometrically using calibrated pH meter (Mettler Toledo pH Meter; FP20). A calibrated Methrohm conductivity meter was used to measure the conductivity of samples.

TSS, TS and TDS were determined by gravimetric methods. BOD was determined using the modified Winkler's Method in 350ml bottles. COD was determined by back titration after refluxing sample mixture with excess oxidising agent (potassium dichromate solution). Acidity, alkalinity and chloride of the samples were determined by titration method using sodium hydroxide (NaOH), hydrochloride (HCl) and silver nitrate ($AgNO_3$), respectively. In the titration for acidity, alkalinity and chloride phenolphthalein, methyl orange and potassium dichromate indicators were employed (Rahmanian et al., 2015).

Potentially Toxic Metals (PTMs) analyses

Water samples were digested with nitric acid and concentrations of PTMs commonly called heavy metals were determined using a calibrated Buck Scientific Model 210 VGP, Serial Number 1619 Flame Atomic Absorption Spectrophotometer (AAS) as in EPA (2016). Specifically, only lead and cadmium were determined because their concentrations have been reported to be higher than other PTMs in animal tissues and blood (Nwude et al., 2010).

Microbial analyses

Microbial analyses of surface water samples were according to the standard methods for water examination as stipulated in APHA (1991; 2005). Pour plate technique was employed for microbial analysis of water collected from the Oko-Oba river. Specifically, total bacteria count (TBC), total coliform count (TCC), total faecal coliform count (TFCC), total fungi count (TFC) were analysed. The water samples were serially diluted, aliquots of diluted samples were inoculated into sterile petri dishes in duplicates and sterile molten prepared culture media were poured into the inoculated plates. The plates were swirled to ensure even distribution of the inoculums. The plates were then allowed to solidify and incubated at 37 ^{O}C for 48 h (TBC and TCC), 44 ^{O}C for 48 h (TFCC) and at 28 ^{O}C for 2-5 days (TFC). The developed colonies were counted in duplicates using colony counter. The culture plates with discrete colonies were taken and recorded. The mean colonies counted were then multiplied by the dilution factor to give the total number of bacteria for population in CFU/ml of the water analysed (Fawole and Oso, 2007).

Quality control and calibration

The samples from field were kept at 4 ^{0}C till analyses. All laboratory glass wares were washed and soaked in 1% nitric acid solution overnight before being used for sampling and analyses. The stipulated sample holding times for water quality parameters analyses as recommended in APAH (2005) were not exceeded. pH meter was calibrated, with three buffer solutions of pH 4.0, 7.0, and

10.0, before measurements were taken. The conductivity meter was calibrated using standard solutions of known conductivity. Each pH and conductivity measurement were taken after submerging and holding the pH probe for a couple of minutes to achieve a stabilized reading. Each pH and conductivity readings, the probes were submerged in 50 ml of sample and allowed to stabilize for some minutes (when the stability indicator disappears) before the value was recorded A four-point calibration on the AAS with a range of 0.00 to 3.00 mg/l for lead was 0.00 to 1.00 mg/l for cadmium for used for quantification. Cross contamination was prevented by rinsing with distilled water and blotting the probes (the pH and conductivity meter) while for the aspirator of the AAS deionised water was used to rinse the tip and aspirate through before the next measurement. Analyses of the various parameters were conducted within the stipulated holding times allowed for each parameter as recommended in APAH (2005). Each water sample parameter was analysed in triplicates. Blanks were carried out for every parameter using distilled water and blank values were subtracted from values obtained for analyses of field samples.

Statistical analysis

Physicochemical parameters of sample were expressed as mean± standard deviation. One-way Analysis of Variance (ANOVA) was used to compare water quality for upstream, midstream and downstream samples from the Oko-Oba River in both the wet and dry seasons. Pearson correlation test was used to compare all water quality parameters for wet season as well as dry season. T- test was carried out to compare the dry and wet season values for each parameter. All the statistical analyses are conducted using Microsoft Excel version 2007.

Results and Discussion

Physicochemical characteristics of surface water upstream, midstream and downstream of the Oko-Oba River Agege, Lagoon

Physical examination of upstream, midstream and downstream samples from the river all appeared brownish, but the upstream samples had the lightest colour in both rainy and dry season. However rainy season samples were generally not as dark as dry season samples. Colour variation in water is an indicator of impurity. Dark colours are due to anthropogenic activities (Daramola et al., 2019) which in this case major activity was abattoir activities beside the river which produces both liquid and solid waste usually deposited directly and indirectly as runoff into the river.

The mid and downstream samples had offensive odours in both dry and rainy season however the odour from dry season samples were more offensive. The offensive smell may have been as a result putrefaction of liquid and solid waste deposited directly and indirectly by run-offs and waste streams of effluents into the river from the Abattoir. Putrefaction of organic waste like blood, animal fat, faeces and waste meat produce hydrogen sulphide. Hydrogen sulphides are known to have offensive smell (Daramola et al, 2019). Offensive odours were observed by Ezeoha and Ugwuishwu, (2011), Akanni et al., (2019) in their studies of rivers by/ around Abattoirs in Nigeria. They attributed the offensive odour to the poor waste management practices of the Abattoirs near the rivers.

Results from the analyses of physicochemical parameters are shown in Table 1 (Table 1S, Table 2S, Table 3S and Table 4S in supplementary data). The salinity of Oko-Oba River ranged between 0.429±0.09 and 1.01±0.15 g/l indicating that it was an oligohaline Estuary. Fresh water has a salinity of less than 0.5g/l. Estuaries are divided into oligohaline (0.5 - <5.0 g/l), mesohaline (5.0 – 18.0 g/l), polyhaline (18.0 – <30.0 g/l), euhaline/ near oceans (seas) have salinity above 30 g/l like oceans (EPA, 2006). Oligohaline habitats are valuable habitats because they act as nursery areas (Feyer et al., 2015; Rozas and Hackney, 1983). Hence the river should be preserved.

Results from analyses of water samples showed that values for upstream samples (for TDS, conductivity, TSS, TS, acidity, alkalinity, lead and cadmium) were lower than for midstream and downstream except for salinity, chloride, BOD, and COD. BOD and COD values were highest in midstream samples followed by upstream samples and downstream samples gave the lowest values which may be attributed to the direct deposition of effluents and waste into the river at Midstream. Lower TDS, conductivity, TSS, TS, acidity, alkalinity, lead, cadmium, TBC and TFCC indicates better water quality (Duressa et al., 2019).

The trend in TDS, conductivity, TSS, TS, acidity, alkalinity, lead and cadmium values may have been due to the direction of River water flow and the impact of Abattoir activities on the River. The River flows from upstream to midstream and then to downstream (as shown in Figure 1) and the values from analyses of physicochemical parameters also increased in like manner. Upstream water samples were taken 400 m before the Abattoir, midstream samples were taken by the Abattoir where all the activities producing waste occurred and the wastes were dumped in the river. Downstream samples were taken about 250 m from the midstream sampling point. Thus, upstream is not impacted directly by the Abattoir activities while the midstream and downstream are impacted by the activities of the Abattoir.

Lower chloride content and salinity experienced at midstream may have been a direct effect of dilution from the waste being directly deposited. Chloride, salinity, conductivity, TS, TDS, BOD and COD values were lower in rainy season than in dry season. This must have been as a result of dilution of the river water by rains which are regular in the rainy season. In dry season, the water is more concentrated, slightly acidic, has more dissolved solids and ions which gave rise to higher conductivity and salinity. Similar trends were observed Sogbamu et al., (2020) and Nwoji et al., (2010) in their seasonal variation study of surface water.

Nwude et al., (2010) reported higher levels of lead and cadmium compared to other potentially toxic metals are found in animal tissues and blood. Blood containing lead and cadmium released into the effluents and subsequently may contaminate the rivers. Oko-Oba River was analysed for lead and cadmium concentration. The concentration of lead ranged between 0.00 ± 0.00 and 0.17 ± 0.06 mg/l in the –Oba River with the water samples from midstream giving the highest values (of 0.17 ± 0.06 mg/ in wet season and 0.13 ± 0.15 mg/l in dry season) and the upstream water samples having the lowest values (Table 1). Cadmium was also detected and quantified in the river water samples and the values obtained were between 0.003 ± 0.006 and 0.017 ± 0.015 mg/l. The upstream samples gave lower values for cadmium while the downstream samples gave highest value for cadmium especially in the dry season (Table 1). All the water samples exceeded their regulatory limits for lead and cadmium except upstream water samples in dry season which complied with the limit for lead. Lead and cadmium can bio-accumulate and bio- magnify along the food chain. Hence the concentration found present potential risk to both aquatic life and humans who will eventually feed on them. Lead and cadmium are carcinogens, (ATSDR., 2011) while lead impacts the central nervous system of the exposed individual. Lead could also cause delayed mental and physical growth in children while affecting the attention span and learning abilities of children (ATSDR., 2011).

The physicochemical parameters (Table 1) of upstream and midstream samples showed 53.85 % compliance (that is only 8 out of 13 physicochemical parameters analysed) with the National Environmental Standards and Regulations Enforcement Agency (NESREA) Nigeria and the Federal Ministry of Environment in Nigeria (formerly known as Federal protection agency (FEPA)) (NESREA 2011; FEPA 2001 and 1988) limits for surface water. TSS, Alkalinity, BOD, COD, lead and cadmium for the two seasons (dry and wet season) did not comply with their regulatory limits. Similarly analyses of downstream samples gave values for physiochemical parameters that showed 46.15 % compliance with the set limits for surface water (that is only 7 out of 13 physicochemical parameters analysed). TS, TSS, Alkalinity, BOD, COD, lead and cadmium values from downstream samples did not comply. The high values of BOD and COD can be attributed to the (especially the very high dry season values) to the presence of excess bacteria in the water, organic and inorganic pollutants in the river water samples. Table 2 showed the presence of a high number of microorganisms. Bacteria consume the available oxygen from the water column cause high alkalinity such as observed in study to disposal of domestic and municipal waste into the river by Haque et al., (2019). At the Oko-Oba river, liquid waste was found to be deposited directly into the river and solid waste were washed into the river by run-offs.

Ojo, (2014) and Oluseyi et al., (2019) also studied the same sampling site, in 2014 and 2011 respectively and a comparison of their results is as shown in Table 2. The pH values for the River was different from Oluseyi et al., (2019) but similar to the 2014 study. The BOD, TDS and TSS values varied from the various studies however, BOD values were close, though there was a gradual increase from 2011 to 2014 and 2019. TDS increased from 2011 to 2014 and TDS decreased in 2019. TSS reduced was found to initially reduce in 2014 but had increased in this study.

Using the classification as described in Table 3 according to Tekenah et al., (2014), indicates the river is acceptable base on pH but base on the TSS value, the river is slightly polluted however, based on the BOD and COD values the river is highly polluted.

Table 1: Physicochemical characteristics of surface water of the Oko-oba River Agege, Lagoon in dry and wet season 2019

	Wet season			Near Dry Season			
Parameter	Downstream	Midstream	Upstream	Downstream	Midstream	Upstream	**FEPA 1991 LIMIT**
pH	7.22 ± 0.09	7.55 ± 0.02	7.30 ± 0.08	6.52 ± 0.09	6.88 ± 0.07	6.60 ± 0.21	6-9a
TDS (mg/l)	898.93 ±17.83	609.77 ± 4.31	329.90 ± 9.24	1169.67 ±15.37	726.60 ± 11.96	653.20 ± 2.76	2000a
Conductivity (µS/cm)	2031.1 ± 97.73	1398.1 ± 41.11	760.13 ± 18.97	2932.0 ± 37.47	1813.7 ± 28.50	1644.7 ± 32.87	4000 [b]
TSS (mg/l)	**323.33 ± 113.72**	**170.00 ± 81.85**	**140.00 ± 36.06**	**283.33 ± 189.30**	**166.67 ± 125.83**	**216.67 ± 57.74**	**30a**
TS (mg/l)	**1222.3 ± 114.93**	779.77 ± 78.34	469.90 ± 26.97	1453.0 ± 200.13	893.27 ± 116.56	869.87 ± 55.87	1000a
Acidity (mg/l)	203.3 ± 41.63	110.00 ± 30.00	103.33 ± 23.09	326.67 ±70.24	96.67 ± 50.33	86.67 ± 5.77	NS
Alkalinity (mg/l)	**1050.0 ± 229.13**	**550.00 ± 427.20**	**433.33 ± 104.08**	**966.0 ± 76.38**	**566.00 ± 57.74**	**566.67 ± 256.58**	**250a**
Chloride (mg/l)	307.67 ± 114.12	260.33 ± 54.23	485.17 ± 40.99	363.17 ± 92.65	307.83 ± 51.68	611.83 ± 92.54	600c
Salinity (g/l NaCl)	0.506 ± 0.19	0.429 ± 0.09	0.800 ± 0.07	0.598 ± 0.15	0.507 ± 0.09	1.010 ± 0.15	2.0a
BOD (mg/l)	**81.00 ± 34.64**	**115.00 ± 11.27**	**86.67 ± 22.28**	**110.67 ± 47.61**	**194.33 ± 28.99**	**436.00 ± 163.24**	**40a**
COD (mg/l)	**177.27 ± 65.98**	**244.87 ± 29.67**	**178.27 ± 51.26**	**243.97 ± 109.84**	**387.47 ± 84.83**	**948.80 ± 386.99**	**60c**
Lead (mg/l)	**0.13 ± 0.23**	**0.17 ± 0.06**	**0.03 ± 0.06**	**0.03 ± 0.06**	**0.13 ± 0.15**	0.00 ± 0.00	**0.015a**
Cadmium (mg/l)	**0.007 ± 0.006**	**0.007 ± 0.06**	**0.003 ± 0.006**	**0.017 ± 0.015**	**0.007 ± 0.006**	**0.013 ± 0.006**	**0.002a**

TDS-Total dissolved solids, TSS- Total Suspended Solids, TS-Total Solids, BOD- Biological Oxygen Demand, COD-Chemical Oxygen demand, b-FEPA 1988, a-FEPA 1991 C- NESREA 2010. **Note:** Values are Mean ± SD (n=3); NESREA, 2010; NS- Not specified. The bolden data in the table shows that the parameter did not comply with its limit.

Table 2: Physicochemical characteristics of surface water of the Oko-Oba River Agege, Lagos in 2011, 2014 and 2019

Parameter	**2011 Study by Oluseyi et al., (2019)**	**2014 by Ojo, (2014)**	**This study**
pH	3.8 to 4.6	6.50 ± 0.30 to 7.00 ± 0.40	6.52± 0.09 to 7.55±0.02
BOD (mg/l)	85.2 to120.36	66.10 ± 0.80 to 151.00 ± 6.60	81.00±34.64 to 436.00 ±163.24
TDS (mg/l)	226.05 to 618.82	2450 ± 40.0 to 6000.00 ± 87.50	329.90 ±9.24 to 1169.67±15.37
TSS (mg/l)	10305.04 to 1100.48	5.00 ± 0.50 to 32.00 ± 40.00	140.00 ±36.06 to 323.33±113.72

Table 3: Classification of surface water according to Tekennah et al., (2014.)

Parameter	Class 1	Class 2	Class 3	Class 4	Class 5
pH	6.5 – 8.0	6.0 – 8.4	5.0 – 9.0	3.9 – 10.1	<3.9 – >10.1
BOD (mg/l)	1.5	3.0	6.0	12.1	>12.1
COD (mg/l)	10	20	40	80	>80
TSS (mg/l)	20	40	100	278	>278

Value of classes; Class 1= excellent, Class 2 = acceptable, Class 3 = slightly polluted, Class 4 = polluted, Class 5=heavily polluted

Microbiological characteristics of surface water upstream, midstream and downstream of the Oko-Oba River Agege, Lagoon

Pathogenic microorganisms in rivers may cause health risk to humans and animals. The TBC, TCC, TFCC, and TFC of the Oko-Oba River were determined for both seasons and the results are shown in Table 4. TBC, TCC, TFC, and TFC values obtained from water samples analyses were high. These high levels are indications of contamination from its environment and could pose a health risk to the consumers of this water resource. The midstream had the highest TBC, TFCC, and TCC in both seasons. This trend was similar to the trend observed with BOD, and COD. This may be due to the proximity of the Abattoir to the midstream. The Abattoir was by the river at the midstream point of sampling and waste steams were discharged at the mid-stream.

Higher TBC and TFCC levels were found in the wet season than in the dry season. A different trend was observed for TFC and TF where higher levels were recorded in the dry season. Higher numbers of pathogenic microorganisms are expected in dry season than in wet seasons due to less rainfall, less surface runoffs and less dilutions of the rivers (Edokpayi et al 2015). However, Edokpayi et al., (2018) reported higher TBC and TFCC in the wet season compared to the dry season. Their findings were similar to this study. They attributed the trend to the discharge of ill-treated waste water from activities on the riverbank and the slightly higher temperature experienced in the wet season of the region in South Africa because, higher temperature favours incubation of bacteria. In this study location, abattoir liquid waste containing some solids was discharged directly into the river. Also, higher temperature is associated with Lagos in June than September when the samples were collected. Ojeh, et al, (2016) who studied urban-rural temperature differences in Lagos between 2014 and 2015 stated that observed mean daily temperature for June was higher (27.1 ^{0}C) than September (26.3 ^{0}C).

Oluseyi et al., (2019) also studied Oko-Oba River water in 2011 found that the river water had, total bacteria count and total fungi count values in the range of 1.80 X 10^{05} to 3.10 X 10^{05}cfu/ml and 3.0 X 10^{03} to 8.0 X10^{03}cfu/ml respectively. In this study TBC and TFC values had a range of 1.29 X 10^{07}± 3.87 X 10^{06} to 4.40X10^{10} ±7.45 X 10^{10} cfu/ml and 1.37 X 19^{02}±1.05 X 10^{02} to 7.30X10^{03}±1.87 X 10^{03} cfu/ml respectively (Table 3). Higher TBC and similar TFC values were obtained in this study compared with the 2011 study. The difference in these studies may be attributed to the difference in time. The river has continually received waste since 2011 till date. The results obtained from this study, indicate that water from Oko-Oba River poses as a potential health risk and is not fit for any domestic use.

Table 4: Microbiological characteristics of surface water of the Oko-oba River Agege, Lagoon in dry and wet season 2019 (cfu/ml)

	Wet season			Near Dry Season		
Parameter	**Downstream**	**Midstream**	**Upstream**	**Downstream**	**Midstream**	**Upstream**
TBC	5.50 $X10^{08}$ ±7.78 $X10^{08}$	4.40$X10^{10}$ ±7.45$X10^{10}$	3.13X 10^{08}±3.01$X10^{08}$	1.36 $X10^{07}$±6.01$X10^{06}$	1.29$X10^{07}$± 3.87$X10^{06}$	5.93$X10^{06}$± 1.91$X10^{06}$
TCC	1.32 $X10^{04}$± 1.35 $X10^{04}$	3.13$X10^{04}$±2.01$X10^{04}$	3.57X 10^{04}±1.65$X10^{04}$	1.10$X10^{05}$±7.87$X10^{04}$	7.70$X10^{04}$± 3.30$X10^{04}$	2.60$X10^{04}$±9.85$X10^{03}$
TFCC	6.33X 10^{03}±5.13 $X10^{03}$	7.33$X10^{03}$±6.43$X10^{03}$	1.83X 10^{03}± 2.75$X10^{03}$	2.17$X10^{03}$±1.26 $X110^{03}$	7.33$X10^{03}$± 1.01$X10^{04}$	2.17$X10^{03}$± 1.04$X10^{03}$
TFC	4.40$X10^{02}$±1.04 $X10^{02}$	1.90 $X10^{02}$±9.54$X10^{01}$	1.37$X19^{02}$±1.05$X10^{02}$	7.50 $X10^{03}$±1.21$X10^{03}$	4.33$X10^{03}$± 9.87$X10^{02}$	7.30$X10^{03}$±1.87$X10^{03}$

TBC-Total bacteria count, TCC-Total coliform count, TFCC –total faecal coliform count, TFC-total fungi count. Note: Values are Mean ± standard deviation (SD) (n=3)

Relationship between physicochemical and bacteriological parameters of Oko- Oba Surface water in dry and rainy season

One-way ANOVA was used to compare the physicochemical and microbiological properties for upstream, midstream and downstream of the Oko-Oba River in both seasons using Excel 2007and the results are shown in Table 5 and Table 6. p values of 0.382594 and 0.867863 for wet and dry season respectively were obtained which are more than the traditional p value of 0.05. The *p*-values obtained were associated with F value of 0.98 and 0.142169. This result shows that there is no significant difference between the values of the Oko-Oba River parameters at the upstream, midstream and downstream statistically in both seasons. This is quite surprising however, looking at Table 1 and Table 2, shows that the river is generally polluted, and many parameters did not comply their limits. The results from one-way ANOVA carried out to compare the upstream, midstream and downstream of the Oko-Oba River in both seasons suggests that though the river is being polluted by the Abattoir other factors/ sources of pollution maybe occurring along the river which may require further investigation.

Matrix correlation study of all the parameters were carried out for wet and dry season and the results are shown in Table 7 and Table 8 respectively. The r-values displayed in Table 7 and Table 8 reveals several relationships between parameters of the water samples. There were some similarities and differences in the r values for dry and wet seasons. Correlation between the physicochemical and microbiological parameters showed that some parameters were strongly associated while some were not. Important relationships ($r \geq 0.600$) were observed between TDS and conductivity, TSS, TS, acidity, alkalinity, lead, cadmium, TFCC in wet season. Similarly, important relationships ($r \geq 0.600$) observed between TDS and conductivity, TSS, TS, acidity, alkalinity, lead, cadmium, TFCC in wet season was also observed with dry season but in addition TDS also correlated positively with TBC, TCC. Solute in water is TDS when it dissolves in water but in suspended state it measured as TS. Solutes are responsible for increasing the conductivity of water. The type of solute impacts on the acidity and alkalinity of a water sample. Lead and cadmium in water are solute which dissolves in water to form ions. Eliku and Leta., (2018) also carried out matrix correlation on many parameters for Awash River in Ethiopia. They found many strong relationships especially with parameters that were related with solutes such as nitrates, phosphate and conductivity among others in dry and wet seasons. Particularly of note in wet season, there was a strong positive correlation between BOD and TBC, COD and TBC, COD and TFCC some positive but not strong correlation (0.35 to 5.90) was observed between BOD and TCC, BOD and TFCC, COD and TCC. However, in the dry season, negative strong correlation was observed between TBC and BOD, TCC and BOD, TBC and COD, TCC and COD. Islam et al., 2019 in their review stated that a positive association was found between COD and the bacterial diversity in combination with other factors such as dissolved organic carbon by Llirós et al., (2014), while in contrast another study by Kagalou et al., (2009) found negative correlation between COD and bacterial count in contaminated water bodies.

Correlation and statistical mean difference between each physicochemical and microbiological parameters of Oko-Oba River in wet and dry season were analysed. The results are shown in Table 9 (Tables 6S to Table 20S in supplementary data). Only pH, TDS, TS, conductivity and TF showed positive correlation between their wet and dry season values at a probability less than 0.05. Thus, seasonal variation was only obvious with these parameters statistically.

A probability value of less than 0.05 indicates that the relationship was not due to chance but was significant. Edokpayi et al, (2018) also carried out a correlation study of dry and wet season parameters of Nzhelele rivers of South Africa. They found significant strong relationship between the turbidity, chloride, nitrates, of dry and wet season of their samples.

Table 5: Comparison of the upstream, midstream and downstream physicochemical and microbiological properties of the Oko-Oba river in wet season using one-way ANOVA

Groups	Count	Sum	Average	Variance
DSSA	17	5.5E+08	32358016	1.78E+16
MSSA	17	4.4E+10	2.59E+09	1.14E+20
USSA	17	3.13E+08	18436704	5.78E+15

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	7.43E+19	2	3.71E+19	0.980272	0.382594	3.190727
Within Groups	1.82E+21	48	3.79E+19			
Total	**1.89E+21**	**50**				

DSSA- mean value for downstream in wet season, MSSA- mean value for midstream in wet season, USSA- mean value for upstream in wet season

Table 6: Comparison of the upstream, midstream and downstream physicochemical and microbiological properties of the Oko-Oba river in dry season using one-way ANOVA

Groups	Count	Sum	Average	Variance
DSSB	17	13686356	855397.3	1.15E+13
MSSB	17	13022827	813926.7	1.04E+13
USSB	17	5967542	372971.4	2.2E+12

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	2.29E+12	2	1.14E+12	0.142169	0.867863	3.204317
Within Groups	3.62E+14	45	8.04E+12			
Total	3.64E+14	47				

DSSB- mean value for downstream in dry season, MSSA- mean value for midstream in dry season, USSA- mean value for upstream in dry season

Table 7: Correlation coefficient (r) among physicochemical and microbial parameters of Oko- oba river in wet Season 2019

	pH	TDS	Conductivity	TSS	TS	Acidity	Alkalinity	Salinity	Chloride	BOD	COD	Lead	Cadmium	TBC	TCC	TFC C	TF
pH	1.000																
TDS	-0.262	1.00															
Conductivity	-0.251	**1.000**	1.000														
TSS	-0.586	**0.936**	**0.931**	1.000													
TS	-0.350	**0.996**	**0.995**	**0.964**	1.000												
Acidity	**-0.659**	**0.898**	**0.893**	**0.996**	**0.935**	1.000											
Alkalinity	-0.565	**0.944**	**0.940**	**1.000**	**0.971**	**0.993**	1.000										
Salinity	-0.452	**-0.742**	**-0.750**	-0.458	**-0.678**	-0.373	-0.481	1.000									
Chloride	-0.452	**-0.742**	**-0.750**	-0.458	**-0.678**	-0.373	-0.481	1.000	1.000								
BOD	**0.995**	-0.165	-0.153	-0.503	-0.255	-0.581	-0.480	-0.538	-0.538	1.000							
COD	**0.971**	-0.022	-0.011	-0.374	-0.114	-0.459	-0.350	**-0.653**	**-0.653**	**0.990**	1.000						
Lead	0.488	**0.714**	0.722	0.421	**0.647**	0.334	0.444	**-0.999**	**-0.999**	0.573	**0.684**	1.000					
Cadmium	0.264	**0.861**	0.867	**0.626**	**0.811**	0.551	**0.646**	**-0.980**	**-0.980**	0.359	0.489	**0.971**	1.000				
TBC	0.966	-0.005	0.007	-0.358	-0.097	-0.443	-0.333	**-0.666**	**-0.666**	**0.987**	**1.000**	**0.697**	0.504	1.000			
TCC	0.562	**-0.946**	-0.942	**-1.000**	**-0.971**	**-0.992**	**-1.000**	0.484	0.484	0.477	0.346	-0.447	-0.649	0.330	1.000		
TFCC	0.425	**0.762**	0.769	0.484	**0.699**	0.400	0.506	**-1.000**	**-1.000**	0.513	**0.630**	**0.997**	**0.985**	**0.644**	**-0.510**	1.000	
TF	-0.576	**0.940**	0.936	**1.000**	**0.967**	**0.994**	**1.000**	-0.469	-0.469	-0.492	-0.363	0.432	**0.636**	-0.346	**-1.000**	0.495	1.000

TDS-Total dissolved solids, TSS- Total Suspended Solids, TS-Total Solids, BOD- Biological Oxygen Demand, COD-Chemical Oxygen demand, TBC-Total bacteria count, TCC-Total coliform count, TFCC –total faecal coli form count, TFC-total fungi count, Note: Bold values indicate the correlation is significant at the 0.05 level

Table 8: Correlation of Physicochemical and Microbial Parameter in dry season 2019

	pH	**TDS**	**Conductivity**	**TSS**	**TS**	**Acidity**	**Alkalinity**	**Salinity**	**Chloride**	**BOD**	**COD**	**Lead**	**Cadmium**	**TBC**	**TCC**	**TFCC**	**TF**
pH	1.000																
TDS	-0.556	1.000															
Conductivity	-0.565	**1.000**	1.000														
TSS	**-0.918**	**0.840**	**0.846**	1.000													
TS	**-0.634**	**0.995**	**0.996**	**0.888**	1.000												
Acidity	**-0.632**	**0.996**	**0.996**	**0.888**	1.000	1.000											
Alkalinity	**-0.661**	**0.991**	**0.993**	**0.904**	**0.999**	**0.999**	1.000										
Salinity	-0.477	-0.465	-0.456	0.089	-0.378	-0.379	-0.345	1.000									
Chloride	-0.477	-0.465	-0.456	0.089	-0.378	-0.379	-0.345	**1.000**	1.000								
BOD	-0.075	**-0.787**	**-0.780**	-0.326	**-0.724**	**-0.725**	**-0.699**	**0.912**	**0.912**	1.000							
COD	-0.131	**-0.751**	**-0.744**	-0.273	**-0.684**	**-0.685**	**-0.657**	**0.934**	**0.934**	**0.998**	1.000						
Lead	**0.905**	-0.149	-0.159	**-0.661**	-0.243	-0.242	-0.277	**-0.806**	**-0.806**	-0.493	-0.542	1.000					
Cadmium	**-0.991**	**0.663**	**0.671**	**0.963**	**0.732**	**0.731**	**0.756**	0.354	0.354	-0.060	-0.004	**-0.839**	1.000				
TBC	0.248	**0.667**	**0.659**	0.156	0.592	0.593	0.563	**-0.970**	**-0.970**	**-0.985**	**-0.993**	**0.638**	-0.115	1.000			
TCC	-0.072	**0.869**	**0.864**	0.462	**0.817**	**0.818**	**0.796**	**-0.842**	**-0.842**	**-0.989**	**-0.979**	0.360	0.206	**0.948**	1.000		
TFCC	**0.980**	-0.382	-0.392	**-0.822**	-0.469	-0.468	-0.500	**-0.641**	**-0.641**	-0.270	-0.324	**0.971**	**-0.945**	0.434	0.126	1.000	
TF	**-0.990**	0.433	**0.443**	**0.853**	0.518	0.517	0.548	0.596	0.596	0.215	0.270	**-0.956**	**0.962**	-0.382	-0.069	**-0.998**	1.000

TDS-Total dissolved solids, TSS- Total Suspended Solids, TS-Total Solids, BOD- Biological Oxygen Demand, COD-Chemical Oxygen demand, TBC-Total bacteria count, TCC-Total coliform count, TFCC –total faecal coli form count, TFC-total fungi count, Note: Bold values indicate the correlation is significant at the 0.05 level

Table 9: Results from correlation of between physicochemical and microbiological parameters of Oko-Oba River in wet and dry season

Parameters	**Correlation value in Oko-Oba River**	**p-value (two tailed) in Oko Oba river**	**Comment with respect to pat 0.05 level**
pH (wet and dry)	**0.854886**	**0.001545**	Significant
TDS (wet and dry)	**0.622805**	**0.000966**	Significant
Conductivity (wet and dry)	**0.367268**	**0.003046**	Significant
TSS (wet and dry)	0.990969	0.468631	not – significant
TS (wet and dry)	**0.972696**	**0.049396**	Significant
Acidity (wet and dry)	-0.93472	0.192016	not – significant
Alkalinity (wet and dry)	0.142857	0.595774	not - significant
Salinity (wet and dry)	0.697817	0.365348	not - significant
Chloride (wet and dry)	0.697817	0.365348	not - significant
BOD (wet and dry)	-0.83075	0.581189	not - significant
COD (wet and dry)	-0.81738	0.562956	not - significant
Lead (wet and dry)	1	0.42265	not - significant
Cadmium (wet and dry)	0.944911	0.225403	not - significant
TB (wet and dry)	0.4381	0.41162	not - significant
TC (wet and dry)	-0.89309	0.286349	not - significant
TFC (wet and dry)	0.640464	0.470529	not - significant
TF (wet and dry)	**0.402823**	**0.025161**	significant

Similar comments / conclusion was obtained when conducted at 0.01level of confidence

Conclusion

Our results show that there were significant and non-significant seasonal variations in the water quality parameters analysed for the Oko-Oba River samples and the water is unfit for consumption since it did not comply with the regulatory limit for many parameters. Results from this study, indicates the river is acceptable base on pH but base on the TSS value, the river is slightly polluted however, based on the BOD and COD values the river is highly polluted. Physicochemical and microbiological analyses of samples showed that upstream samples had lower values except for chloride, salinity, COD, BOD, TFCC, TBC and TCC. Chloride, salinity, had lower concentration at the midstream due to dilution while COD, BOD, TFC, TFCC, TBC and TCC had higher concentrations at the mid-stream due to direct discharge of effluent into the river. However, statistical analyses revealed that there was no significant difference between the upstream, midstream and downstream of the Oko-Oba river in both dry and wet season. This suggests that though the Abattoir is contributing to the pollution of the river some other factors may also be contributing to the pollution of the river. We therefore recommend that these factors be investigated. We also recommend further studies such as animal studies on assessment of the risk associated with the abattoir activities to aquatics organisms and man to aid the understanding of the nature of impact to the fishes and organisms dwelling in the River in line with the UN SDG goal of sustainable life under water (SDG goal 14). Furthermore, the Abattoir should ensure the proper and adequate treatment of its effluents before being discharge into the Oko-Oba River.

Note Supplementary Data available

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