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Effectiveness of Ammonium Chloride and Borax in Improving the Fire Retarding Property of Timber

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ABSTRACT

The impregnation of timber known as Gmelina arborea with varying concentrations of ammonium chloride and borax solutions was carried out .The treated and blank sample was dried and investigated for Add-on (%), ignition time, flame propagation rate and after-glow time. Result showed that ignition time, add-on (%) showed a significant increase and decrease in flame propagation rate using borax while after-glow time showed a remarkable decrease using Ammonium chloride. These results suggest that both flame retardants are effective in the prevalence of fire outbreak.

Keywords: *Flame-retardants, Fire, Timber, Add-on*

1. INTRODUCTION

The immediate environment of man is surrounded by highly combustible and polymeric materials of which the value of timber cannot be underestimated. In our various homes, schools, offices etc the products of timber are the commonest materials around us that we deal with in our day to day activities ranging from doors, tables, chairs, bed, furniture. Wood has a complex chemical structure that is made up of cellulose, hemicellulose and lignin.it is known that the hemicellulose and cellulose contribute to the flammability of wood; with hemicelluloses in particular playing a major role because of their low heat stability. While cellulose and hemicellulose enhance the flammability of wood, lignin which is the other polymer included in wood, promotes the fire resistance of wood by charring [1]. Wood possesses some initial or natural fire resistance because of its low thermal conductivity and ability to char formation. The initial fire retardancy of wood varies, depending on the type of tree from which the wood was obtained. For e.g. it is known that the density, permeability, morphology, moisture content and chemical composition of wood may affect the fire resistance properties [1]. Four elements must be present in order for fire to exist. These elements are heat, fuel, oxygen and chain reaction [2]. This reaction is dependent on material when subjected to heat, unites with oxygen so rapidly that it produces heat and flame. Though fire is known to be important to man, many lives and properties have been lost due to the uncontrolled and destructive fire. The most effective method of wood protection in the event of fire outbreak is treating wood with chemical substances (flame-retardant agents) [3]. In this research work, we reported the effect of ammonium chloride and borax as flame retardant inhibiting the flammable nature of timber known as Gmelina arborea.

2. EXPERIMENTAL

2.1 Materials

The timber known as *Gmelina arborea* was obtained from the local timber market, in Awka, Nigeria. Borax and ammonium chloride were procured from BDH laboratory poole BH151 TD, England and distilled water used were of laboratory grade. The apparatus used were 1000ml volumetric flask, beakers, weighing balance, stop watch, electric oven, cylindrical containers, retort stand and lighter. All chemicals were used as supplied by the manufacturer

2.2 Method

(a) Preparation of material: the timber was sized, cut into wood splints to the length of 30cm, width of 0.5cm, breadth 0.5cm and subjected to further analysis.
Flame-retardant treatment: The timber was dried in the electric oven at 105-110^{o}C to constant weight using weighing balance. Weight of the dry sample were completely immersed in equal volumes but different concentration of flame retardants contained in 1000cm^3 measuring cylinder for a resident time of 48hrs. On removal from the dope, the sample was dried again to constant weight in the electric oven (105-110^{o}C). The weight of flame-retardant absorbed by sample was determined, using the expression [4]:

$$\text{Add-on (\%)} = \frac{[Y-X]}{X} * \frac{100}{1}$$

Where Y= weight of the sample after treatment.
X= weight of the sample before treatment.

(b) Determination of ignition time (IT): the sample was clamped vertically by its upper end and ignited at the base with a cigarette lighter having a constant flame height and a constant distance (i.e. 4cm apart) between its lower tip and small cigarette lighter. Ignition time was recorded as the time interval between the lighter touching wood tip and a tiny visually perceptible flame on the sample [5]. Three readings per sample were taken and the average calculated.

(c) Determination of flame propagation rate [F.P.R]: the flame propagation rate was determined by clamping vertically the sample and igniting at the base in a drought-free room. The distance travelled at a stipulated time interval by the char-front was measured and the average readings were recorded [5].
The rate of propagation was calculated as the distance transverse per second.

Flame propagation rate (cm/s) = [distance moved by char-front (cm)]/ [time(s)]

(d) Determination of after-glow time: this was taken as the time between flame-out and the last visually perceptible glow [5]. The test was carried out for three times and the average was recorded for accuracy.

3. RESULTS AND DISCUSSION

3.1 Effect of retardants on Add-on

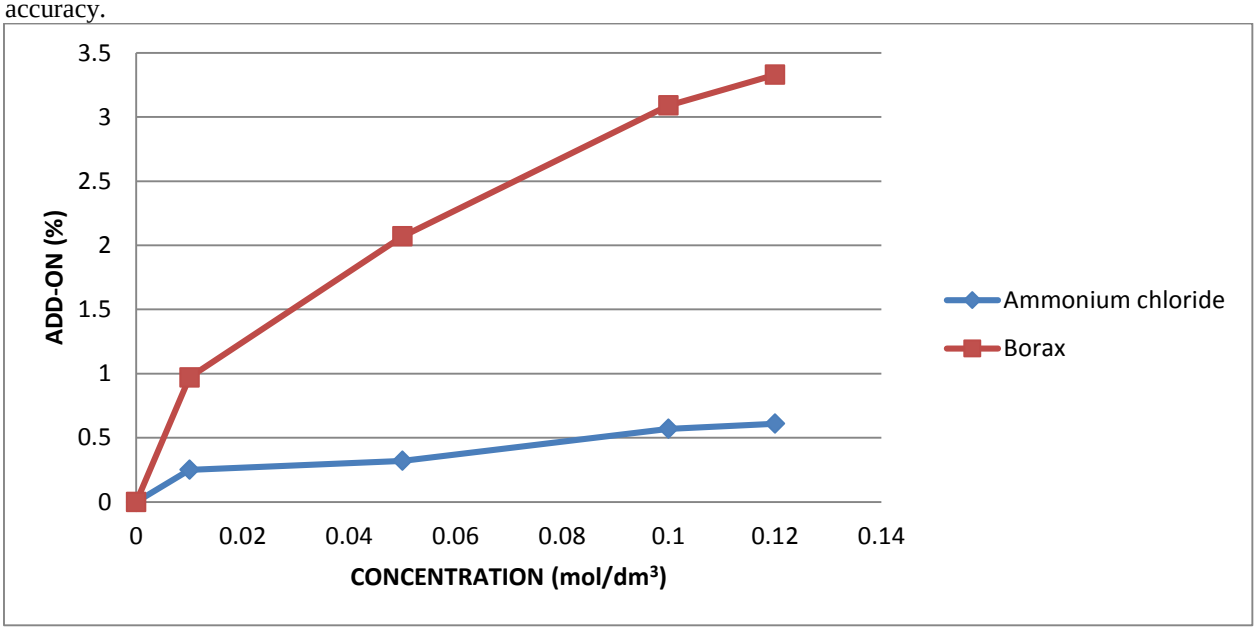

Fig1. The effect of ammonium chloride and borax on add-on (%) of *Gmelina arborea*

The result of the percentage add-on of the flame-retardants is shown in Fig. 1. It is evident that the quantity of flame retardant absorbed by the wood depends on the liquor concentration. In the type of system, i.e polymerics, including cellulosics, the manner of chemisorption is well represented by the Fick's laws. The fick's first law is: J= D [(dc) / (dx)], where J= rate of accumulation of the reagent per unit area of the reference plane orientated normal to the x-axis, D= diffusion coefficient and c= local reagent concentration at a point distance x from the origin of coordinates. A second differential of the first law expression with respect to time is the Fick's second law: [(dj) / (dt)] = D [(d^2c)/ (dx^2)]; which implies that the rate of accumulation of the reagent to the surface and hence its penetration into the wood matrix would essentially be linked to the bath concentration [6]. On the basis of this fact the observation highlighted in Fig.1 is in accord with theoretical considerations. However, there was more increase in add-on using borax than when treated with ammonium chloride.

3.2 Effect of retardants on ignition time

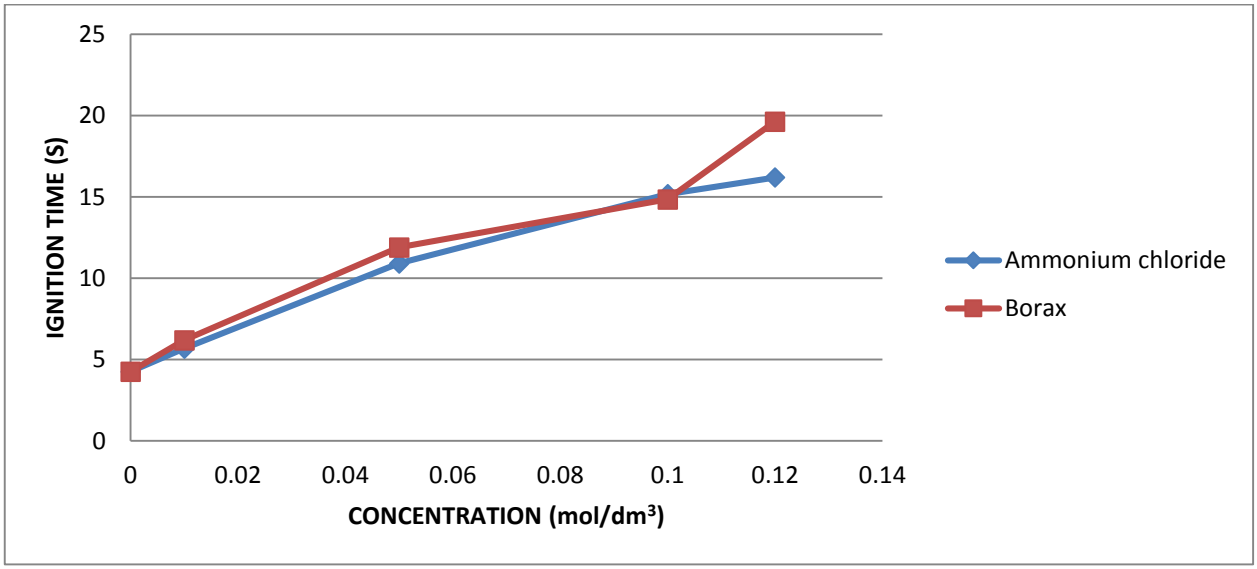

Fig2. The effect of ammonium chloride and borax on ignition time of *Gmelina arborea*

In Fig 2, the result showed that the incorporation of these flame retardants dramatically increases the ignition time. The ignition time for treated sample increases with an increase in dope concentration with respect to untreated sample. It is observed that these flame retardants at high temperature decomposes to give the substances (NH_3, H, Cl, $NaBO_2$, B_2O_3, H_2O) that are susceptible to delay or resist ignition time and deflect heat from the system. However, borax showed the highest ignition time when compared with ammonium chloride.

3.3 Effect of retardants of flame-propagation rate

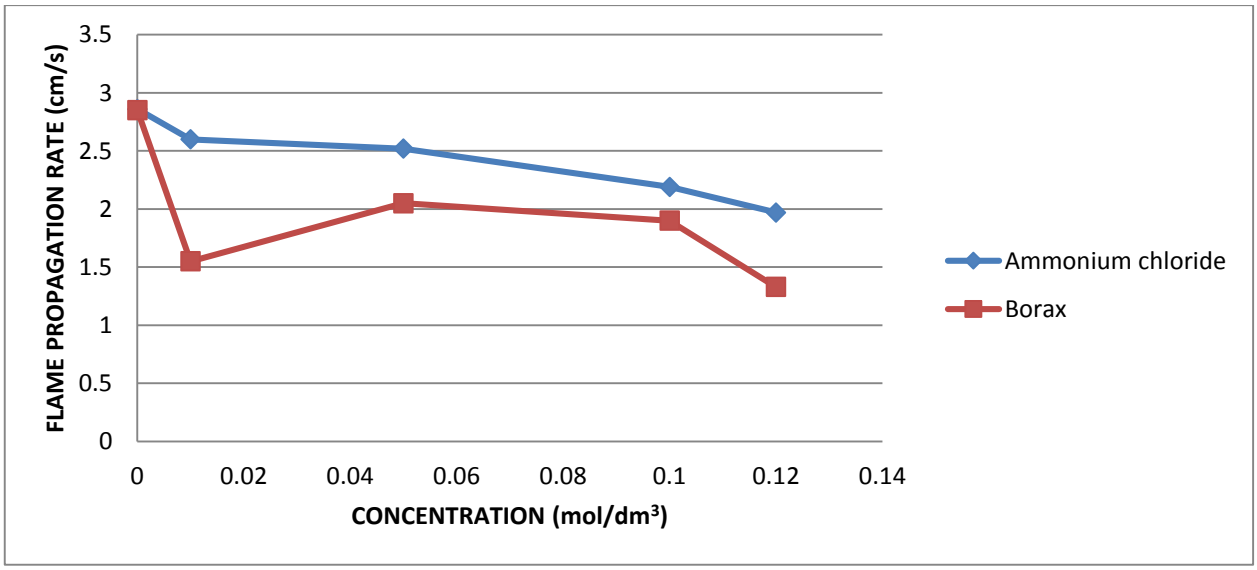

Fig.3. The effect of ammonium chloride and borax on the flame propagation rate of Gmelina arborea

The systematic reduction [Fig 3] in the flame propagation rate and After-glow time [Fig.4] with the flame retardant treatment is as follows:

Disodium tetraborate decahydrate (borax): At high temperatures, it decomposes according to the equation:

$2Na_2B_4O_7.10H_2O_{(s)} = 4NaBO_{2(s)} + 2B_2O_{3(s)} + 10H_2O_{(g)}$ ----------(1)

Ammonium chloride: appears to sublime upon heating. However, this process is actually decomposition into ammonia and hydrogen chloride gas.

$NH_4Cl \rightarrow NH_3 + HCl$ ----------(2)

$HCl \rightarrow H\cdot + Cl\cdot$ ----------(3)

The flame inhibiting property of disodium tetraborate decahydrate and ammonium chloride are interpreted in terms of vapour and liquid mechanism as the case may be. In the case

of borax when heated these formulations decompose to form glass-like coating around cellulosic fibres. Long time exposure to heat causes the coating to dehydrate, generating water. The boron residues also react with the hydroxyl groups of cellulose to generate additional quantities of water and to form difficulty ignitable char. The evolution of water cools the flame as well as dilutes the concentration of flammable pyrolysis products. The glassy coatings not only deflects heat away from the substance but also diminishes aggress of combustible volatile pyrolysates into the combustion zone [7].

The free radicals H· and Cl· have the ability to scavenge the ·OH and ·O radicals that are essential for the sustenance of combustion. The gaseous products NH_3 and HCl contribute as diluents of the pyrolysate concentration.

3.4 Effect of retardants on After-glow time

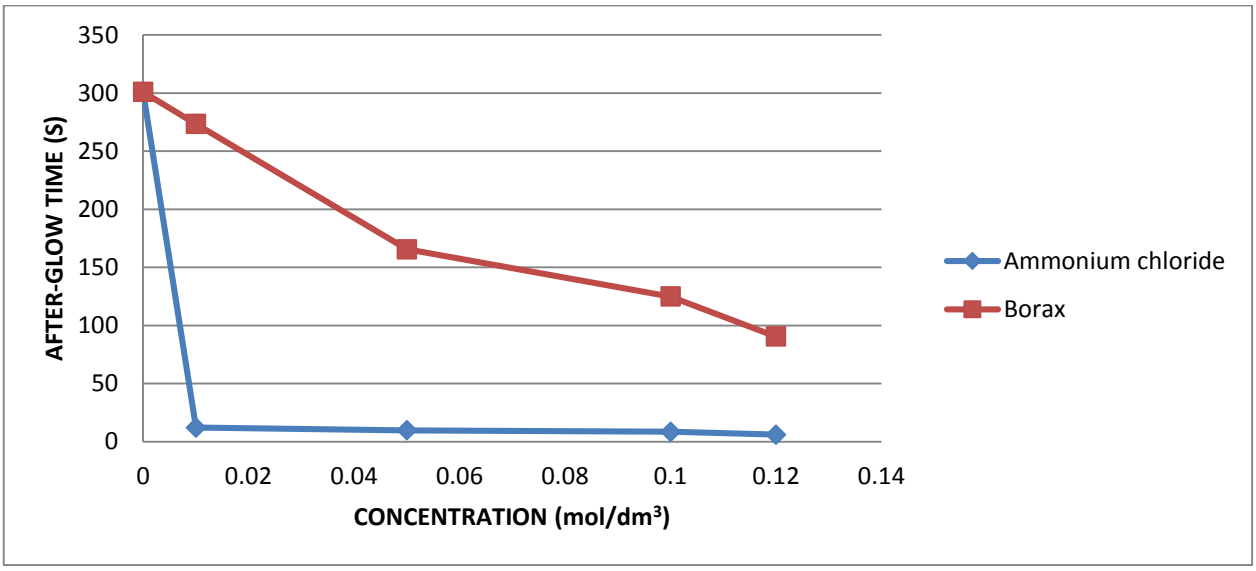

Fig4. The effect of borax and ammonium chloride on the after-glow time of Gmelina arborea

The observation shown in Fig 4 indicates that as the concentration of flame retardants increases, there is a corresponding increase in the amount of char left at the end of pyrolysis/combustion i.e the more the quantity of flame retardants, the lower the decomposition temperature due to enhanced plasticization effect. With the coats on the fibre, the higher the temperature will be required to degrade the cellulose [6]. Ammonium chloride showed more decrease in after-glow time compared to borax.

4. CONCLUSION

It is concluded that ammonium chloride and borax are good fire retardants and showed remarkable improvement in delaying and resisting combustion. The incorporation of these flame retardants to highly combustible material is recommended because of their lost and environmentally friendliness.

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