Original Research Article

Assessment of the effect of commercial activities on the surface water quality of Ogun River, Nigeria

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Abstract

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The problem of getting quality water is increasing as untreated effluents are discharged into surface water bodies. The study aim at assessing the impact of wastes generated from commercial activities such as abattoir, sawmill and locust beans processing activities on the Ogun river. The physical, chemical and bacteriological parameters were investigated in the month of May, July and September at the Upstream, Point of Discharged and Downstream. The results of the study revealed that all of the measured parameters show significant difference in their mean except pH and Temperature. The ranges of the means values of all the parameters measured for pH, Temperature, TDS, Cl_2, NO_3, PO_4, Pb, Zn, Cu, BOD_5, DO, COD, TS, TSS and Feacal Coliform were 6.14-7.30, 24.3-27.5^{o}C, 98-200mg/l, 380-1880mg/l, 35-205mg/l, 52-250mg/l, 0.01-0.6mg/l, 0.01-0.72mg/l, 0.01-0.09mg/l, 10-35.89mg/l, 0.1-8.82mg/l, 350-2500mg/l, 1020-40,000mg/l, 690-7000mg/l and 850-9900cfu/ml respectively. From the values, it was discovered that the values Cl_2, NO_3, PO_4, Pb, COD, TS, TSS and Feacal Coliform exceeded the permissible limits of both the WHO and FEPA standard for drinking and wastewater effluent. Pollution of Ogun River water along it courses is evidenced by the high concentrations of pollution indicators, nutrients and trace metals above the acceptable limits. The current water quality status of River Ogun from the discharge of abattoir waste, wood and locust bean processing therefore poses both environmental and health hazards to users. The study showed a need for continuous pollution monitoring programme of surface water in Ogun state. In order to redress this trend and ensure public health safety, Ogun river will need adequate waste treatment before discharge into the water body.

Keyword: Abattoir, Faecal Coliform, Monitoring, Pollution, Quality, Wastewater

INTRODUCTION

Water is a universal resource which, because of its free occurrence in nature, is often taken for granted and abused, abundant as it may seem, water, in its clean state, is one of the rarest elements in the world (Omole and Longe, 2008). Like all scarce resources which have regulations guiding their exploitation, ownership, preservation, and sustenance; water, throughout the world is protected by laws, policies, and regulations in order to prevent abuse (FGN, 2000). There are no fixed standards with respect to water quality, however it is the use to which the water is to be put that determines the quality standard that would be imposed (Anyata and Nwaiwu, 2000).

Water can either be from underground or surface sources. Surface sources of water can be rivers, streams, lakes, ponds e.t.c. Ogun River is of immense importance

geologically, biologically, historically and culturally. The river provides habitat, nourishment and means of transport to countless organisms. The river provides travel routes for exploration, commerce and recreation. The river leaves valuable deposits of sediments such as sand and gravel along the banks on its way to the ocean. Ogun River is a source of domestic water which supports the populations that have settled on either side of the river's course.

However, it is not being well treated – the river is poorly maintained, faeces and domestic wastes are regularly emptied along its banks leaving the river polluted.

Location and operation of abattoirs are generally unregulated; they are usually located near water bodies where access to water for processing is guaranteed and more reason they are often referred to as "Odo-eran" by typical Yoruba people. The animal blood is released untreated into the flowing stream while the consumable parts of the slaughtered animal are washed directly into the flowing water (Adelegan, 2002). According to Sangodoyin and Agbawle (1992) the major source of risk to public health in South Western Nigeria is improper management and supervision of abattoir activities. Abattoir wastes usually are heterogenous, typically organics containing fat, grease, hair, feathers, flesh, manure, grit and undigested feed, blood, bones and process water (Bull *et al.*, 1982; Coker *et al.*, 2001; Nafarnda *et al.*, 2006). The total amount of waste produced per animal slaughtered is approximately 35% of its weight (World Bank, 1998). Verheijen *et al.* (1996) found out that, for every 1000 kg of carcass weight, a slaughtered beef produces 5.5 kg of manure (excluding rumen contents or stockyard manure) and 100 kg of paunch manure (partially digested food).

The organic load of abattoir waste could be very high, for instance, Tritt and Schuchardt (1992) reported a COD level as high as 375000 mg L^{-1} for raw bovine blood. Comparatively, in another study conducted by Mittal (2004), on abattoirs in Québec, Canada, typical values for a range of parameters in abattoirs wash down were given: TS concentrations (2333-8620 mg L^{-1}); TSS (736-2099 mg L^{-1}); while average levels of Nitrogen and Phosphorus were evaluated at 6 and 2.3 mg L^{-1} respectively. Improper disposal systems of wastes from slaughterhouses could lead to transmission of pathogens to humans who may both consume the water directly or indirectly, and cause zoonotic diseases such as Coli Bacillosis, Salmonellosis, Brucellosis and Helminthes (Cadmus *et al.*, 1999).

Excess nutrients also enrich the water body and it becomes choked with organic substances and organisms. When organic matter exceeds the capacity of the micro-organisms in water that break down and recycle the organic matter, it encourages rapid growth, or blooms, of algae, leading to eutrophication. Improper

management of abattoir wastes and subsequent disposal either directly or indirectly into river bodies portends serious environmental and health hazards both to aquatic life and humans.

MATERIALS AND METHODS

River Ogun which is the focus of this research flows through Abeokuta. The Lafenwa segment of River Ogun where an abattoir is located is the main thrust of the research. The abattoir is a small scale business enterprise and it is managed by an association of independent butchers. The slaughtering areas measures 150m in size, fenced with sandcrete blocks, while the floor is made of concrete slab. An average number of slaughtered animals per day are 100- 150 cows, 20-40 goats and sheep.

METHODS OF SAMPLE COLLECTION

Field sampling began in the month of May subsequently July and September 2010 during the rainy season. Ten water samples labeled A1 to A10 (as shown in figure 1) were collected from the sampling locations along the river course as shown in the map above.

At each sampling location, water samples were collected in polyethylene bottles. These bottles were previously washed with non-ionic detergent and finally rinsed with deionised water prior to usage. Before the final water samplings were carried out, the bottles were rinsed three times with the river water at the points of collection. (Table 1)

Samples for micro-biological analysis were collected in 500ml sterilized bottles with its mouth stopped with foil and rubber band. All the samples were preserved at $4^{o}C$ and transported to the laboratory. The water quality parameters measured were Colour, pH, Temperature, Total Dissolve Solids (TDS), Chloride (Cl), Dissolved Oxygen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solids, Total Suspended Solids, Nitrate, Heavy Metals (Lead, Zinc And Copper). Physical and Chemical parameters were determined by instrumental methods and conducted following standard analytical method (APHA 1995). Cationic and anionic constituents were determined by standard titrimetric and spectrophotometric methods, trace and heavy water were determined by Atomic Adsorption Spectrophotometer. The physico-chemical analysis of the various water quality parameters results as well as other heavy and microbial load were compared with WHO (World Health Organisation, 1997) drinking water quality guideline.
The data collected were subjected to Descriptive and inferential statistics such as Analysis of variance (ANOVA) and Duncan's Multiple Range Test using SAS 1999 for Windows
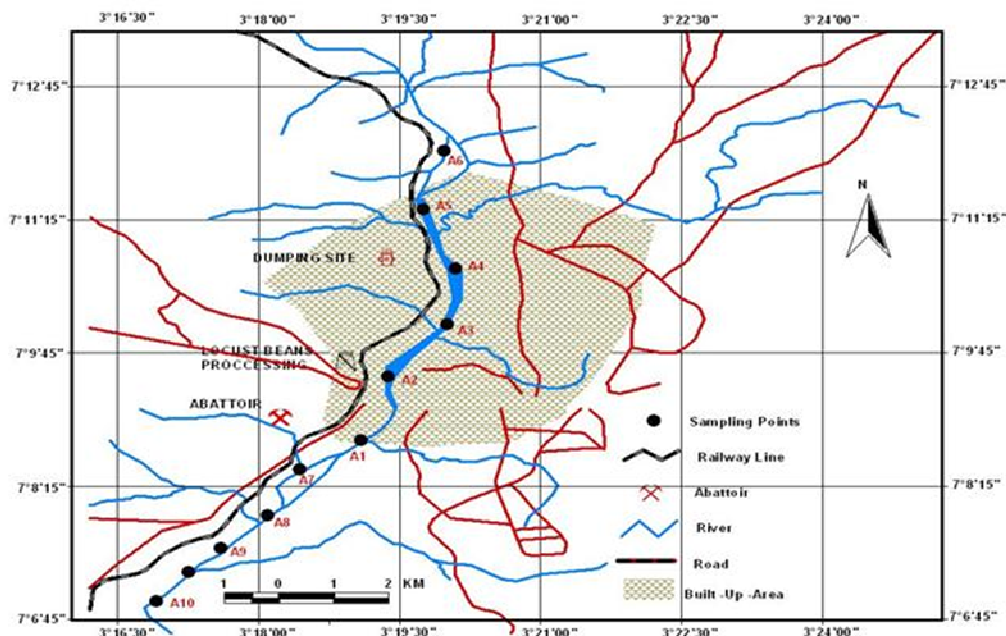
Figure 1. Map of Ogun river showing the sampling locations

Table 1. Description of Sample points and activities

SAMPLING POINT	DESCRIPTION	SURROUNDING ACTIVITIES
A1	Slaughter house for cow, sheep and goat	Skin processing, meat sellers, cooking of food
A2	Washing of Locust beans	Tomatoes sellers, mosque and stores
A3	Wood processing - saw mill	residences and market
A4	Dumping site of waste	Market, residences and bush
A5	A point some distance away after the combination of A1 and A2	Shops and market
A6	A point some distance away after the combination of A3 and A4	residences and saw dust from saw mill
A7	A point after the waste mixes with the river	bush, human faeces along the flow path
A8	Seasonal river flowing through residences	residences, primary school
A9	A point before the waste mixes with the stream	Fishermen
A10	A point before the waste mixes with the stream	Fishermen and residences

RESULTS AND DISCUSSIONS

The quality of Ogun river at the point of discharge of abattoir waste was slightly colored. At the point of production of locust beans, the color was black with impurities due to the washing of locust beans; upstream points had a clear appearance with little impurities while the downstream point after the waste had mixed with the river had light brown coloration. This could be attributed to runoff from the abattoir, dump site and other anthropogenic activities.

The result for the various physical and chemical and bacteriological parameters determined in the water samples from each sampling point along Ogun river are presented below and discussed. The pH value of all the water samples range from 6.14-7.30 from May to September. Generally, the pH values obtained fell within the WHO standard of 6.5-8.5 (WHO 1997). World Health Organization. There was no significant difference between the pH values for the three months in all the collection points at $P<0.05$ significant level. At some points downstream, the pH of A7 became slightly alkaline compared to the other sampling points which were slightly acidic. According to the pH values obtained, majority were in the trend of slightly alkaline. Therefore, the water samples were unlikely to cause health problems such as acidosis (Asamoah and Amorin, 2011). However, pH played a significant role in determining the
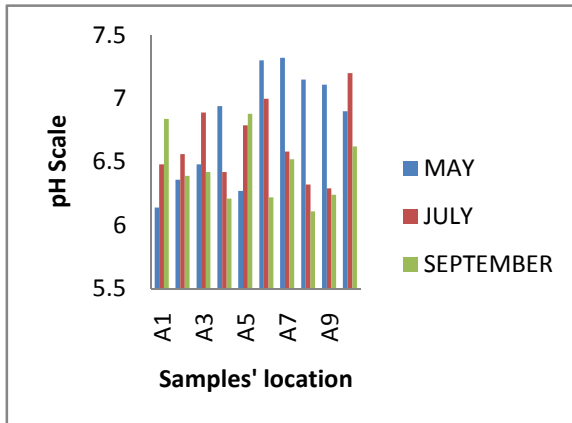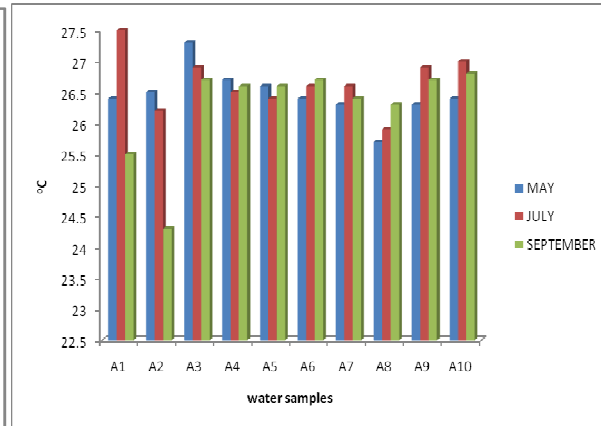
Figure 2. The pH level of the water samples.

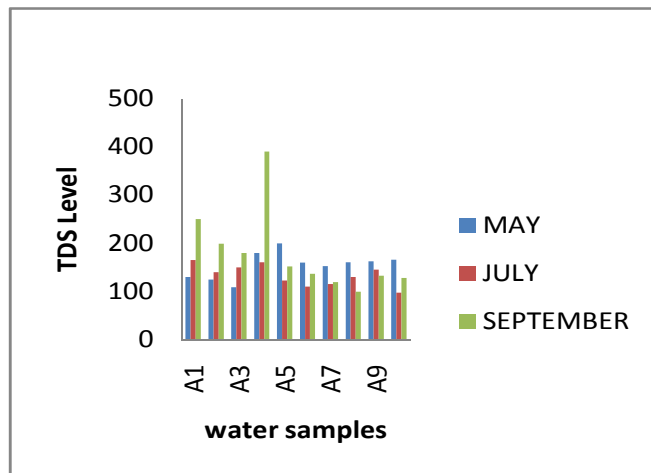**Figure 3.** The temperature level of the water samples

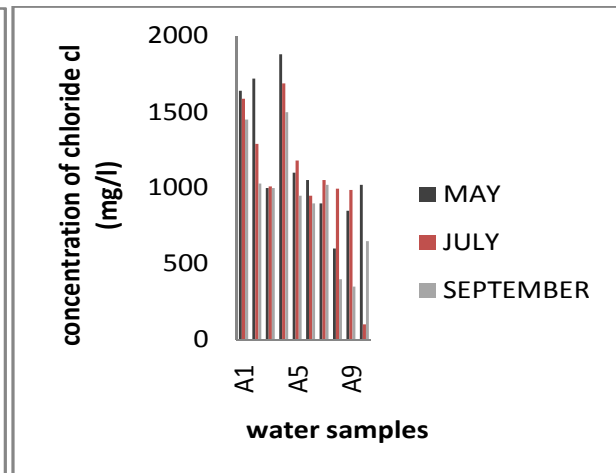**Figure 4.** The TDS level in the water samples

Figure 5. Concentration of Chloride level in water samples

bacterial population growth and diversity in sachet water. Increases in the observed pH, could be attributed to the production of basic metabolic waste products by increasing bacterial population. In their review, Prescott et al. (1999) stated that microorganisms frequently change the pH of their own habitat by producing acidic or basic metabolic waste products.

The average temperature of the ten study location ranges from 24.3 ^{o}C to 27.5 ^{o}C with the month of September generally having the widest range of 24.3 ^{o}C to 27 ^{o}C. The temperature fell within the WHO standard of permissible limit of < 40 ^{o} C. The temperature values obtained throughout the investigation period fall within the optimal growth range for mesophilic bacteria including human pathogens. Prescott et al. (1999) reported 20-45°C as optimal growth temperature for mesophilic microorganisms. According to WHO report (1996), the microbiological characteristics of drinking water are related to temperature through its effects on water-treatment processes and its effects on both growth and

survival of microorganisms. Consequently, growth of microorganisms is enhanced by warm water conditions and could lead to the development of unpleasant tastes and odours. (Figure 2 and 3)

From figure 4, the TDS value of the month of September has the highest value while May has the lowest value. In the month of May, A3 has the lowest TDS value of 109mg/l while A4 has the highest TDS of 180mg/l. In the month of July, A1 has the highest TDS value of 165.2mg/l while A10 has the lowest TDS value of 98mg/l. In the month of September, A4 has the highest TDS value of 390mg/l for all points and this was because A4 is a point of dumping site.

The TDS values obtained range from 98 - 200mg/l which is within the WHO standard of <500mg/l (WHO 1997). High significant values of TDS could be due to salt water intrusion because of short distances to oceans. (Martins and Awokola 1996). (Figure 4 and 5)

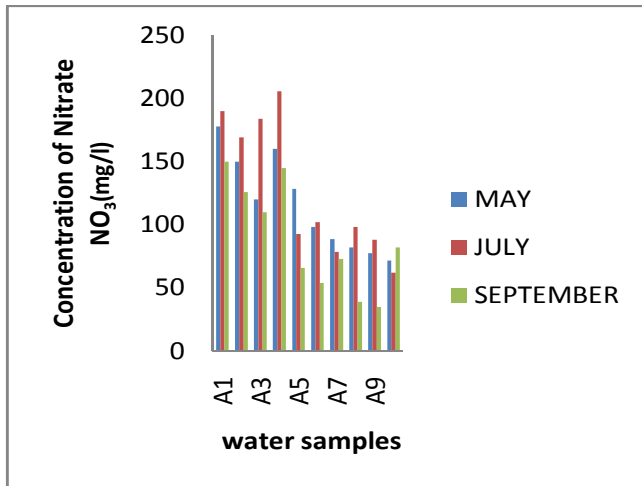From figure 5, the month of May had the highest chloride value of 1900 mg/l as point A4 whereas in the

Figure 6. Concentration of Nitrate level in the water samples
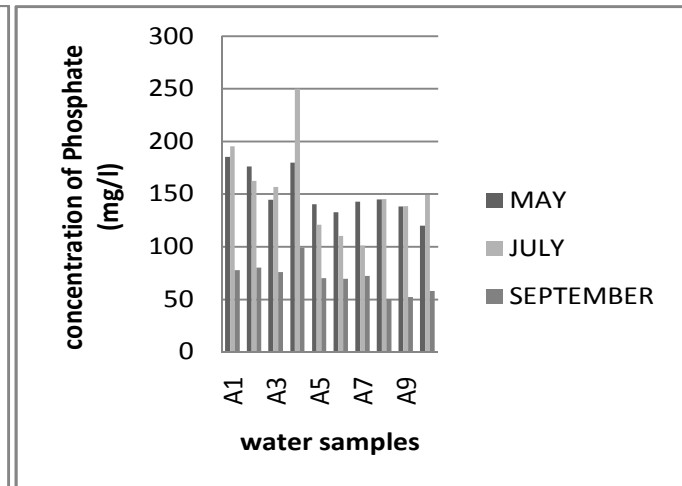

Figure 7. Concentration of Phosphate Level in the water samples

month of May, A9 has the lowest chloride value of 850 mg/l. In the month of July, A1 has the highest chloride value of 1589mg/l while A6 has the lowest chloride value of 980mg/l. Whereas in the month of September Point A1 has the highest value of 1450mg/l and A9 has the lowest value of 380mg/l

The chloride values range from 380 -1880mg/l from May to September which was above the WHO standard of <250mg/l.). This was obviously due to the diffusion of ocean water into the river as a result of tidal action (Ahonkhai and Chukwuogo 1996). The chloride sources could be soluble salt (Nacl and kcl).

The result as obtained in figure 6 showed that the month of September has the lowest value of nitrate 35.0mg/l at some point upstream before the waste mixes with the river water and July has the highest value of nitrate of 205mg/l at some point near a dumping site along the river. In the month of May at a point upstream the lowest nitrate value of 71.8mg/l and the highest value of 178.0mg/l at A1 which is the point of discharge of abattoir waste in the river. In the month of July, A10 has the lowest value of 62mg/l at the point upstream and A4 has the highest value of 205.8mg/l which is a point near a dumping site along the river. In the month of September A9 has the lowest value of nitrate of 35.0mg/l at some point upstream and A1 has the highest value of nitrate which is the point of discharge of abattoir waste into the river. The high values of nitrate recorded at these points may be attributed to commercial activities such as abattoir, sawmill and locust bean production. The disposal of waste is one of the greatest challenges of urbanisation in developing countries. (Figure 6 and 7)

Nitrate the most highly oxidise form of nitrogen compound is commonly present in surface and groundwater because is the end product of the aerobic decomposition of organic nitrogenous matter. Unpolluted surface water usually contain minute amount of nitrate.

The nitrate values obtained range from 35.0mg/l - 205.8mg/l from May to September exceeded the WHO standard permissible limit of <45mg/l.

From figure 7, July has the highest phosphate value of 250mg/l and September with the lowest value of 52.4mg/l in the month of May, A10 which is some meters away upstream had the lowest value of 120mg/l to the highest of 185.4mg/l at A1 which is the point of discharge of abattoir waste into the river. The phosphate values obtained are above the Nigeria Federal Ministry of Environment Maximum permissible value of 0.05mg/l. The high values of phosphate could be attributed to domestic, municipal and abattoir waste (non point sources) flowing into the river as well as washing along the river with detergent. Wastewate treatment into tertiary waste could lead to a decline in phosphorous concentration according to the work carried out by Correll, 1998, in Lake Leman.

From the figure 8 below, the amount of faecal coliform count was recorded the highest and lowest values during the month of July and September with 9900cfu/ml and 850cfu/100ml respectively at point A10 of the stream. In the month of May, A4 which is a dump site of waste had the highest value of 9800cfu/100ml and A9 had the lowest value of 2798cfu/100ml at a point upstream in the month of September. While at the point of discharge of abattoir waste the E.coli count was recorded as 3000cfu/100ml at point A1 signifying that it is not only the abattoir that is contributing to the numbers of E-coli counts within the river system, other factors are responsible for the high number of E-coli as recorded as points A10 which the final lowest point of flow in the study and has many contributing use that washes it waste downstream and A10 had the lowest value of 850cfu/100ml at the upstream point of the river.

All the faecal coliform results from all the site range from 850 – 9900 cfu/100ml which exceeds the WHO
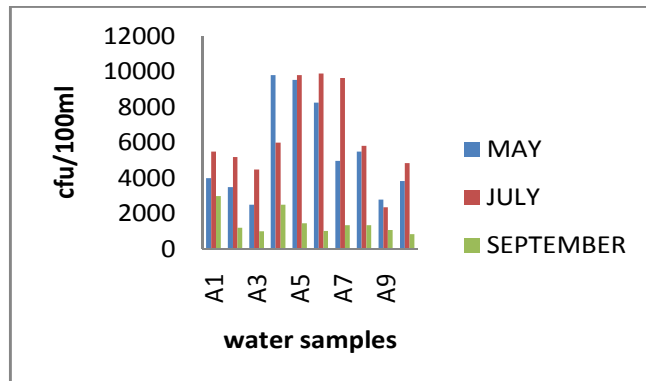
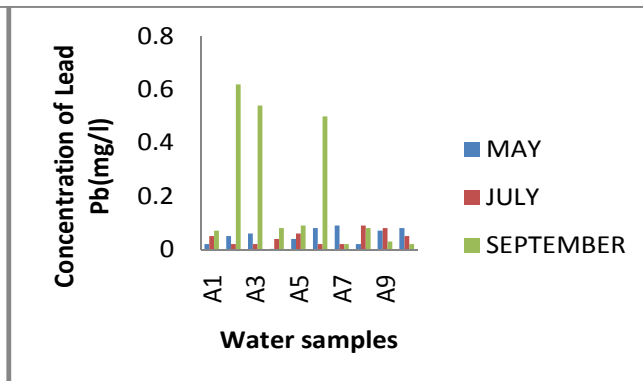**Figure 8.** Concentration of feacal coliform in the water sample

Figure 9. Concentration of Lead in the water sample
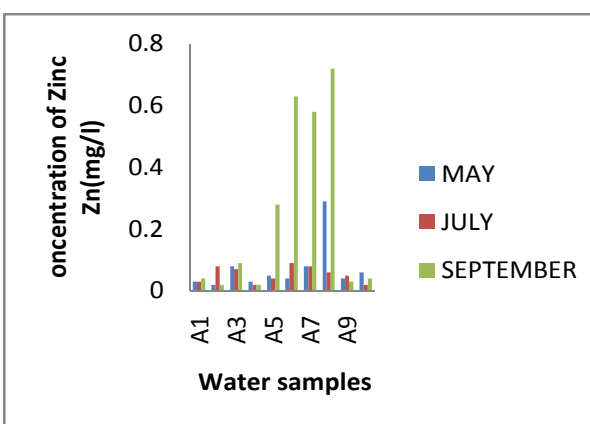

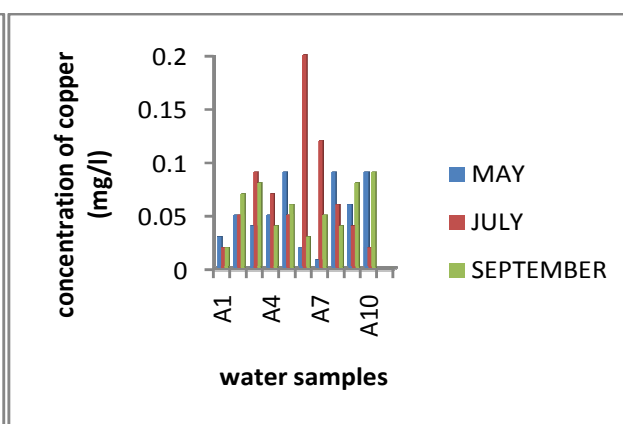**Figure 10.** Concentration of Zinc in the water sample

Figure 11. Concentration of Copper in the water samples

standard of 400Tcfu/100ml. The high faecal coliform value obtained could be attributed to discharges of untreated sewage, animal waste run off, sawmill waste and waste from dumpsite (Fatoki et al, 2001). United Nation Environment programme (1991) attributed high faecal pollution of rivers in developing countries to inadequate sanitation.

It is important to emphasize that the high coliform value obtained might express primary users of water from Ogun river to high risk of water polluted diseases like cholera, diarrhea etc.

Total coliforms are widely used as indicators of the general sanitary quality of treated drinking water while faecal coliforms give a much closer indication of faecal pollution (Ashbolt et. al, 2001). WHO limit is that none should be detected, while FEPA should be 400 Tcfu/100ml. Among the criteria for indicator organisms, Prescott et al. (1999) stated that indicator bacterium should not reproduce in the contaminated water and produce an inflated value. Feacal contamination of drinking water has very serious health implications (Banwart, 2004). The source of these contaminations could be attributed to the deliberate and indiscriminate littering of human and animal waste in adjoining bushes

to the borehole sites. There was a significant difference between faecal coliform and the other parameters.

The concentration of Lead found in the water samples from Ogun river range from 0.6 mg/l in the month of September to 0.01mg/l in the month of May (Figure 9). While the value in the Month of September exceeded the permissible WHO limit, those obtained from the site on the month of May and July does not exceed the WHO standard of 0.1mg/l and this could be attributed to dilution from the dump site. There was a significant difference between lead and the other parameters.

Figure 10 depict the concentration of Zinc as recorded in the month of September and July having the highest and lowest values. The month of May, point A2 and A5 has the lowest and lowest concentration of Zinc of 0.01mg/l and 0.29mg/l respectively.

The values of zinc in the samples range from 0.01 to 0.72 mg/l of the points and in the three period of study, all of which was within the permissible limit of the WHO standard of 5mg/l. They are within the range reported for African inland waters (Calamari and Naeve 1987). There was a significant difference between zinc and the other parameters.
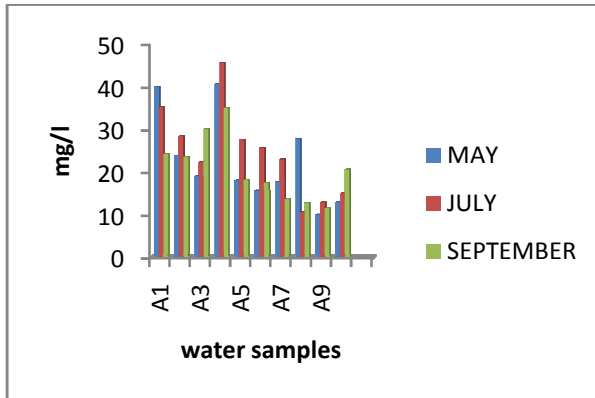
From the figure 11 above, the month of July and May
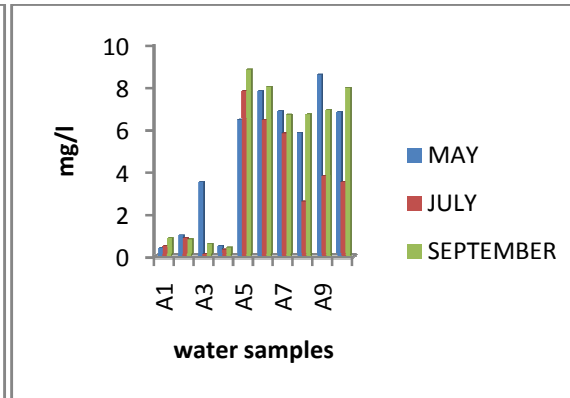
Figure 12. The BOD of the water samples.

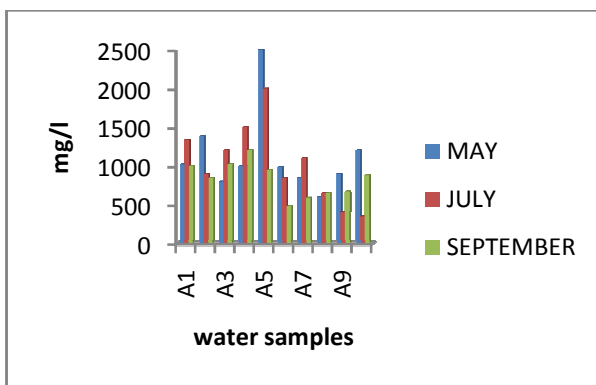**Figure 13.** The DO values of the water samples

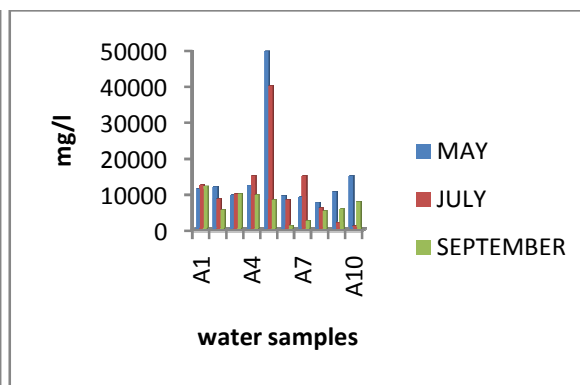**Figure 14.** The COD concentration in the water samples

Figure 15. The concentration of TS in the water samples

had the highest and lowest concentration of copper with values ranging from 0.01 – 0.09mg/l. it is also found that the value of copper in the river were below the WHO standard of 1.0mg/l.

Figure 12 highlight the result so presented for BOD, it was observed that Point A4 has significant high values for all the three period measured with July having the highest (39.85mg/l) which attributed to high abattoir discharged waste following by Point A1 upstream of the River, the lowest value was recorded at point A9 (10mg/l) which is affecting by excess dilution of water to waste. Figure 12 and 13 shown an inverse relationship which is expected, the higher the BOD, the lesser the DO while we can deduce that as the BOD reduces from point A5, there was an improvement in the DO from that same Point A5 to Point A10 along the corridors of flow.

The BOD is an important water quality parameter and is very essential in water quality assessment. Growth of aerobic and facultative anaerobic bacteria will be enhanced by the presence of dissolved oxygen in any waterbody. A decrease in dissolved oxygen was generally observed in all the Points A1-A4 throughout the investigation period; an indication of possible bacterial respiration of organic materials by the bacterial flora of

the River samples tested. WHO (1996) reported that there is tendency for the level of dissolved oxygen to fall with time indicating possible microbial respiration of organic materials amongst other reasons.

The BOD values range from 10.00 - 35.89 mg/l. All the values of BOD in the river samples are within the permissible standard the WHO standard of 50mg/l for waste water. The more organic material presents in the river the higher the BOD.

The DO is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as self purification capacity of the water body. The standard for sustaining aquatic level is 5mg/l. a concentration below this value adversely affect aquatic biological life, while concentration below 2mg/l may lead to death of most fishes, (Chapman,1992).The higher the concentration of DO the better the water quality. The value of DO from River Ogun ranges from 0.1 to 8.82mg/l having largely significant difference between mean values of DO parameters.

The COD value range from 350mg/l in May and 2500mg/l in July being the lowest and highest respectively (See figure 13). High COD values could be due to high organic loading resulting in high Total Solid
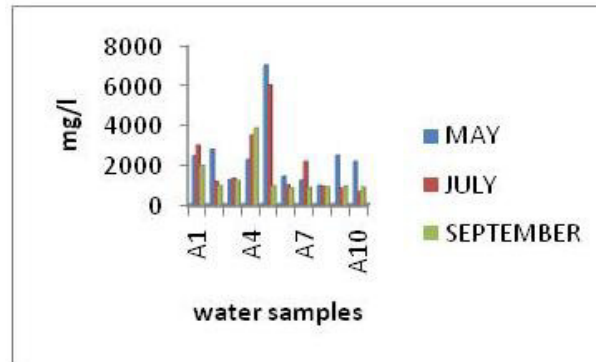
Figure 16. The concentration of TSS in the water samples

materials within the water body as significant in same month and points on figure 15 and thus having a direct relationship to and the Total Suspended Solid concentration in Figure 16. A high value of COD at the downstream points could be attributed to runoff from point of discharge of abattoir waste etc. There was a significant difference between COD means values. The highest TS values of 40,000 mg/l was recorded at Point A5 in July downstream of the river after variable mixing might have occurred and point A10 recording the less concentration as depicted on figure 14. The value of TS range from 1020-40,000mg/l. These values exceeded the permissible WHO standard of 1000mg/l.

The TSS values which ranges from 690 – 7000mg/l is attributed to domestic waste, abattoir waste and dumpsite along the flow path of the river. There was a significant difference between the mean values of TSS. (Figure 16)

CONCLUSION

Physio-chemical and microbiological analyses of surface waters are important in assessing the impact of domestic waste, agricultural waste and waste as a result of commercial activities on such water bodies. there is no doubt that the pollution generated by Lafenwa abattoir, wood processing industry, dumpsite and locust bean production waste is a clear evidence that these industries in Abeokuta, Ogun State has a potential for generating large quantities of waste. the waste generated from the abattoir and dumpsite as high COD, BOD, DO, faecal coliform. The result obtained indicate that river Ogun is highly polluted along Lafenwa flow of the river course. Furthermore using Prati et al (1971) classification of surface water quality. Ogun river fell in the class of grossly polluted water after mixing with waste from the abattoir. While before mixing, it fell in class 3 (slightly polluted). Hence the abattoir urgently needs an waste treatment facility to be installed to reduce the health hazard its waste poses on the abattoir users and users of Ogun river receiving the waste.

This poses a health risk to several communities situated around the river who rely on the river primarily as their source of domestic water. This would worsen scarcity of clean water availability to the generality of the population.

REFERENCES

(2008). Accessed 7th July, 2009

Adelagan JA (2002). Environmental Policy and Slaughterhouse Waste in Nigeria. Proceedings of the 28th WEDC Conference, Calcutta, India. Pp 3-6

Agada OA (1998). Result of baseline studies on water supply and sanitation conducted by Federal Ministry of Water Resources and Rural Development, Nigeria: UNICEF assisted National Water Supply and Sanitation Monitoring Programme-An Overview.FGN-UNICEF WEB Review Meeting, pp: 1-14.

Ahonkhai SI, Chukwuogo EI (1996). Effects of Industrial activities in Warri Area on the Surface Water Quality. In FEPA Monograph (1996). Water Quality Monitoring and Environmental Status in Nigeria. Vol.pp.131-137.

American Public Health Association (APHA) (1995) Standard Methods for the Examination of Water and Wastewater. Washington DC

Anyata BU, Nwaiwu CMO (2000). Setting of Effluent Standards for water pollution Control in Nigeria. Journal of Civil and Environmental Systems Engineering, 1(1), 47-66.

Asamoah DN, Amorin R (2011). Assessment of thequality of bottled/sachet water in theTarkwa-Nsuaem municipality (TM) of Ghana. *Res. J. Appl. Sci. Eng.Technol., 3(5):377-385*Bull, M.A., Sterrit, R.M., and Lester, J.N. (1982) The Treatment of Wastewater from the Meat Industry: A Review, Environ. Technol. Lett., 3: 117-126

Banwart GJ (2004). Basic Food Microbiology, 2nd ed. Chapman & Hall Inc.,NewYork,751 pp.

Cadmus SIB, Olugasa BO, Ogundipe GAT (1999). The Prevalence of Zoonotic Importance of Bovine Tuberculosis in Ibadan, Nigeria. Proceeding of the 37th Annual Congress of the Nigerian Veterinary Medical Association, Kaduna. Pp: 883-886

Calamari D, Naeve H (1987). eds 1994. Review of Pollution in African Aquatic Environment. Committee on Inland Fisheries Association (CIFA) Technical Paper 25. Rome: FAO

Chapman D (1992). Water Quality Assessments a Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. 1st Edn., UNESCO/WHO/UNEP. Chapman and Hall London, pp: 371-460

Coker AO, Olugasa BO, Adeyemi AO (2001). Abattoir Wasterwater Quality in South Western Nigeria. Proceeding on the 27th WEDC Conference, Lusaka, Zambia. Pp: 329-331

Correll DL (1998). The role of phosphorus and eutrophication of receiving waters. A review. J. Environ. Qual., 27, 261-266 (6 pages).

Fatoki SO, Muyima NYO, Lujiza N (2001). Situation analysis of water quality in the Umtata River catchment. Water SA., 27 (4), 467-474

Federal Ministry of Environment (FMENV) (2001). National Guideline and Standard for Water quality in Nigeria (Publ. Federal Ministry of Environment, p. 114)

FGN (2000). Water Supply and Interim Strategy note. Federal Government of Nigeria. Available at: http://siteresources. worldbank.org/NIGERIAEXTN/Resources/wss_1100.pdf. Accessed 17th June, 2010.

Martins O, Awokola OS (1996). Total Dissolved Solids of Selected Rivers in South Western Nigeria. Journal of Mining and Geology 32(2), 113-119

Mittal GS (2004). Characterization of the Effluent Wastewater from Abattoir for Land Application. J. Food Rev. Int., 20: 229-256

Nafarnda WD, Yayi A, Kubkomawa (2006). Impact of Abattoir Waste on Aquatic Life: A Case Study of Yola Abattoir. Global J. Pure Applied Sci. 12:31-33

NESREA (2008). About NESREA. National Environmental Standards and Enforcements Agency.' Available at:http://www.nesrea.org/ about_NESREA.php.

Omole DO, Alonge EO (2007). An Assessment of the Impact of Abattoir Effluents on River Illo, Ota. Nigeria

Prati, L., Pavenello, R and Pesarin, F. (1971) Assessment of Surface Water Quality by a Single Index of Pollution. Water Research 5, 741-751

Prescott LM, Harley JP, Klein DA (1999). The influence of environmental factors on growth. Microbiology. 4th Edition. McGraw-Hill Companies, Inc., USA, pp. 123-132.

Sangodoyin AY, Agbawe OM (1992). Environmental Study on Surface and Groundwater Pollutants from Abattoir Effluents. Bioresour. Technol., 41: 193-200

Tritt WP, Schuchardt F (1992). Material Flow and Possibilities of Treating Liquid and Solid Waste from Slaughterhouses in Germany. Bioresour. Technol., 41: 235-245

United Nation Environmental Protection (1991)

Verheijen LAHM, Wiersema LWD, Hulshoff Pol LW, De Wit J (1996). Management of Waste from Animal Product Processing. Livestock and Environment, Finding a Balance International Agriculture Center, Wageningen, The Netherland.

World Bank (1998). Meat Processing and Rendering: Pollution, Prevention and Abatement Handbook, Environmental Department. 1st Edn. World Bank Washington.

World Health Organisation (1996). International Standard for Drinking Water Quality. Geneva. Switzerland

World Health Organisation (1997). International Standard for Drinking Water Quality. Geneva. Switzerland