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Abstract: The physico-chemical and bacteriological characteristics of Oke-Afa canal water, Nigeria were investigated. Samples were collected during rainy and dry seasons from April 2009 to March 2010. The physico-chemical parameters were assessed by standard methods and the total viable bacteria by multiple tube technique. Antibiotic susceptibility of isolates was by agar-diffusion method. The mean value of physico-chemical parameters investigated include; water temperature ($28.6 \pm 0.3^\circ\text{C}$), pH (6.9 ± 0.1), conductivity ($495.9 \pm 47.8 \mu\text{S cm}^{-1}$), Total Dissolved Solid (TDS) ($288.0 \pm 28.5 \text{ mg l}^{-1}$), Dissolved Oxygen ($4.4 \pm 0.3 \text{ mg l}^{-1}$) and Biological Oxygen Demand ($1.3 \pm 0.2 \text{ mg l}^{-1}$). Conductivity, TDS and turbidity varied significantly ($P = 0.001$) between the seasons. The concentrations of heavy metals (Fe, $0.0 - 0.03 \text{ mg l}^{-1}$, Zn, $0.0 - 0.09 \text{ mg l}^{-1}$ and Mn, $0.0 - 0.02 \text{ mg l}^{-1}$) varied. Nineteen bacterial species were recovered of which *Pseudomonas aeruginosa* and *Klebsiella edwardsii* were the most prevalent. Resistance to antibiotics was in varying proportions-Ceftriazone (50%), nitrofurantoin (37.1%) and cotrimoxazole (18.5%). Nine different multiple antibiotic resistance patterns were observed. The chemical composition of the canal and the quality of bacteria detected could pose serious health hazard to residents around the canal.

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1.0 Introduction

Water in the natural environment contains many dissolved substances and non-dissolved particulate matters. Aquatic environment near cities are usually prone to overloading with a variety of pollutants either through direct or indirect discharges (Ayejuyo *et al.*, 2010). This situation may be worsened by the indiscriminate disposal of untreated wastes often laden with sewage into actively used streams and canals. In addition to their characteristic microflora, sewage-polluted waters carry numerous sewage microflora, some of which pose a public health risk (Olayemi, 1994). The availability of water and its physical, chemical and biological composition affect the ability of aquatic environments to sustain healthy ecosystems; as water quality and quantity are eroded, organisms suffer and ecosystem may be lost. Poor water quality can be the result of natural processes but is more often associated with human activities and is closely linked to industrial development. In Nigeria, a variety of wastes originating from domestic and industrial sources find their way into streams and rivers due to weak enforcement of existing legislation and lack of basic infrastructure, such as sewers and hygienic disposal facilities (Nubi and Osibanjo, 2008). In addition, inorganic nutrients, such as water soluble nitrogen and

phosphorus, can cause excessive growth of algae, forming algal blooms and eventually cause the serious problem of eutrophication in lakes and reservoirs (Junshum, 2007). Untreated organic matter that contains faecal coliform can be harmful to the environment and aerobic decomposition of this material can reduce dissolved oxygen levels if discharged into rivers (Environmental Protection Agency (EPA), 2008).

Microbial contamination of surface and ground waters by pathogenic organisms is probably the most important water quality issue in the developing world. The World Health Organization (WHO) identifies the greatest human health risk of microbial contamination as being through the consumption of water contaminated by human or animal faeces (WHO, 2004). The impact of such canal water on public health is not well documented, especially in Nigeria where houses are built near the canal pathways with bored wells for drinking purpose. Lagos is an industrial city and several inland waters are potential sinks of both effluent and solid waste materials. Many industries are situated around Oke-Afa Canal and this makes it a potential sink for most industrial effluents which pose serious health effect to people living around the Canal, since most homes dug wells from which they drink

from. This canal receives water from Industrial effluents, agricultural run-offs; transport, burning of fossil fuel, animal and human excretion, geological weathering and domestic waste which had been reported to have major contributions to the pollution of water bodies (Ayejuyo *et al.*, 2010).

There is a strong relationship between human activities and pollution of the environment. The recognition of this connection and need to protect human health, recreation and fish's production led to early development of water quality regulations and monitoring methods (Charis and Abbasi, 2005). Their impact on receiving water bodies in most municipal cities such as Lagos state is not well documented. As a result, they are rarely taken into consideration in environmental and water resources management. Industrial growth and its associated environmental problem such as water, soil, plant and air contamination is fast increasing, hence regular assessment of canal water is very crucial to safeguard public health and the environment.

The objective of this investigation was to characterize the canal water using standard physico-chemical and bacteriological factors alongside the seasonal changes. This will provide useful information for sustainable urban and water resources management, and the health risk of the residents around the canal.

2.0 Materials and methods

Study area

This study was carried out in Oke-Afa canal, Ejigbo Local Government area, Lagos state. Oke-Afa canal is a 3.5 km stretch long and it drains Isolo in Lagos metropolis, southwestern Nigeria. This canal is located on latitude 6° 30' 50.994" N – 6° 34' 4.446" N and longitude 3° 16' 27.004" E – 3° 17' 31.828" E. Lagos is the economic centre and the most populated city in the country. Figure 1 shows the map of the sampling stations.

2.1 Characteristics of Oke – Afa Canal

Oke-Afa canal is located around residential areas having a population of more than 300 people. The area was formerly a swampy area but with the increase in population size in the state, the area is now a newly developing residential area with over two hundred houses and ten streets built around and along the canal. Most of the houses built along the canal course drain their waste water directly into the canal water. Very close to the canal are the Isolo open dump site, the Oke-Afa plank market and a cattle ranch.

2.2 Sample collection and field observation.

Water samples were collected from six sampling stations along the canal course quarterly from June 2009 to April 2010. Water samples were collected in a clean 2 litres plastic keg. Water temperature, pH and dissolved oxygen (DO) were determined *in-situ* using

mercury in-glass-bulb thermometer, pH meter and Wrinkler's titrimetric methods respectively. Samples for Biological Oxygen Demand-5 (BOD₅) were collected in 250 ml dark reagent bottles and were incubated in a dark cupboard, after which the amount of oxygen was determined as above in DO determination.

2.3 Laboratory analysis

The concentration of calcium (Ca²⁺) and magnesium (Mg²⁺) were determined using complexometric method (APHA *et al.*, 1991). Turbidity was determined using Nephelometric method at wavelength 540nm. Sulphate concentration was evaluated using Turbidometric method while Phosphate (PO₄³⁻) concentration was determined using spectrophotometric method at wavelength 710nm (Golterman *et al.*, 1978). The concentration of sodium (Na⁺) and potassium (K⁺) were assessed using flame emission spectrophotometer (FES) and chloride (Cl⁻) was determined using Mohr titration. The concentrations of Cadmium, Cobalt, Chromium, Copper, Iron, Manganese, Lead and Zinc were evaluated using atomic absorption spectrometer (AAS) (Golterman *et al.*, 1978). Total dissolved solids (TDS) was assessed gravimetrically (APHA *et al.*, 1991). Total alkalinity and total acidity was determined titrimetrically using N/50 sulphuric acid and 0.02 M NaCO₃ as titrant and mixed indicator (bromocresol green and methyl red) and phenolphthalein indicators respectively (Ademoroti, 1996b).

For bacteriological analysis, 1ml of water samples collected in sterile glass bottles was five-folds serially diluted in physiological saline and plated on nutrient agar for the total viable bacterial (TVB) count. Plates were incubated at 37°C for 24h and colonies were enumerated. Preliminary identification of Isolates was based on their cultural (colonial), morphological and physiological characteristics and further confirmed using appropriate biochemical tests with reference to the Bergey's Manual of Determinative Bacteriology (2003).

Susceptibility of the isolates to some commonly used antibiotics was carried out using agar disc diffusion method (CLSI, 2008). A 24h old sub-cultured isolate was seeded on Mueller-Hilton agar plate. The antibiotics discs (Gram positive and Gram negative) were firmly placed using sterile forceps on the agar plates. The plates were then incubated at 37°C for 24h. Diameters of zone of inhibition were measured with a transparent calibrated ruler (mm) and compared with the CLSI (2008) standard.

2.4 Statistical analysis

One-way analysis of variance (One-way ANOVA) was used to determine the difference in each physical and chemical variable between sampling sites, and between seasons. The relationship among stations

based on the physico-chemical parameters were analysed using cluster analysis, and the contribution of each variable to seasonal and spatial variability/heterogeneity was determined using principal component analysis Za, (1999). All analyses were performed on SPSS 16.0 software.

3.0 Results

The mean, standard error and range values of all variables investigated in the six sampling stations are presented in Table 1. The hydrogen ion concentration (pH), Conductivity, Total Dissolved Solids (TDS), and Total Hardness showed a similar trend with the mean values being highest at station A and no significant difference was recorded in all sampling stations (Table 1).

Table 1. Mean, standard error and range of physical and chemical variables investigated in the Oke – Afa canal in Ejigbo Local Government, Lagos State

Variables	A	B	C	D	E	F	ANOVA	
							F	P
Water Temperature ($^{\circ}\text{C}$)	28.0 \pm 0.4 (27.0 -29.0)	29.0 \pm 0.4 (28.0 -30.0)	28.1 \pm 0.8 (27.0 -30.5)	28.1 \pm 0.8 (27.0 -30.5)	28.9 \pm 0.8 (27.0 -30.5)	29.3 \pm 0.8 (27.0 -30.5)	0.571	0.721
Apparent Colour (pt-co)	419.9 \pm 125.4 (153 -758.9)	217.9 \pm 55.7 (95.3-326.1)	290.3 \pm 51.8 (153-383.8)	290.0 \pm 98.1 (153-383.8)	297.3 \pm 56.5 (181.9-441.5)	282.8 \pm 62.9 (181.5 - 441.5)	0.834	0.542
True Colour (pt-co)	80.9 \pm 34.3 (37.6-181.9)	88.0 \pm 60.5 (8.8-268.4)	102.5 \pm 55.7 (37.6-268.4)	95.3 \pm 58.9 (8.8-268.4)	95.3 \pm 58.9 (0.0-326.1)	102.5 \pm 65.9 (8.8-297.3)	0.041	0.999
Turbidity (NTU)	18.9 \pm 5.3 (13.7-34.9)	28.8 \pm 12.4 (10.6-37.9)	19.7 \pm 10.2 (4.6-25.8)	12.8 \pm 3.4 (4.6-19.7)	18.9 \pm 5.4 (10.6-34.9)	17.4 \pm 3.9 (10.6-28.8)	1.086	0.401
pH (pH Units)	7.0 \pm 0.2 (6.7 -7.5)	6.9 \pm 0.2 (6.7 -7.5)	6.95 \pm 0.2 (6.7 -7.5)	7.0 \pm 0.2 (6.7 -7.5)	6.8 \pm 0.1 (6.7 -6.9)	6.9 \pm 0.1 (6.7 -7.3)	0.239	0.940
Conductivity (μScm^{-1})	523.0 \pm 155.3 (219 - 900)	490.3 \pm 132.2 (221 - 810)	495.5 \pm 137.8 (222 - 840)	472.8 \pm 110.2 (224 - 710)	500.3 \pm 130.0 (224 - 810)	494.0 \pm 122.3 (222 - 770)	0.015	1.000
TDS (mg^{-1})	307.0 \pm 90.6 (132 - 529)	289.0 \pm 78.6 (132 - 476)	285.3 \pm 80.5 (132 - 494)	273.5 \pm 67.2 (132 - 417)	289.5 \pm 78.9 (132 - 476)	283.8 \pm 74.3 (132 - 453)	0.019	1.000
Total Alkalinity ($\text{mg}^{-1}\text{CaCO}_3$)	43.0 \pm 12.9 (22 - 80)	41.5 \pm 12.1 (22 - 76)	45.5 \pm 11.0 (30 - 78)	43.5 \pm 12.8 (20 - 80)	41.5 \pm 12.3 (14 - 74)	44.0 \pm 10.4 (28 - 74)	0.017	1.000
Total Hardness ($\text{mg}^{-1}\text{CaCO}_3$)	61.8 \pm 8.8 (6.1 -18.4)	55.2 \pm 6.9 (6.4 -17.6)	57.2 \pm 4.2 (6.6 -18.2)	54.3 \pm 6.2 (6.6 -18.2)	60.3 \pm 2.9 (6.6 -18.2)	54.7 \pm 6.8 (6.1 -18.2)	0.252	0.934
Total Acidity ($\text{mg}^{-1}\text{CaCO}_3$)	42.0 \pm 23.9 (6.0 -112.0)	50.5 \pm 26.4 (10.0 -128.0)	53.5 \pm 28.1 (8.0 -132.0)	39.5 \pm 25.8 (6.0 -116.0)	43.5 \pm 22.4 (16.0 -110.0)	44.0 \pm 27.5 (10.0 -126.0)	0.043	0.999
Calcium ion (Ca^{2+}) (mg^{-1})	22.8 \pm 3.0 (16.7 -31.1)	20.1 \pm 2.29 (13.5 -23.8)	20.3 \pm 1.0 (18.2 -23.1)	19.8 \pm 1.9 (14.2 -22.3)	22.2 \pm 0.8 (20.2 -23.8)	19.9 \pm 2.2 (13.5 -23.1)	0.390	0.849
Magnesium ion (Mg^{2+}) (mg^{-1})	2.51 \pm 1.27 (0.4 -5.7)	2.51 \pm 1.27 (0.4 -5.7)	2.51 \pm 1.27 (0.4 -5.7)	2.51 \pm 1.27 (0.4 -5.7)	2.51 \pm 1.27 (0.4 -5.7)	2.51 \pm 1.27 (0.4 -5.7)	0.000	1.000
Sodium ion (Na^+) (mg^{-1})	25.7 \pm 7.3 (11.6 -43.5)	26.8 \pm 8.7 (11.0 -50.6)	26.7 \pm 8.9 (10.5 -51.7)	24.5 \pm 6.1 (11.0 -39.6)	24.3 \pm 7.0 (9.9 -42.9)	26.5 \pm 6.9 (11.6 -43.5)	0.021	1.000
Potassium ion (K^+) (mg^{-1})	11.8 \pm 2.1 (8.1 -17.9)	11.7 \pm 2.2 (7.9 -17.9)	11.4 \pm 2.1 (7.7 -17.4)	11.8 \pm 2.3 (7.9 -18.5)	11.8 \pm 2.4 (7.5 -18.7)	12.3 \pm 2.4 (8.2 -19.4)	0.015	1.000
Bicarbonate ion (HCO_3^-) (mg^{-1})	51.6 \pm 15.5 (26.4 -96.0)	49.8 \pm 14.5 (26.4 -91.2)	54.6 \pm 13.2 (36.0 -93.6)	52.2 \pm 15.4 (24.0 -96.0)	49.8 \pm 14.8 (16.8 -88.8)	52.8 \pm 25.0 (33.6 -88.8)	0.020	0.999
Chloride ion (Cl^-) (mg^{-1})	61.8 \pm 20.8 (23.7 -104.4)	56.1 \pm 17.8 (22.7 -97.5)	54.4 \pm 16.2 (23.7 -89.6)	53.9 \pm 16.2 (22.7 -84.7)	54.2 \pm 15.9 (22.7 -87.6)	54.9 \pm 15.9 (22.7 -84.7)	0.030	0.999
Sulphate ion (SO_4^{2-}) (mg^{-1})	9.5 \pm 4.2 (0.0 -18.1)	10.3 \pm 4.4 (1.8 -19.9)	8.6 \pm 3.3 (1.2 -14.9)	7.9 \pm 3.9 (0.0 -17.5)	10.3 \pm 3.7 (1.2 -18.1)	8.7 \pm 4.2 (0.6 -16.9)	0.059	0.997
Dissolved Oxygen (DO) (mg^{-1})	4.3 \pm 0.75 (2.8 -6.4)	4.5 \pm 0.6 (3.2 -5.6)	4.1 \pm 0.8 (2.0 -6.0)	4.5 \pm 0.8 (2.4 -6.0)	4.5 \pm 1.12 (1.6 -6.8)	4.2 \pm 1.0 (1.6 -6.4)	0.041	0.999
(BOD ₅) (mg^{-1})	1.4 \pm 0.34 (0.8 -2.0)	1.5 \pm 0.41 (0.8 -2.4)	1.1 \pm 0.3 (0.4 -1.6)	1.6 \pm 0.43 (0.8 -2.8)	1.3 \pm 0.3 (0.8 -2.0)	0.7 \pm 0.3 (0.0 -1.6)	0.828	0.546
Phosphate ion (PO_4^{3-}) (mg^{-1})	0.6 \pm 0.2 (0.4 -0.9)	0.6 \pm 0.2 (0.3 -0.9)	0.5 \pm 0.1 (0.2 -0.8)	0.5 \pm 0.2 (0.2 -0.8)	0.6 \pm 0.2 (0.2 -0.9)	0.6 \pm 0.2 (0.2 -0.8)	0.035	0.999
Iron (Fe) (mg^{-1})	0.003 \pm 0.003 (0.0 -0.01)	0.005 \pm 0.01 (0.0 -0.02)	0.01 \pm 0.01 (0.0 -0.03)	0.003 \pm 0.00 (0.0 -0.01)	ND	ND	0.971	0.461
Manganese (Mn) (mg^{-1})	0.020 \pm 0.02 (0.0 -0.08)	0.013 \pm 0.01 (0.0 -0.05)	0.013 \pm 0.01 (0.0 -0.05)	ND	ND	ND	0.632	0.678
Zinc (Zn) (mg^{-1})	0.023 \pm 0.01 (0.0 -0.05)	0.031 \pm 0.02 (0.0 -0.09)	0.019 \pm 0.02 (0.0 -0.07)	0.012 \pm 0.00 (0.0 -0.02)	0.021 \pm 0.01 (0.0 -0.04)	0.003 \pm 0.00 (0.0 -0.01)	0.642	0.671
Cadmium (Cd) (mg^{-1})	ND	ND	ND	ND	ND	ND	-	-
Lead (Pb) (mg^{-1})	ND	ND	ND	ND	ND	ND	-	-
Cobalt (Co) (mg^{-1})	ND	ND	ND	ND	ND	ND	-	-
Chromium (Cr) (mg^{-1})	ND	ND	ND	ND	ND	ND	-	-
Copper (Cu) (mg^{-1})	ND	ND	ND	ND	ND	ND	-	-

N = number of sampling runs. A, B, C, D, E, F = sampling stations. ND = Not detect

The seasonal pattern of variation for each variable is shown in Table 2. Total Alkalinity and Total Acidity

did not show similar trend in the sampling stations. Total Acidity, Conductivity, TDS and Total Hardness

showed a very highly significant difference at $p < 0.001$. Cadmium, Cr, Co and Pb were not detected in all sampling stations. Total Acidity, Conductivity, TDS and Total Hardness, varied significantly ($P=0.001$) while Total Alkalinity, pH showed no significant difference in both sampling seasons. The major ions

(Mg^{2+} , Na^+ , Cl^- , SO_4^{2-}) varied significantly at $P=0.001$ except K^+ and Ca^{2+} which varied ($P=0.05$) in both seasons. Dissolved oxygen and BOD_5 varied in both seasons ($P=0.001$). For the heavy metals, there was no significant difference in any of the seasons (Table 2)

Table 2. Seasonal pattern of variation in the physico-chemical parameters studied

Variables	Dry Season (n=12) Mean± S.E (Range)	Rainy Season (n=12) Mean± S.E (Range)	ANOVA	
			F	P
Water Temperature ($^{\circ}C$)	28.4±0.3 (27.0 -30.5)	28.8±0.5 (27.0 - 30.5)	0.44	0.512
Apparent Colour (pt-co)	275.6±34.6 (95.3 - 441.5)	323.7±46.6 (153.0 - 758.9)	0.685	0.417
True Colour (pt-co)	165.0±32.6 (37.6 - 326.1)	29.7±5.5 (0.0 - 66.5)	16.73	0.000***
Turbidity (NTU)	22.5±2.9 (10.6 - 37.9)	16.4±2.8 (4.6 - 34.9)	2.297	0.144
pH (pH Units)	6.86±0.02 (6.7 - 6.9)	7.03±0.11 (6.7-7.5)	2.17	0.155
Conductivity ($\mu S/cm$)	707.0±32.8 (586.0 - 900.0)	284.92±19.3 (219.0 - 371.0)	122.84	0.000***
TDS (mg/l)	415±19.57 (325.0 - 529.0)	161±8.74 (132.0 - 190.0)	140.39	0.000***
Total Alkalinity ($mg/l CaCO_3$)	49.83±8.3 (14.0 - 80.0)	36.5±1.3 (28.0 - 42.0)	2.53	0.126
Total Hardness ($mg/l CaCO_3$)	65.9±1.7 (62.2 - 84.1)	48.6±2.6 (35.3 - 60.7)	32.05	0.000***
Total Acidity ($mg/l CaCO_3$)	76.5±13.6 (24.0 - 132.0)	14.5±2.3 (6.0 - 34.0)	20.12	0.000***
Calcium ion (Ca^{2+}) (mg/l)	22.9±0.8 (20.9 - 31.1)	18.8±1.0 (13.5 - 23.8)	10.081	0.004
Magnesium ion (Mg^{2+}) (mg/l)	4.6±0.4 (3.4 -5.7)	0.47±0.0 (0.4 -0.6)	133.416	0.000***
Sodium ion (Na^+) (mg/l)	36.9±2.7 (26.3 - 51.7)	14.5±1.1 (9.9 - 19.8)	59.670	0.000***
Potassium ion (K^+) (mg/l)	14.4±1.2 (9.7 - 19.4)	9.2±0.4 (7.5 - 11.2)	16.523	0.001***
Bicarbonate ion (HCO_3) (mg/l)	59.8±9.9 (16.8 - 96.0)	43.8±1.6 (33.6 - 50.4)	2.527	0.126
Chloride ion (Cl^-) (mg/l)	85.0±2.8 (73.9 - 104.4)	26.8±1.2 (22.7 - 32.5)	376.194	0.000***
Sulphate ion (SO_4^{2-}) (mg/l)	2.67±0.7 (0.0 - 8.1)	15.8±0.7 (11.2 - 19.9)	171.835	0.000***
Dissolved Oxygen (DO) (mg/l)	3.1±0.3 (1.6 - 4.0)	5.6±0.2 (4.0 - 6.8)	41.194	0.000***
(BOD_5) (mg/l)	1.7±0.2 (0.0 - 2.8)	0.8±0.1 (0.4 - 1.6)	14.355	0.001***
Phosphate ion (PO_4^{3-}) (mg/l)	0.8±0.0 (0.7 - 0.9)	0.3±0.0 (0.2 - 0.5)	308.132	0.000***
Iron (Fe) (mg/l)	0.004±0.00 (0.00 - 0.03)	0.003±0.002 (0.00 - 0.02)	0.278	0.603
Manganese (Mn) (mg/l)	0.0067±0.01 (0.00 - 0.08)	0.008±0.01 (0.00 - 0.05)	0.037	0.850
Zinc (Zn)(mg/l)	0.014±0.01 (0.00 - 0.05)	0.023±0.01 (0.0 - 0.09)	0.915	0.349
Cadmium (Cd) (mg/l)	ND	ND	-	-
Lead (Pb) (mg/l)	ND	ND	-	-
Cobalt (Co) (mg/l)	ND	ND	-	-
Chromium (Cr) (mg/l)	ND	ND	-	-
Copper (Cu) (mg/l)	ND	ND	-	-

ND- Not detected, *** - Very highly significant

The most probable number (MPN) of bacteria recovered during the study is presented in Table 3. During the early and peak rainy season, the MPN of

bacteria in the sampling stations was between 2.3×10^1 to 1.1×10^3 cfu/100ml while in the early and peak dry season it ranged from 1.1×10^3 to $>1.1 \times 10^3$ cfu/100ml.

Table 3. Most Probable Number (MPN) in the Sampling Stations

Season	Stations	MPN presumptive (cfu/100ml)	Confirmatory	Completed	
				30°C	44°C
Early rain	A	23	ECNP	NA	NA
	B	93	ECNP	NA	NA
	C	240	ECNP	NA	NA
	D	1.1×10^3	ECNP	NA	NA
	E	$>1.1 \times 10^3$	ECNP	NA	NA
	F	240	ECP	G	G
Peak rain	A	$>1.1 \times 10^3$	ECNP	NA	NA
	B	$>1.1 \times 10^3$	ECNP	NA	NA
	C	$>1.1 \times 10^3$	ECNP	NA	NA
	D	240	ECNP	NA	NA
	E	$>1.1 \times 10^3$	ECNP	NA	NA
	F	1.1×10^3	ECNP	NA	NA
Early dry	A	1.1×10^3	ECNP	NA	NA
	B	$>1.1 \times 10^3$	ECNP	NA	NA
	C	$>1.1 \times 10^3$	ECNP	NA	NA
	D	$>1.1 \times 10^3$	ECNP	NA	NA
	E	$>1.1 \times 10^3$	ECNP	NA	NA
	F	$>1.1 \times 10^3$	ECNP	NA	NA
Peak dry	A	$>1.1 \times 10^3$	ECP	G	G
	B	$>1.1 \times 10^3$	ECNP	NA	NA
	C	$>1.1 \times 10^3$	ECNP	NA	NA
	D	$>1.1 \times 10^3$	ECNP	NA	NA
	E	$>1.1 \times 10^3$	ECNP	NA	NA
	F	$>1.1 \times 10^3$	ECNP	NA	NA

NA – Not applicable, ECNP – *E. coli* not present, ECP - *E. coli* present, G – Gas production

The bacterial isolates and their occurrence at different sampling seasons is presented in table 4. Nineteen different bacterial isolates were recovered from all the six sampling stations which include *Bacillus coagulans*, *Corynebacterium renale*, *Acinobacter lowfii*, *Ps. aeruginosa*, *Kl. edwardsii*, *Cellulomonas riazotea*, *Alcaligene faecalis*, *Enterobacter cloacae*, *Chromobacterium bovis*, *Brucella* sp, *Aeromonas veronii*, *Erwinia* sp, *Kl. ozaenae*, *Kl. pneumoniae*, *Ps. pseudomallaei*, *Ps. maltophilia*, *Ps. stutzeri*, *Shigella alkalescens* and *Escherichia coli* (Table 4). *Pseudomonas aeruginosa* and *Kl. Edwardsii* had the highest number of occurrence. The bacterial species diversity was greater in the rainy season than in the dry season ($p \leq 0.001$). Of all the isolated bacteria, only *Ps. aeruginosa* and *Kl.*

edwardsii showed a very high significant level at $p \leq 0.001$ at both dry and rainy season (Table 4).

4.0 Discussion

The seasonal variation of pH value observed in the study was higher in rainy season than in the dry season. This was at variance with results of previous studies by Dublin-Green (1990) on Borny River, where the highest pH values were recorded in the dry season and lower values in the late rainy season. This may have resulted from dilution of waters high in organic content, decaying of domestic and industrial waste litter in the residential area contributing to the acidic nature of the water, and this may affect aquatic organisms because most of their metabolic activities are pH dependent (Adeyemo, 2008). In this study, the temperature range recorded could be attributed to the

insulating effect of increased nutrient load resulting from industrial discharge. However, the study conformed to the report of Ekeh and Sikoki (2003) who recorded a lowest temperature of 25°C in the rainy

season and 30°C in dry season in New Calabar River. This could be due to the influx of water during the rainy season hence making the water cooler than in the dry season where water influx is lower.

Table 4. Frequency of bacterial isolates at different Sampling Seasons

Organisms	Sampling seasons			ANOVA			
	Rain (%)	Dry (%)	Occurrence	Rain Mean±S.E	Dry Mean±S.E	F	P
<i>Aeromonas veronii</i>	2 (16.7)	0	2	1.83±0.11	2.0±0.0	2.200	0.152
<i>Corynebacterium renale</i>	3 (25)	0	3	1.75±0.13	2.00±0.0	3.667	0.069
<i>Bacillus</i> sp	3 (25)	0	3	1.75±0.13	2.00±0.0	3.0667	0.069
<i>Acinobacter lowfii</i>	3 (25)	0	3	1.75±0.13	2.0±0.0	3.0667	0.069
<i>Brucella</i> sp	1 (8.3)	0	1	1.92±0.08	2.0±0.0	1.00	0.328
<i>Escherichia coli</i>	2 (16.7)	1 (8.3)	3	1.83±0.11	1.92±0.08	0.355	0.557
<i>Ps. Maltophilia</i>	1 (8.3)	0	1	1.92±0.08	2.0±0.00	1.000	0.328
<i>Alcaligenes faecalis</i>	1 (8.3)	0	1	1.92±0.08	2.0±0.00	1.000	0.328
<i>Chromobacterium bovis</i>	2 (16.7)	0	2	1.83±0.11	2.0±0.0	2.200	0.152
<i>Erwinia</i> sp	1 (8.3)	0	1	1.92±0.08	2.0±0.0	1.000	0.328
<i>Shigella alkalescens</i>	1 (50)	1 (50)	2	1.9±0.08	1.92±0.08	0.000	1.000
<i>Klebsiella Ozoenae</i>	2 (16.7)	1 (8.3)	3	1.83±0.11	1.92±0.08	0.355	0.557
<i>Ps. aeruginosa</i>	4 (33.3)	12 (100)	16	1.67±0.14	1.0±0.00	22.000	0.000***
<i>Enterobacter cloacae</i>	0 (0)	1 (8.3)	1	2.0±0.00	1.92±0.08	1.000	0.328
<i>Cellulomonas riazotea</i>	2 (16.7)	3 (25)	5	1.83±0.11	1.75±0.13	0.234	0.633
<i>Kl. Edwardsii</i>	3 (25)	12 (100)	15	1.75±0.13	1.0±0.00	33.000	0.000***
<i>Kl. Pneumoniae</i>	1 (8.3)	2 (16.7)	3	1.92±0.08	1.83±0.11	0.355	0.557
<i>Ps. pseudomallaei</i>	1 (8.3)	4 (33.3)	5	1.92±0.08	1.67±0.14	2.302	0.143
<i>Ps. Stutzeri</i>	0 (0)	1 (25)	1	2.00±0.00	1.75±0.13	3.667	0.069

The multiple antibiotic resistance profile of the isolates is shown in table 5. Resistance of isolates to antibiotics was generally high. Fourteen of the isolated bacteria were multiple antibiotic resistant types. Six

(37.2%) showed resistance to two antibiotics; seven (37.2%) to three antibiotics while one (5.3%) was resistant to four antibiotics (Table 5).

Table 5. Multiple antibiotic resistance profile of the bacterial isolates

ORGANISM	NUMBER OF ANTIBIOTICS	MAR PATTERN	Number of organism(%)	Total number of organism (%)
<i>Corynebacterium bovis</i>	2	AMX, CXC	1 (5.3%)	6 (31.7%)
<i>Cellulomonas riazotea</i>		ERY, COT	1 (5.3%)	
<i>Pseudomonas stutzeri</i>		CRO, NIT	4 (21.1%)	
<i>Pseudomonas pseudomallei</i>	3	CRO, NIT, COT	1 (5.3%)	7 (37.2%)
<i>Pseudomonas fluorescens</i>		CRO, NIT, COT	1 (5.3%)	
<i>Klebsiella edwardsii</i>		CRO, NIT, COT	1 (5.3%)	
<i>Corynebacterium renale</i>		CRO, GEN, AMX	1 (5.3%)	
<i>Pseudomonas aeruginosa</i>		CRO, NIT, GEN	1 (5.3%)	
<i>Bacillus coagulans</i>		AUG, AMX, COT	1 (5.3%)	
<i>Acinobacter lowfii</i>		CRO, GEN, CPX	1 (5.3%)	
<i>Klebsiella pneumoniae</i>	4	CRO,NIT,COT, AUX	1 (5.3%)	1 (5.3%)

MAR= Multiple antibiotic resistance, AUG = Augmentin; AMX = Amoxicilin; ERY= Erythromycin; TET = Tetracycline; CXC = Cloxacillin; GEN = Gentamicin; COT= Cotromozazole; CHL = Chloramphenicol; CRO = Ceftriazone; NIT = Nitrofurantoin; OFL = Ofloxazin; CPX = Ciprofloxazin; PFX= Pefloxacin

Phosphate is considered to be the most significant among nutrients responsible for eutrophication of lakes as it is the primary initiating factor. In this study, the phosphate concentration was high in the dry season compared to that recorded in the rainy season. This could be attributed to concentration effect as a result of

reduced water volume during the dry season, while the mean value recorded in the wet season could be due to the dilution effect of rains. Similar findings were observed in Cross River, in Eastern Nigeria by Akpan *et al* (1990). The phosphate concentration in the water was above the 0.1mg⁻¹ of World Health Organization

(W.H.O) standard. The excess gives rise to algal bloom and causes risk to human beings as algae produce toxins, which damage neurological system. In this study, the chloride ion concentration reduced down the sampling stations and was within the WHO permissible limit of 200 mg l⁻¹.

The DO concentration of the water examined showed that the canal was poorly aerated, irrespective of sites since it was below the W.H.O standard for permissible limit. The seasonal variation showed that BOD₅ was higher in dry season than rainy season which conformed to the observations of (Akinbuwa 1988, 1999) on Opa Reservoir and Erinle Lakes, respectively. This could be due to the reduced water volume and high microbial activities during the dry season. The conductivity values of the canal water did not fall within the existing record of standard for African waters as indicated by (2010), since the recorded values during the period of study were higher than 600µScm⁻¹ in some stations. In the present study, the conductivity values were greater than the recommended values and hence the water cannot be safely used for domestic and agricultural purposes.

The Canal water exhibited an overall ionic dominance pattern of Na⁺ > Ca²⁺ > K⁺ > Mg²⁺ and Cl⁻ > HCO₃⁻ > SO₄²⁻. The ionic dominance of the Canal water was in contrast with the ionic dominance pattern of Ca²⁺ > Mg²⁺ > Na⁺ > K⁺ and HCO₃⁻ > SO₄²⁻ > Cl⁻ for freshwater bodies (Karikari and Ansa-Asare, 2005). It is apparent that the dominance of chloride over sulphate could be due to the large amount of domestic wastes being discharged into the canal waters.

The presence of Iron in the study area could be attributed to high organic matter and low dissolved oxygen content, in that Iron can easily be absorbed on particulate organic matter or complexes with colloidal organic matter in aquatic environment as pointed out by Deekae *et al.* (2010). The values of Zn at all the Sites were below the 5.0 mg l⁻¹ highest desirable level in drinking water, though this may not pose immediate visible damage, however when it accumulates, it becomes problematic to aquatic ecosystem.

It is evident from the results obtained in this study that water samples from Oke-Afa Canal were heavily contaminated with potential pathogenic bacteria. The index of the microbial load was high and evidently pronounced bacterial pollution. The same trend was observed during the dry and rainy seasons, though more bacteria were encountered in the dry season. This may be due to the high evaporation of the water and subsequent discharge of waste from the residential buildings and industrial facilities around the area during the dry season.

The Total Heterotrophic Bacteria (THB) recorded at the sampling stations was high in stations A and F during the early rainy season. Comparatively, low THB

count was observed at station C. This indicates the dilution effect of the flowing canal water. This agrees with studies observed by Ekhaise and Anyasi (Ekhaise and Anyasi, 2005) on Ikpoba River in Nigeria, due to the flushing action of deep water and also this station is not covered by the overhead bridge and therefore is exposed to bactericidal effect of sunlight. Odeyemi *et al.* (2010) reported similar findings. The relatively high counts in stations B, D, E and F could be attributed to the incidence of human activities such as defaecation, since bushes are around the canal banks and waste effluents from drains of houses built around the canal banks.

The presence of coliforms such as *E. coli*, *Shigella alkalescens*, *Alcaligenes faecalis* in the water samples during the sampling period in stations A and B indicates faecal pollution. The presence of faecal coliform and *E. coli* in all the water samples clearly shows that the canal water is heavily polluted with human faecal materials. This agrees with the submission of Bakare *et al.* (2003) that the presence of *E. coli* in water samples is an indication of faecal contamination of the river. Thus it can be assumed that canal water is exposed to both site and non-site pollution.

The general increase in heterotrophic indicator organism in early and peak dry season is the period of high risk to most residential homes situated around the canal since there is high possibility that other faecal pathogens are washed down in the same manner due to the erratic slow flow of the canal water and easier percolation to ground water supplies in such homes.

Amongst all the identified bacterial isolates, *Pseudomonas aeruginosa* and *Klebsiella edwardsii* were the most prevalent with a very high significance level. *Pseudomonas aeruginosa* is an autochthonic organism of which biological biocenosis of waters and algal blooms may stimulate their development. Regardless of the auto- or allochthonous origin of *Pseudomonas aeruginosa*, it is an epiphyte bacterium and occurs in surface water at the boundary of phases "stable parts-water" which was the case with Oke-Afa canal. The organisms isolated in the canal are potential pathogens, capable of causing various gastrointestinal disorders in human. Resistance of isolates to antibiotics varied. Resistance to gentamycin was low. This study corroborated the report of Odeyemi *et al.* (2010) that demonstrated low incidence of antibiotic resistance to gentamycin. A similar study by Rice *et al.* (1995) collaborates this phenomenon by affirming that high-level gentamycin resistance is rarely detected among enterobacteria bacteria isolated from the aquatic environment.

High prevalence of resistance to erythromycin, ceftriazone, and amoxicillin in this study could partly

be traced to abuse and co-selection of resistance by the organisms.

Conclusion

The concentration of chemical variables, quality and diversity of bacterial species obtained in the study could be hazardous to human health, riparian users and residential homes situated around the canal. The establishment of continuously, co-coordinately monitoring program in Oke-Afa canal will provide a complete overview for the ecological situation of the canal water.

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