ISSN: 2441 – 2866
Volume 8, Number 2, 2016
International Journal of Advancement in Physical Science
Journal homepage:www.bwjournal.org

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, boric acid, and zinc chloride as fire retardant chemicals in timber. Fire which is the most resourceful gift of nature has led to the loss of lives and properties also wood plays an important part in fire outbreak, that is why the need for flame retardant chemicals are very important. Three species of timber which are iroko, mahogany, and arborea was selected for this study with a total of 18 splints were prepared from each timber species for analysis purpose which led to a sum total of 72 splints of timber used for this study, and each splint had a dimension of 20.0cm×1.0cm×0.5cm. Each treatment chemicals was prepared into five different concentrations of 0.05, 0.1, 0.5, 1.0, and 2.0mol/L. Five splints of each timber were immersed in a solution of each of the chemicals in their different concentrations and allowed to stand for 24 hours for thorough impregnation, while a sixth untreated splint serve as a control in each case. After which both the treated and untreated splints were subjected to fire performance test using time based parameters such as absorptivity, ignition time, flame propagation rate, after-glow time, and char formation so as to analyze the effect of borax, boric acid, and zinc chloride treatment on such parameters in the timber. The results obtained showed that the absorptive capacity of the timber species increased with increase in the concentration of the retardant chemical with the peak absorption observed in borax treated timbers at 2.0mol/L concentration. The ignition time of the treated timbers increased in the order Arborea>iroko> mahogany, while the flame propagation rate and after- glow time generally decreased as expected compared with the control, and also the timbers treated with retardant chemicals have higher fire performance or resistance to burning than untreated timbers. It was recommended that since fire retardant chemicals have the potential of increasing the resistance of wood burning, it is therefore recommended that fire inhibitory chemicals such as these should be incorporated into timbers and their derived products to avoid incidence of fire outbreak. It was therefore concluded that borax, boric acid and zinc chloride are effective as fire retardant chemicals with borax having greater proficiency.

INTRODUCTION.
Fire is one of the commonly used resourceful gift of nature to mankind which man has utilized for his well being through the provision of warmth, better processed or prepared food to the manufacturing of goods, and services. However, when there is fire outbreak, it is usually accompanied by destroying lives and properties and it's often devastating.
In Nigeria, fire has led to inestimable loss of lives and properties with billions of naira across the state are of serious concerns damage to major towns, markets, factories, public and residential buildings (Bhatta 2010). For example in 2011, fire outbreak in Lagos led to destruction of 65 shanties in Ebutemetta, while in that same year the Keffi central market in Nassarawa state was gutted by fire consuming about a billion naira commodities (Eboatu et al 2010).
In a research carried out by Zeki et al 2012 on fire performance of laminated veneer lumber (LVL) panels treated with fire retardant chemicals, it was stated that LVL treated panels has better performance than untreated panel and also panels treated with diammonium phosphate has best fire performance when compared with that treated with boric acid and borax.
(Hakan et al 2013) investigate that combustion properties of rowan wood impregnated with various chemicals, it was found that borax and boric acid decreased the combustion temperature of the wood more than all other chemical compound used for the study. Also, it was stated that boric acid is more resistance to material loss than other chemicals thus reducing the risk of a sudden collapse anddistribution in fire.
(Odinma, et al 2013), conducted a comparative study on the effect of three flame retardant compounds on flame behavior of a roofing thatch, using potassium aluminum sulphate, Di- ammonium chloride, it was discovered that there was significant decrease in the flame propagation rate, flame duration time and after-

glow time while an increase in ignition time was noted. In addition, in a study conducted by Ozcifci 2008, on the impact of various fire retardant on red color and yellow color tone of some wood and varnishes, it was stated that while varnishing process increased the combustibility of both red color tone and yellow color tone of the selected woods, impregnation material such as zinc chloride and borax decreased the combustibility of both the red color tone and yellow color tone of the selected woods.

METHODOLOGY

COLLECTION OF SAMPLE

In this study, three dry tree species, Iroko, mahogany, and arborea were collected from Harbour wood market, Udu road, Delta State and processed for assessment of flammability characteristics. Reagents used areof analytical grade.

SAMPLE PREPARATION

Six splints measuring 20.0cm x1.0cm x0.5cm was from each of the timber 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 24hours for a thorough impregnation, while the sixth served as a control. Both treated and untreated (control) splints was weighed and oven dried at 105^{o}C for 48hours. The dry samples were cooled in a desiccators and reweighed until a constant weigh was obtained.

PREPARATION OF SOLUTIONS

Solution of borax, boric acid and zinc chloride were prepare according to standard methods to obtain concentration range of 0.0M- 2.00M for each reagent.
The following parameters where tested with the treated and untreated splits.

ABSORPTIVE CAPACITY (AbC) OF THE WOOD:

The weight different between the post treatment weight (PTW) and oven
Dry weight (ODW) for each splint samples were measured and expressed as

$$\text{AbC } \% = \frac{PTW - ODW}{PTW} \text{ X } 100$$

1.IGNITION TIME

The treated and untreated splits was carefully ignited with cigarette lighter and simultaneously timed with stop clock to monitor the time lag between initial ignition and first perceptible glow.
The different 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

IT = (T_2-T_1)

FLAME PROPAGATION RATE

The oven dry split was clamped vertically unto a retort stand and ignited at the base with the cigarette lighter. Immediately ignition occurred, the source was withdrawn.
The distance travelled by the char front per second or linear flame velocity was measured until the last glow was seen

$$\text{FPR} = \frac{Distance\ travelled\ by\ the\ flame}{Time\ taken\ in\ the\ direction\ of\ the\ flame}$$

2. AFTER GLOW TIME

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

3.PERCENT CHAR

The oven dry splints was weighed on an analytical weighing balance, clamped unto a retort stand and ignited. The splints was allowed to burn until last glow. The burnt remnant was weighed and recorded in percent.

ISSN: 2441 – 2866
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$$\text{Char } \% = \frac{wt.of char generated}{wt.of splint samples} \text{ X } 100$$

RESULTS AND DISCUSSION

The results obtained during this study are presented and discussed as shown below:

Table1: Effect of Borax concentration on the absorptivity of timber species

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	0.00	0.00	0.00
0.05	0.36	0.58	0.64
0.1	0.57	0.54	0.55
0.5	0.61	0.47	0.28
1	0.62	0.50	0.28
2	0.74	0.55	0.41

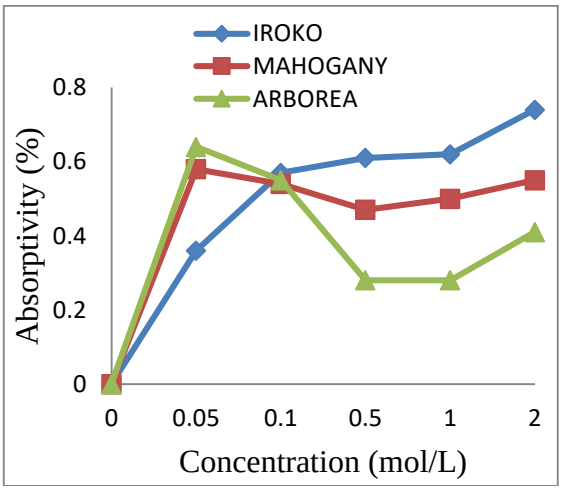

Fig. 1: Effect of borax concentration on the absorptivity of timber.

From table 1 and fig. 1 above, the results for the absorptive capacity of the timber species increased with increase in the concentration of the retardant chemical. 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. Absorption of 0.74%, 0.55%, 0.41% was obtained for Iroko, Mahogany, and Arborea respectively at a concentration of 2.0mol/L in borax treated wood as shown in table 1 above.

Table 2: Effect of Boric Acid concentration on the absorptivity of timber

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	0.00	0.00	0.00
0.05	0.05	0.13	0.05
0.1	0.06	0.13	0.72
0.5	0.11	0.13	0.25
1	0.13	0.17	0.22
2	0.15	0.17	0.22

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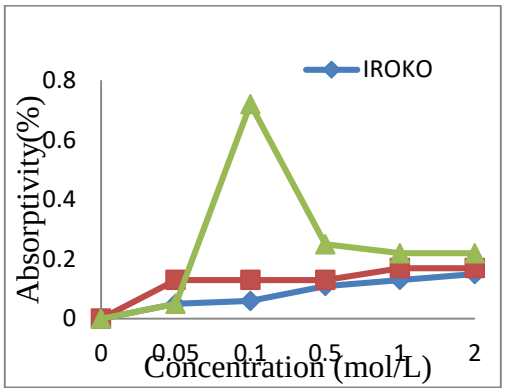

Fig. 2: Effect of boric acid concentration on absorptivity of timber

From table 2 and fig. 2 above, the results for the absorptive capacity of the timber species increased with increase in the concentration of the retardant chemical. The highest absorption was at 2.0mol/L for iroko and mahogany and absorption of 0.15%, 0.17% was obtained while Arborea had its highest at 0.1mol/L with absorption of 0.72% in boric acid treated wood.

Table 4: Effect of Borax concentration on ignition of timber species

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	3.9	6.71	2.3
0.05	4.9	7.93	3.44
0.1	6.6	7.8	3.58
0.5	6.6	8.4	3.59
1	6.2	8.08	4.21
2	7.7	9.08	4.8

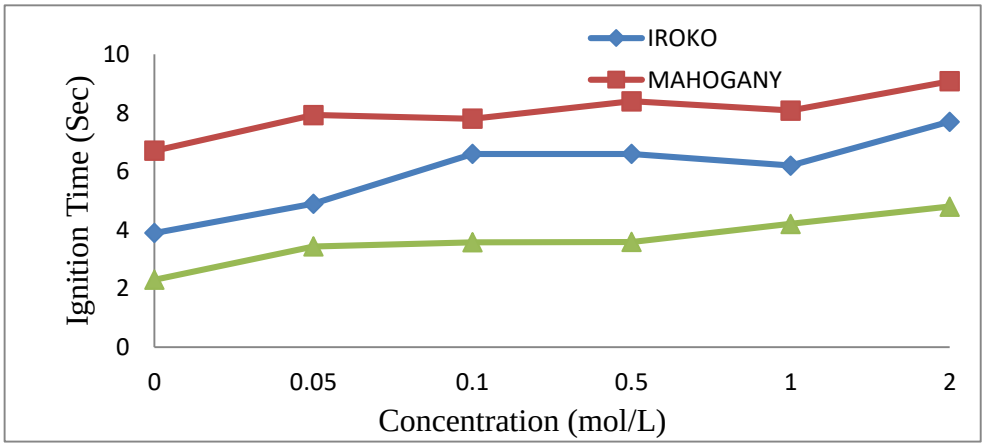

Fig. 4: Effect of borax concentration on ignition time of timber

The ignition time for the timbers treated with borax as shown in table 4 and significantly increased with increase in concentration of the treatment chemical. The ignition time indicate the time lag for a material to imbibe sufficient heat to yield to combustion. For the borax treated timbers, the results showed that the treated wood will be able to resist burning very well when compared with the control. Although all three species of timber show an increase in ignition time with increase in concentration of the chemical, arborea had the best performance with a significant 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. This is well illustrated in fig. 4 above.

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Table 5: Effect of Boric acid concentration on ignition time of timber species

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	3.97	5.3	2.8
0.05	4.18	6.4	3.2
0.1	4.83	7	3.9
0.5	5.31	7	4.3
1	6.23	8.7	5.1
2	6.95	9.2	5.5

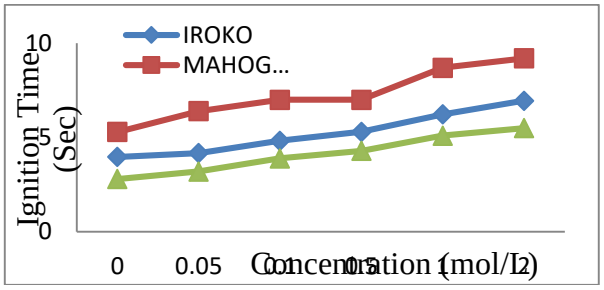

Fig. 5: Effect of boric acid concentration on ignition time of timber

Similarly, the results of boric acid treated timber for ignition time shown in table 5 and displayed in Fig. 5 showed that there is 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.

Table 7: Effect of Borax concentration on flame propagation rate of timber species

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	0.41	0.64	0.95
0.05	0.39	0.31	0.54
0.1	0.33	0.43	0.43
0.5	0.24	0.39	0.4
1	0.27	0.35	0.46
2	0.35	0.21	0.48

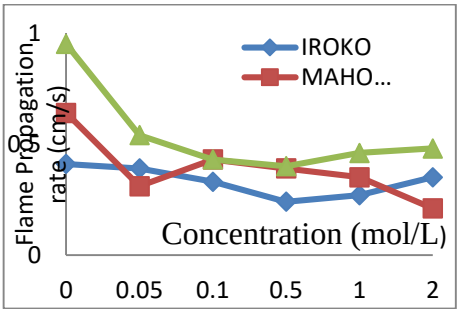

Fig. 7: Effect of borax concentration on flame propagation rate of timber

The flame propagation rate for borax treated timber decreased remarkably with increasing concentration of the retardant chemical as shown in table 7 and fig.7. Although there was remarkable decrease in the flame propagation rate in all timber species, Mahogany had the best performance with

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a 67% decrease, followed by Arborea 49% and the least was Iroko with 15% decrease at a concentration of 2.0mol/L when compared with the control.

Table 8: Effect of Boric acid concentration on flame propagation rate of timber

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	0.37	0.5	0.65
0.05	0.31	0.41	0.32
0.1	0.26	0.38	0.31
0.5	0.26	0.32	0.32
1	0.21	0.27	0.25
2	0.15	0.22	0.18

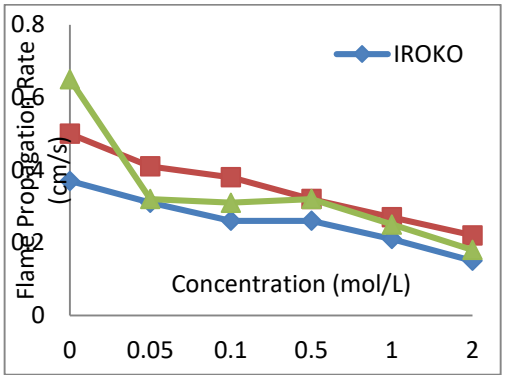

Fig. 8: Effect of boric acid concentration on flame propagation rate of timber

Also, table 8 and fig. 8 shows the result of the flame propagation rate of the boric acid treated timbers. There was a remarkable decrease in flame propagation rate with increase in concentration of the retardant chemical. From the table, we can see 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.

Table 10: Effect of borax concentration on after-glow time of timber

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	0.42	0.55	0.63
0.05	0.39	0.5	0.5
0.1	0.35	0.47	0.49
0.5	0.27	0.39	0.5
1	0.19	0.33	0.42
2	0.19	0.27	0.31

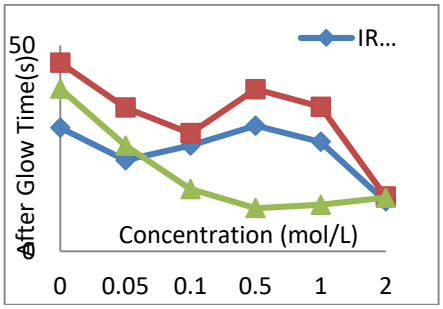

Fig. 10: Effect of borax concentration on after- glow time of timber

ISSN: 2441 – 2866
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The result for the after- glow time of the borax treated timbers are shown in table 4.2 and fig. 10. There was a significant decrease with increase in concentration of the treatment chemical when compared with the control. Mahogany has the best performance with a 71% decrease in after- glow time, followed by arborea with 67%, and iroko the least with a 60% decrease at 2.0 mol/L concentration when compared to the control.

Table 11: Effect of borax concentration on after-glow time of timber

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	18	38.2	29.1
0.05	13	23.6	18
0.1	12.8	20	16
0.5	12.5	17.4	14
1	10.8	13.3	11.5
2	9.4	12.8	9.5

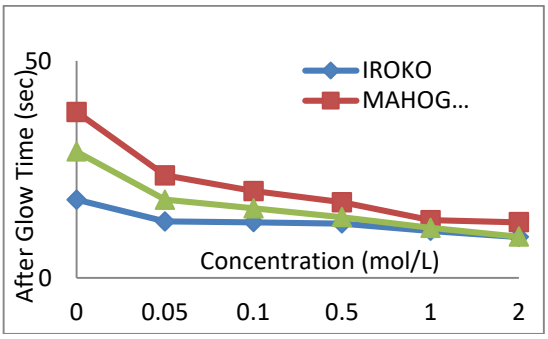

Fig. 11: Effect of boric acid concentration on after-glow time of timber

Similarly, table 11 and fig. 11 illustrate the after-glow time of boric acid treated timbers. There was a significant decrease with increase in 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 a 66% decrease, while Iroko was the least with 48% decrease.

Table 13: Effect of borax concentration on char formation of timber

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	4.7	3.28	2.67
0.05	4.5	3.81	2.95
0.1	4.5	2.99	2.8
0.5	4.3	3.13	2.67
1	4.4	3.24	3.9
2	3.26	3.26	3.26

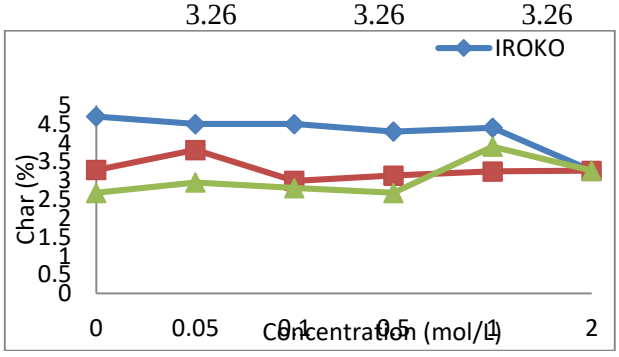

Fig. 13: Effect of borax concentration on char of timber

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A marginal decreasing trend was observed for char formation as the concentration of the fire retardant chemicals increases. For the borax treated splints, fig. 13 show thatArborea 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 concentration of 2.0mol/L when compared with the control.

Table 14: Effect of boric acid concentration on char formation of timber

Conc. (Mol/L)	Iroko	Mahogany	Arborea
0.00	4.6	4	2.4
0.05	5.3	4.5	2.9
0.1	4.6	4.2	3.2
0.5	4.2	3.8	2.9
1	3.9	3.9	2.7

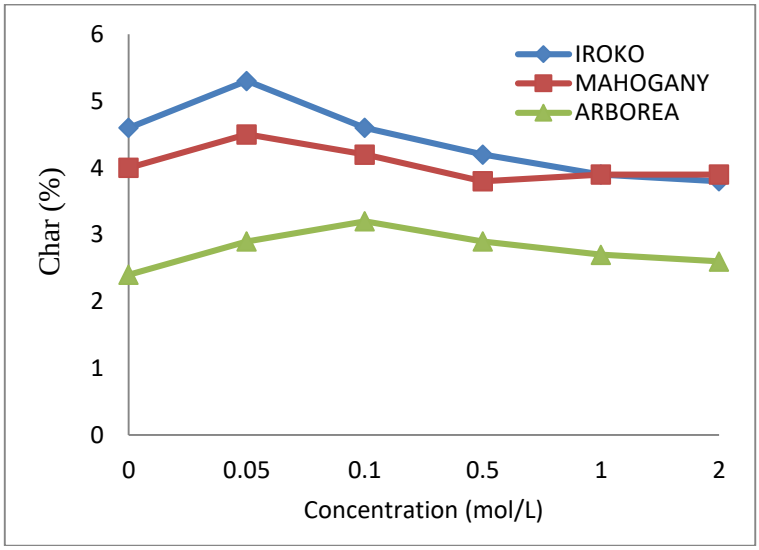

Fig. 14: Effect of boric acid concentration on char of timber.

The result for the boric acid treated timbers as illustrated in fig. 14 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.

CONCLUSION

This project was aimed at evaluating the effectiveness of borax and boric acid as fire retardant chemicals in timber. The objectives were to determine the effect of each chemical on flame propagation and absorptive capacity (ABC) in the selected timbers, ascertain how the retardant affects the after -glow time (AGT), and percent char in the selected timbers, determine the effect of the chemicals on ignition time of the selected timbers, and to compare the fire retardant performance of the treated and untreated (control) splint.

Based on the findings of this study, the following conclusions are drawn;

- Timber treated with fire retardant chemicals can prevent flame spread and avert the danger of fire disaster.
- Borax, boric acid and zinc chloride are effective for treating wood against fire outbreak with borax and boric acid indicating a greater proficiency.
- Arborea compared favorably with other conventional tree species; iroko, and mahogany commonly used as roofing timbers.
- The ignition time of the treated timbers increased in the order Arborea>iroko> mahogany, while the flame propagation rate and after- glow time generally decreased as expected compared with the control, and the char formation increased only in borax and boric acid treated arborea but others did increase as expected.

- Timbers treated with retardant chemicals have higher fire performance or resistance to burning than untreated timbers.

RECOMMENDATION

Since fire retardant chemicals like borax and boric acid have the potential of increasing the resistance of wood to burning, it is therefore recommended that fire inhibitory chemicals such as these should be incorporated into timbers and their derived products to avoid incidence of fire outbreak.

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