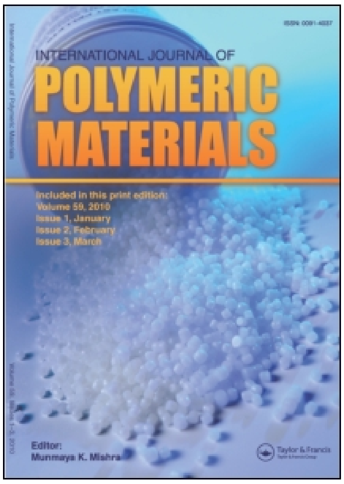

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Effect of Flame Retardant Treatment on the Thermal Characteristics of Some Lignocellulosic Materials

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Effect of Ammonium cupric chloride dihydrate (ACCD) as a flame retardant (FR) on the thermal characteristics of some lignocellulosic materials were presented. Their flame propagation rate and after-glow time were drastically reduced as a result of this treatment. Increase in char-formation was also noted. Gravimetric analysis showed that this retardant acted by condensed phase, and vapour phase mechanisms.

KEY WORDS Flame retardant, thermal, lignocellulosic, after-glow, roofing, rattan, palm, polymer, cellulose and thatch.

INTRODUCTION

Humans have always been plagued by unwanted fires, therefore it is not surprising that considerable efforts had been expended to investigate what makes objects burn, as well as how the flammability of materials could be controlled.[1]

The method by which the flammability of polymers can be reduced by chemical means is of long-standing importance and has engaged the minds of scientists since the times of alchemy and the Roman era.[2] At the seige of Piraeus in 83 BC, for example, the wooden storming towers used, were fire-retarded by treatment with alum. The ancient Egyptians also extensively practiced fire retardancy of cotton fabrics. The early scientists tried a variety of concoctions with the result that by the 19th century, enough knowledge had accumulated to enable Gay Lussac to make a systematic study of the phenomenon and to formulate theories.[3] These theories have since been widely accepted as laying the foundation for the understanding of the mechanism of flame retardancy in polymers. The first recorded effort at applying flame retardants to cellulose was in 1735 when a British patent was granted to Jonnathan Wyld for a flame retardant mixture consisting of borax,

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alum and sulphates.[4,5] Since then so much has been known that the burning behaviour of certain textile materials, papers, plastics and even timbers have been extensively investigated and documented. Nonetheless, it is necessary to state here that it is impossible to make such polymers as celluloses and the plastics completely flame-proof and still retain their advantageous qualities. In fact, for all polymers, it may require an exceptional ingenuity on the part of chemists to obtain the desired safety level and at the same time maintain the fundamental properties of the parent polymer. In most cases, flame retardant treatments aim at a compromise between safety and functional performance. In this article the effect of treating some lignocellulosic materials treated with ammonium cupric chloride dihydrate as flame retardant formulation is presented. The lignocellulosic materials used are: *Andropogon gayanus*, *calamus deeratus*, and *Borassus aethiopun* to be called subsequently by their trade names of Roofing Thatch, Rattan and Roofing palms.

EXPERIMENTAL

Materials

The chemical (ACCD) used was of standard grade obtained from British Drug House Limited (BDH), U.K. The lignocellulosic materials employed in this investigation viz. Roofing thatch, Rattan and Roofing palms were obtained from a local market in Sokoto, Nigeria and have the characteristics shown in Table I.

METHODS

1) Flame retardant treatment: Oven-dry materials were cut into measured splints. Standard solutions of the retardants were made in water and the splits were immersed completely in them. Residence time was 24 hours and on removal from the solution, each sample was dried at 30°C and finally cured in an oven at 102°C for 5 minutes. The samples were then conditioned at the same 30°C and relative humidity of 68% for 3 days before being weighed again. % Add-on was calculated using the expression.

$$\% \text{ Add-on} = \frac{\text{Weight after treatment} - \text{weight before treatment}}{\text{Weight before treatment}} \times 100$$

2) Flame propagation rate: The sample was clamped vertically and then ignited

TABLE I

Material	Roofing Thatch	Rattan palm	Roofing palms
Specific gravity	0.34	0.51	0.58
Moisture content %	26.3	24.0	22.4
Porosity under (% water imbition)	55.10	40.40	36.00

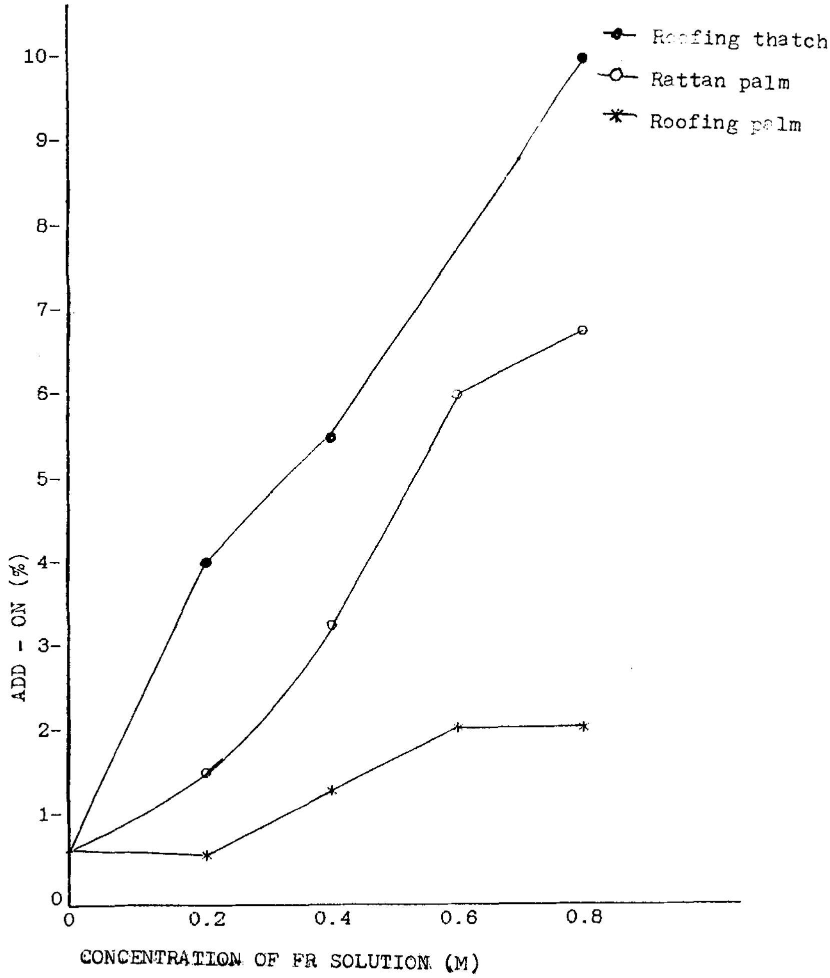


FIGURE 1 Effect of FR treatment on add-on (%) of the materials.

at the base in a draught free room. The distance travelled at a stipulated time interval by the char-front was measured and the rate of flame propagation was calculated as the vertical distance traversed per second.

3) This was estimated by noting the time(s) between flame-out and the last visual perceptible glow.

4) Thermogravimetry: This was performed in an air atmosphere by means of the METLER TA 300/TG 50 system. The sample was ground into powder and subjected to a heating programme. The quantity of char left at the end of the thermal program was also measured.

RESULTS AND DISCUSSION

In Figure 1, it is observed that the add-on increases with FR concentration. It is also apparent that add-on depends largely on the specific gravity (SG) and porosity

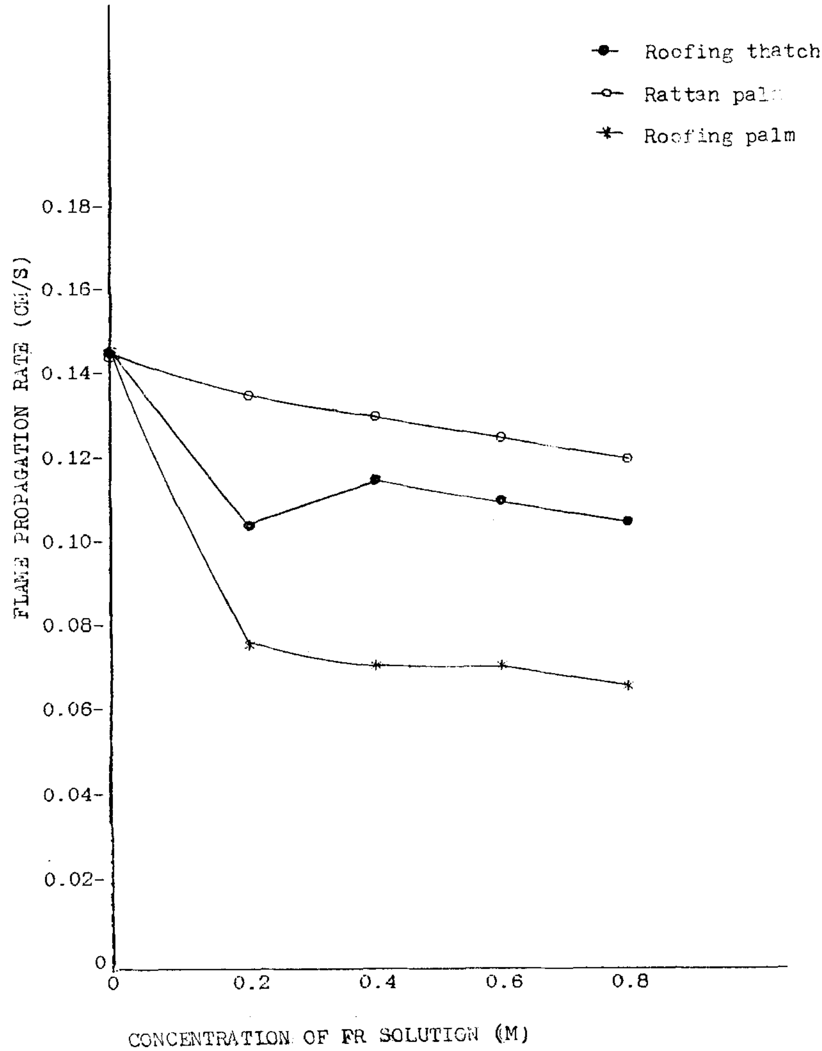


FIGURE 2 Effect of FR treatment on flame propagation rates of the materials.

index of the lignocellusic materials. This is not surprising because larger amounts of the FR liquor are expected to be inbibed by more porous materials. Lighter samples are also more porous and thus should accommodate more FR material.

The drastic decreases observed in the flame velocity of materials (Figure 2) treated with ACCD can be given the following explanations; under the influence of heat, the salt decomposes according to the equation;

$$(NH_4Cl)_2CuCl_2 \cdot 2H_2O \rightarrow 2NH_3 + 2HCl + CuCl_2 + 2H_2O$$

The flame inhibiting properties of ACCD is interpreted in terms of vapour phase and condensed phase mechanisms. Non-combustible products of the decomposed

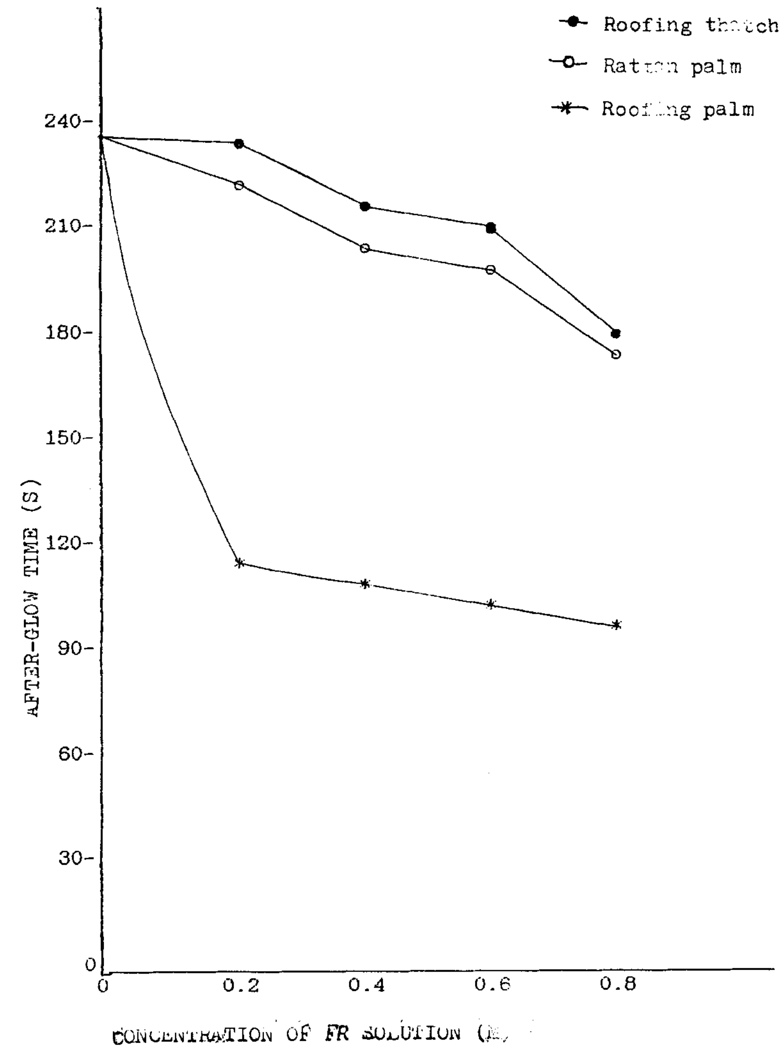


FIGURE 3 Effect of FR treatment on after-glow time of the materials.

FR solution, such as ammonia, water and hydrogen chloride dilute the active pyrolysis products of the materials thereby reducing their concentration in the flame zone. The evolution of water absorbs heat and cupric chloride is an excellent heat conductor that deflects heat away from the pyrolysis/burning surface. It also forms protective layer around the cellulose macromolecule, thus reducing flame propagation rate as in Figure 2.

It was observed that this treatment also reduces after-glow time. In fact, after-glow time decreases significantly with increase in FR concentration (See Figure 3).

Cellulose pyrolysis occurs by either of two known routes. In one, laevoglucosan is first formed which then decomposes to oxidizable volatitles, e.g. CO, alcohols, ketones, aldehydes, etc. The second route, catalyzed by acids, is by evolution of water and char resistant to combustion as shown on next page.

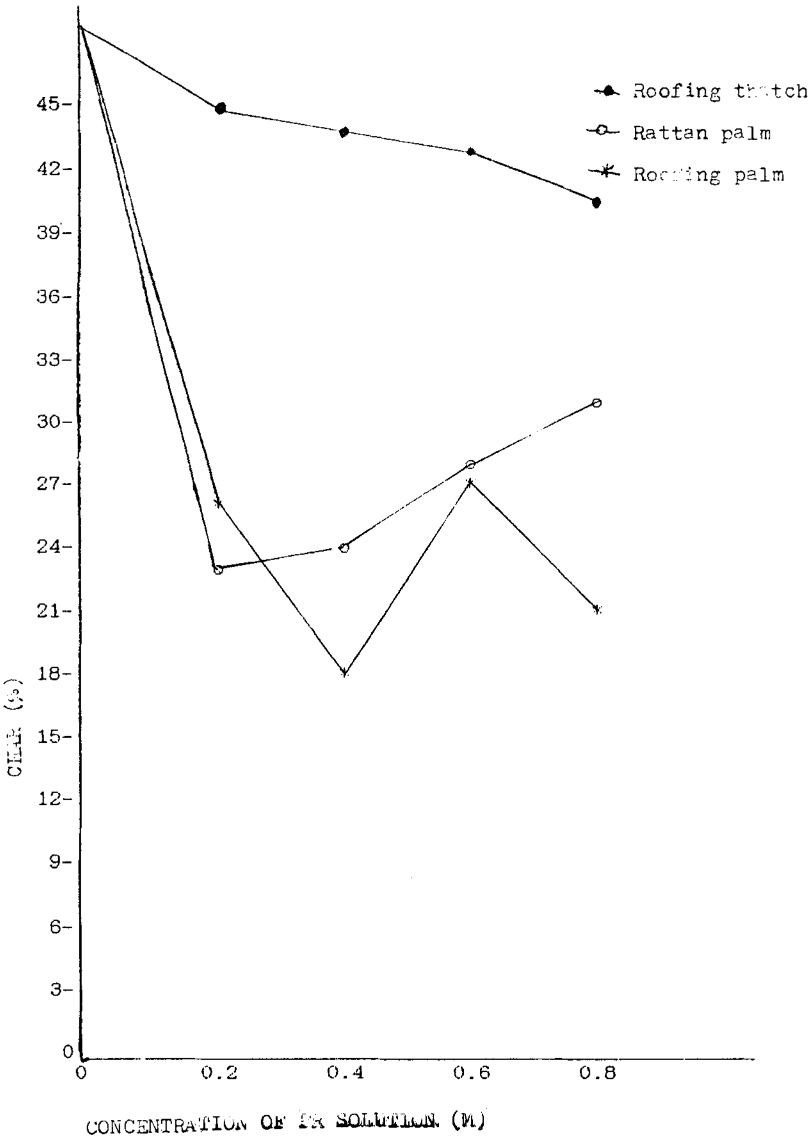
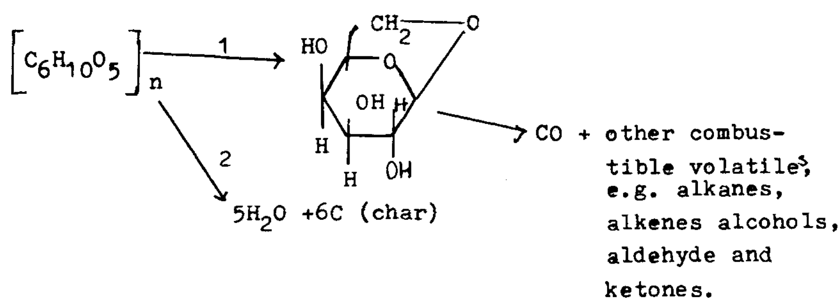


FIGURE 4 Effect of FR treatment on char formation of the materials.



Gravimetric analysis was performed to further elucidate the mode of action of this retardant. Figure 4 shows the effect of FR treatment on the amount of char formed after combustion of both treated and untreated materials. It was observed that FR treatment increases char formation in all cases; perhaps the additives suppressed the production of flammable gases via laevoglucosan formation and promoted the formation of char. This clearly confirms that FR acted primarily by the condensed phase mechanism.

CONCLUSION

Considering the wide application of lignocellulosic materials, there is the need to improve their fire resistance to enhance their service life and reduce the risk of damage caused by fire.

The thermal properties of these cellulosic materials were modified by the controlled addition of ACCD flame retardant. Since the resulting products exhibited high performance levels, it is expected that the devastation caused by fires of these cellulosic materials could be greatly reduced by the ACCD treatment discussed in this study.

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