

Effects of Urea, Borax and Ammonium Chloride on Flame Retarding Properties of Cellulosic Ceiling Board

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Abstract
This work involves the impregnation of urea, borax and ammonium chloride solutions prepared in varying concentrations into strips of cellulosic ceiling board. A formulated solution was also made of equal concentration of urea and borax solution and impregnated into strips of cellulosic ceiling board. The treated and blank samples were dried and investigated for ignitability, flame propagation and afterglow time. Urea was found to give a good effect for ignitability after 28.00sec than borax, ammonium chloride and blank after 26.00sec, 25.00sec and 16.80sec respectively. Urea gave a better effect for flame propagation of $0.13x10^{-2}$cm/sec than borax, ammonium chloride and blank which has $0.24x10^{-2}$cm/sec, $0.28x10^{-2}$cm/sec and $1.95x10^{-2}$cm/sec respectively and also urea has afterglow time of $0.22x10^{2}$sec than borax (0.60 $x10^{2}$sec), ammonium chloride ($0.70x10^{2}$sec) and blank (2.25 $x10^{2}$sec). The formulated solution drastically improved the ignitability from 16.80sec (blank) to 34.00sec and zero flame propagation and afterglow time was recorded. With this result, urea was found to give a better retarding effect, hence could be incorporated in cellulosic ceiling board during production.
Keywords: Urea, borax, ceiling board, ignitability, flame propagation, afterglow time.

1. Intruduction

Cellulosic ceiling boards, although made to provide shelter, beauty and comfort, could however pose danger as they could be flammable and thus be a fire hazard. Wood products (cellulose) are the most attacked by fire. Fire is a rapid but persistent chemical reaction accompanied by the emission of light and heat. The reaction is self-sustaining unless extinguished to the extent that it continues until the fuel concentration falls below a minimum value. Most commonly, it results from rapid exothermic combustion of combustible materials with oxygen. However, fire is very important for man's evolution and development but is also very destructive to man's life and property. For instance, Bauchi/Gombe state alone within ten years had 2925 fire incidents in which 466 lives and property worth millions of naira were lost (Anonymous 1998). This record revealed that about 30% of the fire ignited from the roofs and furniture. The fire statistics in the United Kingdom has shown that most fire hazards that occurs in buildings results from the fire accidents in which furniture and the roofs of the buildings are usually the first point of attack by the fire, which is then followed by falling of the flamed roof to the remaining properties in the building (Anonymous 1991).

The defense against destructive fire has become the main preoccupation of man since the discovery of fire and its uses. Several means of controlling fire have been used in the past which includes fire fighting using different materials like water, blankets and fire extinguisher. Recently more technological approach, which has been used, includes the use of chemical substances, which are capable of reducing part of the available ingredient needed for the fire to be self-sustaining; these chemicals are known as fire retardants (Lyons 1970; Garba and Maduckwe 1997; Parker 1997 and Salaudeen 1999)

Fire retardants are chemicals compounds or mixture of compounds which when added or incorporate in materials will suppress the ease of ignitibility, flame propagation and the spread rate and also make the material to be self extinguishing after the igniting condition has been removed (Eboatu et al. 1992).

Fire and flame retardant have been known since ancient times. Bhat (1980) described fire retardant as material that resists brining when exposed to a relatively high energy ignition source. A flame retardant makes material to withstand burning when subjected to a low energy ignition source. Fire though is known to be important to man, many lives and properties have been lost due to uncontrolled and destructive fire. Fire safety regulation for consumer and other types of goods have caused many manufacturers to make their goods with flame retardant properties. In effort to comply with these regulations many manufacturer apply fire retardant chemical composition to their goods unfortunately, many fire retardant chemical composition are known to contain ingredient that may be toxic to human and the environment (Griem 2007).

Lyons (1970) described the different methods used to modify the burning properties polymers. Some of these methods are; by incorporating halogenated into the polymer matrix, incorporating nitrogen and phosphorus compounds and by adding sodium tetraborate decahydrate to the polymer.

Bhat (1980) described an inorganic composition for use as a fire and flame retardant additive, thermal insulation. Among the best known inorganic chemicals used as flame retardant in all sort of cellulosic product are the borates. Materials treated with borax, boric acid or mixtures of these two include timbers, wood, fibre product paper product and cotton product. According to Bhat (1980) borate promote char formation, which inhibited combustion and also help to protect the substrate from burning by isolating oxygen and heat from the fuel supply. Boric acid additionally possesses the properties afterglow suppression, low water absorption and good resistance to fungal growth. It provides fire and flame retardant and smoke suppression values within the limit prescribed by Federal Specification. The composition is also effective in mold inhibition and has relatively low density.

The effect of fire retardant on cotton cellulosic materials worn by fire men has been studied by Akpabio and Biri (1999). They used borax alum ammonium sulphate and diammonium orthophospahte and combination of these. All the reagents retarded flame significantly by reducing flame propagation rate, after glow time and char length. Borax formed a glassy film and retarded flame by the barrier theory.

The objective of this work is aimed at improving the fire retarding property of cellulosic ceiling board by incorporating fire retarding substance in it, knowing that this cellulosic material because of its physical and mechanical properties, it is used commercially as roofing material and for furnishing in buildings. It is therefore of optimum important to source out for fire retardant that could be incorporated into it in order to reduce the burning rate in the case of fire outbreak in buildings.

2. Material And Methods

2.1 Materials

Celluosic ceiling board was obtained from Muda Lawal Market in Bauchi, Nigeria. Urea, borax, ammonium chloride and distilled water used were of general purpose and laboratory reagent grade. The apparatus used were 100ml volumetric flask, beakers, weighing balance, stop watch, retort stand, desiccators and lighter.

2.2 Methods

The ceiling board was cut into strips of 5cm by 1cm with a saw blade. Different solutions of urea, borax and ammonium chloride was prepared in varying concentration of 5, 10, 15, 20 and 25% respectively. The formulated solution was prepared where 5g each of urea and borax was dissolved in 100ml volumetric flask and made up to mark with distilled water.

Numerous methods have been proposed for flame proofing cellulosic materials. One of the most commonly used is impregnation with various soluble salts (Parker 1997). In this research work the impregnation method was employed.

Equal numbers of prepared strips of cellulosic ceiling board were immersed in equal quantity of solutions of varying concentration of fire retardant for 1 hour. The strips were then withdrawn and dried under laboratory conditions. The dried impregnated strips were then stored in a dessicator after which flame test was conducted on each of the samples treated with different retardants. The procedure was repeated for the formulated solution.

2.2.1 Flame Test

Each of the treated samples was held in position by a tong which was clamped to a retort stand and ignited using a lighter at the base and at the same time a stop watch was activated. The following parameters were measured: ease of ignitability, the distance traveled by the flame to flame out, afterglow time and also the distance traveled by the char front were recorded according to Eboatu et al. (1992).

The following expressions were employed for the determination of:

i. Ignitability = time taken to ignite

ii. $\text{Flame propagation rate} = \frac{\text{Distance traveled by char front}}{\text{Time}}$

iii. Afterglow time = Time between flame out and the last flicker of light

3. RESULTS AND DISCUSSION

3.1 Effects of retardants on ignitability:

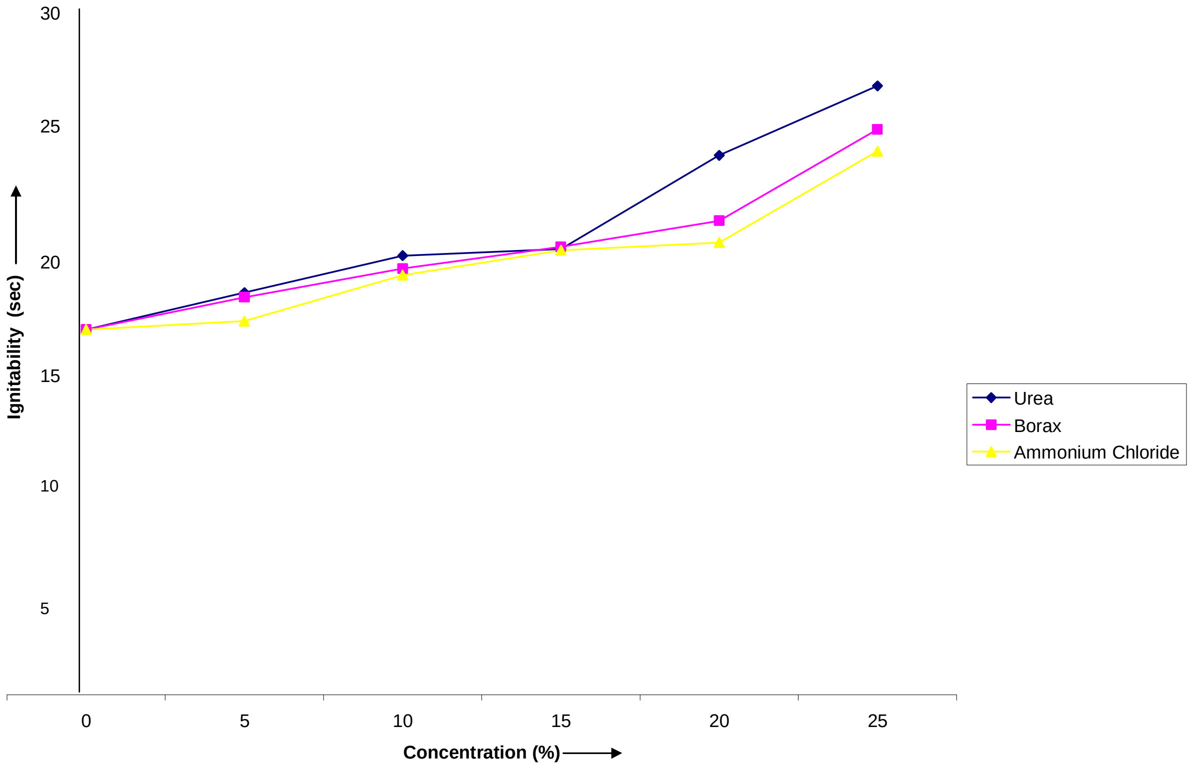

Fig. 1 Effect of Urea, Borax and Ammon ium Chloride on the Ignitibility of Cellulosic Ceiling Board

4. Fig 1 shows the effect of concentration of urea, borax and ammonium chloride on the ignitability of cellulosic ceiling board. The figure 1 shows that as the concentration of the retardants increase there is increase in the ignitability time of the samples. That is to say as the concentration increase, it takes a longer time before the treated sample will ignite.
5. At 0% concentration, the time of ignitability was 16.80sec and as the concentration of urea, borax and ammonium chloride increases to 25% the time taken to ignite also increase to 28.00%, 26.00sec and 25.00sec respectively. Out of the three retardants used they all gave good result in reducing the ignitability of the treated ceiling boards. However, this study suggests that urea showed a better result than borax and ammonium chloride. This result conforms to the results obtained in various works carried out by some researchers (Akpabio and Aliyu 1999; Akpabio and Biri 1999 and Boryo et al. 2010).

3.2 Effect of retardants on flame propagation rate:

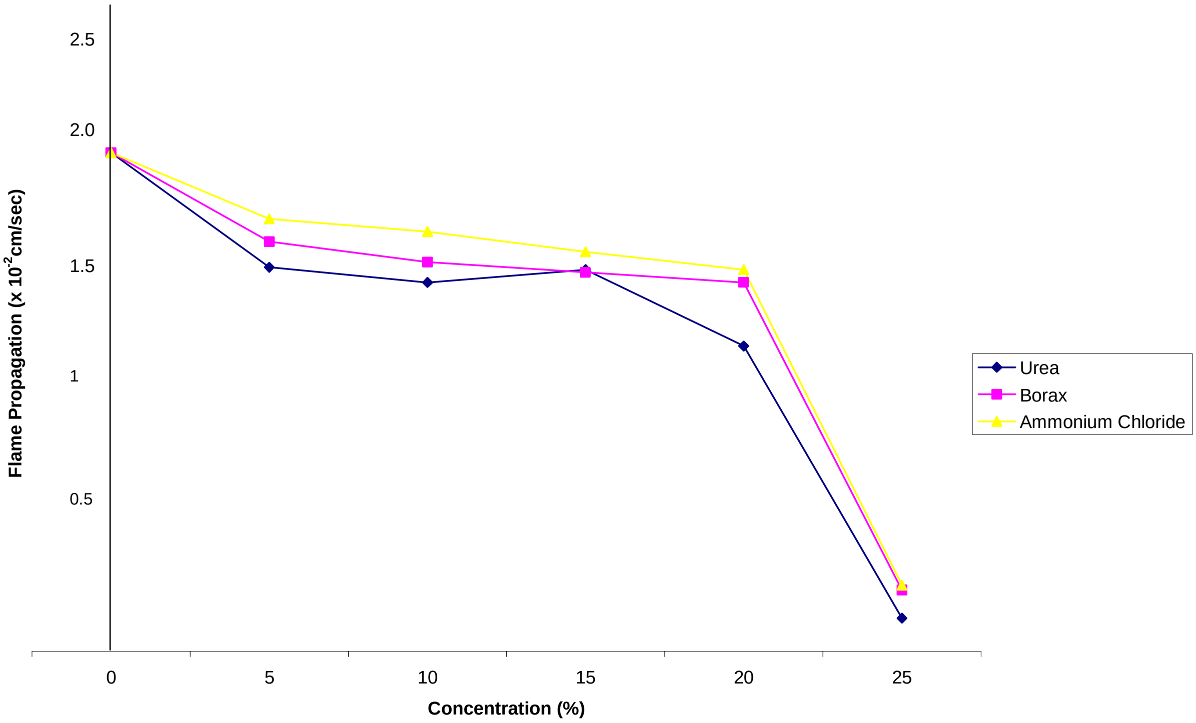

Fig 2 Effect of Concentration of Urea, Borax and Ammonium Chloride on Flame Propagation Rate of Cellulosic Ceilling Board

With reference to Figure 2, the rate of flame propagation decreases as the concentration of retardants increases. However, the extend depends on the type of retardant used, it can be observed that there was a reasonable fall or drop in flame propagation rate for urea from 1.95 x 10^{-2}cm/sec to 0.13 x 10^{-2} cm/sec as concentration increases from 0 to 25%. As for borax, it was a decrease in rate from 1.95x 10^{-2}cm/sec to 0.24 x 10^{-2}cm/sec as concentration increases from 0 to 25% while ammonium chloride recorded a decrease from 1.95 x 10^{-2}cm/sec to 0.28 x 10^{-2} cm/sec as concentration increases from 0 to 25%.

Urea gave a better retarding effect on the rate of flame propagation compared to borax and ammonium chloride. This is because urea on heating decomposes to give ammonia and carbon dioxide as a by products which do not support combustion, it forms a coating around the material and exclude oxygen thereby reducing the part of the necessary ingredient (air) needed for fire to be self sustaining (Garba and Maduekwe 1997; Salaudeen 1999 and Boryo et al, 2010). While on the other hand borax on heating decomposes and release water of crystallization which dilutes the effective concentration of volatile combustible pyrolysate in the optimum pyrolysate oxygen concentration necessary for ignition and sustaining of burning (Lyons 1970; Garba and Maduekwe 1997and Boryo et al. 2010). The ammonium chloride on heating decomposes and gives ammonia and hydrochloric acid as by products, which does not support combustion but forms a coating or blanket around the material and thereby reduce or prevent oxygen from taking part in the chemical reaction involved in fire. The reactions for the combustion of the various retardants used are showed in Scheme 1 (Boryo et al. 2010)

- $(H_2N)_2C{=}O \xrightarrow{\text{Heat}} NH_3 + CO_2$
- $NH_4Cl \xrightarrow{\text{Heat}} NH_3 + HCl$
- $NaB_4O_7.10H_2O \xrightarrow{\text{Heat}} NaB_4O_7.5H_2O + 5H_2O$
- $NaB_4O_7.5H_2O \xrightarrow{\text{Hea}} NaB_4O_7 + 5H_2O$

Scheme 1: Equation for combustion of retardants

3.3 Effects of retardants on afterglow time:

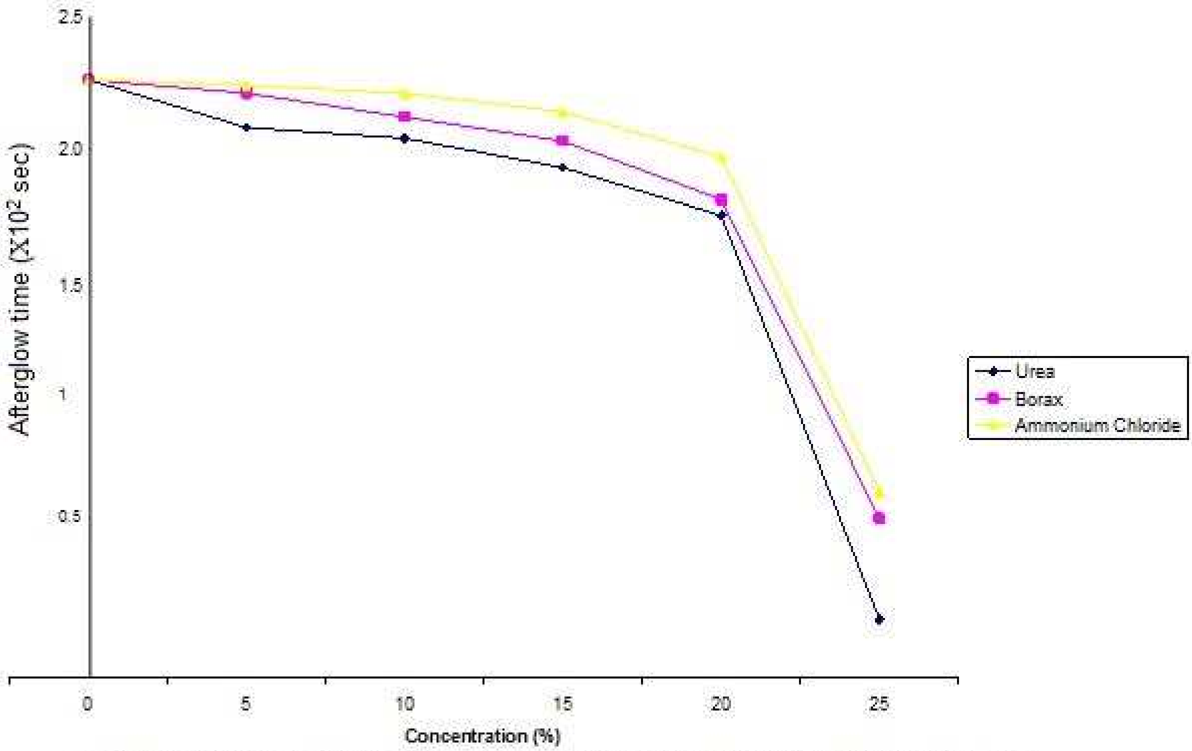

Fig 3. Effect of Concentration of Urea, Borax and Ammonium Chloride on Afterglow Time of Cellulosic Ceilling Board

Results in fig 3 showed that any increase in concentration of retardants (urea, borax and ammonium chloride) yields decrease in afterglow time. Urea also showing a more considerable improvement on the afterglow time than borax and ammonium chloride. At concentration 0% the afterglow time recorded was 2.25x10^{2}sec and as the concentration increases to 25% there was decrease on afterglow time in the following order for urea, borax and ammonium chloride respectively 0.22x10^{2}sec, 0.60x10^{2}sec and 0.70x10^{2}sec which is accompanied by the formation of a solid char.

3.4 Effects of proposed formulation:

Table 1: Effects of formulated solution (Urea and Borax) on the ignitability, flame Propagation and afterglow time of cellulosic ceiling board

Concentration (%)	Ignitability (sec)	Flame propagation (x 10^{-2}cm/sec)	Afterglow (x 10^{2}sec)
0	16.80	1.96	2.25
5urea + 5borax	34.00	0.00	0.00

The effect of the formulated solution on the treated cellulosic ceiling board was observed to ignite the sample after 34sec of exposure to flame and as the flame from the lighter was withdrawn the flame on the ceiling board went off completely without propagating and there was no afterglow. This may be as a result of combined effects of water of crystallization released by borax and the carbon dioxide and ammonia released by urea. These by products collectively act as blanket and oxygen remover needed for sustainable combustion (Boryo et al. 2010).

4. CONCLUSION

All the three retardants (urea, borax and ammonium chloride) gave remarkable improvement on the ignitibility, flame propagation rate and afterglow time. Urea was found to give a better effect than borax and ammonium chloride. A fantastic improvement was recorded for the proposed formulation.

It is therefore, recommended that urea or/and the proposed formulation be incorporated in cellulosic ceiling board during production. This will greatly improve the quality in terms of fire outbreak.

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