The Effects of Wood Ash on Ignition Point of Wood

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Abstract**—**The effects of wood ash from five common tropical woods on the ignition point of four common tropical woods in Nigeria were investigated. The ash and moisture contents of the wood sawdust from Mahogany (*Khaya ivorensis*), Opepe (*Sarcocephalus latifolius*), Abura (*Mitragyna ciliata*), Rubber (*Heavea brasilensis*) and Poroporo (*Sorghum bicolour*) used, were determined using a furnace (Vecstar furnaces, model ECF2, serial no. f3077) and oven (Genlab laboratory oven, model MINO/040) respectively. The metal contents of the five wood sawdust ash samples were determined using a Perkin Elmer optima 3000 dv atomic absorption spectrometer while the ignition points were determined using Vecstar furnaces model ECF2. Poroporo had the highest ash content, 2.263g while rubber had the least, 0.710g. The results for the moisture content range from 2.971g to 0.903g. Magnesium metal had the highest concentration of all the metals, in all the wood ash samples; with mahogany ash having the highest concentration, 9.196ppm while rubber ash had the least concentration of magnesium metal, 2.196 ppm. The ignition point results showed that the wood ashes from mahogany and opepe increased the ignition points of the test wood samples, Danta (*Nesogordonia papaverifera*), Ekpaya, Akomu (*Pycnanthus angolensis*) and Oleku when coated on them while the ashes from poroporo, rubber and abura decreased the ignition points of the test wood samples when coated on them. However, Opepe saw dust ash decreased the ignition point in one of the test wood samples, suggesting that the metal content of the test wood sample was more than that of the Opepe saw dust ash. Therefore, Mahogany and Opepe saw dust ashes could be used in the surface treatment of wood to enhance their fire resistance or retardancy. However, the caution to be exercised in this application is that the metal content of the test wood samples should be evaluated as well.

Keywords**—**Ash, fire, ignition point, retardant, wood saw dust.

I. Introduction

FIRE incidents are ubiquitous, especially accidental fires. Yearly, cases of fire incidents are reported in different countries. The initiation and growth of fire is determined by a multitude of factors including type of fuel (calorific value), fuel load, fuel size (area), oxygen content in the flame, wind speed, and whether the fire is within an open or enclosed space [1]. Fire outbreaks in residential and commercial buildings in Nigeria have become a common occurrence.

In the United States of America alone, between 1996 and 2005, an average of 3,932 human loss and another 20,919 injuries (excluding the events of September 11, 2001) were reported annually as a result of fire accidents [2].

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Most of the fire incidents get worst when they get to the wood materials of a building. Therefore, the treatment of woods used in construction to accord them a considerable fire resistance is necessary. However, the polyhalogenated diphenyl ethers, the commonly used flame retardants produce toxic dioxins, furans, acidic and corrosive fumes during non-flaming thermal decomposition [3]. Other intumescent coating materials like dicyandiamide, melamine, guanidine and urea are expensive [4]. A cost effective and less hazardous flame retardant becomes a necessity. Hence, the investigation on the ashes from some common tropical trees found in Nigeria. Less than 2% of the wood saw dust or shavings from saw mills in Nigeria are used as fuels while the rest are discarded. The ashes from the wood shavings of these trees, the end product of their combustion and supposedly noncombustible materials were investigated for their fire resistance or fire retardant effects using ignition point. This investigation would serve a dual purpose; effective utilization of waste and conversion of waste to wealth.

II. Literature Review

Wood ash is the residue powder left after the combustion of wood, such as burning wood in a home fireplace or an industrial power plant. It is used traditionally by gardeners as a good source of potash for domestic gardens, for the treatment of constipation, making of local soap etc. Typically, between 0.43 and 1.82 percent of the mass of burnt wood results in ash [5].

Wood ash contains calcium carbonate as its major component, representing 25 to 45 percent; less than 10 percent is potash, and less than 1 percent phosphate; there are trace elements of iron, manganese, zinc, copper and some heavy metals. However, the composition may vary as combustion temperature is an important variable in determining wood ash composition. All of these are, primarily, in the form of oxides [5].

The chemical and physical properties of wood ash are important in determining their beneficial uses. These properties are influenced by species of trees, tree growing regions and conditions, method and manner of combustion including temperature and method of wood ash collection [6]-[8].

The chemical composition of wood varies from species to species, but is approximately 50% carbon, 42% oxygen, 6% hydrogen, 1% nitrogen, and 1% other elements (mainly calcium, potassium, sodium, magnesium, iron, and manganese) by weight [9]. Wood also contains sulfur, chlorine, silicon, phosphorus, and other elements in small quantity.

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Aside from water, wood has three main components. Cellulose, a crystalline polymer derived from glucose, constitutes about 41–43%. Next in abundance is hemi-cellulose, which is around 20% in deciduous trees but about 30% in conifers. Lignin is the third component and constitutes about 27% in coniferous wood and 23% in deciduous trees. Lignin confers hydrophobic properties on some wood due to its aromatic rings. These three components are interwoven, and direct covalent linkages exist between the lignin and the hemi-cellulose.

In chemical terms, the difference between hardwood and softwood is reflected in the composition of the constituent lignin.

In order that wood can ignite, its temperature must rise so high that pyrolysis takes place strongly enough and the chemical reactions of combustion start. Therefore, the ignition of a wood is dependent upon some factors: wet wood is difficult to ignite; thin pieces of wood ignite more easily than thick logs, and light wood species ignite quicker than heavy species. External factors having an influence on ignition are the intensity of heat exposure and its form of effect e.g. the distance of flame from the surface. According to reference [10], [11], the dependence of ignition point on time considering the internal properties of the wood materials under exposure to radiant heat can be described by the equations below

$$t_{ig} = \rho c L_o \frac{(T_{ig} - T_o)}{q''_{net}} \quad \text{for a thermally thin product (1)}$$

$$t_{ig} = \frac{\pi}{4} \rho c k \frac{(T_{ig} - T_o)^2}{{q''_{net}}^2} \quad \text{for a thermally thick product (2)}$$

where ρ, c and k are the density, specific heat and thermal conductivity of the material, respectively, L_0 is the specimen thickness; T_{ig} is the ignition temperature, T_0 is the ambient temperature, and q''_{net} is the net heat flux to the specimen surface.

When the thermal thickness of the product is between thermally thin and thick, the exponent describing the effect of the net heat flux q''_{net} and the temperature difference $T_{ig} - T_0$ is between 1 and 2.

III. Materials and Methods

A. Study Area

Asaba, the capital of oil rich Delta State of Nigeria is strategically located on a hill at the western edge of the popular river Niger. The historic river Niger is a trans-African link beginning from West Africa to the Atlantic Ocean. Asaba is a connecting route between western, eastern and northern Nigeria through the River Niger.

Asaba lies at approximately 6^{o}N of the equator and 6^{o}E of the meridian; about 100 miles north of where the river Niger flows into the Atlantic Ocean. Asaba occupies an area of about 300 square kilometers. It maintains an average tropical temperature of 90 degrees during the dry season and an average fertile rainfall of 106 inches during the rainy season.

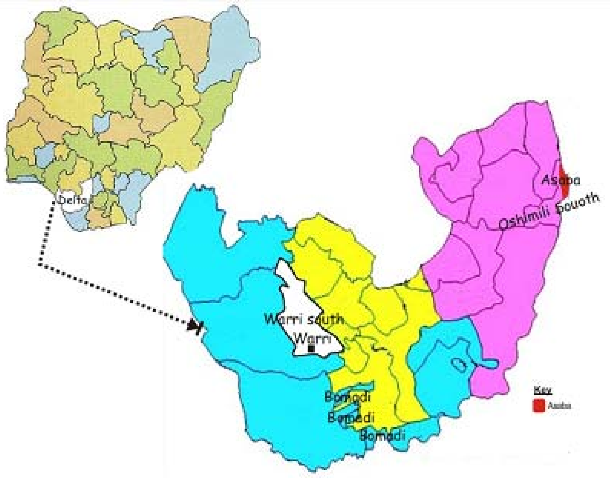

Fig. 1 Map of study area

B. Sample Collection

Five sawdust samples from different wood plants were obtained from the Asaba wood market located along Asaba-Onitsha expressway, Asaba, Delta State, Nigeria. They were collected in the morning during the fresh wood milling into polyethene bags; and properly labeled for easy identification. The samples were collected separately with hand gloves to avoid mixing them together and to avoid contamination.

Four different wood samples were also obtained from the wood market for test of ignition point. They were also properly labeled for easy identification.

TABLE I
Wood Sources of the Sawdusts

Common	Botanical Name
Abura	*Mitragyna ciliata*
Mahogany	*Khaya ivorensis*
Opepe	*Sarcocephalus latifolius*
Poroporo	*Sorghum bicolour*
Rubber	*Heavea brasilensis*

TABLE II
Wood Samples for Ignition Point Test

Trade Name	**Botanical Name**
Danta	*Nesogordonia papaverifera*
Ekpaya	Not available
Akomu	*Pycnanthus angolensis*
Oleku	Not available

C. Sample Pretreatment

The samples were screened to remove foreign materials from them. They were dried in the sun for two days to remove the moisture in the samples which might have been absorbed by the wood during logging, sawing and storage in the container.

D. Moisture Content Determination

10g of each sample was weighed into a crucible and placed inside the oven (Genlab laboratory oven, model MINO/040) and the temperature programmed at 110^{o}C. The temperature was attained within 30minutes.The samples were removed with metal tongs; allowed to cool for about three hours in a dessicator and the weights determined. After the first determination, the samples were placed in the oven and heated again; brought out and kept to cool for another 3hours before re-determining the weights. The heating, cooling and weighing were repeated three times to obtain constant weights.

E. Ash Content Determination

10g of each wood saw dust sample was weighed into a crucible and placed inside a furnace (Vecstar furnaces, model ECF2, serial no. f3077) and heated to a temperature of 600^{o}C. They were removed with metal tongs and placed inside a dessicator to cool before determining the weights. The procedure was repeated at an interval of 3 hours until a constant weight was obtained.

F. Metal Content Determination

The samples were digested by dissolving 2g of the ash in 10ml of concentrated nitric acid to which 30ml of conc. hydrochloric acid was added in a beaker in a fume cupboard. The beaker containing the mixture was warmed over a hot plate with a watch glass placed over it. When the digestion was complete, no noticeable particles were found at the bottom of the beaker. The mixture was allowed to cool and was transferred to a 100ml volumetric flask containing 30ml of distilled water. The beaker was rinsed several times with distilled water in order to ensure complete transfer of the meal. Then, the volume was made up to the mark with distilled water. The samples were then transferred to labeled plastic bottles prior to analysis for metallic content using atomic absorption spectrometer (AAS), Perkin Elmer optima 3000 dv atomic absorption spectrometer.

G. Determination of the Effect of Wood Sawdust Ash on the Ignition Point of Wood

To determine the effect of wood saw dust ash on the ignition point of wood, the ignition temperatures of the chosen wood samples, Danta (*Nesogordonia papaverifera*), Oleku, Ekpaya and Akomu (*Pycnanthus angolensis*) were first determined using a furnace (Vecstar furnaces, model ECF2, serial no. f3077). Then another portion of the same wood samples were coated with the different wood ash by surface treatment to about 1mm depth which is okay for ignition and burning as both are surface processes.

After the surface treatment, the ignition temperatures of the wood samples were re-determined. An increase in ignition point showed that the ash has fire retardancy effects while a decrease in ignition point showed that the ash has rather a ‘fluxing’ effect.

IV. Results

Mahogany (*Khaya ivorensis*) has the highest moisture content while poroporo (*Sorghum bicolor*) has the least. The values of the moisture content range from 2.9711g (29%) to 0.9027 (9.0%)

TABLE III
Moisture Content of Wood Sawdust

Sample	Moisture content (g)	Moisture content (%)
Abura	1.2720	12.70
Mahogany	2.9711	29.71
Opepe	1.0062	10.06
Poroporo	0.9027	9.03
Rubber	1.0279	10.28

TABLE IV
Ash Content of Wood Sawdust

Sample	Ash content(g)	Ash content (%)
Abura	1.1279	11.28
Mahogany	1.7285	17.29
Opepe	0.7893	7.90
Poroporo	2.2631	22.63
Rubber	0.7091	7.10

Poroporo (*Sorghum bicolor*) has the highest ash content and rubber (*Heavea brasilensis*) has the lowest. The values range from 2.2631g (22.63%) to 0.7091(7.10%).

TABLE V
Metal Content of Wood Sawdust Ash (PPM)

Sample	Fe	Ca	Mn	Mg	Mean
Abura	2.192	2.055	1.471	3.996	2.429
Mahogany	6.769	7.733	5.061	9.196	7.180
Opepe	4.611	4.992	3.728	5.825	4.789
Poroporo	2.019	1.207	1.049	2.193	1.617
Rubber	1.386	1.548	0.790	2.933	1.664

Mahogany has the highest metal concentration with magnesium having the highest concentration while poroporo and rubber have the lowest concentration with manganese having the lowest concentration.

TABLE VI
Ignition Point

Wood sample	Ash used for coating	Ignition point (uncoated)^{o}C	Ignition point (coated)^{o}C
Oleku	Opepe	310 -315	389 – 395
Oleku	Mahogany	310 -315	406 – 410
Oleku	Abura	310- 315	302- 309
Danta	Abura	455 -462	400 – 405
Danta	Poroporo	455 -462	365 – 370
Ekpaya	Poroporo	595 -601	381 – 390
Ekpaya	Opepe	595 -601	400 – 410
Ekpaya	Mahogany	595 – 601	670 – 675
Akomu	Rubber	405 408	320 – 330

V. Discussion

The moisture contents of the wood saw dust samples were generally more than the ash contents (Tables III, IV). There was no systematic variation between the ash contents and metal contents (Tables IV, V).

Opepe and mahogany ashes coated on Oleku wood increased the ignition point of oleku markedly as shown in Table VI. However, when both were coated on two different portions of Ekpaya wood respectively, Opepe ash reduced the ignition point of Ekpaya markedly while Mahogany ash increased the ignition point of Ekpaya markedly. Danta wood exhibited a little increase in ignition point when coated with Poroporo ash but Ekpaya wood showed a marked decrease in ignition point when coated with Poroporo ash. Abura and rubber wood ashes, when coated on different wood samples reduced their ignition points as shown in Table VI. The wood ashes of Mahogany and Opepe that are high in metal content contributed significantly to increase in ignition point while those that are low in metal content, Abura, poroporo and Rubber ashes reduced the ignition points. However, when Opepe ash which has a high metal content was coated on Ekpaya there was a reduction in ignition point. Some of the metals like magnesium and calcium are present in the wood as carbonate and decompose to their oxides when heated [12]. So, the ashes which are the products of combustion contain the oxides of these metals. These oxides are refractory and can resist high temperatures. This is perhaps why the ashes from Opepe and Mahogany contributed to the increase in ignition points of some wood samples. It is to be noted here that though Opepe ash has high metal content, when coated on Ekpaya sample led to decrease in ignition point. It is most likely that the metal content of Ekpaya wood sample is more than that of Opepe wood ash, leading to a ‘fluxing effect’. This aspect, that is evaluating the metal content of the wood samples to be used as test samples for ignition effect should be investigated in future.

VI. Prospects

The need to prevent fire risks and reduce the number of fire fatalities empowers the market outlook of high fire performance wood products. The current trend of fire safety systems is gearing towards performance based approach. This development will probably facilitate the use of high fire performance wood products. Performance-based fire design increases the freedom of architects, designers and constructors to choose materials and structures, as far as the solutions meet the fire safety objectives defined for the application. Therefore, high fire performance wood products have equal opportunities with other construction products [13].

VII. Conclusion

Wood ash can have both fire retardant and ‘fluxing’ effect on wood. However, before the application of the wood ash for fire retardancy, the metal content of the test wood sample has to be considered for effective result.

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