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Using Ammonium Chloride and Ammonium Sulphamate to Establish the Effectiveness of Flame Retardants on Mahogany Wood Timber

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Abstract: Splints of mahogany wood were immersed in different concentrations of ammonium chloride, ammounium sulphamate and mixture of the two retardants.. The effectiveness of these flame retardants were determined by characterizing treated and untreated mahogany wood splints for ignition time (IT), flame propagation rate (FPR) and afterglow time (AGT). Results obtained indicated that the ignition time increased with increase in concentration whereas, FPR and after-glow time showed reduction with increased concentration for all the retardants. The reason was that the NH_4Cl liberated gases (NH_3 and HCl) which diluted O_2 concentration and also generated free radicals during flaming. Ammonium sulphamate on the other hand produced non-combustible gases that act as O_2 diluent during combustion.

Key words: Ammonium chloride · Ammonium sulphamate · AGT · FPR · IT · Flame retardant and timber

INTRODUCTION

Wood is the most versatile, renewable and sustainable resources on the planet and has played a major role throughout human history and is also the most commonly used materials in the creation of furniture. Wood has been an excellent building material for many centuries; however, its ability to ignite and burn has limited its use in many applications. However, fire retardant chemicals have expanded the use of wood and provided significant safety to occupants of wooden buildings [1]. Fire is undoubtedly an emotive subject, especially when it comes to scenarios that we can imagine in a closed system (e.g ship or aircraft) and the possibilities to escape are restricted. The high fire hazard posed by furniture, both in historical times and to the present days, are a consequence of the high surface area of the flammability ingredients present and the ease of access to atmospheric oxygen [2]. As comfort and safety are the two relevant factors when furnishing modern living environments, the later should be designed in such a way that the effect is as pleasing as possible. This may result to the use of flame retardants in our homes, offices; hospitals etc since furniture are used in wide range of applications.

Flame retardants are chemicals that are incorporated into combustible materials to improve the resistibility of fire performance [3-7]. They are effective in making materials or products less easily ignitable or reduce flame spread and are extensively used to make materials or products to meet certain test requirements [8]. They are used on all surfaces where they are either desirous or necessary to reduce the burning characteristics of combustible materials or to retard the penetration of heat. In general, fire retardants reduce the flammability of material by either blocking the fire physically or by initiating a chemical reaction that stops the fire [9]. According to [10] several aspects of evaluation of reaction of fire performance include ignitability, heat released, flame spread etcThe basic mechanism of flame retardancy vary depending on the specific flame retardant and the material (in this case, mahogany wood) used.

MATERIALS AND METHODS

Materials: The mahogany wood was obtained from the timber market at Awka, Anambra State. The ammonium chloride and ammonium sulphamate were produced by Loba Chemie PVT, Ltd. India.

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Procedure: The mahogany wood samples were cut into splints of uniform sizes of length 45cm, width 4cm and thickness of 2cm. Splints of wood were prepared for each concentration of ammonium chloride and ammonium sulphamate. They were labelled accordingly, sun dried for 5 hours and oven dried at 110°C until constant weight was obtained for each wood splint.

Different concentrations of NH_4Cl and $N_2H_6SO_3$ were prepared by dissolving each in 800cm^3 of water with various concentrations of NH_4Cl and $N_2H_6SO_3$ each and mixed together. The solution was mixed thoroughly to obtain uniform mixture.

Three splints were immersed in each concentrations and left for 5 days. They were allowed to dry at room temperature for three days and oven dried at 110°C for 30 minutes and weighed to constant weight. The% concentration of the amount of NH_4Cl and $N_2H_6SO_3$ absorbed were calculated.

$$\% \text{ Concentration of the amount penetrated} = \frac{X - Y}{Y} \times 100$$

where
X = Weight of treated wood and
Y = Weight of untreated wood

Determination of flame characteristics such as ignition time, flame propagation rate and after-glow time were carried out to discover the effectiveness of NH_4Cl and $N_2H_6SO_3$ during the combustion of the wood splints.

Determination of the Ignition Time: Each splint was clamped vertically using a retort stand in a draught free room and ignited at the base using a cigarette lighter. The ignition time was taken as the time between which the ignition source came in contact with the base of the sample and the time a tiny spark was observed on the splint. It was performed twice for each sample and the average taken [11].

Determination of the flame propagation rate
As earlier mentioned, the vertically clamped untreated and treated sample splints were ignited at the base with a lighter. The distance travelled by the char front and the time taken were recorded. The same method was repeated for other splints and each concentration repeated twice and the average calculated.

$$\text{FPR (cm/sec)} = \frac{\text{Distance travelled by the char front (cm)}}{\text{time taken (sec)}}$$

where FPR= Flame Propagation Rate

Determination of After-glow Time: This was the time between flame extinction (flame out) and the last visibly perceptible glow (last glow). Again for each concentration two readings were taken and average calculated.

RESULTS AND DISCUSSION

Figure 1 depicts the amount of each flame retardant absorbed by the wood sample. At lower concentration the mixed flame retardant interwoven at some points with ammonium sulphamate but at higher concentration the mixture gave higher pentration. The reason could be that at lower concentration NH_4Cl reduces the rate of pentration since it is the least amount of the flame retardand taken up gy the wood sample.

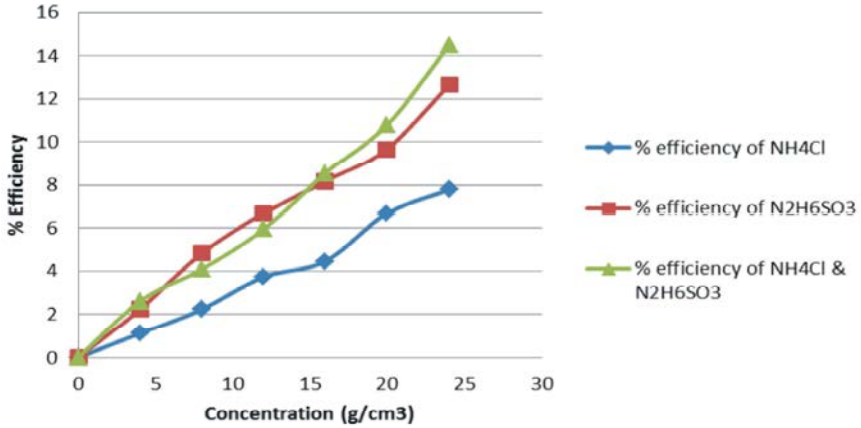

Fig 1: % Efficiency of flame retardants on mahogany wood splints.

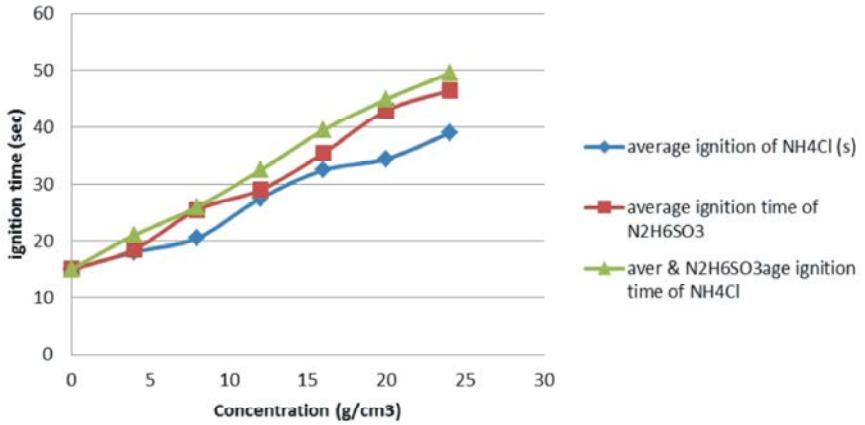

Fig. 2: Effect of flame retardants on mahogany wood splints.

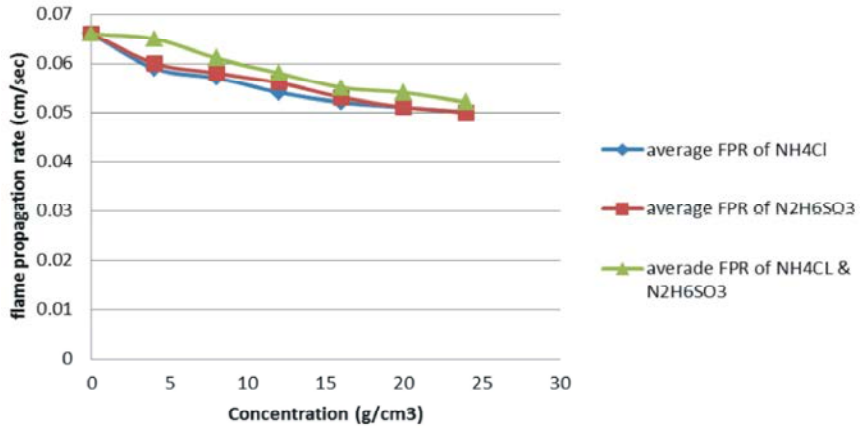

Fig. 3: Effect of flame retardants on mahogany wood splints.

It is evident that the ignition time increases as the concentration of NH_4Cl and $N_2H_6SO_3$ increases. Ignition time is the time it takes for the splint of wood to catch fire. This occurs by forming a protective layer that prevents the wood from igniting easily. The retardant chemicals (i.e NH_4Cl and $N_2H_6SO_3$) form shield which reduces the heat transfer from the heat source to the wood thereby, increasing the ignition time. The ignition time increased due to their higher thermal stability and lower volatility. The mixture of NH_4Cl and $N_2H_6SO_3$ gave the highest reduction in ignitability while NH_4Cl is the least. The may be as a result of presence of NH_3, HCl and SO_3 present in the mixture which are non-combustible gases. The order of ignitability is $NH_4Cl < N_2H_6SO_3 < NH_4Cl$ and $N_2H_6SO_3$

The result obtained in Fig. 3 shows that the flame propagation rate decreased as the concentration of NH_4Cl and $N_2H_6SO_3$ increased. The reason for this is that the chemicals (i.e NH_4Cl and $N_2H_6SO_3$) releases large amount of non-flammable gases such as ammonia and acids which causes charring $NH_4Cl \rightarrow NH_3 + HCl$. The flame inhibiting property of ammonium chloride and ammonium sulphamate is interpreted in terms of vapour and liquid mechanism. The free radicals $H^{\bullet}$ and $Cl^{\bullet}$ of ammonium chloride have the ability to scavenge the $OH^{\bullet}$ and $O^{\bullet}$ radicals that are essential for the sustenance of combustion. The gaseous products NH_3, H_2SO_4 and HCl contribute as diluents of the pyrolysate concentration. The trend is $NH_4Cl > N_2H_6SO_3 > NH_4Cl$ and $N_2H_6SO_3$

It can be seen that as the concentration of NH_4Cl and $N_2H_6SO_3$ increased, the after glow time decreased. There is more decrease of after glow theoretically at lower concentration but as it tends to higher concentration, the effect of synergy emerges with more decreasing observed after glow. This reason could be due to the factors that affect the anisotropy of wood which is in the arrangement of and orientation of the wall materials in the cell making up the woody tissues and the thermal conductivity of wood which depends on direction of heat flow with respect to the grain orientation in the wood, moisture content of the wood and the specific gravity of the wood.

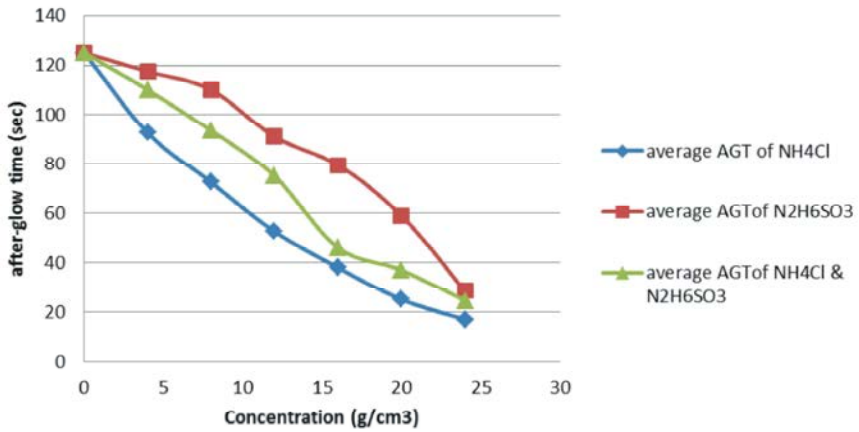

Fig. 4: Effect of flame retardants on mahogany wood splints.

CONCLUSION

The following conclusions can be made from the results of the study. NH_4Cl and $N_2H_6SO_3$ are effective in reducing the flame propagation rate and the after glow time. Ammonium chloride and ammonium sulphamate function as good fire retardants in delaying and resisting ignition, Flame propagation rate and after glow time, though there was remarkable improvement when the wood was treated individually with each of the flame retardants but it was more pronounced when the flame retardants were combined at different concentration depicting the effect of synergy. The reduction of these flame characteristics is paramount in reducing the spread of flame and the flammability of the wood which leads to safety of life and property.

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