Ecotoxicological Consequences of Wood Saw Dust and Wood Ash on the Littoral and Neritic Environments of Ethiope River, Nigeria – A Case for Recycling

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ABSTRACT

Wood saw dust and its combustion product, wood ash are becoming ubiquitous in the proximity of rivers where wood industries and wood markets are located. The cumulative health hazard this may pose had attracted very little or no attention. Therefore, the assessment of the ecological consequences of the wood saw dust generated by the operations of the Ogwanja wood dealers in Sapele, Delta State, Nigeria on the littoral and neritic environments of Ethiope River was undertaken. They were assessed using toxicological tests and the associated instrumental and classical determinations. The combined wood saw dust sample had the highest mean %mortality , 63.0% than the individual wood saw dust samples, Danta(*Nesogordoniapapaverifera*(37%); Obeche(*Triplochiton Scleroxylon*)(30%); Ikpaya(*Lophira Alata*)(20%)and the wood saw dust ash(10%). The lethal concentration (LC_{50}) within 95% confidence limit was lowest in the combined wood saw dust, 69.18mg/kg indicating 'very toxic'. The metals, lead, iron, cadmium and chromium in the water samples, were within the World Health Organisation (WHO) permissible limits. However, some physico - chemical parameters in the water samples, colour, and turbidity and nitrate ions had mean values of 46.6±4.23Pt, 117.64±6.55NTU and

1.34±0.56mg/L respectively which were above the WHO permissible limits suggesting a polluted river. The littoral and neritic environments of Ethiope River are highly susceptible to extensive pollution.

Keywords**:** Toxicology, lethal concentration, Sapele, soil dwelling organisms, wood and Pollution

Introduction

Wood is comprised mainly of organic matter with small amounts of inorganic material. The inorganic component is the result of the trees absorbing minerals from soil. It is a complex biological and chemical material that consists primarily of cellulose, hemicelluloses, lignin and extractives. Cellulose is a linear glucose chain that serves as the wood's skeleton. Hemi-cellulose is a small polysaccharide that may assist in cell growth and maturation while lignin is a high molecular weight polymer of phenoxy I-propane units that functions by holding wood cells together (Holliday et al., 1986). In general, hard woods contain about 43% cellulose, 22% lignin, and 35% hemicelluloses while soft woods contain about 43% cellulose, 29% lignin and 28% hemicelluloses (Casey, 1980).

Wood sawdust or wood dust is a by-product of cutting, grinding, drilling, or otherwise pulverizing wood with a saw or other tool; it is composed of fine particles of wood. It is also the by-product of certain animals, birds and insects which live in wood, such as woodpecker and carpenter ant. Wood factories, including saw mills, are established in their thousands in various states of Nigeria, with thousands of tons of wood shavings and sawdust being generated daily (Aina, 2006). The annual volume of wood waste generation was estimated to be 300,643,230m^3 (Babayemi and Dauda, 2009). At present in Nigeria, apart from the insignificant use as poultry

deep litters, and home heating, the largest percentage of sawdust and wood shavings end up in dump sites as waste, where they are burnt and the ashes carried away by flood into rivers and other aquatic media on a frequent basis every year. When wood is burned, the organic portion is converted to CO_2 and water while the inorganic portion remains as ash (Ogunbode et al.,2013).

Sawdust and its ashes may also collect in piles and add harmful leachate into local water systems, creating an environmental hazard. The harmful heavy metals in them include: cadmium (Cd), mercury (Hg) and lead (Pb), of which Cd is probably of most concern. The Cd concentrations in the wood ash could vary from 4 to 20 mg (Työryhmämuistio, 1993). This work therefore assessed, the magnitude of the deleterious effects of wood saw dusts and wood ash in the littoral and neritic environments of rivers in Nigeria with particular reference tothe River Ethiope which is near Ogwanja wood market, in Sapele, Delta State, Nigeria, thereby highlighting the need for recycling of the wood saw dust to avoid its continuous intrusion into the neritic and littoral environments of River Ethiope.

Materials and Methods

Description of the Study Area

The study site, Ogwanja wood market is located in Sapele, Delta state, Southern Nigeria. It lies along the Benin River just below the confluence of the Ethiope and Jamieson rivers, 98 miles (158 km) from the Escravos Bar Beach and entrance to the Bight of Benin. Ogwanja town is situated on the road that branches to Warri, Ughelli, and Asaba and can be connected by ferry to the road leading to Benin City. Founded in the colonial period on the land traditionally inhabited by the Urhobos and Isokos and Sapele has been a centre for sawmilling of obeche, abura, sapele, and mahogany since 1925. Its plywood and veneer manufacturing plant is one of the largest in West Africa.

The Ethiope River is located in the western part of Delta State of Nigeria and is situated between latitude 5.53^{o} and 6.05^{o} North and longitude 5.30^{o} and 6.05^{o} East. It takes its source from Umuaja in

Ndokwa Local Government Area of Delta State and covers a distance of 96.6 kilometres and flows into the Atlantic Ocean through the Benin River. Umuaja, Umutu, Obi – Iloh,Ebedei-Ukwale, Owa-Abbi, Obinomba, Obiaruku, Umeghe, Urhuoka, Abraka, Ajalomi, Urhuovie, Erho,Oria, Sanubi, Eku,Igun,Okpara waterside, Ekpan-Ovu, Aghaiokpe, Arabga-Okpe, Adarweran, Egbeku, Ibada, Eko, Amukpe, Okirigwhre, Sapele, Jesse, Oghara are communities traversed by the EthiopeRiver(OECD, 2003).

Figure 1: Map of Delta State showing the study area

Sampling

The materials (saw dust samples, wood ash) and water samples were got from Ogwanja saw mill, Sapele, Ethiope River behind the Ogwanjasawmill in Sapele, Delta State, while the test organisms (snails), the common brown-black African snail (*Achatinafulica*) with a mean weight of 0.98 ± 0.08 g and length of 1.50 ± 0.5 cm were got from the farm at Ugbomro in Ughelli, Niger Delta ecological zone of Nigeria with boundary geo references, latitude 005^{o}33$^{'}$59.6”N and longitude 005^{o}49$^{'}$59.8”E.Thewater samples were collected from the middle of the river adjacent to the sawmill, and then 500m and 1000m to the left away from the middle; 500m and 1000m to the right away from the middle as well.

Table 1: Common and Botanical names of somewoods

S/N	Common Name	Botanical Name
1	Danta	*Nesogordoniapapaverifera*
2	Obeche	*Triplochitonscleroxylon*
3	Ikpaya	*Lophiraalata or lanceolata*

Plate 1: The African giant snail (Achatina Fulica)

Sample preservation/ treatment

The water samples were preserved in ice packs for further analysis. The soil and sawdust samples were air dried at ambient temperature of the laboratory.

Acclimation of test organism

The test organisms were acclimated under laboratory conditions for a period of seven days to allow the test organisms to be accustomed to the laboratory condition prior to the experiment.

Methods

Bioassay procedure

The 14-day experimental procedure was carried out using the International Organization for Standardization (ISO) protocol #15952 (ISO, 2006). The concentrations to be used in the definitive test were first determined in a range finding test. The ecotoxicological endpoint indicators considered were mortality and exposure duration. Different amounts of the test substances (sawdust and wood ash) were diluted to give the concentrations used for the bioassay

For the range finding, the concentrations used were 1000 mg/L, 100 mg/L and 10 mg/Lwhile for the definitive test, the concentrations used were 100 mg/L, 50 mg/L, 25 mg/L, 12.5 mg/L and 6.25 mg/L.The snails were acclimated in an unspiked soil for seven days before the commencement of the bioassay. For each of the test concentration, 1000 g (1kg) of natural soil (from organisms' habitat) was placed into the bioassay container to form a thick layer of substrate. 5g of pawpaw (*Carica papaya*) leaves were then placed in each bioassay container. Each test medium was then spiked with 100 mL of water containing varying concentrations of the test substance. The pawpaw (*Carica papaya*) leaves were added to the soil as food for the organisms to avoid starvation (alternatively freshly prepared cellulose could be used).

Snails were kept on moist filter paper for few hours to void the contents of their stomach and intestinal tract before being placed in test jars. Thereafter, ten voided healthy snails were cleaned and weighed. They were transferred from their holding containers to the soils spiked with different concentrations of the test substance. Three replicates per treatment were prepared for five exposure concentrations for the test substance. The control set-up was prepared in conjunction with the test substance as described above except that only water was sprinkled on the leaves and clean substrate. The setup was covered with wire mesh or net to prevent the test medium from drying and kept under the test conditions for the test duration as shown in the experimental set-up in figure 2. Each test vessel was then labeled accordingly.

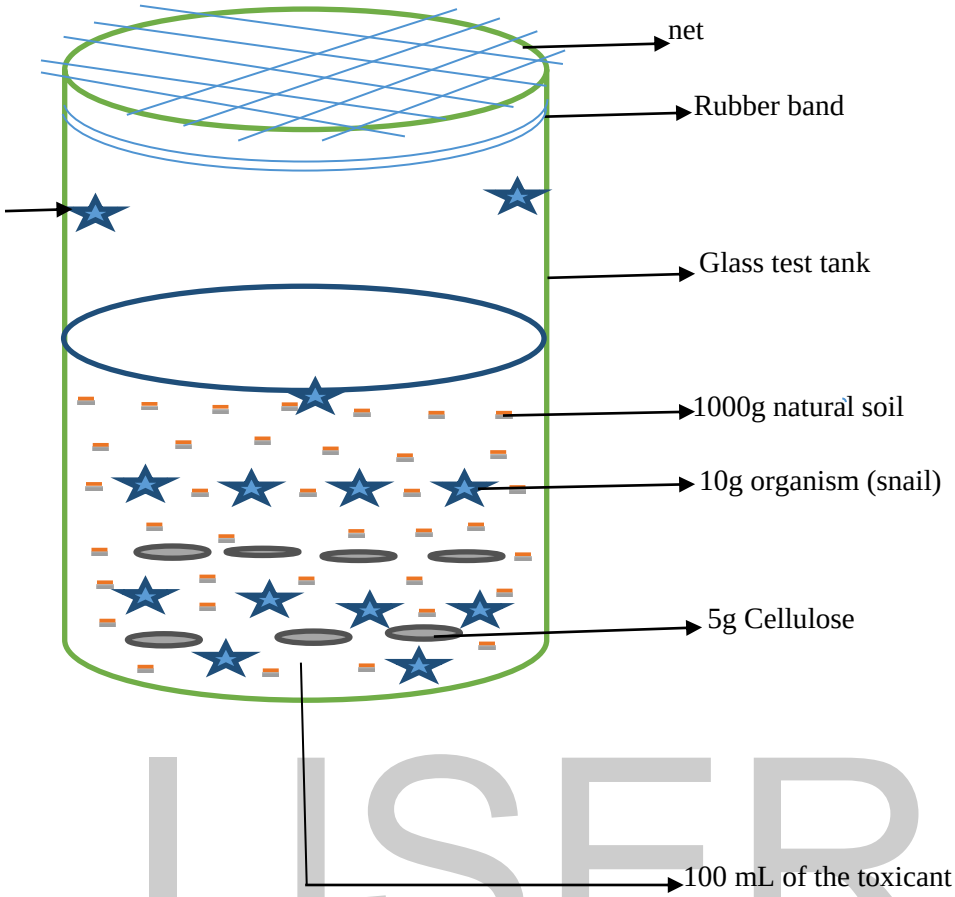

Figure 2: The Experimental Set-up

Experiments were conducted using a total of one hundred and fiftysnails (*Achatinafulica*) per wood type. The entire test was conducted at a controlled temperature of 27 ± 1°C in soils with pH 5.86. The concentrations for the definitive test were chosen after a range-finding experiment. Mortality count was carried out once on day 7 and day14.

Assessment of response (mortality)

Snail mortality was evaluated on day 7 and 14 of the experiment in all replicates in the natural soil. Direct contact was avoided so as not to induce stress on the snails. Percentage mortality (end-point indicator of acute toxicity) was estimated while physical changes (morphology) and behavioral responses were also noted. Snails were considered dead if there was no movement when the foot (pedal) region of the organism was prodded with a pointed metal rod (platinum wire) or if there was no activity after 5 minutes of placing the snail on white filter paper.

Determination of some physico – chemical parameters

In situ parameters for the water sample

The in situ parameters are those parameters that are taken on site that is they were analyzed on the field to avoid any physical or chemical change in the sample over a short period of time. They include: pH, electric conductance, total dissolved solid (TDS), temperature, turbidity and colour. They were determined using digital turbidity meter, pH meter and Hachsension 5 that were appropriately calibrated and standardised (ASTM, 1986).

Metals in water samples

One hundred (100) mL of each sample was transferred separately into different beakers and labelled accordingly. Concentrated trioxonitrate (v) acid, HNO_3 (5 ml) was then added to the content of each beaker. Each beaker with the content was placed on a hot plate and heated until the volume reduced to about 20 ml. After cooling, another 5 ml concentrated $HNO_3$was added and the beaker covered with a watch glass and further heated. A small portion of HNO_3 was added until the solution

appeared light coloured and clear. The beaker walls and the watch glass were washed with distilled water and the sample was filtered and the volume made up to 100mL with distilled water. The concentrations of the metals were determined using the Atomic Absorption Spectrometry (USEPA, 1983).

Metals in sawdust samples

The saw dust samples were digested by dissolving two (2) grams of the sample in a 20ml mixture of HNO_3 and HCl (1:3 v/v) in a beaker placed on a heating mantle in a fume cupboard. The mixture was refluxed. The absence of solid particles at the bottom of the beaker indicated the completion of digestion. The mixture was allowed to cool and thereafter transferred to a 100mL volumetric flask and made up with distilled water. It was filtered with Whatman no 1 filter paper and the filtrate was analysed with atomic absorption spectrometer.

Determination of non-metal contents in water

Chloride content

Measure 10 - 25 mL or an appropriate volume of the sample or standard into a conical/ Erlenmeyer flask and add 3 drops of potassium chromate indicator. Titrate with 0.0141 *M* (0.0141 *N*) silver nitrate solution (depending on the concentration of dissolved solids in the sample) to the first permanent red tinger or brick red of silver chromate. The end point is reached when the tinge persist. Note: The pH of the sample was adjusted to between 7.0-10 with 1N NaOH.

Calculation: mg/L Cl^- = $\frac{\text{mL x N of } AgNO_3 \text{ x MM } (Cl^-)\ 35{,}450}{\text{Vol of Sample}}$

N= Normality of $AgNO_3$

MM = Molar mass of Cl^-

2.2.3.6 Sulphate content

Measure 100 mL sample into a 250 mL conical flask and add 20 mL buffer solution and mix in stirring apparatus. While stirring, add a spoonful of $BaCl_2$ crystal and begin timing immediately. Stir for 60 ± 2s at constant speed. After stirring, measure turbidity at 5 ± 0.5min. Correct for sample colour and turbidity by running blanks to which $BaCl_2$ was not added. Run standard along with samples, obtain a calibration curve and extrapolate concentration of samples from such curve. Express result in mg/L.

Nitrate-nitrogen content in water

Calibration standards were prepared to cover a range, 0 to 1.0mg/L by diluting appropriate volume to 50mL.10mL of each standard solution was pipetted into different Erlenmeyer flask and one sachet of Nitraver V powder pillow added; shaken thoroughly for 1 minute and allowed to stand for 5 minutes. An amber colour developed, and the absorbance of the solution was read at 410nm wavelength on a Direct Spectrophotometer (722 UV vis Spec). Distilled water was used as blank. The calibration graph was plotted and its accuracy against the standard, R^2 value ≥ 0.995. The concentration of the sample was read from the calibration curve using the regression equation.

Statistical analysis

The susceptibility of the snails to the test metals was determined using the Probit method of analysis for median lethal concentration LC_{50} at 14 days. In addition, the analysis of variance (ANOVA) in Statistical Package for Social Science (SPSS) statistical software, version 22.0 was

used to test the mean statistical difference between the controls and the treated groups at significance level of $p = 0.05$.

Results and Discussion

The results obtained from the acute toxicity of snails exposed to different concentrations of the test substances in spiked soils are presented in tables 2- 6. The tables indicate the mortality of the organisms at the end of the 14 day experiment.

Table 2: Toxicological test with obeche sawdust at 14 day exposure

Conc.(mg/L)Saw dust	Number of organism Tested	Number Dead			Mean	Mean Mortality %
		A	B	C		
Control	10	0	0	0	0	0
6.25	10	3	1	1	1.7	17
12.5	10	3	1	2	2	20
25	10	3	2	3	2.7	27
50	10	3	3	2	2.7	27
100	10	4	3	2	3	30

Table 3: Toxicological test with Danta sawdust at 14 day exposure

Conc. (mg/L) Saw dust	Number of organism Tested	Number Dead			Mean	Mean Mortality %
		A	B	C		
Control	10	0	0	0	0	0
6.25	10	1	1	2	1.3	13
12.5	10	1	2	3	2	20
25	10	2	2	3	2.3	23
50	10	2	3	2	2.3	23
100	10	4	3	4	3.7	37

Table 4: Toxicological test with Ikpaya sawdust at 14 day exposure

Conc.(mg/ L)Saw dust	**Number of organism Tested**	**Number Dead**	**Mean**	**Mean Mortality %**

		A	B	C		
Control	10	0	0	0	0	0
6.25	10	0	0	1	0.3	3
12.5	10	1	0	1	0.7	7
25	10	1	2	2	1.7	17
50	10	3	1	1	1.7	17
100	10	3	2	1	2	20

Table 5: Toxicological test with wood ash at 14 day exposure

Conc.(mg/ L)Saw dust	**Number of organism Tested**	**Number Dead**			**Mean**	**Mean Mortality %**
		A	B	C		
Control	10	0	0	0	0	0
6.25	10	0	0	1	0.3	3
12.5	10	1	0	0	0.3	3
25	10	1	1	0	0.7	7
50	10	0	1	1	0.7	7
100	10	1	1	1	1	10

Table 6: Toxicological test with combined sawdust at 14 day exposure

Conc.(mg/ L)Saw dust	**Number of organism**	**Number Dead**	**Mean**	**Mean Mortality %**

	Tested					
		A	B	C		
Control	10	0	0	0	0	0
6.25	10	2	3	2	2.3	23
12.5	10	2	2	3	2.3	23
25	10	2	3	4	3	30
50	10	3	4	4	3.7	37
100	10	4	5	5	4.7	63

Control Test

The control consisted of ten (10) healthy snails in an unspiked soil (soil that does not contain any of the test substances). The results of the experimental bioassay indicated that there was no record of death during the 14 days of the test (Tables2-6). Snails were considered dead if there was no movement when the foot region of the animal was prodded with a pointed metal rod or if there was no activity after 5 minutes of placing them in water.

Exposure of the test organisms to the substances (wood saw dust and wood ash)

The test organisms (snails) exposed to different concentrations of the test substances showed no mortality after seven days of the test. However, after 14 days of the test, the results showed that mortality increased slightly with increase in the concentration of the test substances. For the individual test substances (wood saw dust), danta wood saw dust showed the highest mortality of 37%; obeche 30% and ikpaya 20%; wood ash 10% (Tables 2-5).

The combined saw dust had the highest mean percentage mortality of 63% (Table 6). It is evident from the results that the individual wood saw dust samples were not as lethal as the combined saw dust samples. This is worrisome because it is actually in this combined form that all the wood saw dust waste emanating from the wood industries are heaped around the surroundings of most Nigerian marine environments.

Table7: Mean LC_{50} values for Obeche, Danta, Ikpaya, Wood ash and combined sawdust exposure to snails at the end of 14 days

Test Substance	Time (Days)	LC_{50} (95% CL),mg/L A	B	C	Mean LC_{50}
Obeche Sawdust	14	ND	ND	ND	ND
Danta Sawdust	14	ND	ND	ND	ND
Ikpaya Sawdust	14	ND	ND	ND	ND
Wood ash	14	ND	ND	ND	ND
Combined Sawdust	14	80.65	70.55	56.34	69.18

LC_{50} = Lethal concentration causing 50% death of organisms exposed to chemical for the test duration; CL= Confidence limit; ND= Not determined

The 14 days lethal concentration (LC_{50})

The lethal concentration (LC_{50}) is estimated as the concentration causing 50% death of organisms exposed to a chemical for the experimental test duration. For this study the values of the $LC_{50}$for the individual sawdust samples and wood ash could not be determined. This is because the confidence limit could not be determined as mortality was below 50%.This showed that the test substances were not toxic to the test organisms. However, the combined sawdust sample showed the possibility of been very toxic. It had a LC_{50} of 80.65mg/L in tank 1; 70.55mg/L in tank 2 and 56.34mg/L in tank 3 resulting in a mean LC_{50} of 69.18mg/L according to Organisation of Economic Cooperation and Development(OECD) toxicity rating(OECD,2003) as shown on table 8 below.

The concentration of a chemical in the environment should not exceed 10% of the LC_{50}.The Organization of Economic Corporation and Development (OECD) has a rating of 2 assigned for an LC_{50} value between 1.0 to 10.0 mg/L of active substance in contaminated soils. The results of this study showed that the test substances (individual wood saw dust samples) were not toxic but the combined sawdust sample had a very toxic effect on the test organisms. As shown on table 7, the combined sawdust had a mean $LC_{50}$of 69.18mg/Lwhich falls under the range of 10-100 indicating ‘ very toxic’.

Table 8: Soil toxicity rating

Rating	Designation	LC50 (mg/L)
1	Super toxic	<1.0
2	Extremely toxic	1.0-10
3	Very toxic	10-100
4	Slightly toxic	100-1000
5	Practically non-toxic	>1000

Abbreviations: LC_{50} median lethal concentration. Data from (OECD, 2003)

Table 9: Values of physico-chemical parameters of the surface water

PARAMETERS	SW 1	SW 2	SW 3	SW 4	SW 5
pH	6.30	6.60	6.30	6.50	6.40
Electric Conductivity (µS/cm)	261.00	255.00	374.00	296.00	391.00
Total Dissolved Solid (mg/L)	130.00	127.70	188.30	148.10	195.60
Temperature (^{0}C)	28.90	29.20	28.60	29.20	29.40
Chloride content (mg/L)	50.95	62.49	74.48	71.90	73.48
Sulphate content (mg/L)	8.686	11.480	18.876	16.842	15.600
Nitrate-Nitrogen content (mg/L)	0.920	2.022	2.778	0.222	0.776

Turbidity (NTU)	120.0	198.5	167.6	11.9	90.2
Colour (Pt.Co)	45.0	49.0	56.0	32.0	51.0
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001
Iron (mg/L)	0.060	0.151	1.422	0.583	0.092
Chromium (Cr^{+6}) (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001

As shown on table 9, the pH of the water ranges from 6.30 - 6.60indicating slight acidity. The electrical conductivity, total dissolved solid, temperature, chloride content, sulphate content are within the permissible limits while the nitrate content, the colour and the turbidity were above the permissible limits (WHO, 2006). The level of nitrate in the water could facilitate eutrophication which could induce excessive growth of algae and thus diminished oxygen content to the detriment of other organisms in the water body. The values of the turbidity and the colour could prevent the penetration of sunlight into the water body, thus preventing essential photosynthetic processes and other processes that require sunlight within the water body. Besides, the values indicated that the water is polluted and unsafe for domestic use. The concentration of iron in the water is within the permissible limit while chromium and lead were below the instrument detection limit of 0.00lmg/L(NAS EPA,1972; FAO, 1985 and Alloway, 1995).

Table 10: The metal content of the sawdust

	Sawdust Samples		
Metals, (mg/L)	**Ikpaya**	**Danta**	**Obeche**
Calcium	2.11	14.13	47.92
Magnesium	3.769	5.145	4.584
Chromium	<0.001	<0.001	0.015
Lead	<0.001	0.504	<0.001
Iron	1.763	<0.001	0.347
Cadmium	<0.001	<0.001	<0.001

As shown on table 10, calcium is relatively higher in concentration than magnesium, though the concentrations of both of them were within the permissible limits according to the British Standard Institution, 2012. Lead, cadmium and chromium were not detected in the saw dust as it was in the water samples. Iron was present in the saw dust as in water and also within the permissible limit (BSI, 2012). This suggested an input of calcium, magnesium and iron from the saw dust to the River Ethiope.

CONCLUSION

The results of this investigation showed that the activities of the sawmill industry at Ogwanja, Sapele Local Government; Delta State, Nigeria has a very toxic effect on the littoral and neritic environments of the River Ethiope. The combined saw dust samples contributed more to the very toxic effect than the individual saw dust samples.

The metals and other physico- chemical parameters were within the limits set by different regulatory bodies except nitrates, colour and turbidity.

The operations of the wood merchants in Ogwanja wood market, Sapele, Delta State, Nigeria may have a greater toxic effect on the River Ethiope with time if not checked. Thus, there is an urgent need to commence the recycling of the wood saw dust generated at the Ogwanja wood market, Sapele. A regular monitoring of the littoral and neritic environments of the River Ethiope is a necessity.

ACKNOWLEDGMENTS

The authors appreciate the technologists in the Department of Chemistry, Federal University of Petroleum Resources, Effurun for their assistance in the analysis of the samples. Our Local guides who assisted us in the collection of the samples are greatly appreciated

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