FUPRE Journal of Scientific and Industrial Research
Vol.2, (2), 2018
ISSN: 2579-184 (Print) ISSN: 2578-1129 (Online)

Variation of Ignition Point of Wood with Surface Treatments

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Abstract

The occurrence of fire is ubiquitous; and wood as a constructional material is indispensable. The ubiquity of fire out-breaks has necessitated the re-examination of the different constructional materials particularly wood, and especially the surface treatments given to wood. Therefore, the variations of ignition points of selected wood samples with different surface treatments were investigated. The wood samples were coated with different wood ash suspensions, emulsion paint, oil paint and adhesive binder. The ignition points were determined using Vecstar furnace model ECF2, serial no. f3077. Moisture contents and metal concentrations of the wood samples were determined with oven Search tech model DHG and Perkin Elmer absorption analyst 400 spectrophotometer respectively. Danta wood (*Nesogordoniapapaverifera) and* Ikpaya wood (*Lophiraalata* or *lanceolata)* coated with polyvinyl acetate adhesive binder gave the highest increase in ignition point relative to the uncoated samples, from 427 - 570^{o}C and 410 - 500 ^{o}C respectively while the other coatings, wood sawdust suspension, emulsion paint and oil paints either suppressed the ignition points or gave little increases in ignition points relative to the uncoated samples. Some constituents of the wood samples such as moisture content and metal concentrations were found to have no significant effects on the ignition points of the wood samples. Therefore, treating constructional woods with surface coatings such as adhesive binders offers a considerable fire resistance.

Key words: **Ignition point, wood, fire, moisture and metals**

1.0 Introduction

Wood is a complex material of the skeleton of trees and sometimes defined as the secondary xylem in the stems of trees (Hickey and King, 2001).The importance as well as the various uses of wood cannot be over emphasized; the usefulness of wood cuts across construction of all categories and types, for paper making, erection and construction of bridges, roofing skeleton amongst others as a result of its excellent physical and mechanical properties (Tuula et al., 2005). Throughout history, the unique characteristics and comparative abundance of wood have made it a natural material for home, other structures, furniture, tools, vehicles, and decorative objects (Okigbo, 1996). Today, for the same reasons, wood is prized for a multitude of uses.

Wood is a very important renewable natural resource that has a credible impact in the evolution of civilization and advancement of mankind. It is indispensable to the survival of man and animals; and the basis for the evolution of other natural resources like coal, and even fossil fuels (Hollingbery and Hull, 2010).

Wood is composed of a mixture of cellulose, hemi-cellulose, and lignin bound together in a complex network (EWPAA, 2013). Cellulose constitutes about 50% of this mixture; and it burns naturally if exposed to severe fire conditions, constituting a serious fire hazard (Akpabio and Jauro, 2002).

As a constructional material, the combustible and flammable properties of wood have to be reduced so as to derive the maximum benefit from its constructional use. Different forms of treatments have been used which apparently confers aesthetic properties but a bit unknown fire resistance such as emulsion paints, oil paints and adhesive liquid binders.

Wood ash, a combustion product of wood sawdust and wood, for a long time had been used in agricultural soil applications, due to its potency as fertilizer, though it does not contain nitrogen. Due to the presence of calcium carbonate, it acts as a liming agent as it deacidifies acidic soil by increasing the soil pH (Brumer et al., 2004). Wood ash has also for long been used in ceramic glazes in Asia, though now it is used by many craft potters to act as flux by reducing the melting point of the glaze (Rogers, 2003). Potassium hydroxide can be made directly from wood ash (Etiegni and Campbell, 1991) and in this form it is known as caustic potash or lye, hence the reason it is used traditionally to make wood ash soap.

However, wood ash does not have any fire propelling and combustion strength and is therefore been explored in conjunction with other surface coatings to assess the ignition points of different wood species in comparison with the ignition points of untreated or uncoated wood samples. The results of this investigation may aid wood construction workers to explore alternative and cheaper sources of enhancing the fire resistance of constructional woods. The opportunity of recycling wood saw dust which is abundantly mounded in most river banks where wood industries are usually located may be explored. The intrusion of these wood waste materials into the water bodies constitutes ecotoxicological threat.

2.0 Materials and Methods

2.1 Sampling Location

The wood samples and the wood sawdust were obtained from Ogwanja wood market in Sapele, the headquarters of Sapele Local Government Area in Delta State, Nigeria. Sapele is a cosmopolitan town and an important sea port for trade in timber and timber related products. The business was largely controlled by the African Timber and Plywood Company established by the Miller Brothers in Sapele in 1935. The town also serves as a base for the Nigerian Navy. It is one of the oil producing areas of Delta State (Okumagba and Ozabor, 2014).

Sapele is located in the southern part of Nigeria; it lies $5^{\circ}54''$N and $5^{\circ}40''$E of the equator and the Greenwich meridian respectively. It is close to River Ethiope (Okumagba and Ozabor, 2014)

Figure1: Map of Delta State showing Sampling Location

2.2 Sampling of Saw Dust and Wood Samples

The saw dust samples from the woods listed in table 1, were got directly from the cutting machine, as the timbers were cut into different sizes. A collecting tray was placed near the cutter of the machine which is the passage or exit route for the saw dust, and this was done carefully so as to avoid contamination.

Eight wood samples , Ugbarugba (*Copaifera species*); Obeche (*Triplochitonscleroxylon);* Utuaro (*Heayodendron species);* Baphia (*Baphianitida);* Water ikhimi (*Piptadeniastrumafricanum*)*;* Water ato (*Millettia species*)*;* Danta (*Nesogordoniapapaverifera*) and Ikpaya (*Lophiraalata* or *lanceolata)* were selected for ashing while the last two, Danta (*Nesogordoniapapaverifera)* and Ikpaya(*Lophiraalata* or *lanceolata)* were selected as coating substrates because of their extensive use in constructional works in Nigeria.

Danta wood specifications:

weight: 21.7830g; length: 6cm; width: 4½cm; height: 1½cm

Ikpaya wood specifications:

weight: 22.7242g; length: 6cm; width: 3½cm; height: 1½cm

Table 1: Local and Botanical names of the wood samples

S/N	Local names	Botanical names
1	Ugbarugba	*Copaifera species*
2	Obeche	*Triplochitonscleroxylon*
3	Ikpaya	*Lophiraalata or lanceolata*
4	Utuaro	*Heayodendron species*
5	Baphia	*Baphianitida*
6	Water ikhimi	*Piptadeniastrumafricanum*
7	Water ato	*Millettia species*
8	Danta	*Nesogordoniapapaverifera*

2.2.1 Sample Treatment

The saw dust and wood samples were dried in the sun after collection so as to remove the moisture in the samples which might have been absorbed by the wood during logging and transportation to the saw mill.

2.3 Materials

Reagents used were of analytical grade and standards and are products of sigma-Aldrich chemicals, Buchs, Switzerland and Mallinckradt Baker Inc., Philipsburg, NJ(0886) USA. Paints and binder used were Sandtex emulsion paint, Citizen Enamel paint and V-firm liquid adhesive binder. In emulsion paints, water is used in place of organic solvent as thinners. It is in two phases which are the water phase and the paint phase. It is composed of the binder which is the dispersing agent, stabilizers, surface active agent, driers, antifoaming agent, emulsifying agent, and preservatives (Sharma, 1997).

Oil or Enamel paint gives lustrous and glossy finish to its substrate; they are also known as pigmented varnishes. They are composed of vehicle which is oil i.e. oleoresins (oil and resins), driers (turpentine) (Sharma, 1997). Binder is simply composed of poly vinyl acetate (PVA) and breaks down at high temperature to form a melt which prevents combustion by serving as a barrier between air and inflammable substance (Sharma, 1997).

2.4 Methods

2.4.1 Ashing of Sawdust

This was done using a furnace (Vecstar furnance ECF2), the various sawdust samples were placed in crucibles which are then placed into the furnace and the furnace temperature control was set to 600°c. At the specified temperature it is expected that the sawdust would have been converted to ash. This was allowed to run and observed till all the sawdust completely turned to ash.

2.4.2 Coating of the Wood Samples for Ignition Point Determination

Figure 2a: Coated wood samples

Figure 2b: Uncoated wood sample

2.4.3 Ignition Point Determination in Wood Samples

Ignition point is the temperature at which a substance ignites (burns or catches fire).The wood samples (uncoated) were placed in the furnace (Vecstar furnace ECF2) and the temperature at which they caught fire (their ignition points) determined. Different sets of the wood samples were coated with the suspension of the various saw dust ash in water, emulsion paints, oil paints and binder; and their ignition points determined. The last set of the wood samples was coated with a binder mixed with ash, and the ignition points determined.

2.4.4 Moisture Content Determination

The samples inside the crucibles were placed inside the oven and heated to at a temperature of 120ºC at 10 ºC/ min heating rate. After one hour this temperature was reached, the samples were allowed to cool for one hour and the weights determined. After the first determination, the samples were kept for another 3hours to cool before re-determining the weights. This was repeated three times in order to get a constant weight. The moisture content was determined by weight difference.

2.4.5 Metal Content Determination

The samples were digested by dissolving one (1) gram in a 20mL mixture of HNO_3 and HCl (1:3 v/v) in a beaker in a fume cupboard. The content of the beaker was refluxed over a heating mantle with a watch glass placed over the containing beaker. Once the digestion became complete, no noticeable solid particles were found at the bottom of the beaker. The mixture was allowed to cool before been transferred to a 50ml volumetric flask and made up with distilled water to the 50mL mark. The beaker was rinsed several times in order to attain complete transfer of the meal, the mixture with water was then filtered using filter paper and the filtrate obtained was then transferred into the sample bottle which was clearly labeled. The sample was analyzed for metals using Atomic Absorption Spectrophotometer (Perkin Elmer absorption analyst 400) equipped with relevant elemental hollow cathode lamps and digital display read out.

3.0 Results and Discussion

Table 2: Moisture content of wood saw dust

S/N	SAMPLE	MEAN MOISTURE CONTENT(g)	MOISTURE CONTENT (%)
1	Obeche	0.3518 ± 0.011	35.18
2	Ikhimi	0.1647±0.001	16.47
3	Ato	0.1490±0.012	14.90
4	Bafia	0.1276±0.001	12.76
5	Ugbarugba	0.1865±0.005	18.65
6	Danta	0.1834± 0.002	18.34
7	Ikpaya	0.1609±0.001	16.09
8	Utuaro	0.1942±0.015	19.42

The moisture content ranges from 0.3518g (35.18%) to 0.1276g (12.76%) with Obeche having the highest moisture content,0.3518g (35.18%) and Bafia having the least, 0.1276g (12.76%).

Table 3: Metal content of wood ash and wood sawdust (ppm)

S/N	SAMPLE	Fe	Ca	Pb	Cr	Mg
1	Obeche ash	ND	143.88±2.05	ND	0.54± 0.01	22.15±0.02
2	Ikhimi ash	0.06± 0.01	76.72± 3.25	0.241±0.01	0.391±0.01	25.44± 0.03
3	Ato ash	ND	33.00±0.51	ND	ND	10.07±0.01
4	Bafia ash	ND	128.88±6.85	ND	ND	9.06± 0.001
5	Ugbarugba ash	ND	258.58±3.85	ND	ND	24.53±0.03
6	Danta ash	ND	143.38±5.34	ND	0.50±0.02	20.22±0.03
7	Ikpaya ash	ND	252.58±4.55	ND	0.382±0.01	13.03±0.02
8	Utuaro ash	ND	90.59±2.10	ND	0.028±0.001	19.14±0.01
9	Obeche sawdust	0.347±0.01	47.92±3.30	ND	0.015±0.001	4.584±0.05
10	Ikhimi saw dust	0.363±0.01	19.94±0.55	0.415±0.05	0.032±0.001	5.32±0.05
11	Ato saw dust	ND	63.55±0.75	0.444±0.05	0.403±0.06	4.137±0.06
12	Bafia saw dust	0.132±0.01	20.36±1.25	ND	0.143±0.02	3.344±0.15
13	Ugbarugba saw dust	ND	49.48±1.35	ND	0.162±0.05	5.473±0.35
14	Danta saw dust	ND	14.13±1.25	0.504±0.01	ND	5.145±0.15
15	Ikpaya saw dust	1.763±0.01	2.11±0.02	ND	ND	3.769±0.15
16	Utuaro saw dust	0.670±0.05	25.47±2.05	ND	ND	5.473±0.20

ND means,' Not detected or below the detection limit of the instrument'

The metals were more concentrated in the wood ash samples than in wood saw dust sample as shown on table 3. This is perhaps due to the elimination of most of the interfering constituents during the ashing process before the arrival at the destination product, ash. Calcium (Ca) and magnesium (Mg) were the predominant and consistent metals in all the samples. This is not surprising as both of them are constituents of wood in the form of magnesium and calcium carbonates (Brumer et al.,2004). Ugbarugba ash has the highest metal concentration with calcium being the highest (258.58±3.85ppm) while Utuaro ash has the least metal concentration, chromium (0.028±0.001ppm) as shown on table 3.

3.1 Relationship between Moisture Content and Metal Concentration

The influence of moisture content on the accumulation or absorption of the two predominant metals (Ca & Mg) by the wood plants was constructed from the values obtained. The coefficient of correlation (R^2) was 0.015, which suggests an insignificant relationship as shown in figure 3. Therefore, the moisture content of the wood plants did not in any way facilitate the metal accumulation in the wood plants.

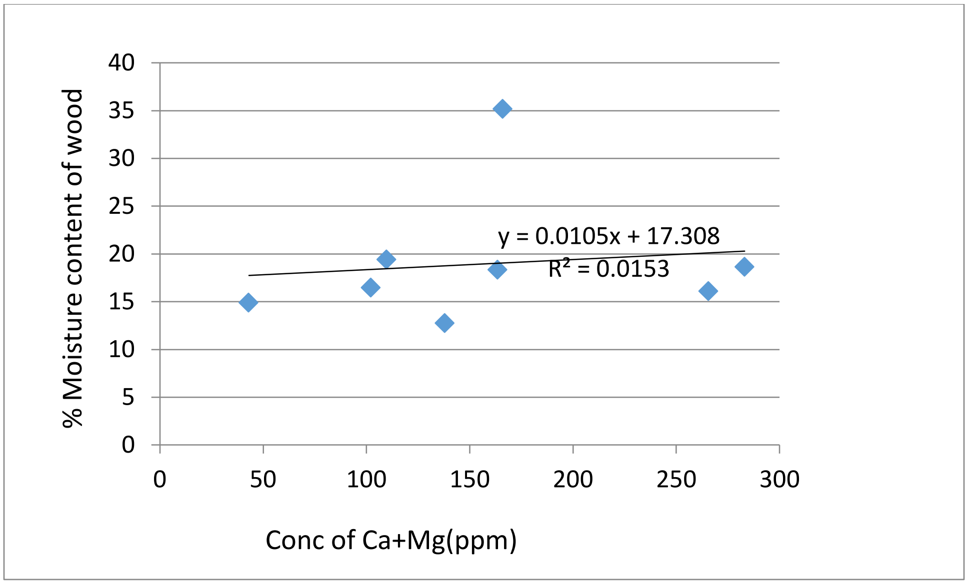

Fig. 3: Moisture content of wood saw dust versus Ca+Mg Conc

3.2 Comparative Ignition Points of the Different Wood Treatments

Two wood samples, Ikpaya(*Lophiraalata* or *lanceolata* and Danta(*Nesogordoniapapaverifera)* used for the investigation of the different coating treatments showed that the coating treatment with a polyvinyl acetate liquid adhesive binder on ash suspension had a marked effect on the ignition point of the wood samples than the other three treatments- ash suspension coating, emulsion paint coating and oil paint coating as shown on tables 4 and 5. The polyvinyl acetate liquid adhesive binder on ash suspension elevated the ignition point of Ikpaya wood sample from 410^{o}C uncoated wood sample to 500^{o}C in the coated sample, an increase of 90^{o}C while that of Danta wood sample increased from 427^{o}C uncoated to 570^{o}C in the coated sample, an increase of 143^{o}C.

Furthermore, the observed results from the other three treatments may be attributed to the poor adherence of the coatings on the wood sample. Ash suspension in water has poor adhesion on wood; emulsion paint is water soluble produced mainly for aesthetic coating. Most oil paints are pigments ground in a drying oil like linseed oil which dry by atmospheric oxidation of the unsaturated portion of the oil. They easily disaggregate with temperature increase; providing only corrosion resistance, rust prevention, water proof and glossy appearance unlike the polyvinyl acetate adhesive binder which formed a heat protective layer around the wood sample that has to be burnt out first before the fire can actually ignite the wood samples(Sharma, 1997).

Table 4: Ignition points of uncoated and coated Ikpaya wood samples

Wood Type	Uncoated (°C)	Coated with Suspension of ash in water (°C)	Coated with Emulsion Paint on ash (°C)	Coated with Oil Paint on ash (°C)	Coated with Binder on ash (°C)
Wood sample	Ikpaya wood	Ikpaya wood	Ikpaya wood	Ikpaya wood	Ikpaya wood
Uncoated	410	-	-	-	-
Ikpaya ash	-	410	400	390	500
Obeche ash	-	380	350	356	470
Danta ash	-	390	438	440	460
Ugbarugba ash	-	417	400	426	490
Ikhimi ash	-	420	385	385	480
Bafia ash	-	390	382	407	475
Utuaro ash	-	400	420	440	480
Ato ash	-	410	417	445	500

3.3 Effects of Moisture Content and Metal Content on the Ignition Point of Wood

The effects of moisture content and metal concentrations of the wood samples on the ignition points of the selected wood samples were constructed from the obtained values of the moisture contents and metal contents. The correlation coefficients of the moisture contents versus ignition points; and the metal contents versus ignition points were all less than 0.1 as shown in figures 4-8. This suggests that both the moisture content and metal concentration of the wood samples did not influence the ignition points. Therefore, the surface coatings given to wood samples may have been the factor influencing their ignition points. This, in turn affects the fire retardancy of the wood samples.

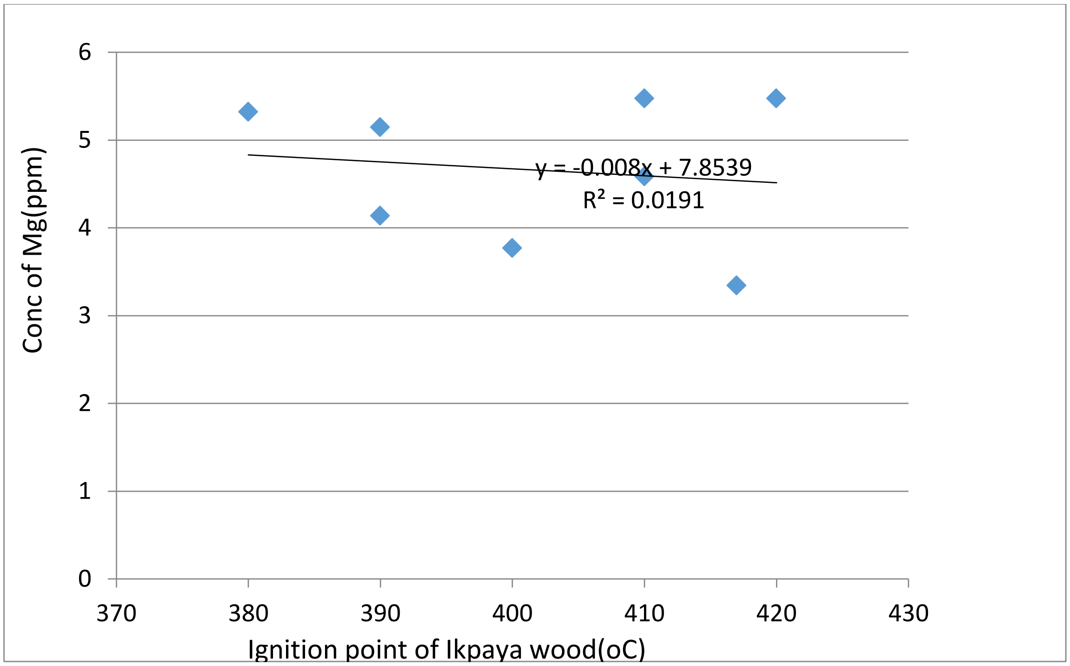

Fig.4a: Ignition point of Ikpaya wood versus Magnesium Concentration

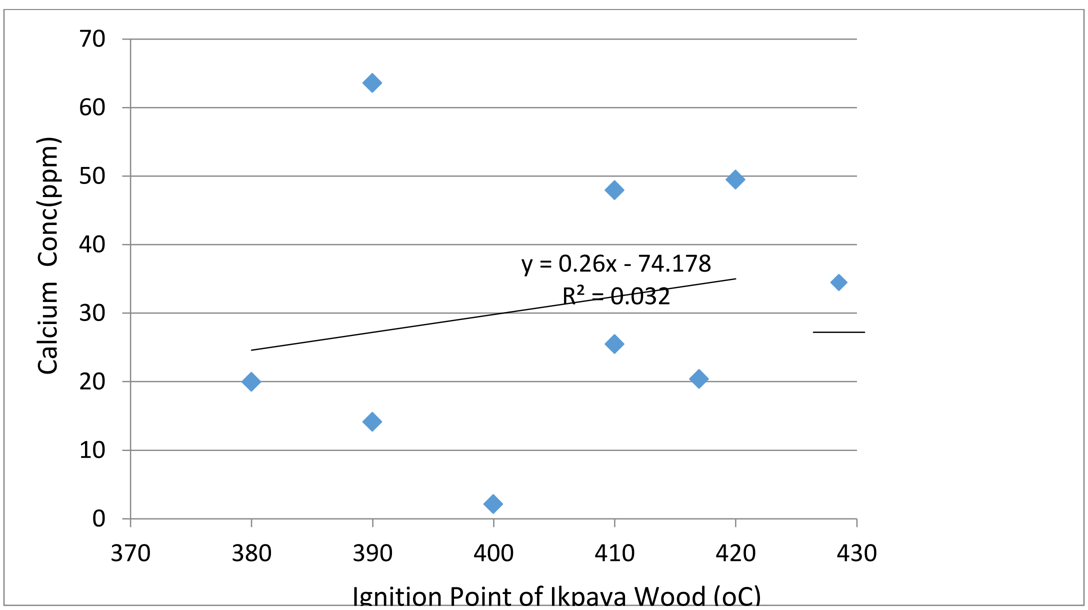

Fig.4b: Ignition point of Ikpaya wood versus Calcium Concentration

Table 5: Ignition points of uncoated and coated Danta wood samples

	Uncoated (ºC)	Coated with suspension of ash in Water (ºC)	Coated with Emulsion Paint on ash (ºC)	Coated with Oil Paint on ash (ºC)	Coated with Binder on ash(ºC)
Wood sample	Danta wood	Danta wood	Danta wood	Danta wood	Danta wood
Uncoated	427	-	-	-	-
Ikpaya ash	-	415	400	385	570
Obeche ash	-	410	355	372	525
Danta ash	-	445	410	430	555
Ugbarugba ash	-	440	435	390	530
Ikhimi ash	-	390	390	450	550
Bafia ash	-	410	370	415	520
Utuaro ash	-	415	440	440	550
Ato ash	-	460	395	425	500

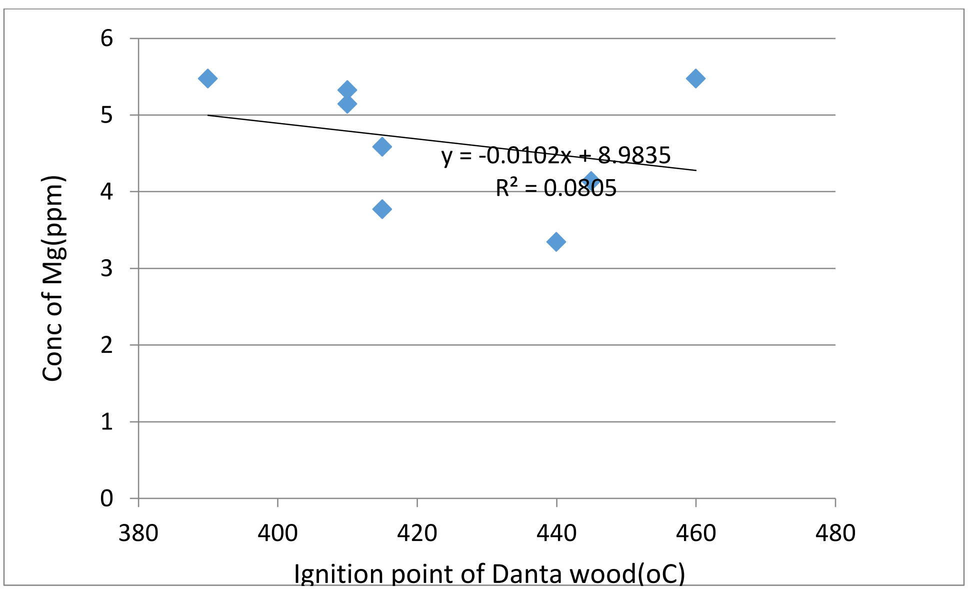

Fig.5a: Ignition point of Danta wood versus Magnessium concentration

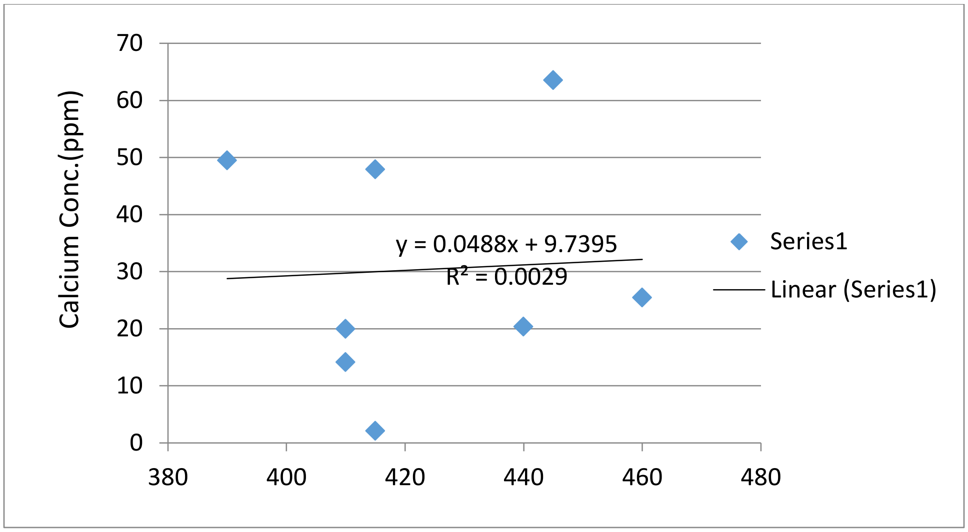

Fig.5b: Ignition point of Danta wood versus Calcium concentration

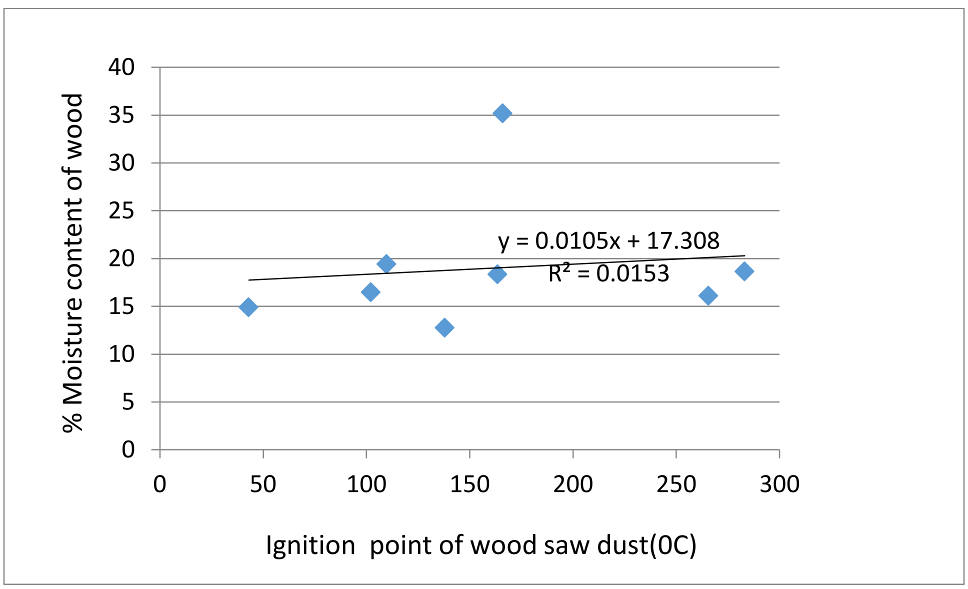

Fig.6: Ignition point versus moisture content of wood saw dust

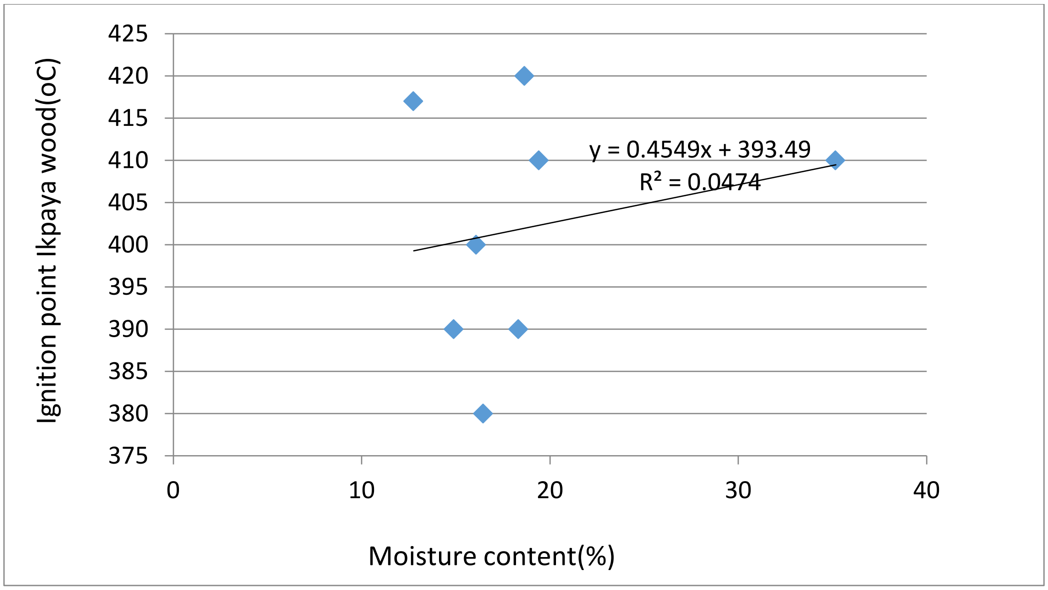

Fig. 7: Moisture content versus ignition point of Ikpaya wood

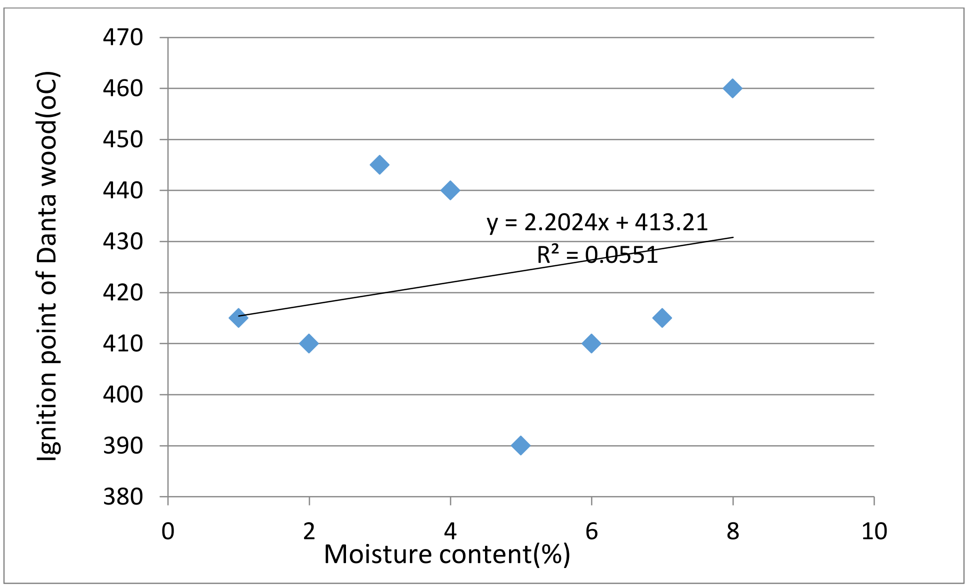

Fig. 8: Moisture content versus ignition point of Danta wood

Conclusion

The water content and metal concentrations of wood samples studied had little or no effect on their ignition points. The ash suspension in water, emulsion and oil paints used in coating the selected wood samples did not affect their ignition points significantly too. However, the adhesive binder coating provided more fire resistance, enhancing the ignition point of the wood samples. Therefore, adhesive binders should be used beyond mere binding agents in wood constructional works, and be used equally as a foundational coating on constructional woods before any other coating. Alternatively, adhesive binders could be harnessed and used in paint production to offer additional fire protection.

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Acknowledgment

The authors are grateful to the wood sellers in Ogwanja wood market in Sapele, Delta State, Nigeria for their assistance in the procurement of the wood samples and identifying the local names of the wood samples. We also appreciate the technologists in the Department of Chemistry, Federal University of Petroleum Resources, Effurun for their support in the analysis of the samples.