Preliminary Investigation of the State of Pollution of Ogun River at Kara Abattoir, Near Berger, Lagos

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Full Length Research Paper

Preliminary Investigation of the State of Pollution of Ogun River at *Kara* Abattoir, Near Berger, Lagos

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Abstract

Intense pollution pressures are exerted on Ogun River, especially at Kara abattoir, by human activities. This river serves as a source of drinking water for the cattle waiting to be slaughtered. It is equally used for domestic activities by the residents along its bank. On daily basis, huge quantities of meat products are transported into Lagos and surrounding states for consumption from the *Kara* abattoir. The consumption of the meat products from the abattoir could pose a great health risk to all consumers. Uptake and accumulation of toxic heavy metals by aquatic organisms from water and sediment are possible. The physic-chemical parameters as well as the heavy metal contents of water and sediments from Ogun River at *Kara* were assessed. Sample digestion was carried out using concentrated nitric acid and the extracts analysed using Atomic Absorption Spectrophotometer. The physic-chemical parameters revealed a high pollution of the river. Water analysis revealed that Cd (0.009 to 0.016mg/L), Cr (1.286mg/L), Fe (0.428 to 2.486mg/L) and Pb (0.109 to 0.109mg/L) exceeded WHO limits. Sediment analysis revealed that Cu (1.51 to 7.04mg/Kg), Zn (4.51 to 43.44mg/Kg), Fe (65.78mg/Kg) and Pb (15.12mg/Kg) exceeded FME limits.

Keywords: Abattoir, Ogun River, Heavy metals, Physico-chemical parameters, Water, Sediment, Atomic Absorption Spectroscopy, Risk assessment.

INTRODUCTION

Pollution is one of the menaces currently threatening human existence on the planet earth. Pollution became a popular issue after World War II, due to radioactive fallout from atomic warfare and testing. The causes of the problem of environmental pollution in our society are not far-fetched. Population explosion, industrialization, urbanization and agricultural activities are the major causes of damage to our environment. These all contribute to the global environmental problems of air and water pollution, solid waste, occupational health and safety, ozone layer depletion, acid rain, green house effect and global warming (Ademoroti, 1996). Also, man's ignorance of the laws of nature and his over-exploitation of natural resources further aggravates the problem. Such is the case at *Kara* abattoir, popularly known as *Kara* market, which is on the outskirt of Lagos, along Ibadan-Lagos Expressway, near the popular Ojudu Berger Bus stop. The *Kara* abattoir is one of the many abattoirs along the river's course. The abattoir itself is very significant to the residents of the area and those of the metropolitan megacity of Lagos. The significance of the abattoir lies in its role in the daily life and activities of the residents. Over 50% of the meat consumed daily in Lagos city is from the *Kara* abattoir.

Ogun River is a significant river in the western part of Nigeria. The river is a waterway that rises in Oyo State near Shaki at coordinates 8°41′0″N 3°28′0″E and flows through Ogun State and discharges into the Ikorodu axis of the Lagos Lagoon at coordinates 6.745589°N 3.34259°E. At one time, the river formed an

ABBREVIATIONS

BOD - Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
DNA – Deoxyribonucleic acid
EQS – Environmental Quality Standard
FME – Federal Ministry of Environment
FTU – Formazin Turbidity Unit
TDS – Total Dissolved Solids
TS – Total Solids
TSS – Total Suspended Solids
WHO – World Health Organization

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important route for traders carrying goods by canoe between Abeokuta and the Lagos Colony. In densely populated areas the river is used for bathing, washing and drinking. It also serves as a drain for mostly organic wastes from abattoirs located along the river's course (Ikenweirwe et al., 2007). The wastes generated from the *Kara* abattoir are mainly cow droppings, waste water, unused animal feeds, ash, black smoke, gaseous emissions and partially combusted materials. Others include plastics, metal scraps, used cans and tins, domestic wastes, sewage wastes, agricultural wastes, industrial wastes, and market-related wastes. In a study conducted on five slaughterhouses in Ibadan, Nigeria, it was found that Total Suspended Solids was between 590 to 1050 times the accepted limited (Omole, and Ogbiye, 2013).

Discharges from industries such as petroleum, mining, iron and steel, pharmaceuticals, and textiles among others have increased the contents of sulfates and nitrates in water bodies and has altered properties such as color and odor (Adelegan 2004). Woke et al. (2007) reported that common wastes from abattoirs include condemned meats, undigested ingesta, bones, horns, hairs, aborted foetuses, blood, gut contents, urine, waste water, bile, dissolved detergents, chemicals, faeces, hooves, heads, slurry of suspended solids and other organic materials.

Such wastes are a big risk as they are hazardous to health. They are known to contain heavy metals and persistent organic pollutants. The metals and other chemical substance increase the toxicity of water bodies as well as soils. This preliminary study will be more concerned with the heavy metals in the water and sediments of Ogun River.

Metals are notable for their wide environmental dispersion from such activity; their tendency to accumulate in select tissues of the human body; and their overall potential to be toxic even at relatively minor levels of exposure. Some metals, such as copper and iron, are essential to life and play irreplaceable roles in, for example, the functioning of critical enzyme systems. Other metals are *xenobiotics*, i.e., they have no useful role in human physiology (and most other living organisms) and, even worse, as in the case of lead and mercury, may be toxic even at trace levels of exposure. The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals that are harmful to humans include mercury, lead, and arsenic. Chronic exposure to these metals can have serious health consequences. Humans are exposed to heavy metals through inhalation of air pollutants, consumption of contaminated drinking water, exposure to contaminated soils or industrial waste, or consumption of contaminated food. Food sources such as vegetables, grains, fruits, fish and shellfish can become contaminated by accumulating metals from surrounding soil and water. Heavy metal exposure causes serious health effects, including reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Today, much more is known about the health effects of heavy metals. Despite abundant evidence of these deleterious health effects, exposure to heavy metals continues and may increase in the absence of concerted policy actions. Mercury is still extensively used in gold mining in many parts of Latin America. Arsenic, along with copper and chromium compounds, is a common ingredient in wood preservatives. Lead is still widely used as an additive in gasoline. Increased use of coal in the future will increase metal exposures because coal ash contains many toxic metals and can be breathed deeply into the lungs. The presence of these metals in Ogun River can have serious health consequences. The Ogun River serves as a sink for all the wastes from the abattoir and also as the source of drinking water for the animals. During our visit to the area, people were seen washing whole slaughtered goats, sheep and cow parts in the river. Hence, consumers of the milk and meat products from the abattoir may be at risk of chemical poisoning and health complications arising from the dangerous organic pollutants and heavy metals. There is also the possible risk of fish poisoning and contamination in the river and this can exposes humans at the top of the food chain to diseases associated with heavy metals. Urgent and adequate attention should therefore be given to the issue of pollution of Ogun River at *Kara* abattoir. It is important to know how to control, minimize or prevent pollution to ensure a safe environment for our generations yet unborn and therefore, achieve sustainable development (Bhatia, 2002). The decline of water quality due to land-based human activities, such as the introduction of sewage and wastewater from industrial, domestic, and agricultural runoff as well as coastal urbanization, are priority issues in West Africa (UNEP/GPA 2006). The objectives of this study therefore are: To assess the physic-chemical parameters of the water and sediments of Ogun River at *Kara* abattoir; and to carry out a preliminary investigate on the chemical availability of heavy metals in the water and sediments of Ogun River at *Kara* abattoir. Figure 1,2 and 3.

MATERIALS AND METHODS

Sample collection

The water samples were randomly collected at five different points along the river, during a mild rain, in amber glass bottles and properly labeled. The sediment samples were also collected at the same points using Ekman sediment grab sampler. The samples were wrapped in aluminum foil, labeled and stored at temperature below 4oC prior to extraction. The sample locations are shown in table 1.

Figure 1. Ogun River at *Kara* abattoir viewed from the bridge top

Figure 2. *Kara* abattoir wastewater discharging into Ogun River

Figure 3. A herd of cattle drinking from Ogun River at *Kara* abattoir

Table 1. Samples locations.

LOCATION CODE	GPS READING	DESCRIPTION OF LOCATION
S1	Elevation :9m N06˚38'51.5" E003˚28'00.1"	Near the dredged area, upstream.
S2	Elevation:11m N06˚38'55.4" E003˚22'45.6"	At the point where a smaller stream joins the Ogun river.
S3	Elevation:17m N06˚38'45.2" E003˚22'48.9"	At the point where the abattoir wastewater discharges into the river, upstream just before the bridge.
S4	Elevation: 5m N06˚38'41.9" E003˚22'54.1"	Near a dump site, downstream just after the bridge.
S5	Elevation:11m N06˚38'38.0" E003˚23'02.6"	Near new Isheri village by Golden Spring hotel, downstream after the bridge.

Sample preparation and analysis for metals

Each of the five water samples was thoroughly shaken together. Then, 100ml of each was transferred into a beaker and 5ml of concentrated nitric acid was added. The beaker was placed on a hot plate and evaporated to dryness. It was then cooled and another 5ml concentrated nitric acid was added. Heating was continued until a light-coloured residue was observed. Then 1ml concentrated nitric acid was added and the beaker was warmed slightly to dissolve the residue. The walls of the beaker were then washed with distilled water. The extract was filtered and cadmium, iron, copper, manganese, lead, chromium, cobalt, nickel and zinc were determined in the filtrates using the Atomic Absorption Spectrophotometer.

About 5g of each of the five air-dried, sediment samples, passed through a 2mm sieve, was digested with 10ml nitric acid in a standard conical flask until the brown fumes disappeared. Each was cooled and distilled water added to make up to 50ml in the standard conical flask. The extract was filtered and cadmium, iron, copper, manganese, lead, chromium, cobalt, nickel and zinc were determined in the filtrates using the Atomic Absorption Spectrophotometer.

Determination of physicochemical parameters

Colour

The colour was determined using HACH DR 2000 direct reading spectrophotometer, method 8025. Each sample was first filtered and measured against previously filter deionized water as blank at wavelength of 455nm.

pH

The pH of each water sample was estimated using Test-2 pH meter. The pH meter was first of all standardized against buffer solutions ph4, 7, and 9.2 after which samples were tested in.

Electrical conductivity

The electrical conductivity of each water sample was measured using potable combine Electrical conductivity/TDS/Temperature meter (HM Digital COM-100). The electrical conductivity meter was standardized with 342ppm sodium-chloride calibration solution after which the different water samples were tested in turn.

Turbidity (FTU)

The turbidity of each water sample was measured using HACH DR 2000 direct reading spectrophotometer method 8237. The turbidity of the sample was estimated against deionized water as a blank at a wavelength of 450nm.

Total Solids (TS)

The total solid was determined gravimetrically by taking aliquot of each water sample in a clean, dry beaker. He water was then evaporated on a hot plate until all the water was almost dry. The drying process was completed in an oven whose temperature was set at 150˚C. The difference in mass of empty beaker and the beaker containing the solids was computed.

Total Suspended Solid (TSS)

The TSS of each water sample was measured using HACH DR 2000 direct reading spectrophotometer, method 8006. The TSS of each sample was estimated against deionized water as blank at a wavelength of 810nm.

Total Dissolved Solids (TDS)

The TDS of each water sample was measured using potable combine Electrical conductivity/TDS/Temperature meter (HM Digital COM-100). The electrical conductivity meter was standardized with 342ppm sodium chloride calibration solution after which the different samples were tested in turn.

Nitrate (NO_3^- N)

The nitrate was determined using the HACH DR 2000 direct reading spectrophotometer method 8039. The HACH nitraVer 5, nitrate pillow was used in 25ml of water sample against sample not treated with nitraVer 5 reagent as blank at a wavelength 0f 500nm.

Phosphate (PO_4^{3-} P)

The phosphate was determined using the HACH DR 2000 direct reading spectrophotometer method 8048. The HACH phosver 3, phosphate powder pillow reagent was used in 25ml of the water sample against deionized water as blank at a wavelength of 890nm.

Dissolved Oxygen (DO)

The DO of each water sample was determined using a portable Orion 3. DO meter. The DO meter was calibrated with water saturated with air after which the different water samples were tested in turn.

Biological Oxygen Demand (BOD_5^{20})

The BOD was determined using the Winkler method. The method involves estimating the dissolved oxygen content of the water sample at zero day (day of sampling) and then, the fifth day of five days of incubation at 20˚C in the dark against a blank.

Chemical Oxygen Demand (COD)

0.4g of $HgSO_4$ was placed in a reflux flask and 20ml of water sample was added and mixed properly. 10ml of 0.25N K_2Cr2O_7 solution, four seeds of antibumping granules and 30ml of H_2SO_4-Ag_2SO_4 reagent were added and the flask was then connected to the condenser, and slowly heated. The mixture was refluxed for 2 hours, then cooled and the walls of the condenser washed down into the flask with distilled water. The resulting mixture was diluted to 150ml and titrated with 10N FAS solution using ferroin as indicator. A colour change from blue green to wine red indicated the end point. A blank experiment with distilled water in place of sample was also performed. The procedure was repeated for each sample and the COD value calculated.

Oil and Grease

The oil and grease was determined using the HACH DR 2000 direct reading spectrophotometer method 8041. The solvent, 1,1,1-trichloroethane was used to extract aliquot portions of the water samples against fresh pure 1,1,1-trichloroethane as the blank at a wavelength of 450nm.

Alkalinity

The alkalinity was determined by the acid-base titrimetric method. Aliquot portion of each water sample was titrated with standard solution of sulphuric acid (0.05M) using methyl orange as indicator.

Acidity

Two drops of phenolphthalein indicator was added to 50cm3 of each water sample. Each was then titrated with 0.02N NaOH until the colour changed to faint pink, characteristic of pH 4.5. Acidity as mg/L $CaCO_3$ was calculated.

Total Hardness

100cm^3 of water sample was measured into a 250cm^3 conical flask and 2.0ml buffer solution was added and mixed. Eight drops of Erichrome black T indicator was introduced followed by titration with 0.01M EDTA solution. A colour change from wine red to pure blue indicated the end point. The entire procedure was carried out for each of the water samples. The Total hardness, for each sample, was then computed in mg/L $CaCO_3$.

Calcium Hardness

100cm^3 of the water sample was measured into a 250cm^3 conical flask and 1cm^3 of 4M NaOH and 200g of munexide indicator were added. This was then titrated with 0.01M EDTA to a violet colour end point. The procedure was repeated for each water sample and the hardness computed in mg/L $CaCO_3$.

Cation Exchange Capacity (C.E.C)

The C.E.C of each sediment sample was determined by reading the concentrations of Na^+, Ca^{2+}, Mg^{2+} and K^+ in each sample using the AAS.

Moisture

The moisture content of the sediment samples was determined by gravimetric method at 105˚C.

RESULTS AND DISCUSSIONS

Physicochemical parameters of Ogun River water and sediment

The physicochemical parameters of the water and sediment samples are shown in tables 2 and 3.

The results indicated high risk of contamination when compared with the UNEP and WHO limits for effluents discharged into rivers. The risk was even more pronounced at point S3 where the abattoir wastewater discharges into the river.

The colour of the Ogun River water at *Kara* was yellow at all the points. This was possibly caused by the discharge of waste from the abattoir, domestic, sewage, agricultural, industrial, and market-related sources, and even human faeces. Human faecal contamination (e.g. faecal coliforms) in water and in biota (mainly shellfish) destined for human consumption indicate the presence of other human derived microbial pathogens. Microbial pathogens can accumulate in filter feeding organisms to levels that can be harmful to humans and perhaps other consumers (e.g. birds) (Cole et al., 1999). The bacterial contaminant load of this water would likely be very high. Studies in the Sakumo catchment between the cities of Accra and Tema (Yawson, 2004) showed that such high bacterial loads makes the water unfit for contact with humans.

The pH of the water which ranged from 7.00 to 7.89 was within the WHO and UNEP limits of 6.5 - 9.2 and 5.5 - 9.0 respectively. Water conductivity ranged from 167.00 to 194.00µSm, and was within the WHO limit of 250 µSm. Water turbidity which ranged from 63.00 FTU at WS4 to 161.00 FTU at WS3 were all above the WHO limit of 5-25 FTU.

Total solids (TS), total suspended solids (TSS) and total dissolved solids (TDS) ranged from 82.50 – 93.90, 1.60 – 2.40 and 81.00 – 92.00ppm respectively. Waste generated by abattoirs include solid waste, made up of paunch content, bones, horns, and faecal components; slurry of suspended solids, fat, blood and soluble materials (Sangodoyin et al., 1992) The level of suspended solids depends on a variety of factors including: substrate type, river flow, tidal height, water velocity, wind reach/speed and depth of water mixing (Parr *et al.,* 1998). The level of suspended solids can be enhanced by anthropogenic activities in the river catchment as well as within the river.

Dissolved oxygen (DO), ranged from 2.6 to 4.0. The major factor controlling DO concentrations is biological activity: photosynthesis producing oxygen and respiration and nitrification consuming oxygen. It was observed that where the DO was low, the biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were high. According to Cole et al. (1999), oxygen demand results principally from the microbial degradation of organic matter and from nitrification, although some chemical oxidation may also be taking place (hence biochemical oxygen demand). Alkalinity ranged from 12.00 to 20.00ppm; Acidity ranged from 2.50 to 4.0; total hardness ranged from 48.00 to 80.00ppm; and calcium hardness ranged from 32.00 to 60.00ppm. It was observed that point WS3 had the lowest acidity and the highest alkalinity, calcium hardness and total hardness. Cadmium uptake from water by aquatic organisms depends on the species and various environmental conditions, such as water hardness (notably the calcium ion and zinc concentration), salinity, temperature, pH, and organic matter content.

The majority of chelating agents decrease cadmium uptake but some, such as dithiocarbamates and xanthates, increase uptake. Increasing temperature increases the uptake and toxic impact, whereas increasing salinity or water hardness decreases them (Cole et al., (1999). The physicochemical parameters indicated that the level of pollution of the Ogun River water varied at different locations but the statistical analysis gave a clearer picture of the water pollution situation across the different locations of the river. Levene’s test for the physicochemical parameters in Ogun river water which gave p value $< .05$ (.986) showed that variance was homogeneous for this group of samples. ANOVA test with p value of .877 accepted the null hypothesis that physicochemical parameters in Ogun river water at different locations were not significantly different (were equal) therefore could not be relied upon in this case. Thus Kruskal Wallis test with p value of .951, though also accepted the null hypothesis, was more reliable.

Multiple comparisons using a Post Hoc tests (Tukey HSD and Duncan tests) statistically compared the physicochemical parameters in Ogun River water at five locations with respect to a single location. Both tests showed that all the locations accepted the null hypothesis with p value of .874 and .404 respectively, indicating no statistical significant difference in physicochemical parameters in Ogun river water at all

Table 2. Physicochemical parameters of Ogun River water at *Kara*.

Parameter	WS1	WS2	WS3	WS4	WS5	Sample Mean	WHO Limit WHO (2001)	UNEP Limit Dara, (1993).
Colour	Light yellow	Light yellow	Light yellow	Light yellow	Light yellow	Light Yellow	-	---
pH	7.00	7.89	7.85	7.88	7.89	7.70	6.5-9.2	5.5-9
Conductivity (µsm)	167.0	192.0	194.0	171.0	172.0	179.2	250	
Turbidity (FTU)	**64.0**	**87.0**	**161.0**	**63.0**	**69.0**	**88.8**	5-25	
TS (ppm)	82.50	93.90	93.60	83.40	82.50	87.18		
TSS (ppm)	2.20	1.90	2.50	2.40	1.60	2.12	-	100
TDS (ppm)	80.30	92.00	91.10	81.00	80.90	85.06	1500	2100
NO_3 (ppm)	32.40	27.60	29.40	31.20	30.60	30.24	100	18
PO_4 (ppm)	**17.80**	**15.30**	**23.30**	**17.20**	**17.50**	**18.22**	50	5
DO (ppm)	3.2	2.8	2.6	3.3	4.0	3.18		
BOD (ppm)	**40**	**55**	**52**	**41**	20	**41.6**		30
COD (ppm)	90	106	102	96	44	87.6		250
Alkalinity (ppm)	12.0	16.0	20.0	16.0	12.6	15.32	120	
Acidity (ppm)	4.00	3.40	2.50	3.20	3.70	3.36		
Total hardness (ppm)	48.0	60.0	80.0	76.0	72.0	67.2	500	
Ca Hardness (ppm)	32.0	40.0	60.0	52.0	48.0	46.4		NA

* Highlighted values indicate pollution.

Table 3. Physicochemical parameters of Ogun River sediment at *Kara* abattoir.

Parameter	Samples					Sample mean
	SS1	SS2	SS3	SS4	SS5	
pH	8.24	7.40	7.75	8.20	7.36	7.79
Conductivity (µSm-1)	53.80	187.0	103.0	20.60	365.0	145.88
Moisture (%)	43.39	18.98	25.24	21.58	71.06	36.05
C.E.C (meq100g)						
A) Na^+	0.04	0.020	0.120	0.013	0.130	0.065
B) Ca^{2+}	0.139	0.341	0.442	0.231	0.432	0.317
C) Mg^{2+}	0.022	0.110	0.132	0.121	0.132	0.1034
D) K^+	0.010	0.012	0.014	0.016	0.019	0.0142

the locations. This was an indication that the entire water was generally polluted. The physicochemical parameters of the water therefore showed that the wastewater from the abattoir and the surrounding was highly contaminated and posed a great danger to aquatic lives, the river and its users. The Ogun river is therefore unfit for human and animals (cattle, goat, sheep, etc which drink freely from the river) consumption.

The pH of the sediment ranged from 7.40 to 8.24. Sediment conductivity ranged from 20.60 to 365.00 μSm^{-1}, with locations SS5 and SS2 having the highest values of 365.00 μSm^{-1} and 187.00 μSm^{-1} respectively. Table 3 shows the cation exchange capacity (CEC) of the sediment. Ca^{2+} was found to be higher (ranging from 0.139 meq100g at SS2 to 0.442 meq100g at SS3) than the other metals (ranging from 0.010 meq100g of K^+ at SS1 to 0.132 meq100g each of Mg^{2+} at SS3 and SS5).

Nutrients status in Ogun River at *Kara* abattoir

The concentrations of nutrients (nitrogen and phosphorus) obtained as nitrates and phosphates are shown in figure 3. The nitrate concentrations in the water column which ranged from 27.60 to 32.40ppm were found to be higher at all the sample points than the phosphates which ranged from 17.20 to 23.30ppm.

The nutrient levels were lower than the WHO limits at all the points. On the other hand, they all exceeded the UNEP limits. However, the phosphate concentration at S3 (figure 4), the point where the abattoir wastewater discharges into the river, upstream just by the bridge was higher than the nitrate at other points. According to Cole et al., (1999), phosphates contribute to turbidity in the water column with potential to suppress production of phytoplankton, macroalgae and other submerged

Table 3. Physicochemical parameters of Ogun River sediment at *Kara* abattoir.

Parameter	Samples					Sample mean
	SS1	SS2	SS3	SS4	SS5	
pH	8.24	7.40	7.75	8.20	7.36	7.79
Conductivity (µSm-1)	53.80	187.0	103.0	20.60	365.0	145.88
Moisture (%)	43.39	18.98	25.24	21.58	71.06	36.05
C.E.C (meq100g)						
E) Na^+	0.04	0.020	0.120	0.013	0.130	0.065
F) Ca^{2+}	0.139	0.341	0.442	0.231	0.432	0.317
G) Mg^{2+}	0.022	0.110	0.132	0.121	0.132	0.1034
H) K^+	0.010	0.012	0.014	0.016	0.019	0.0142

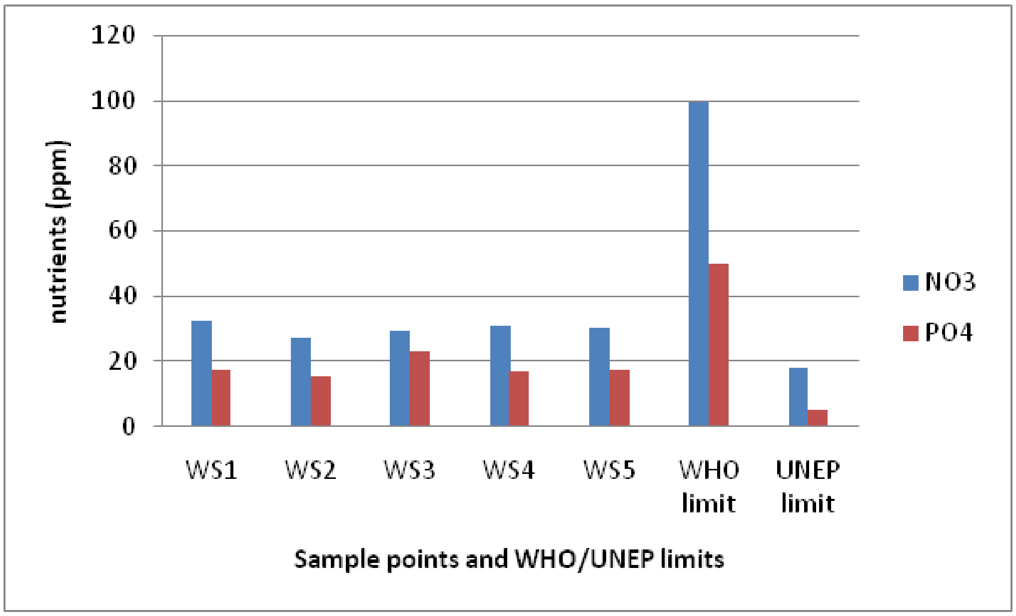

Figure 4. Concentrations of nutrients in the water of Ogun River at *Kara*

aquatic plants. This was in agreement with our result which reflected highest turbidity of 161.00 FTU at S3 (point with highest phosphate concentration) compared to other sample points which ranged from 63.0 FTU at S4 to 87.0 FTU at S2, a point where a smaller stream joins the Ogun river. Increasing nitrogen concentrations have been shown to be related to increasing phytoplankton standing crops (reflected in increasing chlorophyll concentrations) (Cole et al., 1999). The indirect effects of increased inputs of nitrogen are associated with changes in aquatic ecosystems resulting from the stimulation of algal and other plant communities in the water column. Phytoplankton blooms can contribute to an increase in turbidity in the water column which reduces the light availability to macroalgae and plants growing in the photic zone and resulting in a reduction in the depths of colonisation for several species (Birkett *et al.,* 1998). This explains the plant growths observed in some points on the Ogun River (figures 1, 2 and 3). Reduced levels of dissolved oxygen in the water column can result in the release of phosphate from suspended particles and the sediment (Nixon et al., 1995). This was confirmed in our result in table 2, where the lowest DO of 2.6ppm and highest phosphate of 23.3ppm were observed at S3. Nutrient and organic enrichment can have a positive effect on populations by increasing the supply of organic carbon to the sediments, stimulating the production of sediment-dwelling invertebrates and enhancing the food supply (Cole et al., 1999).

Heavy metals in water samples

The concentrations of heavy metals in Ogun River water samples are shown in figure 5.

In the water samples, chromium, cobalt, copper, iron, manganese and zinc were found in all the points under investigation. Cadmium and lead were found in only two points, S5 and S3, in concentrations above permitted limits. As shown in figure 5, heavy metal concentrations were high in three locations, S5 (a point

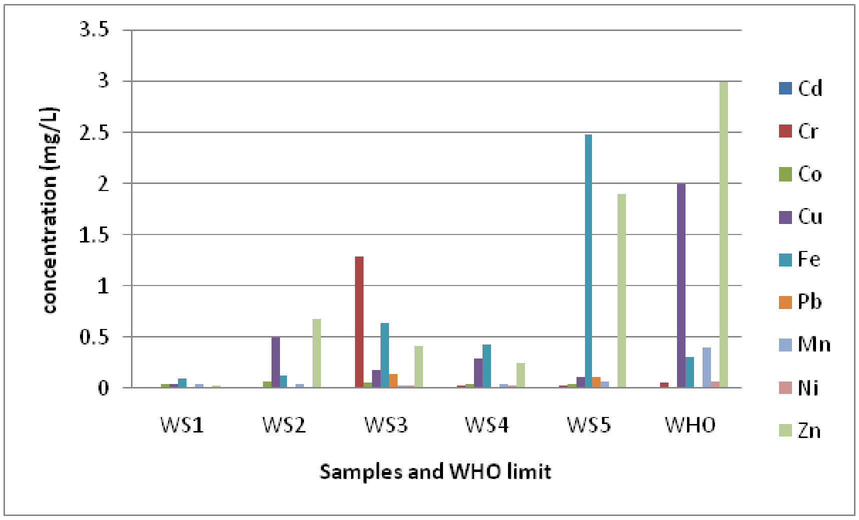

Figure 5. Heavy metal concentration of water samples at different points

near new Isheri village by Golden Spring hotel, downstream after the bridge), S3 (a point where the abattoir wastewater discharges into the river), upstream just before the bridge and S2 (a point where a smaller stream joins the Ogun River). Iron exceeded limit at three points, S3, S4 (a point close to a dump site, downstream just after the bridge) and S5. This result revealed that the point close to Golden Spring hotel was the point of highest input of heavy metals, with Fe, Zn, Pb and Cd exceeding the WHO limits. The most abundant heavy metals, iron (2.47mg/L) and Zn (1.90mg/L), were found at this point. The second highest source of heavy metals in the Ogun River at Kara was the point where abattoir waste water was discharged into the river (S3). This point had Cd (0.016mg/L), Cr (1.286mg/L), Fe (0.641mg/L) and Pb 0.129mg/L) exceeding WHO limits (table 4). Levene's test for the heavy metals in Ogun river water which gave p value < .05 (.001) showed that variance was not homogeneous for this group of samples. ANOVA test with p value of .237 accepted the null hypothesis that heavy metals in Ogun river water at different locations were not significantly different (were equal) therefore could not be relied upon in this case. Thus Kruskal Wallis test with p value of .178, though also accepted the null hypothesis, was more reliable.

Multiple comparisons using a Post Hoc tests (Tukey HSD and Duncan tests) statistically compared the heavy metals in Ogun River water at five locations with respect to a single location. Both tests showed that all the locations accepted the null hypothesis with p value of .210 and .057 respectively, indicating no statistical significant difference in heavy metals in Ogun river water at all the locations. This was an indication that the entire water was generally polluted with heavy metals.

Statistical assessment indicated variation in concentrations of individual heavy metals in the sediments. Levene's test for individual heavy metals in Ogun river sediment which gave p value < .05 (.043) showed that variance was not homogeneous. ANOVA test with p value of .080 accepted the null hypothesis that heavy metals in Ogun river sediment at different locations were not significantly different (were equal) therefore could not be relied upon in this case. Thus Kruskal Wallis test with p value of .001 was more reliable, and this is an indication that the concentrations of individual heavy metals differed significantly in the Ogun river sediments. Mann-Whitney test which gave a p-value of .008 confirmed this. In agreement with this statistical analysis, it can be seen in figure 5 above that, the concentrations of some of the heavy metals in the water samples were very high compared to others. Table 4.

Heavy metals in sediment samples

The concentrations of heavy metals in Ogun River sediment samples are shown in figure 6.

In the sediment samples, chromium, cobalt, copper, iron, manganese and zinc were found in all the points under investigation, just like in the water samples. Cadmium and lead were found in only two points, S1 and S2, but only lead (15.12mg/Kg) exceeded the permitted limit at S2. As shown in figure 6, heavy metal concentrations exceeded limits at three locations, S2 (a point where a smaller stream joins the Ogun River), S4 (a point close to a dump site, downstream just after the bridge) and S1 (a point near the dredged area, upstream). The high concentration of heavy metals at S2, where a stream empties to Ogun River, is in agreement with the report by Alani (2011b) that a fluvial source of pollutants, present outstandingly high pollutant concentrations. Statistical assessment indicated

Table 4. Limits of heavy metals in effluent water and sediments

S/N	Heavy Metal	**FME Limit** FEPA (1999a)	**WHO Limit**** WHO (2008)
1	Cd (ppm)	<1	0.003(2)
2	Cr (ppm)	<1	0.05(0.1)
3	Co (ppm)	NA	-
4	Cu (ppm)	<1	2(3)
5	Fe (ppm)	20	0.3(3)
6	Pb (ppm)	<1	0.01(0.1)
7	Mn (ppm)	5	0.4(2)
8	Ni (ppm)	<1	0.07(3)
9	Zn (ppm)	<1	3(5)

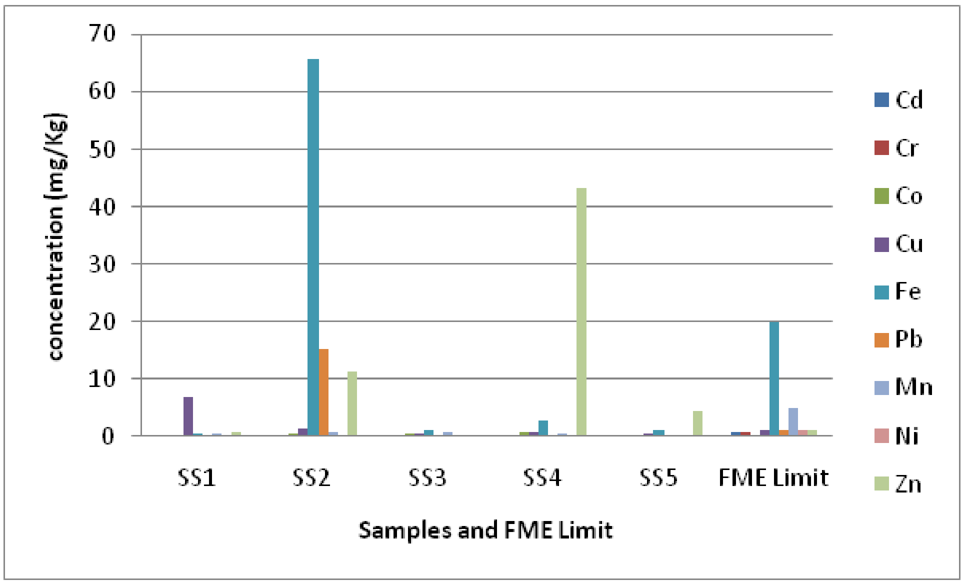

Figure 6. Heavy metal concentration of sediment samples at different points

variation in concentrations of individual heavy metals in the sediments. Levene's test for individual heavy metals in Ogun river sediment which gave p value < .05 (.040) showed that variance was not homogeneous. ANOVA test with p value of .360 accepted the null hypothesis that heavy metals in Ogun river sediment at different locations were not significantly different (were equal) therefore could not be relied upon in this case. Thus Kruskal Wallis test with p value of .000 was more reliable, and this is an indication that the concentrations of individual heavy metals differed significantly in the Ogun river sediments. Mann-Whitney test which gave a p-value of .008 confirmed this. In agreement with this statistical analysis, the concentrations of some of the heavy metals in the sediment samples were very high compared to others. Four heavy metals, Cu (1.51mg/Kg), Fe (65.78mg/Kg), Pb (15.12mg/Kg) and Zn (11.38mg/Kg) exceeded FME limits at S2. Zn also exceeded FME limit at S4 (43.4mg/Kg) and S5 (4.51mg/Kg). The high concentration of Zn at S4 was an indication that certain activities that generate Zn are taking place in that area. Zinc can be mobilized from particles by microbial degradation of organic matter and displacement by calcium and magnesium. In the turbidity maximum, zinc associated with suspended sediment will be deposited with flocculated particles where it can accumulate particularly in anaerobic sediments (Cole et al., (1999). This was possibly the reason for observing zinc in the sediment and not in the water. Cu concentration was also found to be quite high (7.04mg/Kg) and exceeded the FME level at S1. It was observed that point S3 had the lowest sediment content of heavy metal, unlike the water. This could be as a result of constant abattoir discharge flow (figure 3), which possibly prevented the settlement of the metals at that point, though they were present in the water column. With respect to locations, the concentrations of heavy metals in Ogun river sediments varied at different locations. Levene's test for heavy metals in Ogun river sediment which gave p value < .05 (.001) showed that variance was not homogeneous for this group of samples. ANOVA test with p value of .289 accepted the

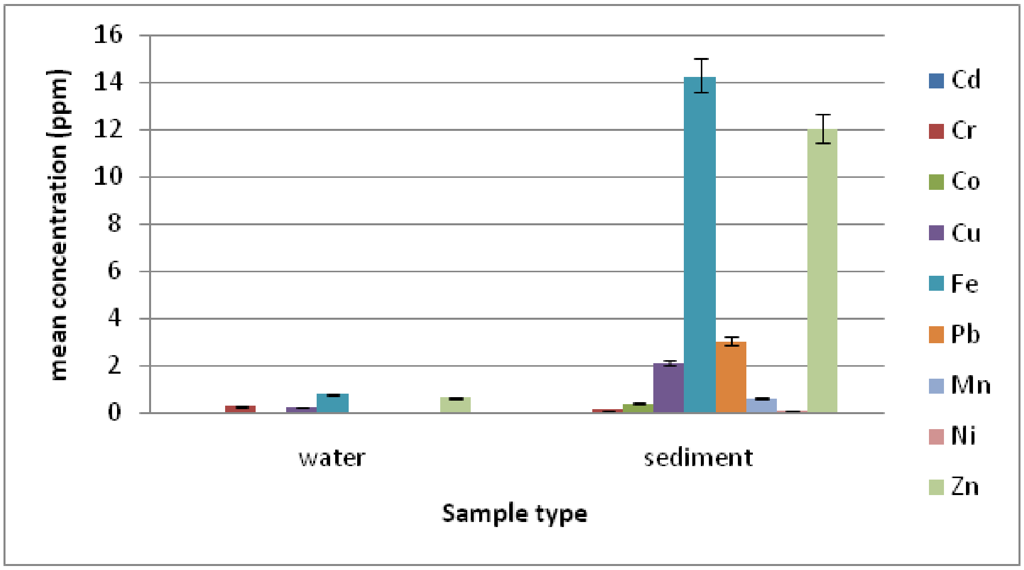

Figure 7. Mean concentrations of heavy metals in water and sediments

null hypothesis that heavy metals in Ogun river sediment at different locations were not significantly different (were equal) therefore could not be relied upon in this case. Thus Kruskal Wallis test with p value of .178, though also accepted the null hypothesis, was more reliable. Multiple comparisons using a Post Hoc tests (Tukey HSD and Duncan tests) statistically compared the heavy metals in Ogun river sediments at five locations with respect to a single location. Both tests accepted the null hypothesis with p value of .347 and .101 respectively, indicating no statistical significant difference between the locations, showing that all the locations were polluted with heavy metals.

Impacts of heavy metals on Ogun River at *Kara*

The concentrations of heavy metals in the sediment samples were very high compared to the water concentrations as shown in their mean concentrations in figure 7.

In the water column, Cd, Cr, Zn, Fe and Pb exceeded permitted limits. In the sediment, Cu, Fe, Pb and Zn exceeded the permitted limits.

Cadmium: Cadmium concentration (0.016mg/L) in the water exceeded the WHO limit of 0.003mg/L. Cole et al., (1999) reported that at low concentrations (10 µg cadmium L^{-1}), cadmium inhibits ion transport systems and induces metallothionein synthesis (< 1 µg cadmium L^{-1}) in freshwater fish. Cadmium toxicity has been found to be variable in fish, with salmonids being particularly susceptible to cadmium. Sub-lethal effects in fish, notably malformation of the spine, which have been reported by Cole et al., (1999), would possibly occur in fishes in Ogun River at *Kara.*

WHO (1992) reported that current measurements of dissolved cadmium in surface waters of the open oceans gave values of < 5 ng L^{-1}. The vertical distribution of dissolved cadmium in ocean waters is characterized by a surface depletion and deep water enrichment, which corresponds to the pattern of nutrient concentrations in these areas (Boyle *et al*., 1976). Nutrient enriched areas have high Phytoplankton growth. Absorption of cadmium by phytoplankton occurs in water surface where there is cadmium enrichment and thus leads to elevated levels in plankton (at the beginning of the trophic levels in the food web) unconnected with human activity (Martin and Broenkow, 1975). This is an indication of bioaccumulation and biomagnification in the foodwebs (with humans at the top of foodwebs) in the Ogun River. At the Kara abattoir the animals drink cadmium enriched water from the Ogun River and so there are possibilities of cadmium accumulation in the meat obtained from that abattoir. Animals eating or drinking cadmium sometimes get high blood-pressures, liver disease and nerve or brain damage. Human uptake of cadmium takes place mainly through food. Foodstuffs that are rich in cadmium can greatly increase the cadmium concentration in human bodies. Cadmium accumulates in kidneys, where it damages filtering mechanisms. This causes the excretion of essential proteins and sugars from the body and further kidney damage. It takes a very long time before cadmium that has accumulated in kidneys is excreted from a human body. Other health effects that can be caused by cadmium are: diarrhoea, stomach pains and severe vomiting, bone fracture, reproductive failure and possibly even infertility, damage to the central nervous system, damage to the immune system, psychological disorders, possibly DNA damage or cancer development. There is no consistent interaction between cadmium and zinc in fish (WHO, 1992b).

Chromium: Chromium concentration (1.286mg/L) in the water exceeded the WHO limit of 0.05mg/L. Potential effects include acute toxicity to invertebrates and fish at concentrations of dissolved chromium above the EQS of 0.05mg/L (annual average) in the water column. The fish and invertebrate obtained from Ogun River at Kara are likely contaminated with chromium and there are possibilities of accumulation in the meat obtained from that abattoir since the animals drink from the chromium polluted water. For most people eating food that contains chromium (III) is the main route of chromium uptake. The health hazards associated with exposure to chromium are dependent on its oxidation state. Adverse effects of chromium on the skin may include ulcerations, dermatitis, and allergic skin reactions. Inhalation of hexavalent chromium compounds can result in ulceration and perforation of the mucous membranes of the nasal septum, irritation of the pharynx and larynx, asthmatic bronchitis, bronchospasms and edema. Respiratory symptoms may include coughing and wheezing, shortness of breath, and nasal itching. There are potential risks of chromium associated diseases on consumption of meat products from Kara abattoir.

Copper: Copper concentration (1.51 – 7.04mg/Kg) in the sediment exceeded the FME limit (<1mg/Kg). Copper can accumulation in sediments and can pose a hazard at concentrations above 18.7 mg kg-1 according to Canadian interim marine sediment quality guidelines (Grimwood and Dixon, 1997). Copper can bioaccumulate in organisms posing a potential hazard to marine organisms, including fish and birds. Copper can be found in many kinds of food, in drinking water and in air. Because of that, we absorb eminent quantities of copper each day by eating, drinking and breathing. The absorption of copper is necessary, because copper is a trace element that is essential for human health. Although humans can handle proportionally large concentrations of copper, too much copper can still cause eminent health problems.

Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomach aches, dizziness, vomiting and diarrheoa. Intentionally high uptakes of copper may cause liver and kidney damage and even death. Chronic copper poisoning results in Wilson's Disease, characterized by a hepatic cirrhosis, brain damage, demyelization, renal disease, and copper deposition in the cornea.

Zinc: Zinc concentrations (4.51mg/Kg at S5, 11.38mg/Kg at S2 and 43.4mg/Kg at S4) in the sediment exceeded the FME limit (<1mg/Kg).

Zinc accumulates in sediments and can pose a hazard to sediment dwelling organisms at concentrations above 124 mg kg^{-1}, according to Canadian interim marine sediment quality guidelines (Grimwood and Dixon, 1997).

Iron: Iron concentration (0.43, 0.64 and 2.49mg/L) in the water exceeded the WHO limit of 0.05mg/L at S3, S4 and S5 respectively. Also, 65.78mg/Kg in sediment exceeded FME limit (20mg/Kg) at S2. A more common problem for humans is iron deficiency, which leads to anaemia. A man needs an average daily intake of 7 mg of iron and a woman 11 mg; a normal diet will generally provided all that is needed. Iron can be found in meat, whole meal products, potatoes and vegetables. The human body absorbs iron in animal products faster than iron in plant products. Iron is an essential part of hemoglobin; the red colouring agent of the blood that transports oxygen through our bodies. Iron may cause conjunctivitis, choroiditis, and retinitis if it contacts and remains in the tissues.

Lead: Lead concentrations (0.129mg/Kg at S3 and 0.109mg/Kg at S5) in the sediment exceeded the WHO limit of 0.01mg/L. Also, 15.12mg/Kg in sediment exceeded FME limit (<1mg/Kg) at S2. The Ogun River at Kara abattoir was therefore found to contain lead at dangerously high concentrations. This was a pointer to the risk of lead poisoning from consuming meat products from Kara abattoir. Lead affects almost every organ system in the human body. The central nervous system is particularly vulnerable in infants and children under age six. The effects are the same whether it is breathed or swallowed. Large amounts of lead exposure may lead to blood anemia, severe stomachache, muscle weakness, and brain damage. Lower levels of exposure, may affect a child's mental and physical growth leading to learning disabilities and seizures. Cole et al., (1999) reported acute toxicity to algae, invertebrates and fish at concentrations of dissolved lead above the proposed EQS of 0.01mg/ L (annual average) in the water column. A lower guideline value of 0.005mg/ L of dissolved lead has been suggested by Grimwood and Dixon (1997) for sites of nature conservation importance where particularly sensitive algal species are to be protected. Lead accumulation in sediments and can pose a hazard to sediment-dwelling organisms at concentrations above 30.2 mg/ kg, according to Canadian interim marine sediment quality guidelines. Lead bioaccumulate in the food chain posing a hazard to fish, birds and humans. Apart from the meat products, fish and invertebrates obtained from the Ogun River at Kara abattoir would likely be contaminated with lead. The Ogun river is therefore unfit for human and animals (cattle, goat, sheep, etc which drink freely from the river!) consumption.

CONCLUSION

From the physicochemical parameters of the water and sediments, it can be concluded that Ogun River at *Kara* abattoir is highly contaminated. Heavy metal analysis of the water and sediment also revealed dangerously high concentrations. It can be concluded that the river poses a potential risk to its users, aquatic lives, the animals, and humans. Intense pressures are exerted on Ogun

River, especially at Kara abattoir, by human activities, and this requires serious commitment and preventive actions at local and state levels.

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