EVALUATION OF BORAX AND BORIC ACID AS FLAME RETARDANT ON SELECTED TIMBERS

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Abstract
This work aimed at evaluating the effectiveness of borax and boric acid as fire retardant chemicals in timber. Three species of timbers namely; Iroko, Mahogany, and Arborea were selected for this study. The treated and untreated splints were subjected to fire performance test using absorptivity, ignition time, flame propagation rate, after-glow time, and char formation parameters, in order to determine the effect of borax and boric acid treatment on the timbers. From the results obtained the absorptive capacity of the timber species increase as the concentration of the retardant chemical increases. The ignition time of the treated timbers increases in the order of Arborea, Iroko to Mahogany, while the flame propagation rate and after-glow time decrease as compared with the control sample. It was observed that timbers treated with retardant chemicals have higher fire resistance to combustion than untreated timbers.

Keywords: Absorptivity; Combustion; Fire; Flame Retardant; Ignition time; Flame propagation rate; After-glow time; Char formation

1. INTRODUCTION

The importance of fire to mankind cannot be over-emphasized. However, when there is fire outbreak, it is usually accompanied by wanton destruction of lives and properties. In Nigeria, fire outbreak has led to an unquantifiable loss of lives, properties, and economic goods, ranging from damages incurred in marketplaces, factories to residential buildings (Bhatta, 2013; Eboatu, 2010; Eboatu and Garba, 1990). However, fire retardant chemicals could assist during fire outbreaks. Candan et al. (2012) investigated the performance of laminated veneer lumber (LVL) panels treated with fire retardant chemicals. He found that that LVL treated panels had better performance than the untreated panel and also panels treated with di-ammonium phosphate had the best fire resistance when compared with boric acid and borax. Relatedly, Keskin et al. (2013) studied the combustion properties of rowan wood impregnated with various chemicals and found that borax and boric acid were good fire retardant chemicals. Also, Odinma et al. (2013) conducted a comparative study on the effect of three flame retardant compounds on the flame behavior of a roofing thatch, using potassium aluminum sulphate, Di-ammonium chloride. They observed that there was a significant decrease in the flame propagation rate, flame duration time and after-glow time while an increase in ignition time was noted. Additionally, Ozcifci et al. (2008) studied the impact of various fire retardant on red color and yellow color tone of some wood and varnishes, they found that while varnishing process increased the combustibility of both red and yellow colored tone of the selected woods, impregnation material such as zinc chloride and borax decreased the combustibility of both red and yellow colored tone of the selected woods. In Nigeria, economic wood (such as Iroko, mahogany, Arborea) are endangered and susceptible to fire attack during fire outbreak. In the study, an attempt is made to determine the effect of fire retardant chemicals such as borax and boric acid on Iroko, mahogany and Arborea wood.

2. MATERIALS AND METHODS

I. 2.1 Collection of Sample

In this study, three species of wood namely; Iroko, mahogany, and Arborea were collected from Harbour Wood Market, Udu Road, Delta State, Nigeria and processed for assessment of flammability characteristics. Reagents used were of analytical grade.

II. 2.2 Sample Preparation

Six splints measuring 20.0cm x1.0cm x0.5cm were obtained from each of the timber and were weighed and labeled. Five out of the six samples was immersed in a solution of each of the chemicals in their different concentration and allowed to stand for 24 hours for a thorough impregnation, while the sixth sample served as a control. Both treated and untreated (control) splints were weighed and oven dried at 105^{o}C for 48 hours. The dry samples were cooled in desiccators and reweighed until a constant weight was obtained.

III. 2.3 Preparation of Solution

Solutions of borax and boric acid were prepared according to the required standard to obtain concentration range of 0.0M- 2.00M for each reagent. The following parameters were tested with the treated and untreated splits.

2.3.1 Absorptive Capacity (A_bC) of the Wood

The weight difference between the Post Treatment Weight (PTW) and Oven Dry weight (ODW) for each splint samples was measured and expressed as:

$$A_bC = \frac{PTW - ODW}{PTW} \times 100\% \quad (1)$$

2.3.2 Ignition Time

The treated and untreated splits were carefully ignited with lighter and simultaneously timed with stop clock to monitor the time lag between initial ignition and first perceptible glow. The difference in time in second, between the initial ignition (T_1) and the time of first perceptible glow (T_2) gave a measure of the ignition time I_t, and it was expressed as;

$$I_t = I_t - I_t \quad (2)$$

2.3.3 Flame Propagation Rate

The oven-dry split was clamped vertically unto a retort stand and ignited at the base with lighter. When ignition occurred, the source was withdrawn. The distance traveled by the charred front per second or linear flame velocity was measured until the last glow was seen. The flame propagation rate FPS is expressed as;

$$FPR = \frac{Distance\ travelled\ by\ the\ flame}{Time\ taken\ in\ the\ direction\ of\ the\ flame} \quad (3)$$

2.3.4 Afterglow Time

On ignition of the splint, the time in seconds between the first flame and the last perceptible glow was measured with a stopped clock as afterglow time.

2.3.4 Percent Char

The oven-dry splints were weighed on an analytical weighing balance, clamped into a retort stand and ignited. The splints were allowed to burn until last glow. The burnt remnant was weighed and recorded in percent. The char percentage is expressed as;

$$Char\ \% = \frac{wt.of\ char\ generated}{wt.of\ splint\ samples} \times 100\% \quad (4)$$

3. RESULTS AND DISCUSSION

From figure 1, the results for the absorptive capacity of the timber species increase as the concentration of the retardant chemical (borax) increases. The highest absorption was at 2.0mol/L and was therefore used as a basis for characterizing the timber in terms of ignition time, flame propagation rate, after-glow time and char formation. Absorptions of 0.74%, 0.55%, 0.41% were obtained for Iroko, Mahogany, and Arborea, respectively, at a concentration of 2.0mol/L in borax treated wood.

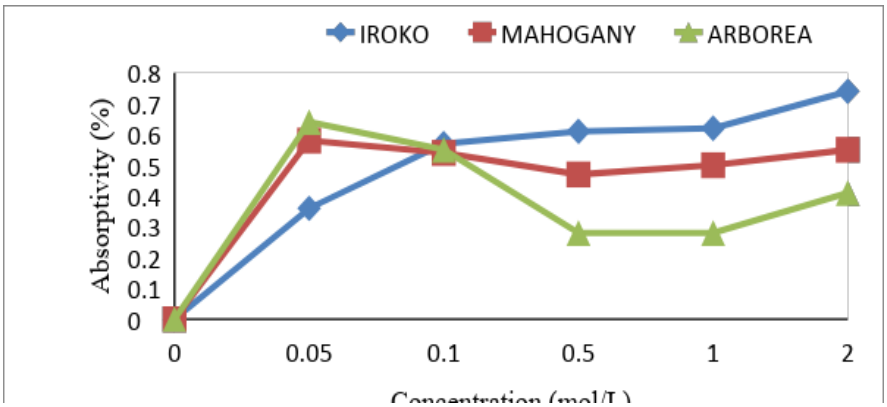

Figure 1: Effect of Borax concentration on the absorptivity of timber.

Figure 2 shows the absorptive capacity of the timber species increases as the boric concentration of the retardant chemical increases. The highest absorptions of 2.0mol/L for iroko and mahogany were 0.15%, 0.17%, respectively. While Arborea had its highest at 0.1mol/L with the absorption of 0.72% in boric acid treated wood.

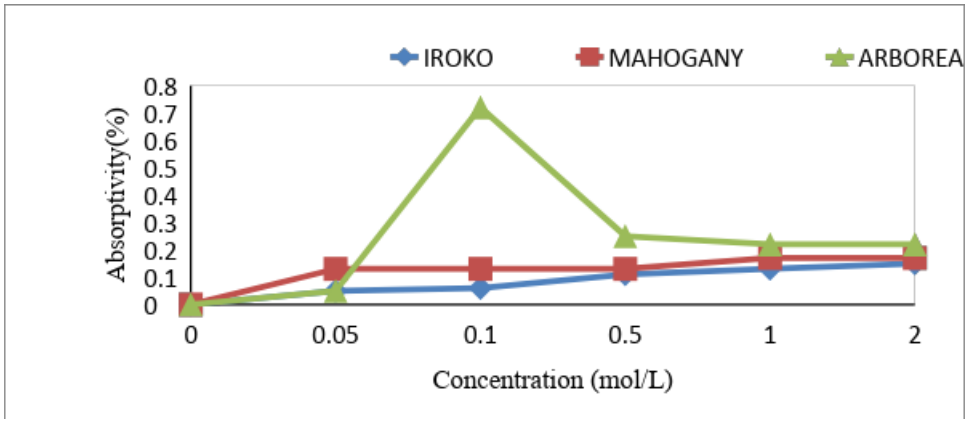

Figure 2: Effect of Boric acid concentration on absorptivity of timber

The ignition time indicates the time lag for a material to imbibe sufficient heat to yield combustion. The ignition time for the timbers treated with borax is shown in Figure 3. The ignition time significantly increases as the concentration of chemical increases. For the borax treated timbers, results showed that the treated wood will be able to resist burning very well when compared with the control sample. From the plot in figure 3, Arborea had the best performance with a significance of 52% increase, followed by Iroko with 49%, while mahogany had the least performance of 26% at 2.0mol/L concentration when compared with the control.

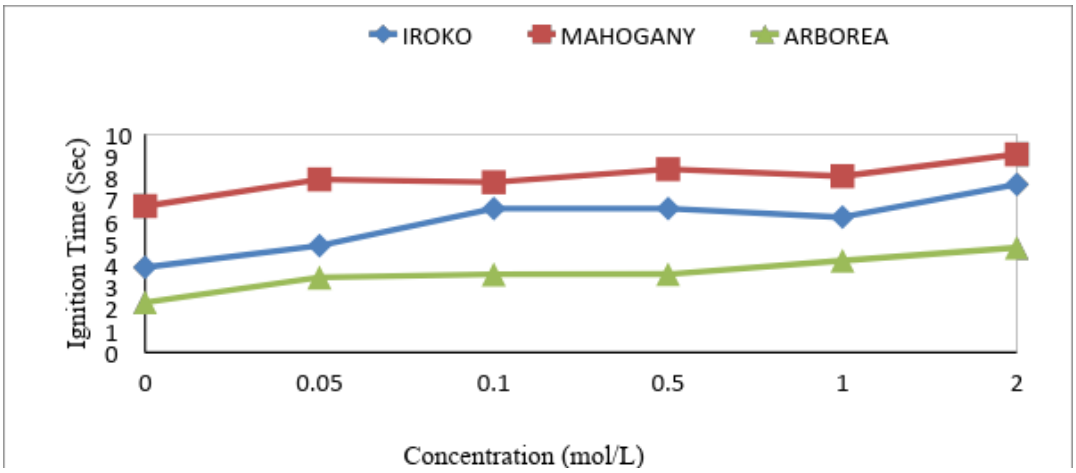

Figure 3: Effect of Borax concentration on ignition time of timber

Similarly, the result of boric acid treated timber for ignition time is shown in figure 4. It shows that there is a significant increase in ignition time of the treated timbers. Arborea had the best performance with 49% increase in ignition time, followed by Iroko with 43%, and mahogany had the least with a 42% increase at 2.0mol/L concentration when compared with the control.

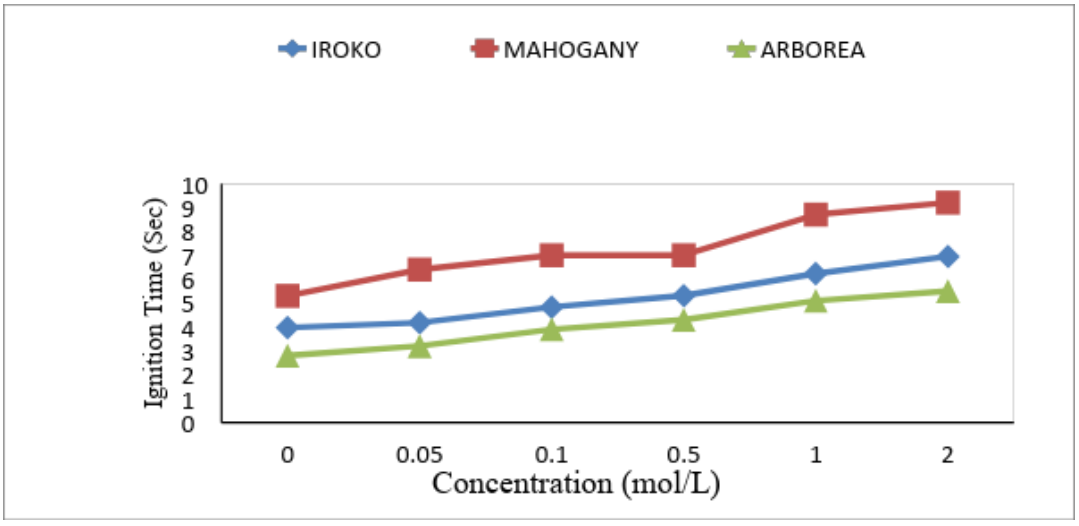

Figure 4: Effect of Boric acid concentration on ignition time of timber

The flame propagation rate for borax treated timber decreased remarkably with increasing concentration of the retardant chemical as shown in figure 5. Although there was decrease in the flame propagation rate in all timber species, Mahogany had the best performance with a 67% decrease, followed by Arborea 49% and the least was Iroko with 15% at a concentration of 2.0mol/L when compared with the control.

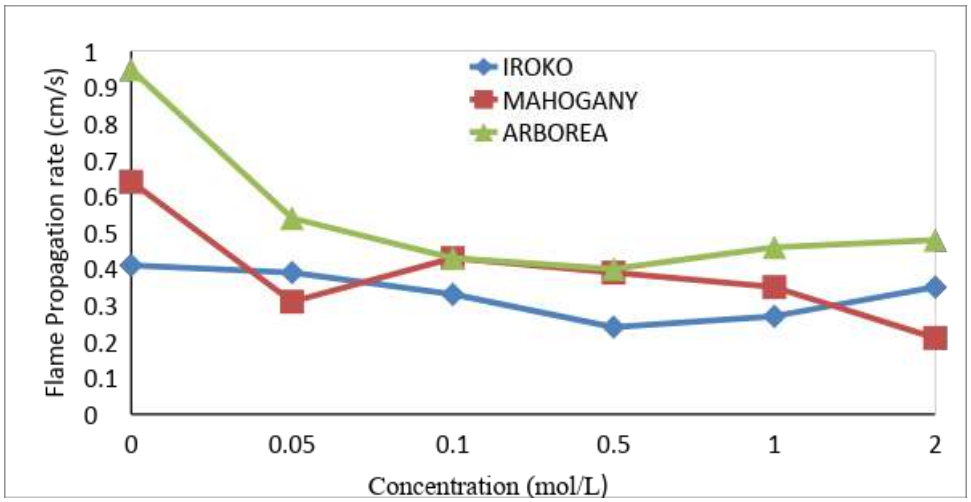

Figure 5: Effect of Borax concentration on flame propagation rate of timber

Also, figure 6 shows the result of the flame propagation rate of the boric treated timbers. There was a decrease in flame propagation rate with increase in the concentration of the retardant chemical. From the figure 6, we observed that Arborea had the best performance with a 72% decrease in flame propagation rate, followed by Iroko with 59% decrease, while the least was mahogany with a 52% decrease at 2.0mol/L when compared with the control sample.

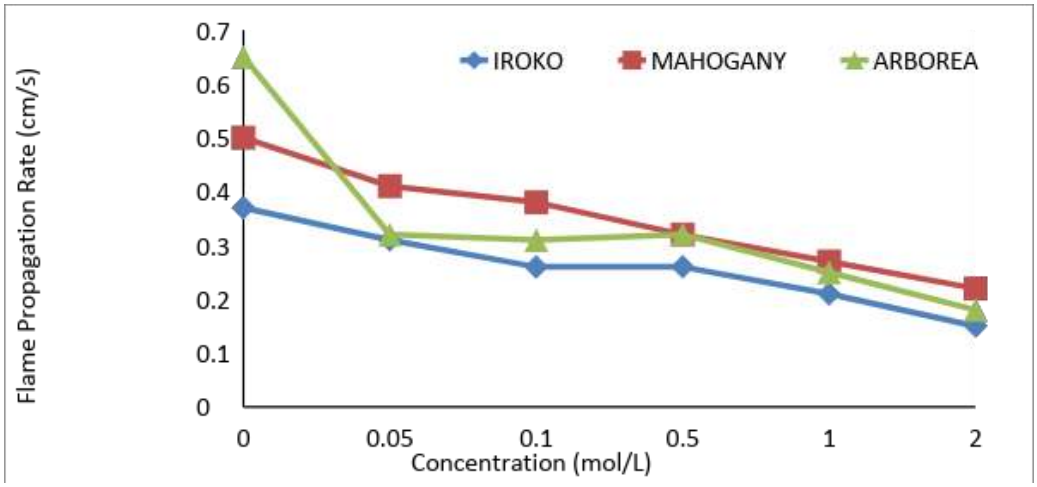

Figure 6: Effect of Boric concentration on flame propagation rate of timber

The result for the afterglow time of the borax treated timbers is shown figure 7. There was a significant decrease in after-glow with an increase in the concentration of the chemical when compared with the control. Mahogany has the best performance with a 71% decrease in afterglow time, followed by Arborea with 67%, and Iroko, the least with a 60% decrease at 2.0 mol/L concentrations when compared to the control sample.

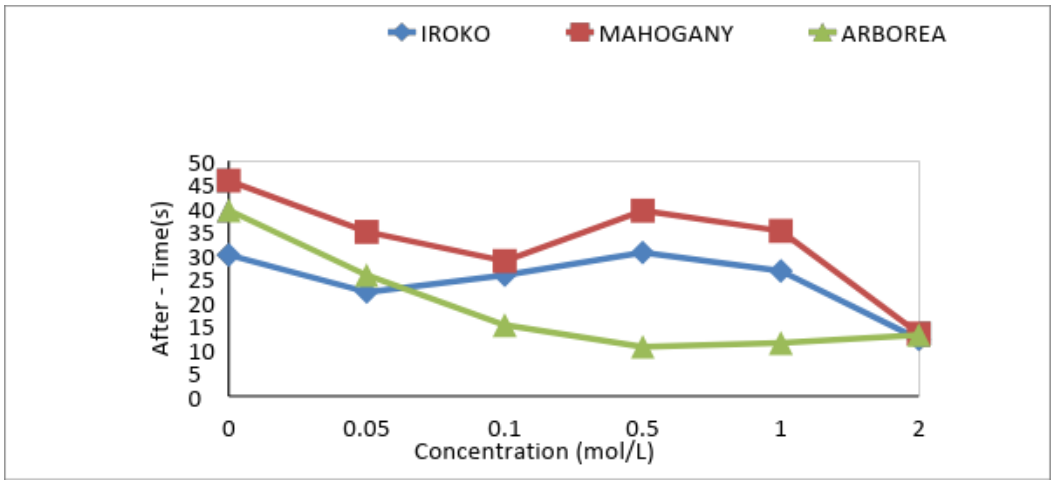

Figure 7: Effect of borax concentration on after- glow time of timber

Similarly, figure 8 illustrate the after-glow time of boric acid treated timbers. There was a significant decrease in after-glow with an increase in the concentration of the retardant chemical when compared with the control. At a concentration of 2.0mol/L, mahogany had the best performance with a 67% decrease, followed by Arborea with 66% decrease, while Iroko was the least with 48% decrease.

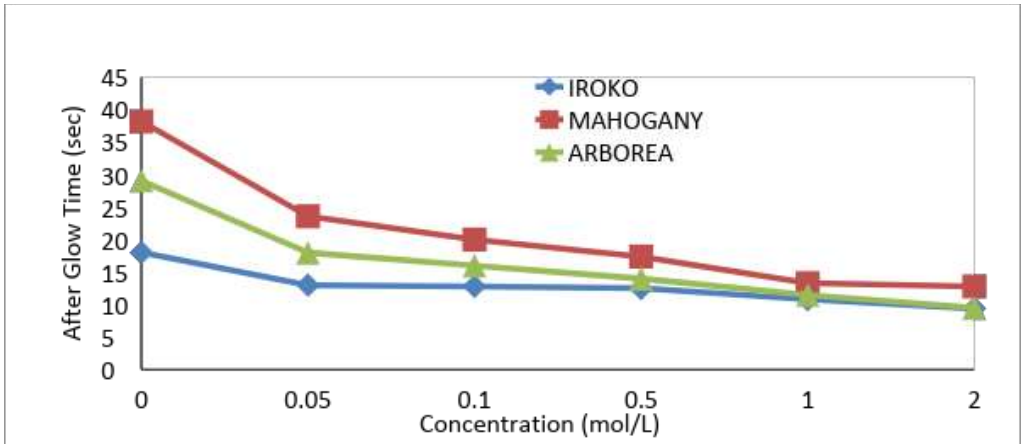

Figure 8: Effect of boric acid concentration on after-glow time of timber

A marginal decreasing trend was observed for char formation as the concentration of the fire retardant chemicals increases. For the borax treated splints, figure 9 shows that Arborea had the best performance with an 18% increase in char formation, followed by Mahogany with 1% increase; Iroko had the least with a 22% decrease in char formation at a concentration of 2.0mol/L when compared with the control sample.

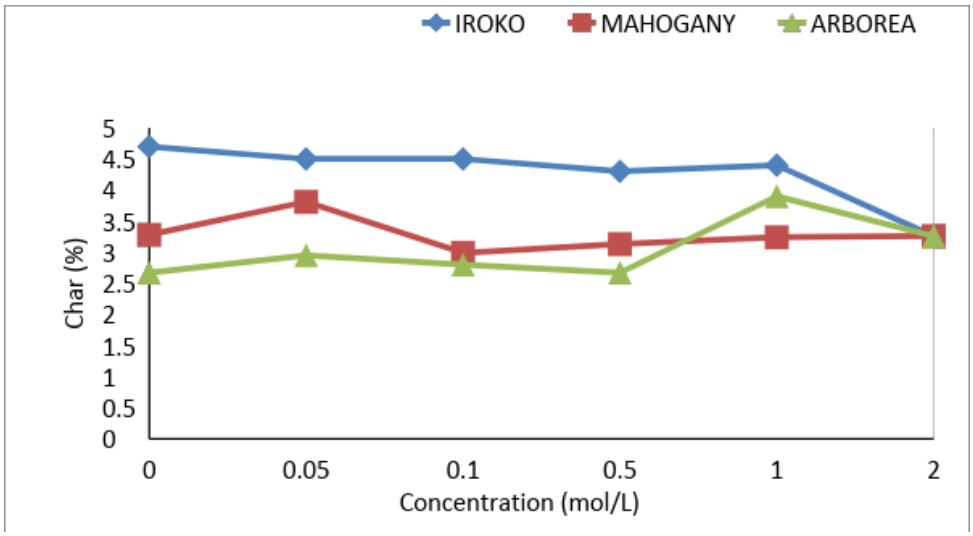

Figure 9: Effect of boric acid concentration on char of timber

The result for the boric acid treated timbers as illustrated in Figure10 shows that Arborea had the best performance with a 2.5% increase in char formation, while Mahogany and Iroko performed poorly with a decrease of 7.7% and 17% char formation respectively at 2.0mol/L concentration when compared with the control.

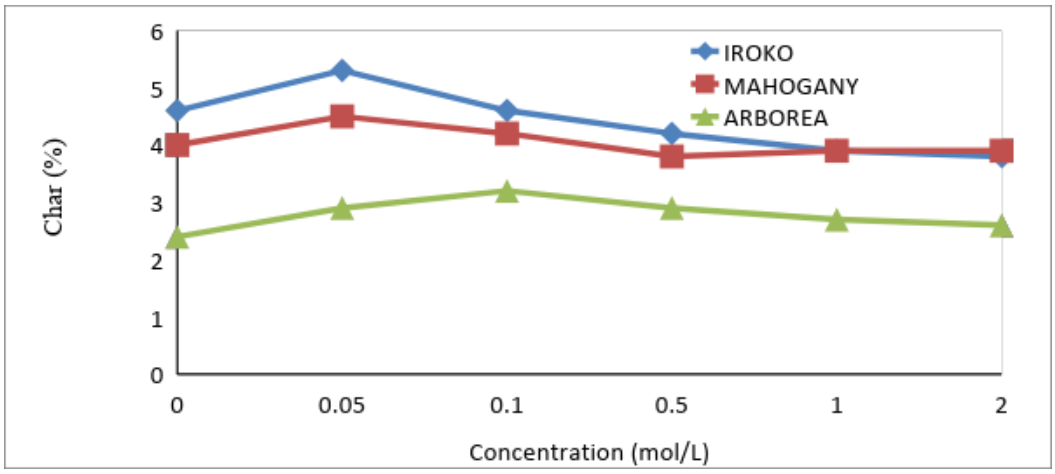

Figure 10: Effect of boric acid concentration on char of timber.

4. CONCLUSION

In this study, the effect of borax and boric acid as fire retardant chemicals in timber had been evaluated on Iroko, mahogany, Arborea. Based on the findings, the following conclusions are drawn;

i. Timber treated with fire retardant chemicals can prevent flame spread and avert the danger of fire disaster.

ii. Borax and boric acid are effective for treating wood against fire outbreak with borax and boric acid indicating a greater proficiency.

iii. Arborea could compete favorably as treated fire retardant material with other conventional tree species such as Iroko, and mahogany commonly used as roofing timbers.
iv. The ignition time of the treated timbers increased in the order of Arborea, Iroko to Mahogany, while the flame propagation rate and afterglow time generally decreased as compared with the control sample, and the char formation increase only in borax and boric acid treated Arborea but less in Iroko and Mahogany.
v. Timbers treated with retardant chemicals have higher fire resistance to burning than untreated timbers.
Since fire retardant chemicals like borax and boric acid have the potential of increasing the resistance of wood to combustion, it is therefore recommended that fire inhibitory chemicals such as these should be incorporated into timbers and their derived products for effective fire control during fire outbreak.

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