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Impact of Abattoir effluent on Water quality, Plankton community and Microbial Load of Opa River , Ile Ife, , Nigeria.

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Abstract

A preliminary study, aimed at assessing the effect of abattoir effluent discharge on physico-chemical parameters, plankton community and microbial load of Opa River, was carried out from August 2015 to January 2016 in three stations (A (upstream); B (discharge) and C (downstream). Standard methods of American Public Health Association (APHA) were used to collect and analyse monthly water, plankton and microbial samples. The results reflected the effect of the abattoir effluent on the concentration of nine (9) out of 15 investigated water quality parameters which were highest at the discharge as compared to other stations. The mean concentration of BOD_5, chloride and sulphate as well as the mean level of pH, conductivity and alkalinity were also highest at the discharge while dissolved oxygen had the lowest concentration at this effluent receiving station. Moreover, lowest abundance (5880 ind/m3) of planktonic species as well as the highest occurrence of microbial organisms (16 species) was recorded at the discharge station. The order of species richness revealed Bacillariophyceae and Eurotatoria, which are associated with organic pollution, as most diverse phytoplankton and zooplankton respectively in Opa River. All the bacterial (11) and fungal (5) genera reported at the discharge and downstream were of human health concern. Notable microbial species identified at the discharge include *Salmonella* spp., *Rhizopus stolonifer*, *Escherichia coli*, *Vibrio* spp., *Staphylococcus aureus*, and *Klebsiella pneumonia*, all of high health significance.This study confirms the fact that untreated abattoir effluents generated along Opa River poses a serious health problem to people using the waterbody for domestic and other purposes including processing meat for market, hence appropriate measures should be established to ensure the safety of meat being consumed by millions of people.

***Keywords**: Plankton abundance, diversity, microbes, effluent, water quality, Opa River,*

Introduction

Pollution resulting from various human activities along river courses are on the increase in recent times because rivers serve as accessible and cheap means of waste disposal hence the need for quality monitoring of waterbodies that serve as sources of drinking water and other purposes (Ahmad *et al*., 2010, Amadi, 2011). Water pollution is a complex process that leads to changes in water composition (aquatic flora and fauna) and poor water quality with consequent adverse effects on economic and recreational activities and deleterious effects on human health (Duane *et al*., 1995, Novotny, 2003, Florescu *et al.*, 2011). In Nigeria, many waterbodies are polluted as a result of the

discharge of untreated wastewater and other organic wastes directly into them (Jaji *et al.*, 2007; Obire *et al.*, 2008) through the establishment of abattoirs.

Abattoirs are generally known all over the world to pollute the environment either directly or indirectly from their various processes (Adelegan, 2002). Abattoir effluents refer to water laden with waste organic materials which are highly nitrogenous, biodegradable with high concentration of suspended, dissolved solids, and colloidal matter such as proteins, cellulose, fat scraps, blood, gut contents, detergents, hair and hide scraps (Nunez and Martinez, 1999, Alonge, 2001, Caixeta *et al.*, 2002). In Nigeria, abattoirs are usually situated near aquatic environment into which different untreated waste are discharged (Sangodoyin *et al*., 1992; Benka-Coker and Ojior , 1995; Adelegan, 2002). These wastewaters are often released directly into aquatic ecosystems without adequate treatment thereby posing serious threats to surface water quality, general environmental safety and health (Mittal, 2006; Arvanitoyannis and Ladas, 2008). However, the impact of wastewater effluents on the quality of receiving water bodies depends on the volume of the discharge, chemical and microbiological concentration/composition of the effluents (Akpor and Muchie, 2011).

The impact of the biodegradable organic matter from abattoir effluents on receiving waters include high competition for oxygen within the ecosystem hence high levels of biochemical oxygen demand (BOD) and a reduction in dissolved oxygen, which is detrimental to aquatic life (Wu 1999), Foroughi *et al.*, 2010). In addition, the limiting nutrients (nitrogen and phosphorus) enrichment could lead to eutrophication by stimulating the growth of algae. While the adverse effects of eutrophication include increased biomass of plankton and macrophyte vegetation as well as epiphytic algae; increased toxins from bloom-forming algal species; loss of commercial and sport fisheries; reduction in carbon availability to food webs; increased taste and odour problems; reduction in species diversity; increased treatment costs prior to human use, and decreased aesthetic value of the water body (Smith and Schindler 2009, Badruzzaman *et al*., 2012). Algae bloom and finally collapse might lead to hypoxia/anoxia due to aquatic dissolved oxygen depletion, hence mass mortality of benthic invertebrates and fish over large areas (Wu, 1999; Foroughi *et al*., 2010). These effects include negative impact on biodiversity, with sensitive species being eliminated leading to major changes in ecosystem structure and probable human health hazards (Foroughi *et al*., 2010). Moreover, according to Nwanchukwu *et al.* (2011) animal blood washed into stream or river could also lead to increase in microorganism diversity, some of which may be pathogenic. Thus, the aim of this study was to estimate the extent of surface water pollution arising from the runoff and direct disposal of abattoir wastewater through assessment of water quality, plankton population and microbial profile of Opa River.

MATERIALS AND METHODS

Study area

The sampling stations were located on the outflow of Opa River from Opa Reservoir. These are located along Ede Road, Ife Central Local Government Area of Osun State, Nigeria (Fig. 1). Opa River was dammed in the year 1978 with other rivers: Amuta, Esinmirin and Obudu (Ifabiyi, 2008, Fawole and Arawomo, 2009) within Obafemi Awolowo University (OAU), Ile-Ife, for domestic purposes. It serves as a source of drinking water and other purposes within the University. River Opa, whose source is in Esa-Oke in Osun State Western Nigeria, is one of the major rivers in Ile-Ife

with a lot of seasonal streams as tributaries (Adeoye, 1989, Ifabiyi, 2008). This river is mostly recharged by annual rainfall (mean annual rainfall: 1300-1400 mm, maximum: above 2500 mm) and non-forested wetlands located within the city (Olajuyigbe *et al*., 2012, Adefioye and Ujoh, 2012). The study area was located within longitude 4º 30' 40" E to 4º 30' 50"E and latitude of 7º 30' 0"N to 7º 30' 10" N.

The substratum of the river is mainly mud and sand. The vegetation around the river is mainly rain forest composed of tall trees with thick foliage, and there are dense bamboos and shrubs along the river bank. The foliage cover or canopy affects the amount of sunlight that gets into the forest environment, which plays important role in the distribution of living organisms in the habitat. There are two main seasons prevailing in the area; the rainy season which extends from April to October, and the dry season which extends from November to March. The river receives high discharge of water during the rainy seasons as run-off from farmlands and high lands of the catchment area, hence the water becomes turbid.

Samples were collected monthly for a period of six months from August 2015 to January 2016 between 07.00 to 10.00 hours of day. Three stations were chosen along the course of River Opa viz: station A (552 meters upstream of abattoir effluent), station B (the point of effluent discharge from the abattoir) and station C (184 meters downstream after the effluent discharge point).

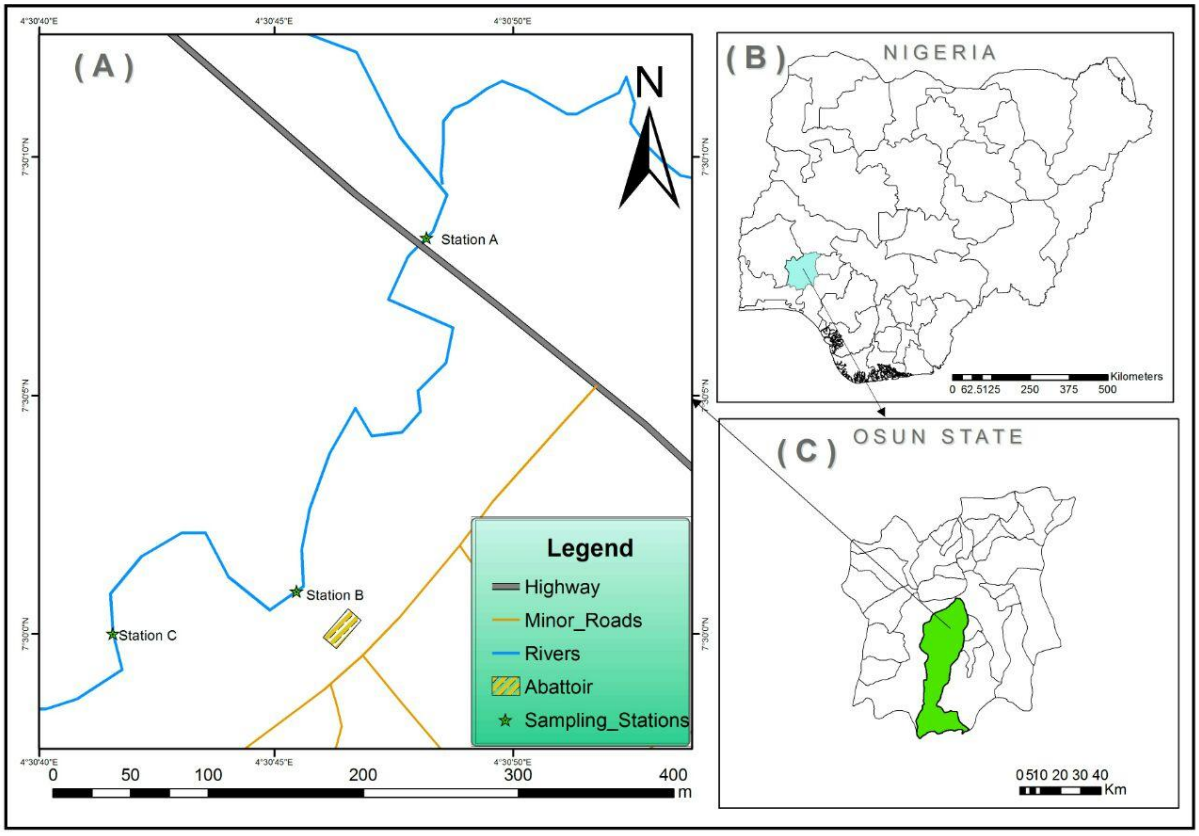

Fig. 1. Map of Opa River showing the sampling stations (A), (B) and (C)

Physico-chemical Water quality analysis

Water samples for physico-chemical analysis were collected into 2 L sterilised containers ateach station. Some of the physico-chemical parameters (temperature, pH and electrical conductivity) were measured *in-situ* using standard methods (APHA, 2000) with a mercury-in-glass thermometer for water temperature ($^{\circ}$C). pH-EC-TDS meter previously calibrated with buffer solutions were used for pH while conductivity was measured with a conductivity meter calibrated with potassium chloride solution. The dissolved oxygen content of the water samples were fixed on site by addition of Winkler's A (manganous sulphate solution) and Winkler's B (alkali-iodide) reagents to the collected sample. The samples were transported to the laboratory where they were titrated with sodium thiosulphate solution. Water samples collected in dark oxygen bottle for the determination of Biological oxygen demand were incubated in a cupboard for 5 days at room temperature. Then, the Winkler's method APHA (2000) was used to determine the amount of dissolved oxygen at the end of the incubation period. Total Solid (TS) was determined gravimetrically by evaporating a known volume of water sample to dryness in a pre-weighed crucible on a steam bath at 105°C. Nitrate was determined using brucine sulphanlic acid method (Marczenko, 1986). Chloride (Cl^-) was analysed by titrating a known volume of water sample with standardized 0.01N mercuric (II) nitrate solution while total hardness was also determined by the tritimeticmethod using a dropper to addEthylenediamine tetra-acetic acid (EDTA) solution to the water sample. Total Suspended Solids (TSS) and Total dissolved solids (TDS) were determined by gravimetric method at 105^{o}C and 180^{o}C respectively (APHA, 2001).

Plankton analysis

Quantitative plankton samples were collected by filtering 30 L of water fetched from Opa River through a 55µm mesh Hydrobios net. The concentrated samples obtained was then preserved in a specimen bottle with 5% formalin and 3 drops of Lugol's solution for sedimentation of organisms before subsequent analysis in the laboratory. Plankton samples were left to settle for at least 24 hours after which decantation method was used to reduce to 10mL. Encountered organisms were sorted, and counted using Omax Binocular Compound Light Microscope (Model MD827S30L) and pictures taken. Taxonomic keys : Kemdirim (2001), Fernando (2002) and Opute and Kadiri, (2013) were used for identification of plankters. The abundance of each species encountered was estimated based on the count records of the subsample with respect to the original volume of water filtered with plankton net. The result was then expressed as number of organisms per cubic metre of the original sample using the following equation:

$$A = \frac{ab}{c} \times 1000 \text{ (Goswami, 2004)}$$

Where A = abundance of species per litre,
a = total number of plankter in the counting chamber
b = concentrate volume of water used (1.5mL),
c = original volume of water strained (30L)

Microbiological analysis

A total of eighteen water samples were collected by sampling the three stations fortnightly from November 2015 to January 2016 in order to assess the occurrence of microbial organisms in Opa River at this reach. Clean, sterilized, wide mouthed sample bottles with tight screw dust proof

stoppers were used in collecting water samples for microbial analysis. Prior to this, 0.1 mL of 18 % Sodium Thiosulphate (a reducing agent) was added to each container to prevent oxidation of the effluent samples and continuation of bacteria activities during sample transit. 10 mL of the sample was diluted in 90mL of sterile distilled water and serial dilution was done to determine the population of organisms by reducing the count in the series of dilution. Ten-fold serial dilution of the water sample was prepared aseptically in sterile physiological saline up to 10^{-6} dilution. Later, an aliquot of 0.1 mL of the appropriate dilutions was inoculated on dried nutrient agar and Sabouraud dextrose plates in triplicate using the spread plate technique for enumeration of total bacteria and fungi counts respectively. Nutrient Agar plate were incubated for 24 hours at 35^{O}C under aerobic condition while the Sabouraud dextrose Agar plate were incubated at 25 ^{o}C for 3-5days. The colonies appearing on the agar plates were grouped based on their colonial morphology. Representative colonies were purified by repeated streaking on the media and incubation conditions of the original isolation. The pure cultures were coded, transferred to nutrient agar or Sabouraud dextrose Agar slants for bacterial and fungal isolates respectively and stored in the refrigerator, for subsequent characterization and identification following standard morphological and phenotypic methods (Harrigan and McCance, 1998; Kurtzman *et al*., 2011). Plates containing 30-300 bacterial colonies were selected and counted while the number of colony forming units per mL (cfu/mL) was calculated by multiplying the number of colonies per dilution factor. The fungi isolates were identified using lactophenol cotton blue stain while the bacterial isolates were identified using sense of biochemical reaction cfu/mL = number of colonies per ml plated / total dilution factor. The identification was done according to the methods described in Bergey's Manual of Systematic Bacteriology (Sneath *et al.*, 1986).

Serial diluents were inoculated in an aseptic environment onto different plates of melted sterile medium after cooling to 450°C and a glass spreader was used to spread the inoculum. Sub-culturing was done until distinct colonies (pure cultures) were obtained. Total heterotrophic bacteria (THB) were enumerated with nutrient agar (NA) (Oxoid) while total heterotrophic fungi (THF) were enumerated with potato dextrose agar (PDA) (Cullimore, 2007).

Statistical analysis

The data obtained were subjected to descriptive and multivariate statistics analysis using SPSS version 23, and PAST. Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) were used to test variations among physico-chemical parameters, plankton abundance and microbial load spatially while t-test was used to compare temporal variations. Principal component analysis was used to measure the interrelationship amongst the investigated water parameters as well as between them and the encountered planktonic taxa. Plankton community structure was determined using Species diversity indices (Shannon and Weaver, 1949), Dominance (Magurran, 2004), Species equitability or evenness (Pielou ,1966) and Species richness (Margalef, 1951, Menhinick, 1964).

Results

Physico-chemical characteristics:

Nine out of the 15 physicochemical parameters investigated, namely pH, alkalinity, BOD_5 , calcium, magnesium, chloride, nitrate, organic matter and bicarbonate, had their highest value at the discharge receiving station**.** The effect of the abattoir effluent was also revealed in the varied mean values of pH, conductivity, alkalinity, BOD_5, chloride, and sulphate which were highest at the

discharge station (Station B) while the mean dissolved oxygen and bicarbonate value was lowest at the discharge station (Table 1). Spatial variations were also recorded in acidity and nitrate values being lowest upstream and highest downstream. Although water temperature, organic matter, calcium, magnesium and total hardness was highest upstream, the observed spatial variations in their mean values were not significant statistically ($p > 0.05$) (Table 1).

Temporal variations were recorded in the mean values of temperature, pH, acidity, dissolved oxygen (DO), BOD_5, chloride and nitrate being higher during the dry season while bicarbonate, conductivity, organic matter, alkalinity, calcium, magnesium, sulphate and total hardness values were higher during rainy season (Table 2). Despite these temporal variations, only pH, and sulphate showed significant seasonal variations ($p<0.05$). Cluster analysis of the physicochemical parameters to reveal the correlation amongst the parameters produced two clusters at $p < 0.05$ (Fig. 2). Cluster 1 consist of water temperature, BOD_5, nitrate, sulphate, chloride, organic matter, magnesium, acidity, pH, calcium, and DO while cluster 2 was composed of Total hardness, Alkalinity, bicarbonate, and conductivity.

Plankton community structure

Thirty-two (32) plankton species belonging to 13 classes were identified during the study. The total number of species recorded per month ranged between 10 and 20 species with the least number of species (10) recorded in October 2015 while the highest (20) was recorded in September. Likewise,the highest number of individuals (3965 individual per m^3) was recorded in August 2015 followed by 3390 individuals per m^3 recorded in September 2015 (Table 3). Spatially, the highest number of occurrence (28 Species) of planktonic species (15 phytoplankton and 13 zooplankton respectively) was recorded downstream. While highest species abundance was also recorded upstream (6835 ind/m^3) and 5880 ind/m^3 recorded at the discharge point was the lowest. The highest mean abundance was also recorded upstream for all phytoplanktonic taxa except zygnematophyceae whose abundance was even for all the inveatigated stations while zooplanktonic taxa highest mean abundance were observed downstream except branchiopoda which had it highest mean abundance at the discharge point dominated by *Allonella sp* (Table 4). There exists significant ($p < 0.05$) spatial variations in the abundance of Dinophyceae and Bacillariophyceae, both having highest abundance upstream while very highly significant ($p < 0.001$) difference was recorded for Coscinodisceae and Insecta which were abundant at the discharge and downstream respectively (Table 4). Seasonal variations were recorded in mean planktonic abundance with higher abundance of Bacillariophyceae, Dinophyceae, Maxillopoda, Branchiopoda and Prostomatae taxa during the rainy season while Chlorophyceae, Coscinodisceae, Zygnematophyceae, Cyanophyceae, Eurotatoria and Insecta were higher during the dry season. Moreover, the phytoplankton and zooplankton group collectively were more abundant during the rainy and dry season respectively while highest number of species were recorded for the two groups during the dry season. Dinophyceae and Bacillariophyceae were significantly higher during rainy season while Chlorophyceae, zygnematophyceae, Cyanophyceae, and Eurotatoria were significant higher during dry season (Table 3).

The order of species richness of the recorded taxa as revealed by Margalef's index for phytoplankton is thus Bacillariophyceae > Cyanophyceae > Dinophyceae > Chlorophyceae > Zygnematophyceae > Coscinodisceae. While the species richness order of zooplankton group is as

Table 1. Spatial variations in physico-chemical parameters of Opa River

Parameter	Upstream		Discharge		Downstream	
	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD
Temperature (ºC)	25-32	27.58±2.42*	26-27	26.3±0.5	25-28	26.25±1.08#
pH	8-8.4	8.22±0.18#	8.1-8.5	8.28±0.16*	8.1-8.4	8.28±0.11
Conductivity($\mu Scm^{-1)}$	149.1-155.1	151.85±2.25*	148.8-151.8	150.4±1.13#	149.8-153.7	151.4±1.73
Acidity ($mgCaCO_3/L$)	6-18	11.8±4.9#	7.0-20	14±5.5	7.0-22.0	14±6.2*
Alkalinity ($mgCaCO_3/L$)	54-68	60±5.33	55-70	61.3±6.12*	48-64	55.7±6.38#
DO (mg/L)	2.6-8.4	6.6±2.03*	1.8-7.6	5.3±2.0#	3.6-7.2	6.1±1.51
BOD (mg/L)	0.2-1.6	0.9±0.52#	0.6-4.4	1.9±1.47*	0.4-2.8	1.17±0.91
Calcium (mg/L)	8.97-14.26	10.65±1.93*	8.36-17.22	10.55±3.39	6.82-13.52	10.07±2.29#
Magnesium (mg/L)	0.89-7.5	4.71±2.19*	2.21-8.23	4.46±2.39	2.05-7.91	4.22±2.52#
Chloride (mg/L)	2.79-3.69	3.0±0.35#	2.89-4.41	3.4±0.61*	2.13-3.87	3.3±0.66
Nitrate (mg/L)	0.31-2.55	1.26±0.79#	0.31-2.79	1.31±0.93	0.56-2.79	1.55±0.84*
Sulphate (mg/L)	0.1-2.54	0.87±0.91	0.1-2.54	1.19±0.97*	0.1-2.54	0.81±1.11#
Organic Matter (mg/L)	2.2-3.3	2.8±0.54*	1.5-3.3	2.4±0.77	1.5-2.3	1.9±0.48#
Bicarbonate (mg/L)	64.8-81.6	72.0±6.39	66.0-84	73.6±7.35*	57.6-76.8	66.8±7.65#
Total Hardness ($mgCaCO_3/L$)	30.07-56.18	45.93±9.87*	30.44-54.99	44.86±9.24	31.81-49.54	42.48±7.08#

* - Highest Mean; # - Lowest Mean

Table 2. Seasonal variations in physico-chemical parameters of Opa River

Parameter	Rainy season		Dry season	
	Min-Max	Mean ± SD	Min-Max	Mean ± SD
Temperature (ºC)	25 - 28	27.32 ± 5.42	26 - 32	28.58 ± 11.65
pH	8.3 - 8.5	8.4 ± 0.05	8.0 - 8.2	8.51 ± 0.08***
Conductivity($\mu Scm^{-1)}$	149.1-155.1	151.38 ± 2.01	148.8 - 153.7	151.08 ± 1.61
Acidity ($mgCaCO_3/L$)	6.0 - 12.0	8.67 ± 2.12	14.0 - 22.0	17.89 ± 2.76***
Alkalinity ($mgCaCO_3/L$)	46.0 - 70.0	61.67 ± 7.28**	50.0 - 61.0	56.33 ± 3.28
DO (mg/L)	1.8 - 8.4	5.47 ± 2.42	5.2 - 7.6	6.51 ± 0.81
BOD (mg/L)	0.2 - 2.4	0.93 ± 0.68	0.6 - 4.4	1.71 ± 1.28*
Calcium (mg/L)	8.36 - 17.2	11.46 ± 2.93	6.82 - 11.31	9.44 ± 1.42
Magnesium (mg/L)	2.21 - 6.54	4.65 ± 1.50	0.98 - 8.23	4.28 ± 2.86
Chloride (mg/L)	2.13 - 3.65	2.96 ± 0.46	2.87 - 4.41	3.51 ± 0.52*
Nitrate (mg/L)	0.31 - 2.79	1.39 ± 1.07	0.81 - 2.21	1.40 ± 0.52
Sulphate (mg/L)	0.1 - 2.54	1.42 ± 0.91*	0.1 - 2.54	0.49 ± 0.80
Organic Matter (mg/L)	1.8 - 3.3	2.52 ± 0.62	1.2 - 3.3	2.20 ± 0.75
Bicarbonate (mg/L)	57.6 - 84	74.0 ± 8.74**	60.0 - 73.2	67.6 ± 3.93
Total Hardness ($mgCaCO_3/L$)	42.59 - 53.73	47.70 ± 4.20*	30.07 - 57.18	41.14 ± 10.41

Note: Higher mean values are in Bold print
*** - Very highly Significant variation ($p < 0.001$)
** - highly Significant variation ($p < 0.01$)
* -significant variation ($p < 0.05$)

Follows: Eurotatoria > Branchiopoda > Prostomatea > Maxillopoda > Heterotrichea > Loboda > Insecta (Table 5). also had The least value Simpson's Dominance index (D) recorded for Bacillariophyceae followed by Eurotatoria also revealed that them as the most diverse taxa. Shannon Weiner index calculated values for the recorded taxa were mostly between 1.5 and 3.5 except for Coscinodisceae, Loboda and Insecta thus confirming the taxa species richness and even distribution. Likewise, evenness index values were all close to 1(one) revealing complete evenness in distribution of all the taxa recorded (Table 5).

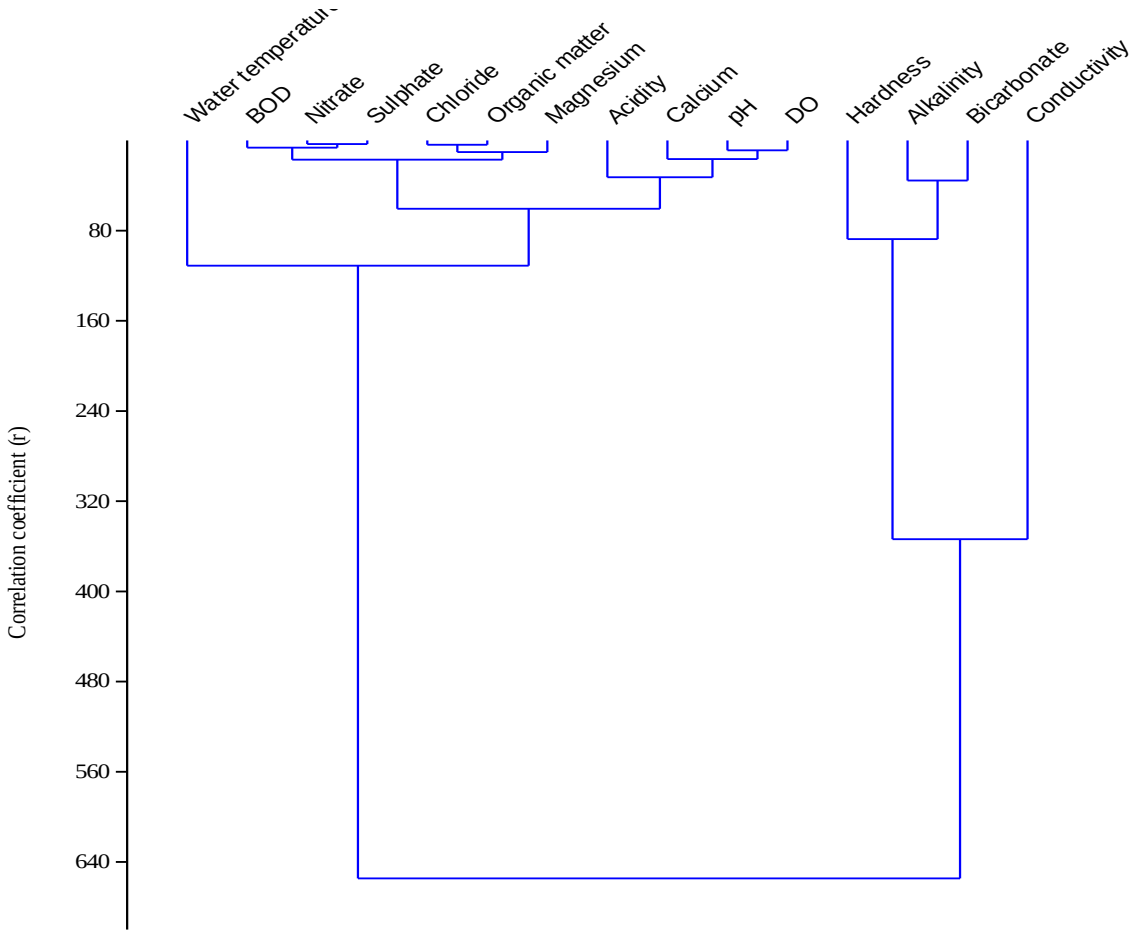

Fig. 2. Cluster diagram showing relationship between the physico-chemical parameters of Opa River.

Spatially, Margalef species richness index revealed gradual increase in phytoplankton's richness from upstream to downstream while lowest richness in zooplankton was observed at the discharge and highest downstream (Table 6). The Simpson's dominance index also showed the downstream as most diverse in phytoplankton and zooplankton than upstream and discharge stations.

Principal component analysis as depicted in Figure 3 revealed that all the environmental variable investigated had negative influence on the taxa segregation. Based on plot of component 1 against component 2 , which both which explained 80.08% of the total variance, six different groups were identified. Cyanophyceae abundant had strong affinity for water temperature, alkalinity, bicarbonate and total hardness of the investigated stations while Eurotatoria abundance correlated with conductivity. Bacillariophyceae and Maxillopoda abundance were each distinctly segregated from physico-chemical parameters and other identified taxa thus free of competitive pressure. Moreover, the abundance of Heterotrichea, Dinophyceae, Prostomatea and Branchiopoda were not affected by any physico-chemical parameters and they had strong affinity for each other.

Table 3. Temporal Variations in Phytoplankton assemblage of Opa River.

Taxa	August 2015	September 2015	October 2015	November 2015	December 2015	January 2016	Rainy season	Dry season
PHYTOPLANKTON								
CHLOROPHYCEAE								
Cladophora glomerata	-	30	-	-	-	-	30	-
Spirogyra particalis	-	-	-	60	120	30	-	210
Total (Mean ± S.D)							30(15±21.21)	210(105±148.49)**
BACILLARIOPHYCEAE								
Nitzschia sigmoidea	685	520	310	180	130	-	1515	310
Tabellaria fenestrate	160	100	-	-	30	-	260	30
Synedra crystalline	270	160	60	80	350	150	490	580
Asterionella glacialis	-	-	100	-	-	-	100	-
Asterionella gracillina	-	-	50	50	-	-	50	50
Total (Mean ± S.D)							2415(483±601.87)**	970(194±248.86)
COSCINODISCEAE								
Coscinodiscus sp	-	-	-	-	100	-	-	100

Total (Mean ± S.D)							0(0±0)	100(0±0)
ZYGNEMATOPHYCEAE								
Zygnema stellinum	-	-	-	-	30	-	-	30
Closterium ehrenbergii	-	30	-	-	-	30	30	30
Total (Mean ± S.D)							30(15±21.21)	60(30±0)***
DINOPHYCEAE								
Ceratium furca	300	600	100	90	200	100	1000	390
Total (Mean ± S.D)							1000(0±0)*	390(0±0)
CYANOPHYCEAE								
Oscillatoria amoena	200	100	100	150	350	-	400	500
Oscillatoria annae	-	-	-	80	-	-	-	800
Oscillatoria coprophila	-	50	-	50	-	-	50	50
Lyngbga birgei	-	-	-	-	50	100	-	150
Lyngbga aestuariis	-	-	-	-	50	100	-	150
Lyngbga contorta	50	-	360	-	100	90	410	190
Microcystis aeruginosa	-	-	-	100	-	-	-	100
Total (Mean ± S.D)							860(122.86±193.62)	1940(174.29±151.31)**

ZOOPLANKTON								
EUROTATORIA								
Platyis quardricornis	-	150	-	-	150	100	150	250
Keratella lenzi	-	100	-	100	-	500	200	700
Filinia pejleri grandi	-	50	-	-	-	100	50	100
Hexarthra mira	100	100	-	250	100	100	200	450
Trichocerca insulana	250	150	-	300	450	-	400	750
Total (Mean ± S.D)							900(180±135.09)	2250(450±280.62)**
MAXILLOPODA								
Cyclopoid nauphius	50	-	400	100	-	250	450	350
Cryptocyclops bicolors	800	100	200	400	-	-	1100	400
Total (Mean ± S.D)							1550(775±459.62)	750(375±35.36)
BRANCHIPODA								
Chironomid pupa	-	150	-	-	100	100	150	200
Leptodora spp	400	100	-	200	200	100	500	500
Allonella sp	150	-	-	250	100	200	150	550
Total (Mean ± S.D)							800(266.67±202.07)	1250(416.67±189.29)

HETEROTRICHEA								
Blepharisma sp	400	500	-	-	100	350	900	450
Total (Mean ± S.D)							900(0±0)	450(0±0)
PROSTOMATEA								
Coleps sp	100	100	800	200	100	450	1000	750
Total (Mean ± S.D)							1000(0±0)	750(0±0)
LOPODA								
Amoeba protus	50	250	-	100	-	100	300	200
							300(0±0)	200(0±0)
INSECTA								
Chaoborus pupa	-	50	-	-	-	200	50	200
Total (Mean ± S.D)							100(0±0)	200(0±0)
SPECIES DIVERSITY (S)	15	20	10	18	19	19	25	30
SPECIES ABUNDANCE (N)	3965	3390	2480	2740	2810	3150	9935	9520

Note: Higher values are in Bold Prints
***-Very Highly Significant
** -Highly Significant
* -Significant

Table 4. Spatial variations in abundaceof planktonic goups in Opa River

Taxa	Station A	Station B	Station C
PHYTOPLANKTON			
CHLOROPHYCEAE			
Cladophora glomerata	90	60	60
Spirogyra particalis	0	0	30
Total	**90(45±63.64)**	60(30±42.43)	90(45±21.21)
BACILLARIOPHYCEAE			
Nitzschia sigmoidea	1035	560	230
Tabellaria fenestrata	50	150	90
Synedra crystalline	610	300	160
Asterionella glacialis	100	0	0
Asterionella gracillima	0	50	50
Total	**1795(359±240.39)***	1060(212±100.96)	530(106±90.71)
COSCINODISCEAE			
Coscinodiscus sp.	0	100	0
Total	0(0±0)	**100(0±0)*****	0(0±0)
ZYGNEMATOPHYCEAE			
Zygnema stellinum	0	0	30
Closterium ehrenbergii	30	30	0
Total	30(15±21.21)	30(15±21.21)	30(15±21.21)
DINOPHYCEAE			
Ceratium furca	960	400	30
Total	**960(0±0)***	400(0±0)	30(0±0)
CYANOPHYCEAE			
Oscillatoria amoena	400	250	250
Oscillatoria annae	0	50	30
Oscillatoria coprophila	0	50	50
Lyngbga birgei	100	0	50
Lyngbga aestuariis	0	50	100
Lyngbga contorta	310	230	60
Microcystis aeruginosa	0	50	50
Total	**810(115.71±169.49)**	680(97.14±99.45)	590(84.29±76.13)
ZOOPLANKTON			
EUROTATORIA			
Platyis quardricornis	250	0	150
Keratella lenzi	300	300	200
Filinia pejleri grandi	0	0	150
Hexarthra mira	300	100	250
Trichocerca insulana	250	200	700
Total	1100(220±125.49)	600(120±130.38)	**1450(290±232.92)**
MAXILLOPODA			
Cyclopoid nauphius	200	150	450
Cryptocyclops bicolors	0	700	800
Total	200(100±141.42)	850(425±388.91)	**1250(625±247.49)**
BRANCHIPODA			
Chironomid pupa	100	100	150
Leptodora spp	400	200	400
Allonella sp	100	600	0
Total	600(200±173.21)	**900(300±263.57)**	550(183.33±202.08)
HETEROTRICHEA			
Blepharisma sp	350	500	500

Total	350(0±0)	500(0±0)	500(0±0)
PROSTOMATEA			
Coleps sp	700	500	550
Total	**700(0±0)**	500(0±0)	550(0±0)
LOPODA			
Amoeba proteus	150	200	150
Total	150(0±0)	**200(0±0)**	150(0±0)
INSECTA			
Chaoborus pupa	50	0	200
Total	50(0±0)	0(0±0)	**200(0±0)*** **
SPECIES DIVERSITY (S)	**22**	**25**	**28**
SPECIES ABUNDANCE (N)	**6835**	**5880**	**5970**

Note: Higher mean values are in Bold print

*** - Very highly Significant variation (p < 0.001) ** - highly Significant variation (p < 0.01) * - significant variation (p < 0.05)*

Microbial Load

Eleven (11) bacteria genera and two (2) fungal genera were identified in the water samples collected from Opa River. Of this population, five bacterial genera (*Aeromonas spp, Escherichia coli, Enterobacter spp, Pseudomonas aeruginosa* and *Proteus mirabils*) were the dominant genera. The fungal population consisted mainly of *Aspergillus* genera (*Aspergillus fumigatus, Aspergillus oryzae, Aspergillus terrus, Aspergillus niger*) as recorded from all the sampled stations while *Rhizopus stolonifer* was only found at the discharge station. The presence of Enterobacter species upstream and E. coli at both discharge and downstream was an indication of faecal contamination of Opa river at the reach.The discharge station also had the highest number of bacterial and fungal occurrence (12 species) while only 5 and 6 species were encountered upstream and downstream respectively (Figures 4, 5 and 6). The dominant species upstream were *Enterobacter spp, Pseudomonas aeruginosa* and *Proteus mirabils* (Fig. 4) while *Aspergillus fumigatus and Aeromonas spp* were dominant downstream (Fig. 6) during the period of study. *Salmonella spp and Rhizopus stolonifer* were found to be dominant at the discharge (Fig. 5). All bacterial and fungal genera recorded at the discharge station and downstream were of human health concern. Bacterial species recorded that are of high human health significance include *Salmonella* spp, *Vibrio* spp., *Staphylococuss aureus* and *Klebsiella pnuemonae* as found only at the discharge point.

Discussion

High values of pH, alkalinity, BOD_5, calcium, magnesium, chloride, bicarbonate, organic matter and nitrate at the discharge point may have resulted from the abattoir effluent entering the river at this point and the subsequent microbial activities which made use of the available oxygen (Osibanjo and Adie 2007). The segregation of the plant nutrient parameters (Nitrate, organic matter), oxygen parameters (BOD5, DO), major ions (Ca^{2+}, Mg^{2+}, Cl^- and salinity parameter (pH and acidity) as revealed by clustering analysis could also be denoting organic pollution. However, the highest mean nitrate observed downstream implies high dissolution of abattoir effluents and other particulate matters as it is being transported along the course of Opa River while the highest organic matter mean value observed upstream could probably be due to agricultural runoffs from agricultural activities noticed around this station. These agriculture runoffs and discharges into the waterbody also could have lead to the highest abundance of planktonic organisms recorded

upstream and lowest recorded at the discharge point with only coscinodisceae found dominant because of the taxa tolerance ability. The observed order of species richness, with Bacillariophyceae and Eurotatoria been the most diverse phytoplankton and zooplankton respectively, revealed an ecological community that is associated with eutrophication.

The current study dominance of Bacillariophyceae could be due to their ability to proliferate in the aquatic environment. Bacillariophyceae have also been shown to exhibit a boom and bust lifestyle in freshwater and marine environments (Richard and Stickley, 2010).

Table 5. Diversity Indices of recorded Planktonic classes from Opa River

	Taxa (S)	Individuals	Dominance D	Shannon (Hs)	Evenness (E)	Margalef (d)
Chlorophyceae	5	240	0.219	1.560	0.951	0.730
Bacillariophyceae	38	3385	0.047	3.331	0.736	4.553
Coscinodiscaece	1	100	1.000	0.000	1.000	0.000
Zygnematophyceae	2	60	0.500	0.693	1	0.244
Dinophyceae	10	1390	0.152	2.082	0.802	1.244
Cyanophyceae	20	1330	0.066	2.876	0.887	2.641
Eurotatoria	22	3150	0.061	2.956	0.874	2.607
Maxillopoda	11	2250	0.125	2.235	0.850	1.296
Branchiopoda	12	1850	0.099	2.400	0.919	1.462
Heterotrichea	9	1350	0.117	2.172	0.975	1.110
Prostomatea	11	1750	0.135	2.199	0.819	1.339
Loboda	5	500	0.260	1.471	0.871	0.644
Insecta	3	300	0.389	1.011	0.917	0.351

They effectively utilize nutrients and light availability to compete and quickly dominate other phytoplankton species (Buchan *et al.*, 2014). Their dominance feature was further depicted by their distinct segregation in the PCA plot. Another general ecological implications of the composition of phytoplankton species obtained at the three sampling stations during study period was indicative of existence of potentially harmful microalgae such as Dinophyceae and Cyanophyceae species which are known to produce toxins. According to Siyambalapitiya *et al*. (2012), Dinophyceae are potentially harmful red tide forming species. High abundance of certain recorded species of Cyanophyceae such as *Oscillatoria* and *Microcystis* spp. are known to produce microcystins toxins (Kyewalyanga and Lugomela, 1999) which are associated with aquatic pollution (Ekwu and Sikoki, 2006) and could cause serious illness in both humans and other mammals (Anago *et al*., 2013). Moreover, the presence of *Nitzschia sigmoidea* as the most abundant species was also an indication of high organic pollution.

Table 6. Spatial and Temporal Diversity Indices of Planktonic groups recorded from Opa River

	Upstream		Discharge		Downstream		Rainy season		Dry season	
	Phytoplankton	Zooplankton	Phytoplankton	Zooplankton	Phytoplankton	Zooplankton	Phytoplankton	Zooplankton	Phytoplankton	Zooplankton
Taxa (S)	29	23	29	23	27	30	37	36	39	37
Individuals	3685	3450	2280	3550	1220	4700	3845	5550	2660	5600
Dominance D	0.054	0.059	0.047	0.051	0.042	0.049	0.049	0.040	0.036	0.034
Shannon (Hs)	3.128	2.989	3.201	3.050	3.227	3.223	3.293	3.402	3.497	3.504
Evenness (E)	0.787	0.864	0.847	0.918	0.934	0.837	0.728	0.834	0.847	0.899
Margalef (d)	3.410	2.701	3.621	2.691	3.659	3.430	4.361	4.06	4.819	4.171

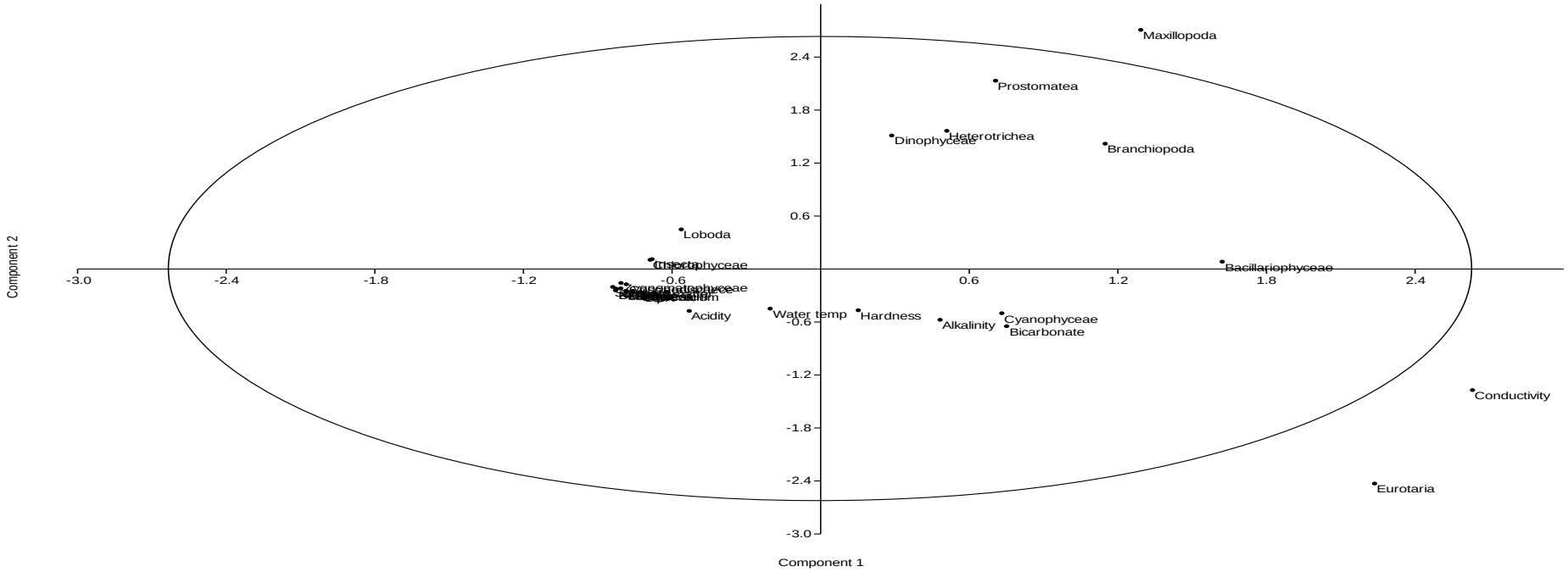

Fig. 3: Principal Component Analysis showing the relationship between the physico-chemical parameters, plankton community and microbial load of Opa river

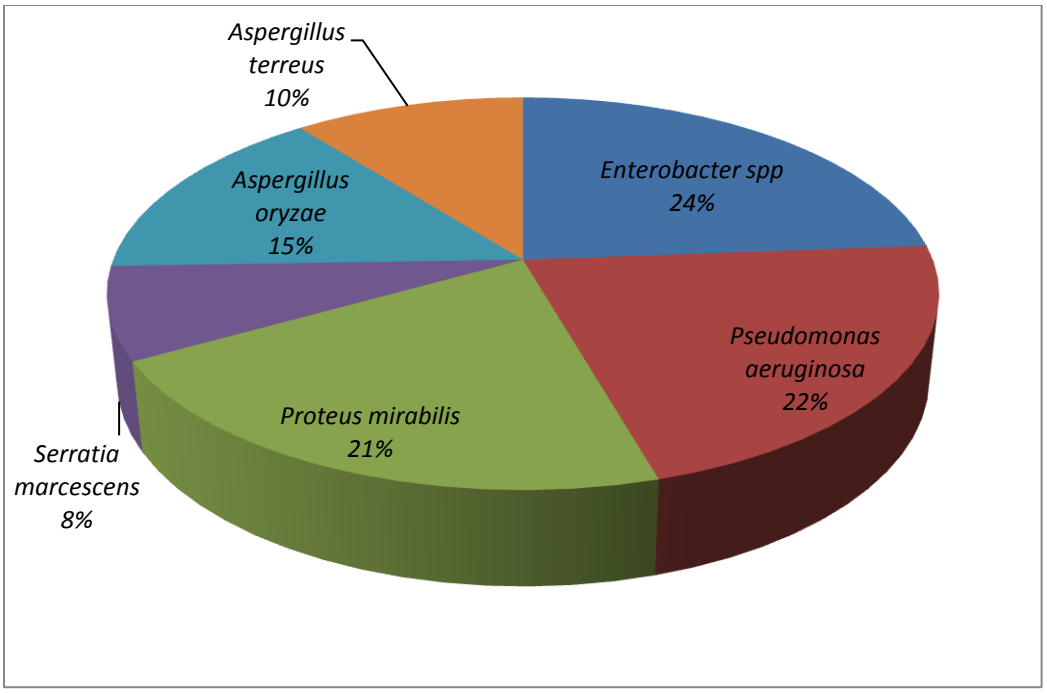

Fig. 4. Bacteria and fungi species isolated from Upstream

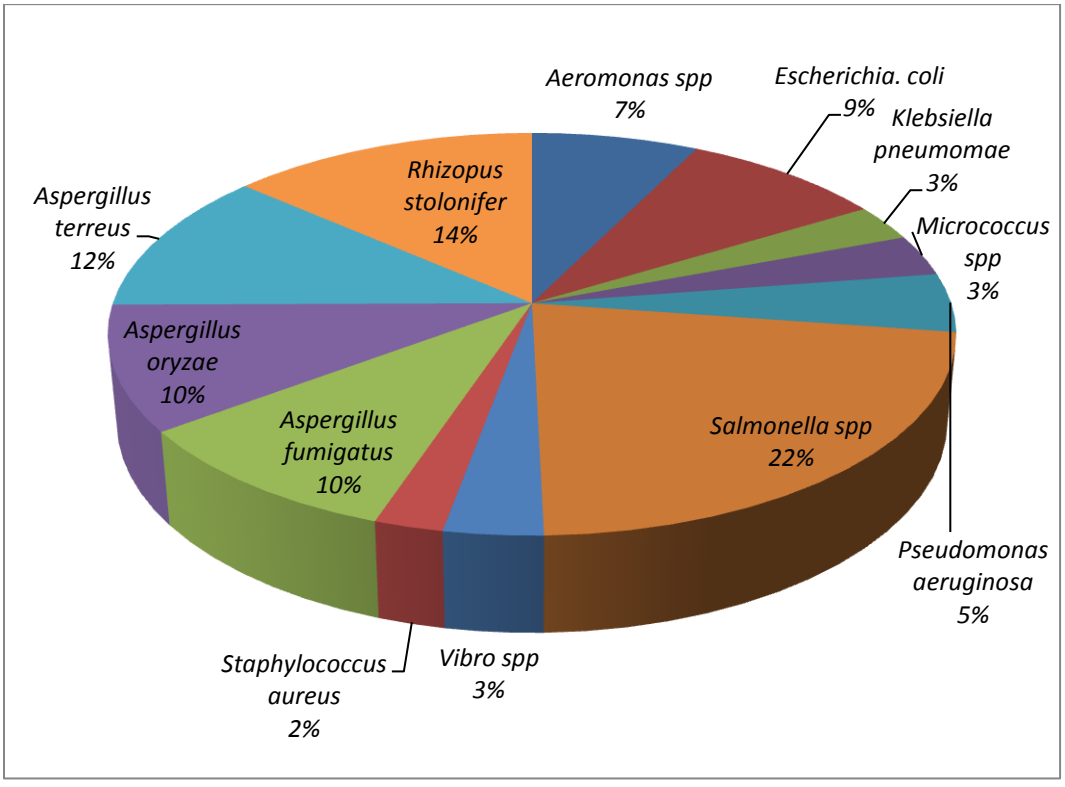

Fig. 5. Bacteria and fungi species isolated from Discharge point.

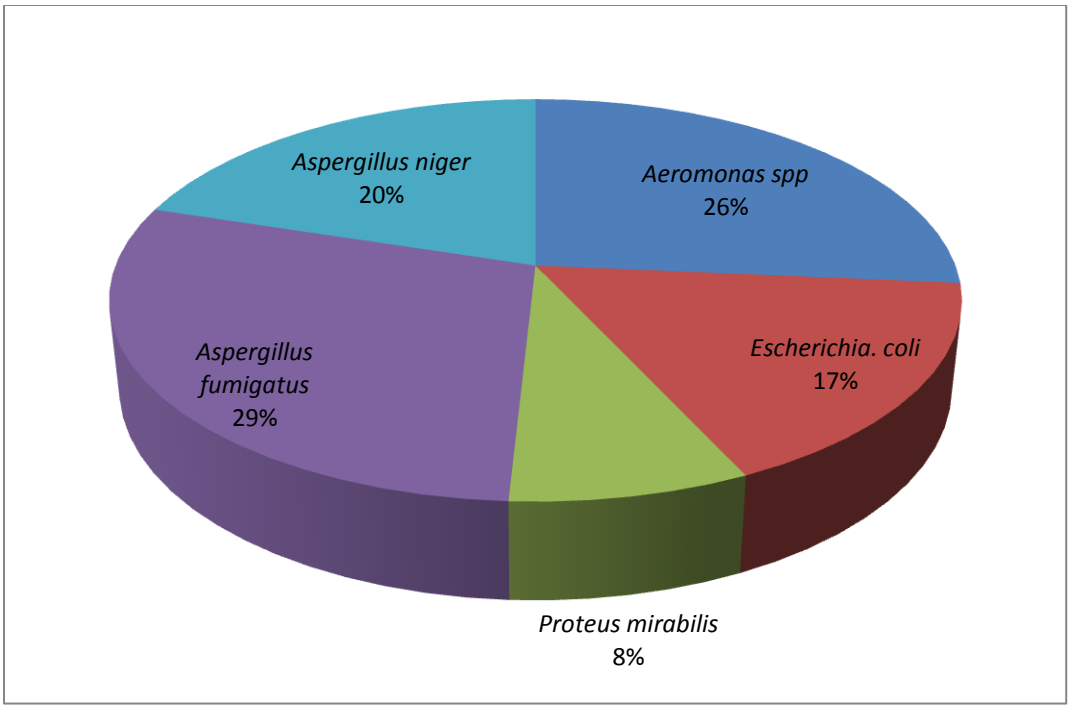

Fig. 6: Bacteria and fungi species isolated from downstream

The organic pollution according to Okojin and Obi (1999) is known to promote the growth of smaller sized zooplankton especially the rotifers which explained the recorded abundance of *Eurotatoria* as the most diverse zooplankton. In addition the abundance of rotifers has been associated with their capacity to adapt quickly to environmental disruption in a physico-chemical unstable system hence their wide geographical distribution (Arimoro and Oganah, 2010)

The microbial composition of the stations investigated also confirmed organic pollution as most of the recorded microbes were indicators of feacal contamination, being of moderate to high health significance (WHO, 2015).The highest occurrence of these microbes (12 species) was recorded at abattoir effluent discharge receiving station with high prevalence of *Salmonella* spp and *Rhizopus stolonifer*. This conforms with the works of Nafaranda *et al.*, (2011) on the elevation bacterial population in wastewaters from the slaughterhouses.The presence of *Salmonella* spp. and *Entaamoeba coli* at the discharge could be a threat to human health as these bacteria are known to cause *haemorrhagic colitis* (Kerr *et al.*, 1999), diarrhoea, nausea, abdominal cramps, fever, and vomiting (Ocepek *et al.*, 2011), and cholera (Shanan *et al.*, 2011). Several studies have reported a statistically significant increase in gastrointestinal illness in populations that drink contaminated water with different types of coliform bacteria (Payment *et al.*, 1997). According to recommendations from the WHO (World Health Organization) and CAWST (Center for Affordable Water and Sanitation Technology), drinking water must be free from *E. coli*, *Salmonella* spp., and *Vibrio cholera* (Ashbolt *et al*., 2001, WHO, 2011, CAWST, 2009).

The recorded prevalence of *Pseudomonas aeruginosa* upstream could probably be due to their known presence in oligotrophic aquatic system with high dissolved oxygen and low plant nutrient (Costerton and Anwar, 1994) hence the decrease in its occurrence at the discharge and total absence downstream.

Conclusion

The discharge of abattoir wastewater into the aquatic environment without proper treatment has impacts on the water, planktonic and microbial quality as depicted by the study. The investigated physico-chemical water quality parameters of the Opa river receiving abattoir wastewater during the study period varied within sample stations and the composition of planktonic as well as microbial organisms recorded was indicative of faecal and organic pollution as well as prevalence of enteric pathogens. This study, therefore, revealed the fact that untreated abattoir effluents generated along Opa river abattoirs could lead to serious health problem for people using the waterbody for domestic and other purposes including processing meat for market Hence it is important to adopt appropriate abattoir wastewater treatment measures to prevent the contamination of the waterbodies in the vicinity of abattoirs hence ensure the safety of meat being consumed by millions of people.

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