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Dependency of Average Metal Concentration (AMC) of Some Tropical Timbers On Their Oven Dry Densities (ODD)

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Abstract Timber is an essential raw material needed in constructing one thing or the other in all fields of human endevour. It is combustible. In this research, fire characteristics of fifty-seven (57) tropical timbers were investigated. The characteristics studied are: average metal concentration (AMC) and oven dry density (ODD). The tropical timbers with the highest of these characteristics are *P. africana* and Manilkara while the ones with the least of these fire characteristics were *C. pulcherima* and *B. bonopozense* respectively. Although some tropical timbers with lower ODDs possess high AMC, some of the timber with higher ODDs possess lower AMC, it can be said that there is neither inverse nor direct relationship between the AMC of the tropical timbers and their oven dry densities. Though density is an important factor, in determining the fire characteristics of timber, the cellular structure, molecular composition, orientation of fiber (direction of grain) and timber extractives (*e.g.* resins) deserve a special attention in explaining the results. The aims and objectives of this work is to identify the timbers that are fire resistant and those that are not and to compare the AMC of these tropical timbers with their oven dry densities.

Keywords Tropical timbers, average metal concentration, oven dry densities, fire characteristics, fire resistant and non-fire resistant timber

Introduction

Timber is the wood (heart wood) used for various building purposes: houses, boats, bridges ,ship , etc; for making furniture, packing boxes, matchsticks and boxes; for making plywood, tea chests, flush doors, partitions, walls, ceiling, shelves, cabinets, prefabricated houses, commercial boards, etc, and for railway sleepers. In addition, wood chips and shavings are used for making compressed wood which is in demand for paneled door, table tops, room partitions, hard blocks etc. Timber and firewood (fuel), together with many useful forest products, constitute the forest wealth of a country. The present rate of deforestation in Nigeria is a warning to the future need of wood in the country. Systematic afforestation is the only means of maintaining a balance between loss and gain. The quality of timber depends on its hardness, strength, weight, presence of natural preservatives like tannin, resin, etc, durability against heat, moisture and insect attack, workability, grains, colour, porosity and capacity to take polish and varnish. Timber is said to be formed from stem or trunk of tree by the process of secondary growth. Secondary growth in thickness is the growth that is responsible for the increase in diameter of stems and roots. There are two types of secondary growths in dicotyledonous stems. These are normal and anomalous secondary growths. As the names imply, one is normal while the other shows some anomalies. This type of growth commences very soon after the primary cells or tissues have been fully formed. Secondary growth in thickness is able to come about due to the meristematic nature of cambium ring (fascicular and inter- fascicular cambium) and the cork cambium or phelloderm. The cambium is made up of two types of cells-the fusiform initials and the ray initials. The former gives rise to all the elongated cells of the vascular bundle (xylem and phloem) while the latter gives rise to secondary medullary rays.

Trees and shrubs experience two types of growth-primary growth and secondary growth. Apical or primary growth increases the length of stems and roots. Secondary growth in thickness increases the girth or diameter of plants. The cambium which is meristematic in function produces new cells of xylem and phloem. Later, cork-cambium makes its appearance in the peripheral region and begins to form other secondary tissues (phellem and phelloderm). ' This increase in thickness due to the addition of secondary tissues cut off by the cambium and the cork-cambium in stellar and extra-stellar regions respectively is spoken of as secondary growth' [1]….. 'commences very soon after the primary tissue have been formed' [2].'Monocotyledonous as well as diocotyledonous plants which develop into trees show a marked increase in girth' [3].

The cambium ring as a whole becomes actively meristematic and gives off new cells both externally and internally. Those cut off on the outer side are gradually modified into the elements of phloem; these constitute the second phloem. The new cells cut off by the cambium on its inner side constitute the secondary xylem' [4]. 'The cork tissue of cork oak *Quercus suber*, a Mediterranean plant, is of considerable thickness and is the source of bottle cork' [1]. Still another person declared, 'the cork of *Quercus suber* (the cork oak), is a well known commercial product' [5]. 'Many of the fibres of commerce such as jute, hemp, flax, rhea (or ramie) etc are the bast fibres of secondary phloem [1]. 'From the plant's point of view the importance of secondary growth is that it greatly increases the thickness and strength of stem, thereby enabling it to grow to a much greater height than would otherwise be possible'[4]. The wood and planks from these giant trees are used in producing varieties of things, For example Furniture-chair, table, cardboard etc agricultural implements such as hoes, shovels, heads of knives and diggers etc; Domestic utensil- wooden spoons and plates, mortars and pistles, etc; musical instruments- wooden gong, wooden organ etc; educational materials-Black boards and easels, rulers, book rack, etc.

If there is nothing like secondary thickening, plants and shrubs can neither stand nor anchore firmly in the soil and the slightest wind will blow them down. Occurrence of such an incident will bring about the extinction of some group of animals which depend on such plants for food. Biological equilibrium will be disturbed and ecosystem will be adversely affected since animals and plants, the two major living components of the environment, live an inter-dependent life. The oxygen generated by these plants (trees) is what sustains the metabolic processes in living things. One can say specifically, that if there is no plant, there will be no life.

Again, there would be nothing like wood and timber. There would be nothing like the use of wood as a source of heat energy and the manufacture of producer gas by the gasification of coke. Invention of biogas as a source of energy would not have been thought of. This includes the fermentation of cellulose that results to the formation of alcohol fuel.

(1) **Gasification of coke**

$$\underset{\text{Air}}{2C + O_2 + N_2} \longrightarrow \underset{\text{Producer gas}}{2CO_{(g)} + N_{2\,(g)} + \text{Heat}}$$

$$\underset{\text{Steam}}{H_2O_{(g)}} + \underset{\text{white hot coke}}{C} \longrightarrow \underset{\text{Water gas}}{CO + H_2}$$

(i) Fermentation of cellulose to produce ethanol

$$\underset{\text{Cellulose}}{(C_6H_{12}O_6)_n} + nH_2O \xrightarrow{\text{dil } H_2SO_4} \underset{\text{glucose}}{nC_6H_{12}O_6}$$

$$\underset{\text{glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} \underset{\text{ethanol}}{2C_2H_5OH} + 2CO_2$$

Experimental procedures: *Sample collection and preparation:* The fifty-seven (57) tree species samples were collected from eleven states in Nigeria. The states are: Anambra, Imo, Enugu, Sokoto, Katsina, Kano, Kebbi, Yobe, Edo, Zamfara and Gombe.

Some of the tree species were living trees cut down. Some were the already felled trees. Dulmer machine was used to cut out part of the tree drunk. Thirty-two timbers were obtained from the timber sheds or saw mills at Onitsha, Nnewi and Awka. The states from where these timbers were collected were ascertained from the timber dealers. The tree species were authenticated by the Forest Officer in each of the State or the Local Government Area where the timbers were collected. The timber dealers or the saw millers were able to say the botanical names of few timbers collected from the timber shed. Most of the timbers collected there were taken to the Forest Officer in that Local Government Area where the tree species were got. By mentioning the local or common name of tree species and by having a look at the parts of tree species, the Forest Officers were able to say the botanical names of the tree or timber species.

After the collection and authentification, they were occasionally conveyed to the saw mill where each timber was cut into two different shapes and sizes; They are:

(i) Splints of dimensions of 30cm x 2.5cm x 0.6cm

(ii) Cubes of dimensions of 2.5cm x2.5cm x2.5cm i.e. 15.625 cubic centimeter. The splints of timber were dried in an oven at 105^0C for 48hours before the experiment. American Standard for Testing and Materials (ASTM) was employed in the analysis.

Determination of elemental content:

The elements analysed for each tree species are lead, copper, calcium, zinc, mecury , sodium, potassium , cadmiun and magnesium . The steps adopted in the elemental analysis are:

(i) Ashing the sample

(ii) Digestion of the sample and

(iii) Analysis of the elements using the Atomic Absorption Spectrophotometer (AAS).

Ashing of the sample: The sample was ashed as described under the ash content determination. Two grams of each sample was ashed.

Digestion of the sample: Two Moles of HCl was prepared and used for the digestion. The samples were digested using the standard procedures.

Elemental analysis: The digested samples were taken to the Central Laboratory, Obafemi Awolowo University, Ile – Ife. The Atomic Absorption Spectrophotometer used is Model PG 990, Manufacturer; PG Instrument Ltd. U.S.A., Serial No;15-0990-01-0317, Figure 1**.**

In this model of AAS, the sample is first aspirated with a very small narrow tube. It enters the Nebulizer which sprays, energizes and atomises it. At this stage, it becomes excited and enters the burner. The sample also absorbs the EMR (Energy of magnetic radiation) emitted by the cathode lamp. The absorbed energy is the characteristic of the element being analysed. Each element has its own lamp. With this absorbed energy, the sample burns and gives out flame at the burner end. After a time, there will be a fall in energy. The fall in energy is also the characteristic of the element being analysed.

Figure 1: Atomic absorption spectrophotometer and 57 samples

Determination of Oven Dry Density (ODD):

Three 2.5 cm cubes of each timber were randomly selected from one hundred and eighty cubes of the tree species. Each was weighed with Top loading balance, Model: PL 203, Make: Mettler Toledo. After recording the initial weight, the sample was transferred into the drying oven at the temperature of 105 ^{o}C. The sample was left in the oven for three hours. After the heating, the oven was switched off, and the sample left overnight to cool. The sample was re-weighed after twelve hours. Care was taken to ensure that sample did not absorb moisture before and during weighing. After recording the second weight for each, the samples were taken back into the oven for another 3 hrs at that same temperature. This was repeated until any two subsequent weights were equal i.e. constant weight attained. Three cubes of each tree specie were tied together with a copper wire and weighed as a single entity. Cu wire was removed and the three samples re-weighed. The weight of a cube was obtained by calculating the average of the three samples of each tree specie. The dimensions of the three 2.5cm cubes were measured and the volume of each was calculated. The average volume of the three samples was recorded as the volume of each samples of the timbers. Finally the oven dry density of each tree species was determined by dividing the average dry weight of the three samples by the average volume of three samples.

$$ODD = \frac{\text{Average dry wt of samples g}/dm^3}{\text{Average volume of samples}}$$

Results and Discussion

The results of the investigations carried out in this work are given in Table 1 and 2, Figure 2 and 3**.** The results of fire characteristics of fifty – seven (57) tropical timbers are discussed in this Chapter.

Discussion:

The thermal characteristics of tropical timbers investigated in this research include; ignition time **(IT)**, flame propagation rate **(FPR),** flame duration **(FD)**, afterglow time **(AGT)**, oven dry density **(ODD)**, moisture content, water saturation capacity, ash content, elemental analysis and thermal conductivity .

Table 1: Names of the selected fifty-seven (57) tropical timbers from Nigeria

Tree species No	Botanical name	Common name	Vernacular names
1.	*Cola nitida*	Colanut	Ibo - oji, Hausa – goro Yoruba - obi gbanja, Nupe – Chigban'bi
2.	*Newboldia levis*		Ibo – Ogilisi, Hausa – aduruku, Yoruba – akoko,Benin – Ikhimi
3.	Crysophyllum albidium	White Star apple	Ibo – udala Yoruba-Agbalumo,Edo-Otien
4.	*Treculia africana*	African bread fruit	Ibo – ukwa
5.	*Psidium guajava*	Guava	Ibo – gova
6.	*Citrus sinensis*	Sweet orange	Ibo – oloma
7.	*Dacroydes edulis*	Native pear	Ibo – ube
8.	*Chlorophoro exelsa*	Iroko	Ibo – orji, Hausa – loko, Yoruba – iroko, Benin – uloko Nupe – rook,Ijwa – olokpata
9.	*Gaeis guineensis*	Oil palm tree	Ibo – nkwu
10.	*Cocus nucifera*	Coconut tree	Ibo – aku oyibo
11.	*Persea Americana*	Avocado pear	Ibo – ube oyibo
12.	*Irvingia smithii*		Ibo – ogbono
13.	*Irvingia gabanensis*		Ibo – ugiri, Yoruba – Oro, Benin – Ogwe, Efik – Oyo Nupe – pekpeara,Ijaw – ogboin
14.	*Caesalpina pulcherima*	Pride of Barbadose	
15.	*Terminalia catappa*	Umbrella tree or Indian Almond	
16.	*Spathodea campanulala*		Ibo – echichii
17.	*Ricinovenvron heudenocii*		Ibo – okwe
18.	*Ficu natalensis*		Ibo – ogbu
19.	*Banbax*		Ibo – Akpu ,Yoruba –

	bonopozense		Puopola,Benin – oboidia Ijaw – idoundu
20.	*Ceiba petandra*	Silk cotton plant	Ibo – akpu ogwu,Yoruba – araba,Benin – okha, Efik – ukem Ijaw – afalafase
21.	*Cola gigantia*		Ibo – ebenebe, Hausa – bokoko, Yorubo – ogugu, Benin – ukpokpo, Efik – dikir, Ishan – abolo
22.	*Acacia nilotica*	Cacia	Hausa – bagaruwa, Kanuri – kangari,Fulani – gaudi
23.	*Nauclea diderrichii*		Ibo – uburu mmiri, Yoruba – opepe, Benin – obiakhe, Ijaw – owoso,Urhobo – urherekor
24.	*Gmelina arborea*	Bushbeech or Meligna	Ibo – malina,
25.	*Pteracarpus soyauxi*		Ibo – oha
26.	*Annoa senegalensis*		Ibo – oghulu, uburu ocha, Yoruba – abo,Hausa – Swandar daji,
27.	*Canarium schwanfurthii*		Ibo – ube okpoko
28.	*Pinus carribean*	Whispering pine	
29.	*Albizia ferruginea*	Albizia	Ibo- Ngwu or ngu Yoruba – Ayinre oga, Benin – uwowe
30.	*Brachystegia nigeria*		Ibo – ufi, Yoruba – akolodo,Benin – okwen, Ishan – eku Ijaw – akpakpa, Efik – ukung,Boki – kpeunik, Ekoi – etare
31.	*Dialuim guineensis*		Ibo – icheku
32.	*Napoliana vogelii*		Ibo – nkpodu
33	*Accio bateri*		Ibo – araba
34.	*Brachystigia eurecomya*		Ibo – achi mkpuru,Yoruba – akolodo,Benin – okwen Ijaw – akpakpa,Ishan – eku,Ekoi – etare, Boki – kepuruk Efik – ukung
35	*Pluneria africana*		
36.	*Walteria americana*		
37.	*Azadirachta indica*	Neem plant	Hausa – dogonyaro
38.	*Khaya senegalensis*	Mahogany	Hausa – madacu
39.	*Manilkara*		Ibo – ukpi
40.	*Alstonia congensis*		Ibo – egbu
41.	*Tectona grandis*	Teak	
42	*Mansonia altissima*	Mansonia Iron tree	Yoruba-ofun
43	*Isoberlinia tomentosa*	Berlinia	Ibo – uboba, Hausa – faradoka (white doka) Nupe – baba
44.	*Isoberlinia doka*	Berlinia	Ibo – ububra ibu, Hausa – doka Nupe – babarochii bokun, Tiv – mkovol

45.	*Garcinia kola*	Bitter kola	Ibo – ugolo/adi, Yoruba – orogbo Benin –edun, Efik – efiari, Ijaw – okan Ibibio – efiat
46.	*Garcinia gnetoides*	Wild ugolo	Ibo – ugolo agho
47.	*Baphia nitida*		Ibo – aboshi ojii, Yoruba – irosun,Benin – otun, Efik – ubara Ijaw – abodi, Itsekiri – orosun, Urhobo – arhua
48.	*Baphia gracilipes*		Ibo – aboshi ocha
49.	*Terminalia brownie*	Congo afara	Ibo – edo, Hausa – baushe,Yoruba – idiodan
50.	*Terminalia superba*	Akmond tree (white afara)	Ibo – edo, Yoruba – afara,Benin – egboin nofua, Efik – afia eto,Ijaw – gbarada, Nupe –eji,Urhobo – unwonron
51.	*Terminalia glaucescens*	Black afara	Ibo –edo, Hausa – baushe,Yoruba – idiodan
52.	*Mangifera callina*	Kerosene mango	
53.	*Mangifera banganpalli*	Ordinary mango	Ibo – mango nkiti
54.	*Mangifera indica*	Mango with fibre	Ibo – opiolo mango
55.	*Mangifera indica*	Gernan mango	
56.	*Pentaclethra macrophyllum*	Oil bean tree	Ibo – ukpaka
57.	*Nauclea popeguinii*		Yoruba – opepe

Table 2: Average Metal Concentration and ODD of fifty-seven (57) tropical timbers.

Tree species No	**Botanical name**	**AMC Average Metal Concentration x 10^1 ppm**	**ODD Oven dry density x 10^{-2} g/cm^3**
1.	*Cola nitida*	40.47	66.6
2.	*Newboldia levis*	38.11	68.1
3.	*Crysophyllum albidium*	57.44	62.7
4.	*Treculia africana*	51.23	58.8
5.	*Psidium guajava*	44.28	85.5
6.	*Citrus sinensis*	49.15	86.5
7	*Dacroydes edulis*	39.33	51.1
8.	*Chlorophoro exelsa*	42.90	58.4
9.	*Gaeis guineensis*	38.56	59.9
10.	*Cocus nucifera*	30.01	60.1
11.	*Persea Americana*	36.38	43.4
12.	*Irvingia smithii*	69.27	81.7
13.	*Irvingia gabanensis*	55.06	87.8
14.	*Caesalpina pulcherima*	29.89	46.5
15.	*Terminalia catappa*	53.93	65.4
16.	*Spathodea campanulala*	35.11	32.0
17.	*Ricinovenvron heudenocii*	71.99	34.2

18.	*Ficu natalensis*	49.94	48.5
19.	*Banbax bonopozense*	57.79	24.0
20.	*Ceiba petandra*	73.46	35.5
21.	*Cola gigantia*	49.30	54.0
22.	*Acacia nilotica*	60.38	64.6
23.	*Nauclea diderrichii*	30.50	54.1
24.	*Gmelina arborea*	59.08	58.6
25.	*Pteracarpus soyauxi*	53.56	47,5
26.	*Annoa senegalensis*	50.81	37.0
27.	*Canarium schwanfurthii*	66.58	41.3
28.	*Pinus carribean*	37.33	40.7
29.	*Albizia ferruginea*	54.96	66.8
30.	*Brachystegia nigeria*	44.15	72.1
31.	*Dialuim guineensis*	32.13	73.1
32.	*Napoliana vogelii*	66.66	74.3
33.	*Accio bateri*	34.97	97.5
34.	*Brachystigia eurecomya*	67.43	77.2
35.	*Pluneria africana*	83.26	60.3
36.	*Walteria americana*	66.55	50.1
37.	*Azadirachta indica*	56.03	79.0
38.	*Khaya senegalensis*	69.68	77.5
39.	*Manilkara*	47.81	109.7
40.	*Alstonia congensis*	78.53	40.1
41.	*Tectona grandis*	45.07	55.1
42.	*Mansonia altissima*	57.61	59.6
43.	*Isoberlinia tomentosa*	63.92	49.6
44.	*Isoberlinia doka*	53.08	45.1
45.	*Garcinia kola*	42.60	92.1
46.	*Garcinia gnetoides*	46.44	68.3
47.	*Baphia nitida*	50.35	88.6
48.	*Baphia gracilipes*	66.37	79.2
49.	*Terminalia brownie*	50.03	69.3
50.	*Terminalia superba*	70.75	55.6
51.	*Terminalia glaucescens*	70.01	56.2
52.	*Mangifera callina*	48.22	60.9
53.	*Mangifera banganpalli*	76.63	65.3
54.	*Mangifera indica*	48.99	74.8
55.	*Mangifera indica*	45.98	44.4
56.	*Pentaclethra macrophyllum*	63.40	78.8
57.	*Nauclea popeguinii*	39.42	63.2

Discussion

Figure 2 identifies the bar chart of average metal concentration of tropical timbers. The average metal concentration of these tropical timbers are arranged in increasing order of magnitude. The tropical timber with the least average metal concentration of 29.89 x 10^{-1} ppm or mg/kg orµg/g is *C. pulcherima* while *P. african* has the highest average metal concentration of 83.26 x 10^{-1} mg/kg.

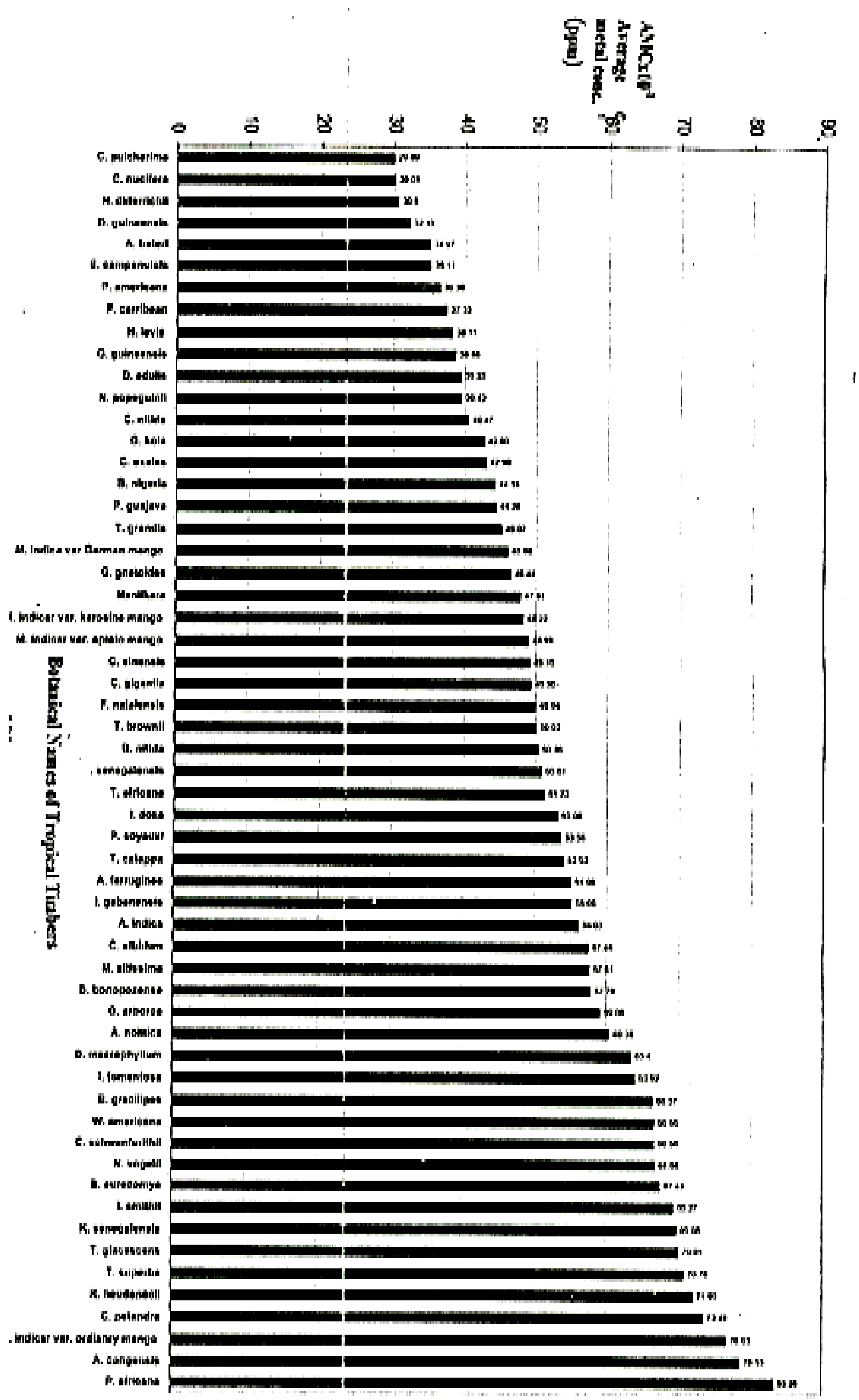

Figure 2: Graph of (AMC) Average metal concentration

Figure 3 indicates the graph of average metal concentration Vs ODD. The tropical timber – *B. bonopozense* with the least ODD of 24x10^{-2} g/cm^{3} has the average metal concentration of 57.79 x 10^{-1} mg/kg, while the timber – *Manilkara* with the highest ODD of 109.7 x 10^{-2}g/cm^{3} has the average metal concentration of 48.81 x 10^{-1} mg/kg. With respect to average metal concentration, *P. africana* has the highest amount of 83.26 x 10^{-1}mg/kg. This is followed by *A. congensis and M. indica Var. ordinary mango* with 78.53 x 10^{-1}mg/kg and 76.63 x 10^{-}

[1]mg/kg respectively. The three tropical timers; *P. africana, A. congensis and M. indica var, ordinary mango* have the ODDs of 60.3 x 10^{-2}g/cm^3, 40 x 10^{-2}g/cm^3 and 65.3x10^{-2}g/cm^3 respectively. It is remarkably observed that there is neither direct nor inverse relationship between the average metal concentrations and oven dry densities of these tropical timbers.

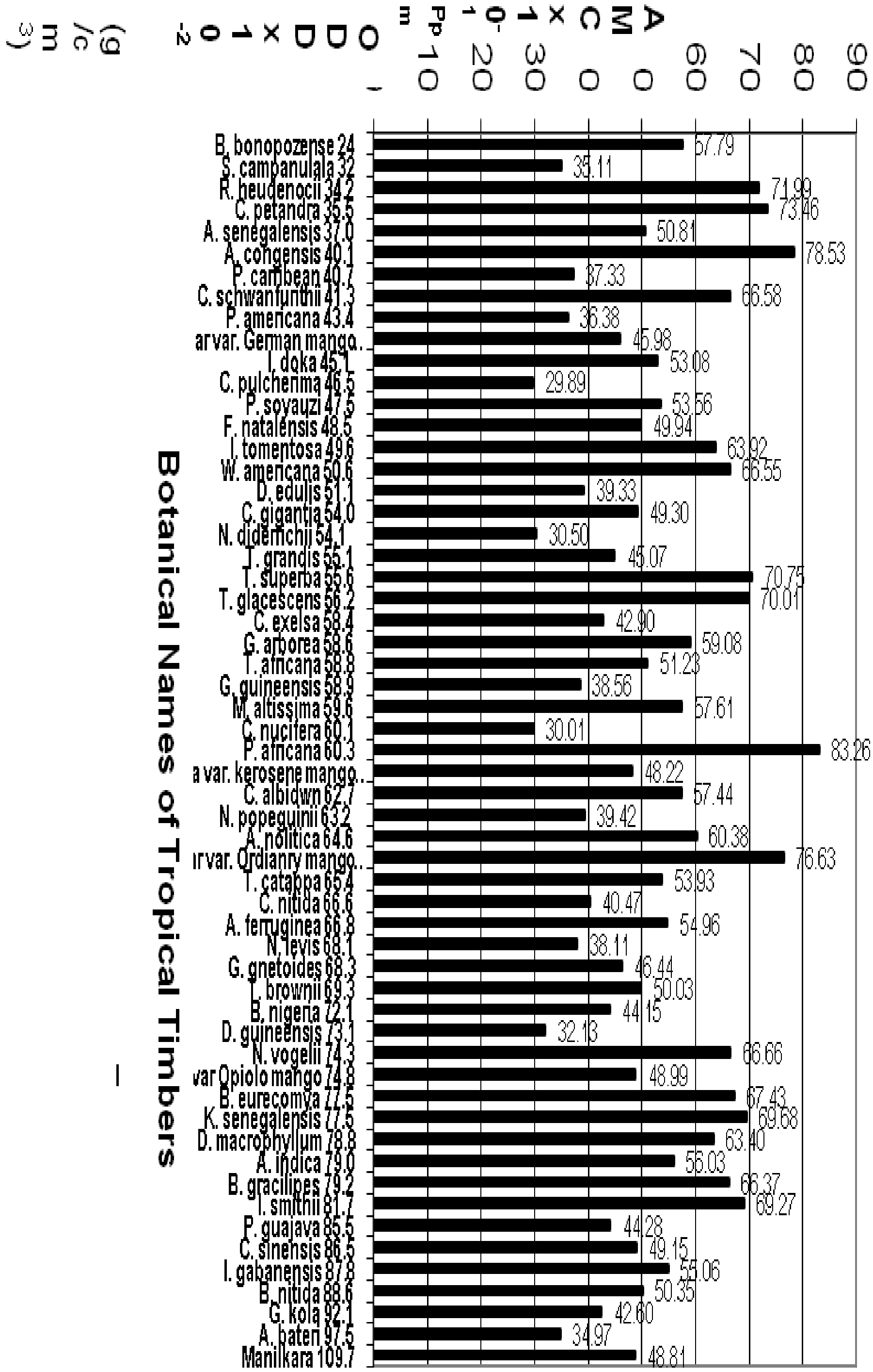

Figure 3: Graph of (AMC) vs (ODD) Oven dry density

This observation is clear and well expected. The average metal concentrations of these tropical timbers will not be dependent on their oven dry densities. This is because research findings have proved to some extent that *the accumulation of certain metals in plants and animals depends on their environments and locations. For* *instance, if a plant or animal grows in an area where the environment is polluted with some heavy metals, the plant or the animal is bound to incorporate large quantity of the metals into its cells and tissues* [6-7].

Aquatic plants that grow near the rivers and seas containing nourishing or micro constituent elements imbibe the elements into their tissues. This is because they absorb the water (solution of the element) from the sources. It was said that *" one of the sources of iodine is seawater and that some amount of this element is present in the brown seaweed called larminaria"* [8].

Researches again reveal that *Fishes caught in polluted seas and rivers contain some amount of heavy metals in their tissues* [9].

Research reports have unmasked the fact that *metals occur in significant amounts in both temperate and tropical timbers* [10].

Research investigation had proved that *metals, though varying in concentrations in the timber species, influence some characteristics of the timbers, such as thermal conductivity, flammability, after-glow time, ignition time and evolution of smoke particulate* [11].

It was pointed out earlier, that behaviour of wood in response to fire is dependent on many factors which include moisture content, oven-dry density, pore content and arrangement of grains (fiber). Wood irrespective of its biogenesis consists essentially of three major components; the cellulose fibre, the binding material or lignin and relatively small percentage of hemicellulose [12]. The amount of these macromolecules vary in wood species. In considering the thermal properties of these tropical timbers in relation to their average metal content, these major factors must also be put into consideration: the amount of these three major components of wood and the arrangement of grain.

Conclusion

There is neither direct nor inverse relationship between the average metal concentrations and oven dry densities of these tropical timbers.

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