Characterisation of Sawdust from Entandrophragma Cylindricum (Sapele), Diospyruscrassiflora (Ebony), Triplochitonscleroxylon (Obeche) and Chlorophora Excelsa (Iroko) Woods

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Abstract— This research work examined and characterized saw dust from Entandrophragma cylindricum (Sapele), Diospyruscrassiflora (Ebony), Triplochitonscleroxylon (Obeche) and Chlorophora excelsa (Iroko) wood using both proximate and elemental or ultimate analysis. This was carried out to facilitate engineering analysis and engineering application of composites resulting from a blend of polymer and these saw dusts. The particle size was determined using sieves of 3.35mm, 2.80mm and 1.18mm aperture, while moisture content was examined using oven-dry method and from the moisture content it is seen that the moisture content of the samples investigated fall within the standard average of 20 to 60 %, with Sapele, Ebony, Obeche and Iroko having moisture content of 33.3%, 25.0%, 53.8% and 23.3% respectively. Hydrogen and oxygen content were determined quantitatively using the fact that water is made up of these gases. The carbon content was also investigated and the result shows that both oxygen carbon are relatively abundant in the sawdust's investigated. The sawdust char (carbon) content and pH were also determined using a pyrolysis reactor and pH meter respectively. Both Ebony and Obeche are neutral while Sapele and Iroko are slightly alkaline and acidic respectively. The properties are in agreement with previous data obtained for an average of 11 hardwood and soft wood.

Index Terms— Characterisation, Chlorophora excelsa (Iroko), Composites, Diospyruscrassiflora (Ebony), Entandrophragma Cylindricum (Sapele), Sawdust, Triplochitonscleroxylon (Obeche), Sawdust, Characterization.

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1 Introduction

Wood is a naturally occurring organic composite material that is hard and made up of cellulose fibrous structural tissue. This fibrous strong in tension structures embedded in leguminous matrix are found in the stems and roots of trees and other woody plants. They resist compressive stress. In its dried state wood has been used for thousands of years for both fuel and construction material [39]. Like man made composite that can be tailored to have specific properties for specific purpose as is the case with polymer composites, [3], wood has naturally built in properties that can be improved on by treatment. As a rule of thumb, a relationship exists between characteristics of a wood type and its source tree. One notable characteristic of wood is its density. Depending on the source and specie the density of wood varies and correlate with its strength (mechanical properties) and determines its end use. For instance, while mahogany is a medium-dense hardwood with excellent ability for fine furniture crafting, Balsa is useful for model building because of its light weight. Wood can also be characterized as either soft or hard, [39], [37], [38]. The wood from conifers (e.g. pine) is called softwood, and the wood from dicotyledons (usually broad leaves trees e.g. Oak) is called hardwood. These classifications are a bit misleading as hardwoods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some soft woods (e.g. yew) are harder than many hardwoods. Some other classification as "hardwoods" or "softwoods" is based on a botanical difference. Softwoods (or "gymnosperms") are the conifers [1], that is needle-bearing trees that are often evergreen while Hardwoods (or "angiosperms") are broadleaved, mostly deciduous trees. Characteristics of hardwood include the fact that it is dense, hard and found all over the world. Conversely, softwoods are soft and found only in the northern hemisphere mostly. Hardwoods are dark and heavy, while softwoods are light in colour and weight. Also, the quality of wood can be defined relative to the properties that make them useful for particular purpose [48]. Amongst others, density and micro fibril angle (indicators of strength and stiffness respectively) are primary determinants of what a wood quality is said to be [9], [10]. Different professionals define the quality of wood differently. As discussed by Addis et al [1] the saw miller for economic reasons considers production and the value of the grade as deciders to consider in wood qualities categorization. For the structural engineer wood quality is based on stiffness level. The usability of a type of wood for him as essential components of structures such as beams, joists, purlins studs and trusses a high stiffness level indicates quality wood as this property is the most important. wood density and long fiber length with low lignin content is important for the wood technologist and the paper and pulp miller respectively. The pulp miller considers longer fiber length as reasons for increased value of wood [11]. Wood density and wood specific gravity both indicate the amount of actual wood substance present in a unit volume of wood [47]. Murphy et al Osew and O'sullivan [28], [29], [30] and Panshin and de Zeeuw [32] all acknowledged that wood density is not a simple characteristic [33], [34]. Pashin and de Zeeuw [32] stated that the quality of

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wood that gives specifics as to the wood cell size, strength, stiffness, ease of drying, machining, hardness and other paper making properties. This fact is corroborated by Brazier and Howell [46]. They explained that density is one of the most important properties that determines the use of a timber. According to them, it Emphasizes the effect on the technical performance of wood, the strength and processing behavior of sawn wood and veneer, and the yields of wood fiber in pulp production. Basic density is closely related to end-use quality parameters such as pulp yield and structural timber strength [19], [45].

However, whatever the classification, every wood has the same components and three other main components [39]. Cellulose a Crystalline polymer derived from glucose constitutes about 41-43%. Next in abundance is hemicellulose, which is around 20% in deciduous trees but near 30% in conifers. It is mainly 5-carbon sugars that are linked in an irregular manner, in contrast to the cellulose lignin is the third components at around 27% in coniferous wood versus 23% in deciduous trees, [12],[13],[14],[15].

In chemical terms, the difference between hardwood and softwood is reflected in the composition of the constituent lignin. Hardwood lignin is primary derived from sinapyl alcohol and coniferyl alcohol. Softwood lignin is mainly derived from coniferly alcohol [39].

For effective usage wood has to be subjected to cutting, grinding, drilling, sanding or otherwise sawing wood with a saw or tool. The resulting by-product of any of these processes is sawdust. It is composed of fine particles of woods. It is also the by-product of certain animals, birds and inserts which live in wood such as the woodpecker and carpenter ant. The sawdust or wood dust presents a hazard in terms of its flammability. A major use for wood dust is a pulp or as a fuel (sawdust pellets that has grown in production over the years [44]. It is also used in the manufacture of charcoal briquettes [39]. Entandrophragma cylindricum (Sapele), Diospyruscrassiflora (Ebony), Triplochitonscleroxylon (Obeche) and Chlorophora excelsa (Iroko) woods are among the most dominant and major hardwood used in many countries around the world and in the Niger Delta region of Nigeria. Their huge availability makes it readily available for use for construction works and other areas especially in energy production (burning) and these make their sawdust a nuisance or hazard which needs attention. In the light of this the Canadian Centre for Occupational Health & Safety [41] reported that the exposure to wood dust has negative health implication due to the natural chemicals in the wood, or other substances like bacteria, fungi or moulds in the wood. Again, sawdust is considered carcinogenic to humans and it is grouped under category 1, (Group 1) according to the International Agency for Research on Cancer (IARC) [42]. IARC classified sawdust as carcinogen causing nasal cavity (nose area) and paranasal sinuses (spaces in and around the nasal cavity) and of the nasopharynx (upper part of the throat, behind the nose). Sawdust has also been associated with toxic effects, irritation of the eyes, nose and throat, dermatitis, and respiratory system effects which include decreased lung capacity and allergic reactions. Based on the need for the use of the abundant sawdust this research examined the chemical compounds in these woods in other to recommends safe usage methodology and practicality in matrix formation with polymers. Prevention of hazards to man and the environment when they are used in other manufacturing processes such as waste water treatment [24], preparation of anion exchangers [23], or recycled are other key considerations.

Araceli et al [5] reported that the search for a standard method to analyze hardwood saw, dust in the midst of other dust is still on. However, the tannin content that is, the polyphenol compounds, classified as hydrolysable (gallic and ellagic acid derivatives) and condensed tannins, with the basic unit as flavone (quercetin, catechin, epicatechin, myricetin etc.), in a sample can be helpful in distinguishing between softwood and hardwood particles [7], [8] since hardwoods such as oak or mahogany have a higher tannin concentration than softwoods (e.g. pine, spruce fir). It is worthy of note that analysis of the total tannin content does not provide clear identification of the hardwood type (e.g. oak, beech or ash dust particles). Mämmela [26], [27] identified that the tannin content differs within and between wood species. Therefore, it is only when the specific phenol compound is identified that it can be said that identification has taken place. The analytical procedure usually consists of digestion of the sawdust, usually by ultrasonication in an alcohol, separation by high performance liquid chromatography (HPLC) and mass spectrometry (MS) detection.

Mämmela [27] researched on the different phenol composition in beech, birch and ash with the aim of finding a specific compound(s) to characterize each wood. The result showed that the phenol composition in the three species was different from that found in oak sawdust (mostly gallic acid derivatives); birch sawdust did not contain gallic acid. However, the phenol content varied considerably within the same species and so an appropriate surrogate could not be identified. The author suggested that a more powerful analytical technique, such as Nuclear Magnetic Resonance (NMR) spectroscopy, could help to identify sawdust sources. In several studies it has been reported that Gallic acid (3,4,5-trihydroxybenzoic acid) and egallic acid (2,3,7,8-tetra hydroxychromeno[5,4,3-cde] chromene 5,10-dione) are good indicators of the presence of oak dust [7], [8], [16] [26], [27]. Acacia, chestnut and Oak have also shown high peaks of gallic species [8]. Gori *et al* [8] developed a method to assess specific exposure to teak sawdust. A method to isolate wood dust from other environmental dust particles has been developed by Rando *et al* [36]. The method uses diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) analysis of the cellulose content of the wood. The method specifically identifies cellulose which is not present in non-wood dust particles (e.g. paint sprays, mineral particles, etc.). only poly urethane spray on finish showed insignificant interferences. According to Rando et al [36], a major shortfall in this methodology is that DRIFTS analysis is sensitive to changes in the particle size distribution. Therefore, particle size distribution of the sawdust being sampled must match the expected analytical standard used for the quantification. The method is valid for filter mass loadings from 0.1-0.4 mg, which corresponds to about 0.10-4.20 mg/m^3 for sampling 8hrs at a flow rate of 2.0l/min. Therefore, it is seen that it is possible to chemically analyze samples to determine specific hardwood dust components. The different methods reported indicate that hardwood can be distinguished from softwood from the tannin content in the dust. Other methods have been developed that allow identification of specific hardwood species [17],[18]. However, if different hardwood species are present in the dust then analysis of tannins content of the hardwood species and establishment of the tannin content equivalent to 1mg/m³ of inhalable dust gives a lee way. This might have to be established for each hardwood species and variety within each species since the tannin content differs in between the species of the same wood.

This study analyzed quantitatively four hardwood species namely Sapele, Ebony, Obeche and Iroko woods with their binomial name as Sapele (Entandrophragma cylindricum), Ebony (Diospyruscrassiflora), Obeche (Triplochitonscleroxylon) and Iroko (Chlorophora excelsa) and determined their moisture content, alkalinity, acidity and the amount of hydrogen, Oxygen, sulphur and hydrogen present in the various samples of their sawdusts.

2.0 MATERIAL AND METHODS

2.1 MATERIALS AND EQUIPMENTS

The materials and equipment used in this research is as listed in section 2.11 and 2.12 below. Following recent publications on timbers of Ghana [31], the basic nomenclature of scientific and family name follows that of Hall and Swame. Each species is first identified by its botanical name, followed by the local name.

2.11 MATERIALS

The materials that were used are; Triplochiton scleroxylon (Obeche) wood dust, Enatandrophragm cylindricum (Sapele or Sapelli) wood dust, Chlorophora excels (Iroko) wood dust and Diospyros crassiflora (Ebony) wood dust.

And these sawdusts were obtained from the saw mill around Port Harcourt, Rivers State Nigeria.

2.12 EQUIPMENTS

The equipments used are: Digital weighing balance, Oven, Beakers, measuring cylinders, Gas burner, Containers, and Cooling water. And all the experiments were carried out in the laboratory in chemical-petrochemical department, Faculty of Engineering of Rivers State University, Nkpolu – Oroworukwo, Port Harcourt, Rivers State Nigeria.

3.0 RESEARCH METHODOLOGY

For this research, the main biomass fuel analyses were done for: The particle size, Carbon content and Hydrogen content. Others are Oxygen content, Nitrogen content and Acidity/ alkalinity.

Although the chemical constituents like cellulose, hemicellulose and lignin are also important they were not considered in this research work. The constituents like carbon, hydrogen, oxygen, nitrogen and halogen gases are usually termed as Elemental or Ultimate analysis. This analyses provides weight percentage of carbon, hydrogen, oxygen, nitrogen and so on. The analysis that provides the weight fraction of moisture content, volatile and non-volatile contents including Tar, charcoal and ash are termed Proximate analysis. Sometimes, the yield of dry wood under combustion conditions may be further subdivided into light hydrocarbon, tar, carbon monoxide, hydrogen and moisture yield.

3.1 PROXIMATE ANALYSIS

3.11 *Particles Size Determination*

The biomass samples have various size, thus the average sizes of the particle was adopted. Sieves of various apertures were used to separate the particle into sizes and their average size was determined. The 3.35mm, 2.80mm and 1.18mm sieve apertures were used for sieving 600g of each wood dust samples, their collections were weighed and their average size gave the particles average size.

3.12 *Moisture Content Determination*

For the moisture content determination, the oven-dry method was adopted. In this method, the blended samples (i.e. the samples of Iroko, Sapele, Ebony and Obeche wood dust) were obtained and weighed to determined their initial weight. The known mass of the sample was then oven dried at a temperature of about 103- 105^{o}C for 120 minutes. Then the samples were taken out and allowed to cool in an air-tight container before determining its new weight called the Dry weight on a digital. It was observed that there was loss in weight due to the removal or evaporation of its water/moisture content from the sample.

Therefore, using the following formula the water/moisture content of the blended sample could was determined;

$$\text{Moisture content} = \{(WW–DW)/DW\}\times100\% \qquad (1)$$

Where: WW = wet weight, DW=dry weight

These experiments were carried out on pure sample of each wood sawdust to determine their moisture content individually. Their initial weight was chosen to be 100g of each sample and their various dry weights was determined and their various moisture contents noted.

3.2 ELEMENTAL/ ULTIMATE ANALYSIS

3.21 *Hydrogen and Oxygen Content Determination*

The amount of hydrogen of the wood sample (wood dust) was determined based on the knowledge of the amount of water present in the sample. Using the Stiochiometric relationship we obtained the amount of hydrogen from its percentage composition in water or as a mass fraction. Chemically, water is made up of hydrogen and oxygen only i.e.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

This method was applied to the various woods samples and their blends. The same methodology was used for oxygen content determination

3.22 Carbon Content Determination

To obtained the amount of carbon content in the wood samples. The dried saw dust obtained during the moisture content determination was sent to a pyrolysis plant to decompose the saw dust into its structural components consisting of volatile liquid and a residue of char (otherwise known as carbon). The pyrolysis was carried out in a temperature of 300- 350°C for about 90 minutes. After the pyrolysis process, the char inside the reactor was extracted enclosed in an air-tight container to avoid adsorption of air. The char (carbon) was then measured to determine its weight/ mass upon which its percentage composition in the ground sample waSs being calculated. The percentage of the carbon content was obtained using:

Carbon content (%) = {(WoD–WaP)/WoD}x100% (2)

Where: WoD = Weight of Dry sample, WaP = Weight after pyrolysis.

3.23 Nitrogen Content Determination

The percentage of nitrogen content in the sawdust samples were obtained using Kjeldahl- Gunning-Arnold method. While the acidity of the various wood dust samples were determined by measuring an equal amount of various wood samples and adding 100 ml of distilled water. It was stirred vigorously and taken to a pH meter to determine their various levels of acidity or alkalinity.

4.0 RESULTS AND DISCUSSION

The elemental and proximate composition of various woods (Sapele, Iroko, Ebony and Obeche) is presented below. The result indicate that the composition of wood varies depending on the type of tree species (variation within species, locality, handling process, density and strength) [47].

PROXIMATE ANALYSIS

Particle Size Determination

The actual particle size of the sawdusts could not be determined because they contain various sizes of particles, so their average was adopted. When 600g of each samples of sawdust weere sieved through 3.35mm, 2.80mm, 1.18mm sieve aperture, the following readings tabulated in Table 1 were obtained.

Table 1. weight of sawdust after sieving.

Sieve Aperture(mm)	Weigh after sieving (g)			
	Obeche	Sapele	Iroko	Ebony
1.18	390	540	505	450
2.80	575	580	580	562
3.35	580	587	590	572

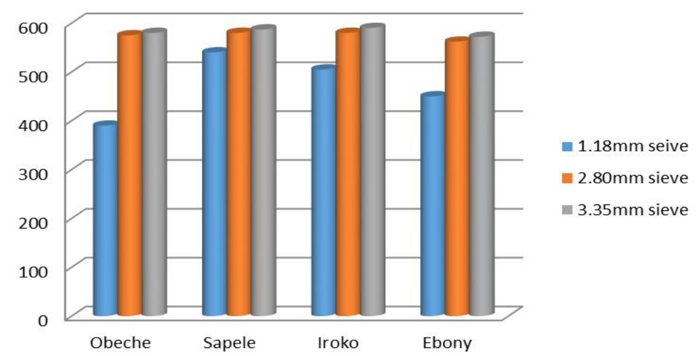

Figure 1: Weight of the various saw dust in the sieve after sieving.

From Table 1 and Figure 1, it can be seen that more particles are retained in 1.18 and 2.8mm sieves and their average is 1.99mm, which is approximately the same with the report of Johnson *et al* [21].

Moisture Content Determination

The sawdust moisture content depends on the species, age and the amount of drying of the wood or tree. Table 2 gives the result of 100g of each sample of the sawdust (with moisture) after oven-drying.

TABLE 2
THE DRY WEIGH AND % MOISTURE CONTENT OF THE FOUR SAMPLES OF WOOD

Sample	Dry weight (g)	% moisture content
Obeche	65	53.85
Sapele	75	33.33
Iroko	81	23.35
Ebony	80	25.0

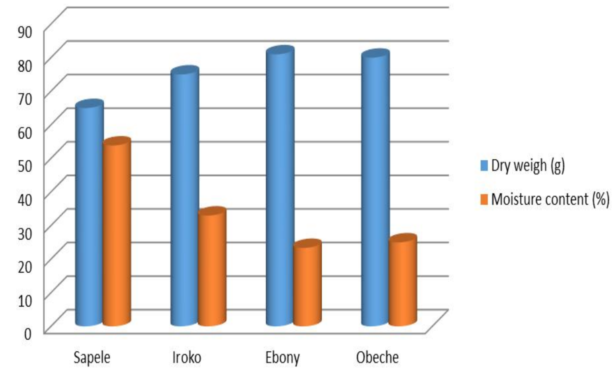

Figure 2. weight of the dry weight and moisture content of the four saw dust.

Figure 2 shows that Iroko and Ebony have the least % moisture content likely because they were obtained dried at the time of the experiment. But normally, moisture content of wood chips is between 20-60%. Again, the results of this work falls within range.

Acidity/Alkalinity Determination

The result tabulated in Table 3, gives the pH value of the various samples. The result as expressed in Figure 3 shows that both Ebony and Obeche are neutral while Sapele and Iroko are slightly alkaline and acidic respectively.

TABLE 3
THE PH OF THE VARIOUS SAMPLES

Sample	pH
Entandrophragma cylindricum (Sapele)	8
Chlorophora excelsa (Iroko)	6
Diospyruscrassiflora (Ebony)	7
Triplochitonscleroxylon (Obeche)	7

Elemental Analysis

The elemental analysis gives the hydrogen, oxygen, nitrogen, carbon and sulphur content of the various samples of the sawdust. The nitrogen and sulphur were not given consideration because its content in many woods is approximately zero or can't be easily detected.

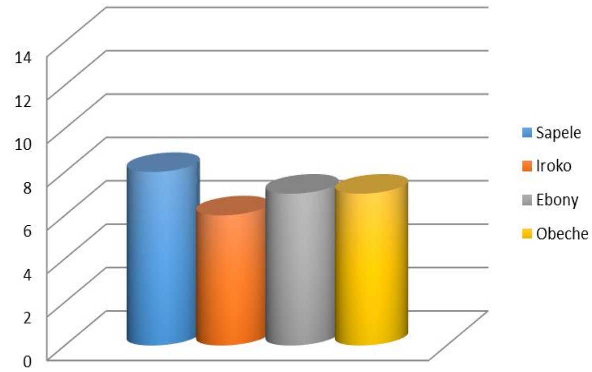

Figure 3. pH of the four samples of wood dust.

The result of this analysis is outlined below for the four samples of saw dusts. Figure 4.4 below shows the amount of char (carbon) after pyrolysis, the hydrogen, oxygen, nitrogen and sulphur content in the various samples of the sawdust. While Figure 4.5 gives the work of Ragland *et al* [35] which confirm the authenticity of the analysis.

TABLE 4.
THE ELEMENTAL ANALYSIS RESULTS OF THE VARIOUS SAMPLES OF WOOD DUST.

Element	PERCENTAGE (%)			
	Obeche	Sapele	Iroko	Ebony
Carbon(char)	48.73	54.6	57.46	53.54
Hydrogen	5.78	4.7	4.57	6.67
Oxygen	45.47	40.69	38.05	39.78
Sulphur	0	0	0	0
Nitrogen	0.02	0.01	0.01	0.01

TABLE 5
THE RESULTS OF RAGLAND *ET AL* [35].

Element	Average of 11 hard wood	Average of a soft wood	Oak bark	Pine bark
C	50.2	52.7	52.6	54.9
H	6.2	6.3	5.7	5.8
O	43.5	40.8	41.5	39.0
N	0.1	0.2	0.1	0.1
S	——	0	0.1	0.1

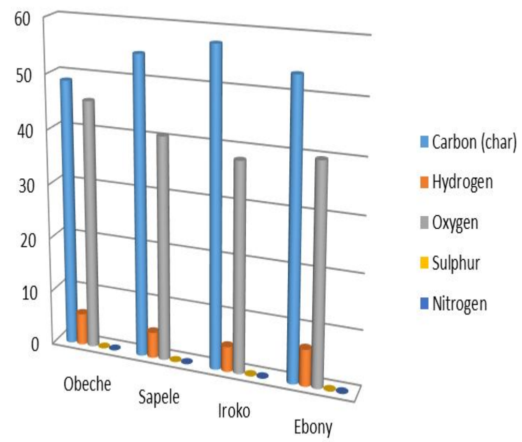

Figure 4. The elemental analysis of the four saw dust.

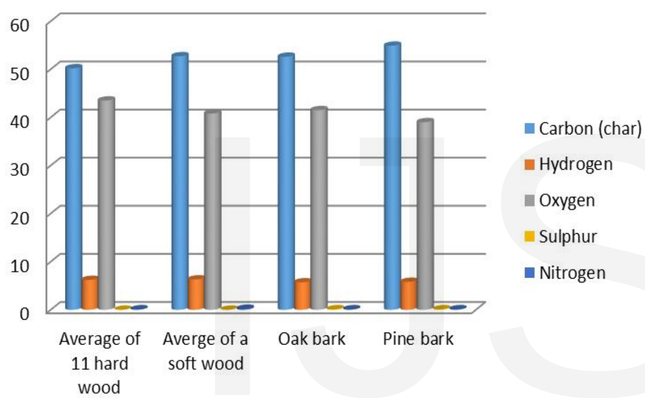

Figure 5. The results of the Ragland et al [35] for hard and soft woods.

CONCLUSION

The values of the analysis or characterization of sawdusts from four different trees have been compiled and reviewed in this work. The results are good tool in determining reaction possibilities when they are used in composite formation with polymers with single or double bonds in their backbone. The carbon char is also an indication of their ability to play the role of good fillers in composite formation. However, their potential to absorb water indicates need for treatment when required for use in composites that will be exposed to humid environment. The fact that the combustion of wood can result in a number of pollutants is verified, and that the amount of constitutes in the various saw dusts have been seen to depends on the species of the tree, age of the tree and other numerous factors that are not considered in this work. Thus, industrial activities or application of sawdust such as their blend with polymers should be done in consideration to the possible health implications and environmental hazard for endusers of resulting composites.

Again this research reinforces the need for care during combustion or degradation of sawdust since they no doubt emit hazardous substances that are carcinogenic into the environment. Great consideration should be given to sawdust from wood in areas prone to crude oil spill. Izionworu and Amadi [4] revealed that crude oil pollution in soil from such polluted environment weakens the compressive strength of resulting polymer concrete and this is a clear indication that for woods in areas polluted with crude oil, the impact on composite from resulting sawdust will show weak mechanical strength. In Powell's study [20], it was seen that pollution by hydrocarbon results in inhibition or reduction of plant growth and the death of the plant. This shows the fatal effect of hydrocarbon on wood. hence the need to investigate to ascertain the level of impact on composites made from wood in crude oil polluted environment.

REFRENCES

[1] T. Addis, A.H Buchanan. and J.C.F. Walker Stiffness and Tensile Strength Variation within and between Radiata Pine Trees. *Journal of the Institute of Wood Science,* vol. 13 no. 5, pp. 513-518, 1995a.

[2] A. Addis, A. H. Buchanan and J.C.F. Walker, A comparison of Density and Stiffness for Predicting Wood Quality or Density: The Lazy Man's Guide to Wood Quality. *Journal of the Institute of Wood Science;* vol. 13, no. 6: pp. 539-543, 1995b.

[3] V.O. Izionworu, and K. K. Dagde,. Characterization Of Polymer Concrete Made Of Coconut/Glass Fibers and Natural Silica Sand from Niger Delta. *Nigeria International Journal of Scientific & Engineering Research*, Vol. 5, no. 12, pp. 776 – 780. 2014.

[4] V.O. Izionworu,. and S. A. Amadi, The Impact of Crude Oil Contaminated Natural Sand on Polymer Concrete. *Current Studies in Comparative Education, Science and Technology,* vol. 3, no. 1, pp. 217-226. (2016).

[5] S.J. Araceli, V.T. Martic and W.C. John, *A Review of Monitoring Methods for Inhalable Hardwood Dust: Summary* Research Report p. 937. 2011, / 1A: IOM.

[6] ASTM, Wood Standard; www.ASTM.org/standards/wood-standards.html, 2012.

[7] M. A. Bianco, and H. Savolainen, Wood Worker's Exposure to Tannins. *Journal of Applied Toxicology;* 14: pp. 293- 295, 1994.

[8] M.A. Bianco, A. Handaji and H. Savolainen, *Quantitative Analysis of Ellargic Acid in Hardwood Samples: The Science of The Total Environment*. 222: pp. 123- 126, 1998.

[9] B.G. Butterfield and B. A. Meylan, *Three Dimensional Structure of Wood: An Ultrastructural Approach. London*, New York; Chapman and Hall, pp. 99,1980. *http://www.ask.com/question/characteristics-of-hardwood-and-softwood* CharacteristicsofHardwoodandSoftwood,.

[10] M. Chudmoff,, Tropical Timber of the world. 23: pp. 213- 216, 1984.

[11] G. K. Elliot, *Wood density in Conifers*. Technical Communication; Commonwealth Forestry Bureau, Oxford, England. 1970.

[12] K. Femi and S.O. Ogunmole, *Quantitative Analysis of Some Nigeria Wood Species as Local Material in printing Technology*. Akure, Odo State, Nigeria. 2011.

[13] For Wood Lovers. 2007. *www.thewoodbox.com/data/wood/Ebony.info. htm.*

[14] J. R. George, R. M. Seaborg and R. L. Mitchell, *the Factors Affecting the Quantitative Determination of Lignin By 72% H2So4*. 3: 32- 38. 1932.

[15] W.T. Gladstone, A.C. Barefoot and B. J. Zobel, Kraft Pulping of Early Wood and Late Wood from Loblolly Pine. *Forest products Journal*; vol. 20 no. 2, pp. 17-24. 1970.

[16] G. Gori, E. Bonfiglio, M. Carrieri, M. Lazzarin, C. Cecclinato, M.L. Scapellato, I. Macca and G.B. Bartolucci, *Tannins and Gallic Acid as a Marker of Exposure to Hardwood Dust*. Gital Med Lav Ergon. 27: 332- 400. 2005. (Article in Italian)

[17] G. Gori, M. Carrieri, M.L. Scapellato, G. Parvoli, D. Ferrara, R. Rella, A. Sturaro and G.B. Bartolucci, *2-Methyl Anthraquinone as a Marker of Occupational Exposure to Teak Wood Dust in Boat Yards. Annals of Occupational Hygiene*. 53: pp. 27- 32. 2009.,

[18] Hardwood Structure, www.UWSP.edu.

[19] C. Harvald, and P. O. Olesen, the Variation of the Basic Density within the Juvenile Wood of Sitka Spruce (Picca Sitchensis). *Scandinavian Journal of Forest Research* 2: pp. 525- 537. 1987.

[20] H. A. Hassan and A.A.A. Basim, Consequences of Soil Crude Oil Pollution on Some Wood Properties of Olive Trees. *Ibn Al-Haitham Jour. for Pure & Appl. Sci* , vol. 27, no. 1, pp. 1- 6. 2014.

[21] G.R. Johnson, B.L. Gartner, D. Maguire and A. Kanaskie, *Influence of Bravo Fungicide Application on Wood Density and Moisture Content of Swiss Needle Cast Affected Douglas-Fir Trees*. Forest Ecology and Management 186: pp. 339-348. 2003.

[22] A. Kaninska, *Method for Increasing the Calorific Value of Fragmented Wood Biomass*. Cracow University of Technology. p. 101. 2011.

[23] A. Keränen, T. Leiviskä, B.Y. Gao, O. Hormi and J. Tanskanen, Preparation of novel anion exchangers from pine sawdust and bark, spruce bark, birch bark, and peat for the removal of nitrate. Chemical Engineering Science, 98: pp. 59-68. 2013

[24] L. Leiviskä, Sawdust for Wastewater Treat ment. J Bioremed Biodeg 5:e159. 2014. doi:10.4172/2155-6199.1000e159.

[25] P. Mämmela, *Phenolics in Selected European Hardwood Species by Liquid Chromatography Electrospray Ionisation Mass Spectrometry Analyst*. 126: pp. 1535- 1538. 2001.

[26] P. Mämmela, A. Tuomainen, H. Savolainen, Determination of Gallic Acid in Wood Dust as an Indicator of Oak Content. *Journal of Environmental Monitoring* 3: pp. 509- 511. 2001b.

[27] P. Mämmela, A. Tuomainen, T. Vartainen, L. Lindroos, J. Kangas and H. Savolainen, Biological Monitoring of Wood Dust Exposure in Nasal Lavage by High Performance Liqiud Chromatography. *Journal of Environmental Monitoring* 4: 184- 189. 2002.

[28] P. G. Murphy and A. R. Pfeifer, Wood Density and Branching Characteristics of Sitka Spruce Provenance Grown in Ireland*; Paper Presented at 1990 Joint Meeting of Western forest Genetics Association and UFRO Working Parties* S2: pp. 2-5. 1990.

[29] Y. A. Osew, New School Chemistry; For Senior Secondary School , pp. 234. 2013.

[30] P. O'sullivan, *The Influence of Initial Emplacement and thinning Regime upon Wood Density in Sitka Spruce (Picea Sitcherus)*; *M.Agr. Sc. Thesis*, University College Dublin. 1929.

[31] D. Louppe, A.A. Oteng-Amoako and M. Brink, Timbers 1. Prota. Plant Resources of Tropical Africa vol. 7, no. 1, 2008.

[32] A. J. Panshin and C. de. Zeeuw, *Text book of*

Wood Technology; 4 ed, New York: MC Graw-Hill, pp. 722. 1980.

[33] J.A. Petty, D.C. Macmillian and C.M. Steward, *Variation of Density and growth Ring Width in Stone of Sitka and Norway Spruce*, Forestry vol 63, no. 1: pp. 39- 49. 1990.

[34] Pfeifer, Sitka Spruce Provenance Trials*; A Summary of Results to Date. Coilite, Research and Development, Paper No. 2*. Coilite Offices, Dublin Road, Newtown Mount Kennedy, Co.Wicklow, Ireland. 1991.

[35] K. W. Ragland, D. J. Aerts and A. J. Bakers, *Properties of Wood for Combustion Analysis*. Bioresources Technology, Great Britain. p. 164. 1991.

[36] R. J. Rando, R. A. Gibson, C.W. Kwon, H.G. Poovyz and H.W. Glindrueyer, On Filter Determination of Collected Wood Dust by Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS). *Journal of Environmental monitoring* 5: pp. 675- 680. 2005.

[37] Timbers, *Their Properties and Uses.* 2013. www.home-extension.co.uk/ timber.pdf.

[38] What is Obeche wood?;www.eHow.com/html-8397723-Obeche-wood. html.

[39] Wood, m.wikipedia.org/wiki/wood. 2014.

[40] M.T. Adam, Forest Products Extension. 2003. http://web.utk.edu/~mtaylo29/pages/ Hardwoods%20and%20softwood.html

[41] Canadian Centre for Occupational Health & Safety. Wood Dust – Health Effects, 2018

[42] International Agency for Research on Cancer (IARC), 2018. http://monographs.iarc.fr/ENG/Classification/

[43] IARC. *Wood Dust*. In *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. Volume 62: Wood Dust and Formaldehyde. Lyon, France: World Health Organization International Agency for Research on Cancer, p.70. 1995

[44] M. Teresa, M. Irene, J.S. Francisco, I.A. José, V.R. Carmen, and N. Sergio, A Review of Pel lets from Different Sources. *Materials. Vol. 8*, pp. 1413-1427, 2015. doi:10.3390/ma8041413

[45] W. S. Thompson, and W.N. Darwin. Weight, Volume, and Moisture Content Of Sawdust from Selected Southern Species FPJ Technical Note, p1. 1968.

[46] J.D. Brazier and R.S. Howell. The use of a breast height core for estimating selected whole tree properties of Sitka spruce. Forestry vol. 52, no. 2, pp. 177-185. 1979.

[47] B.J. Zobel, and J.B. Jett. Genetics of wood pro duction. Springer-Verlag, Berlin, pp. 337. 1995.

[48] L. A. Jozsa and G. R. Middleton, A discussion of wood quality attributes and their practical impli cations. Forintek, Canada Special Publication pp. 34.1994

[49] E.B. De Guth, Relationship between wood density and tree diameter in Pinus elliottii of Missiones Argentina. IUFRO Conf. Div. 5 Ox ford, England. pp1. 1980.