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The Effect of *Trichlia emetica* Leaf Extract on the Flammability of Flexible Polyurethane Foam

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ABSTRACT

Due to the health and environmental consequences of conventional flame retardants the incorporation of new plant based flame retardants becomes imperative. Hence the choice of the leaves of *Trichlia emetica* as a flame retardant on flexible polyurethane foam based on Hausa folklore tradition that it is used as a flame retardant. Analysis of the treated flexible polyurethane foam revealed that add on percentage ranged from 9-21%, Ignition time between ranged within 6-14 sec, flame propagation rate 0.42-0.22 cm/s, after glow time decreased from 12 sec to 2 sec and char formation increased from 18% to 26%. Which indicated a modification of the flammability characteristics of the flexible polyurethane foam

Keywords: Add on, After glow, Char, Flame propagation rate, Flame retardants, Ignition time, Polyurethane

Introduction

In every part of Nigeria, burning represents a useful cultural tradition that cannot be done away with. Fire is used as a work tool generally by rural populations. Fires serve for land clearing for agricultural purposes, disposal of wastes, pasture management for livestock, honey gathering and animal tracking and hunting. (Balogun and Ajayi, 2006).

Fire fighting units exist in urban areas to control fires in urban areas to the detriment of fire management in rural areas, forest and wildlife reserves. Fire suppression and prevention facilities are either non-existent, non functioning or obsolete. Fire breaks and towers are not well maintained. Presently, there are no operational fire early warning, detection and monitoring systems in Nigeria. (Balogun and Ajayi, 2006).

Coupled with this is the fact that flexible polyurethane foams are found in every corner of our society and are highly combustible. This sad situation makes the use of fire retardant materials imperative in the Nigerian society in order to reduce fire accidents, injury and death. In this regard, extract of the leaves of *Trichlia emetica* was incorporated into the flexible polyurethane foam formulation to ascertain it's suitability for use as flame retardant based on "Add on" which is the amount of the flame retardant imbibed by the substrate. Another parameter is "After glow" which is the time in seconds between the flame out and the last perceptible glow. There is also "Flame propagation rate" which is the distance traversed per second by the flame on the substrate after being ignited. "Ignition time" is the time in seconds it takes the sample to catch fire when the Bunsen burner strikes the surface of the substrate. "Char formation" is the amount of char formed when the sample is crushed in a crucible with a lid and heated in a muffle furnace.

Trichilia emetica is an evergreen tree usually up to 21m tall but occasionally reaching 30m, trunk swollen at the base, sometimes becoming fluted with age. Bark is grey brown or red brown with fine, shallow striations and smallish scales. Branches are erect or partly spreading, producing a pyramid-shaped crown when young oval rounded and dense when mature with a diameter sometimes exceeding 15m (Orwa *et al.*, 2009*)*. The tree has a non-aggressive root system (Orwa *et al.*, 2009*)*.

It is used in agroforestry. The oil is used in making soap, cosmetics and candle. The leaves are used as a fodder for animals, as well as an antidote for the irritation caused by buffalo bean. It is used as an anti emetic (Orwa *et al*., 2009). According to Hausa folklore tradition it is used as a fire retardant.

The aim of this study is to develop novel plant based fire retardant for flexible polyurethane foam that is free from the shortcomings of the conventional flame retardants.

Materials and Methods

Sample Collection and Identification

Two kilogram (2kg) of *Trichlia emetica* leaves sample was collected along Hadejiya-Mallam Madori road in Jigawa State using simple random sampling method where the first tree was selected for collection of the sample and the next tree rejected. The selection was continued alternatively until the bulk sample was obtained. Representative sample was obtained from the bulk sample. The sample was transported to the laboratory, Department of Chemistry at Usmanu Danfodiyo University, Sokoto in large paper bags.The sample was identified and authenticated at the Harbarium of the Botany unit, Usmanu Danfodiyo University, Sokoto, Nigeria.

The polyurethane foam materials which comprised of Polyol, toluene diisocyanate (TDI), Methylene Chloride, Dimethylethylamine, Tin (II) Isooctaoate and Silicon Oil were obtained from Concord Foam and Allied Chemicals Ltd opposite Sa'ad Petrol Station along western bye pass and Latex Foam Company in Rinjin Sambo industrial layout, all in Sokoto.

Preliminary Sample Extraction

One kilogram (1kg) of the plant leaf material (representative sample) was thoroughly washed with clean water, dried at room temperature and then powdered using a grinder. About 200g of the powdered plant material was soaked in water ($200cm^3$) for 48 hours. At the end of the extraction the extract was filtered using Whatman filter paper.The filterate was concentrated to dryness in an oven at 70^0C and stored until further use (Kubmarawa *et al.,* 2007, Mann *et al.,* 2008).

Sample Preparation

(a) *Preliminary Screening of The Fire Retardant Plant*

Preliminary screening of the plant leaf extract for flame retardancy was done by soaking the extract of this plant in commercial polyurethane foam obtained from Latex Foam Factory and it's efficacy tested based Add on, Ignition time, Flame propagation rate, After glow time and Char formation. Flame retardant activity was observed which prompted the final selection of this extract as a flame retardant in flexible polyurethane foam.

(b) *Flexible Polyurethane Foam Preparation*

Flexible polyurethane foam was produced by mixing the TDI ($2.5cm^3$) with the mixture of the polyol ($12cm^3$), tin (II) isooctaoate ($0.1cm^3$), silicon oil ($0.2cm^3$), distilled water ($0.5cm^3$) and dimethylethanalamine DMEA ($0.1cm^3$). The mixture was thoroughly mixed with a glass stirrer to get a good dispersion of the reagents so as to get a foam which will be used as a blank sample in the experiment (Ikeh, 2011).

Five series of different weight (0.2, 0.4, 0.6, 0.8, 1.0g) of the plant extract (dried) were measured and incorporated into the above formulation as a monomer. The resultant foams produced were left to cure for 48 hours in order to get a foam of good cell structure.

Analyses

(a) *Add on* %

The flexible polyurethane foams produced after inoculation with the flame retardant was weighed and the one without flame retardant (blank) was also weighed and the difference divided by the weight of the untreated foam (blank) multiplied by 100. The same dimension was used for all the samples, that is, 2cm × 2cm × 5cm, (Abdulrahman *et al.,* 2001, Garba and Eboatu, 1990).

$$Add\ on\% = \frac{Weight\ of\ Treated\ Foam - Weight\ of\ Untreated\ Foam}{Weight\ of\ Untreated\ Foam} \times 100 \ldots\ldots\ldots (1)$$

(b) ***After Glow Time***

The afterglow times were calculated using a stop watch to find out the time in seconds between the time the flame extinguished and the time the material stopped glowing (Abdulrahman *et al.,* 2001; Garba and Eboatu, 1990).

(c) *Flame Propagation Rate*

The sample was clamped vertically at a distance of 5cm from a Bunsen burner flame and ignited. The time in seconds it takes the fire after being ignited to travel across the substrate were recorded and the flame propagation rate were calculated by dividing the distance by the time obtained using a stop watch clock The same dimension was used for all the samples, that is, 2cm × 2cm × 5cm, (Abdulrahman *et al.,* 2001; Garba and Eboatu, 1990).

$$Flame\ Propagation\ Rate = \frac{Distance\ Travelled(\ cm)}{Time\ (s)} \ldots\ldots\ldots (2)$$

(d) *Ignition Time*

The sample was clamped vertically at a distance of 5cm and ignited at the base. The ignition time was calculated by recording the time in seconds after the Bunsen burner flame stroke the sample surface to the time when the sample caught fire (Abdulrahman *et al.*, 2001; Garba and Eboatu, 1990).

(e) *Char Formation*

The amount of char formed was obtained by first crushing the sample in a crucible and weighing the content. It was then put in an electrically heated muffle furnace at 700^{o}C for 20 minutes and weighing the samples. It was calculated by dividing the weight of the material after burning by the weight of the material before burning multiplied by 100 (Abdulrahman *et al.*, 2001; Garba and Eboatu, 1990).

$$\text{Char \%} = \frac{\text{Weight of Material After Burning}}{\text{Weight of Material Before Burning}} \text{ x } 100 \ldots\ldots\ldots (3)$$

Results and Discussion

The incorporation of flame retardant into a flexible polyurethane foam formulation can result to some extent in combustion modified urethane foams (Ashida, 2007). Addition of a flame retardant may also alter the rise time of the flexible polyurethane foam depending on the flame retardant type and the amount of the flame retardant used (Ashida, 2007). But in this case the concentration of *Trichlia emetica* leaf extract does not affect the rise time of the foams.

From Fig. 1 *Trichlia emetica* leaf extract has a good add on % with the highest as 21% and the lowest as 9% It was observed that add on depended on the dope concentration of the flame retardant material and the specific gravity of the material. It is the amount of the flame retardant material imbibed by the substrate (Abdulrahman *et al.*, 2001). The result showed that add on % increases as the concentration of the dope increases in all the foams. This is in agreement with the cited literature (Ikeh, 2011) because they follow the same pattern despite the fact that the result varies which could be due to the difference in the dope concentration of the flame retardants used in both cases.

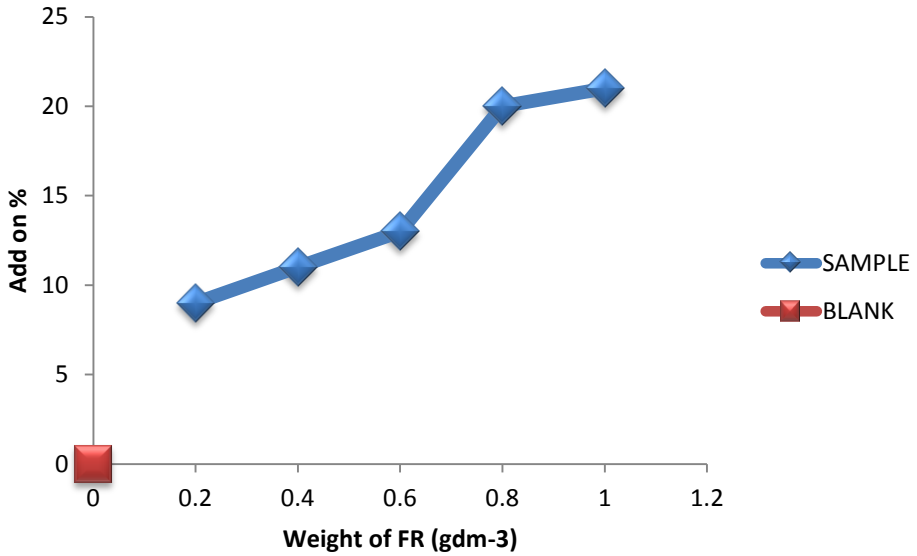

Fig. 1: Effect of Weight of Flame Retardant on Add-on %

The extract has effect on ignition time as shown in Fig. 2. The lowest ignition time recorded in the series was 6 seconds and the highest was 14 seconds while that of the blank sample was 1 second. According to Ashida (2007) among the isocyanate based foams, polyurethane both flexible and rigid are more inherently flammable, thus, increasing the ignition time, that is, the time before the foam is ignited is important. Moreover, the ignition time increases as the dope concentration increases in the subsequent concentrations. This is in concert with Ikeh (2011).

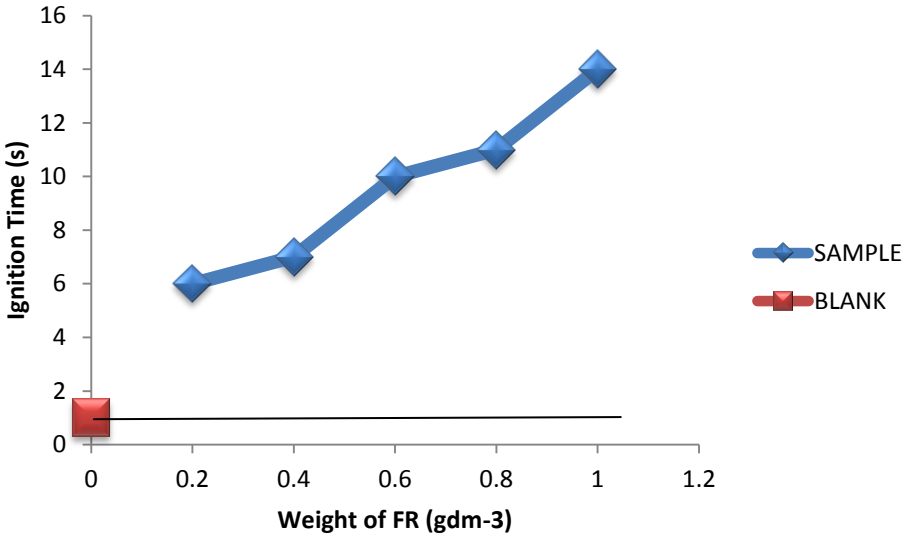

Fig. 2: Effect of Weight of Flame Retardant on Ignition Time

The sample analysed has moderate flame propagation rate as shown in Fig. 3. The highest flame propagation rate recorded was 0.22cm/s and the lowest was 0.42cm/s while that of the blank sample was 0.98cm/s indicating good flame retarding activity The spread of a flame along a substrate takes place in the following manner; piloted or radiant heat raises the temperature of the material to pyrolysis level. The resultant volatile and combustible pyrolysates ignite at the right air or oxygen concentration. Some of the exothermic heat of combustion is lost to the surrounding while some parts are re-channeled back for further pyrolysis of the substrate, hence, combustion is sustained. The rate of this pyrolysis or combustion scheme along the substrate determines the rate of flame propagation (Abdulrahman *et al,. 2001)*.

The flame propagation rate is inversely proportional to flammability resistance of foams. If the flame propagation rate is increasing the flammability resistance is decreasing and vice versa. This assertion is true for the extract as the flame propagation rate decreases as the dope concentration increases along the series. The blank sample burn while dripping the burning portion continuously

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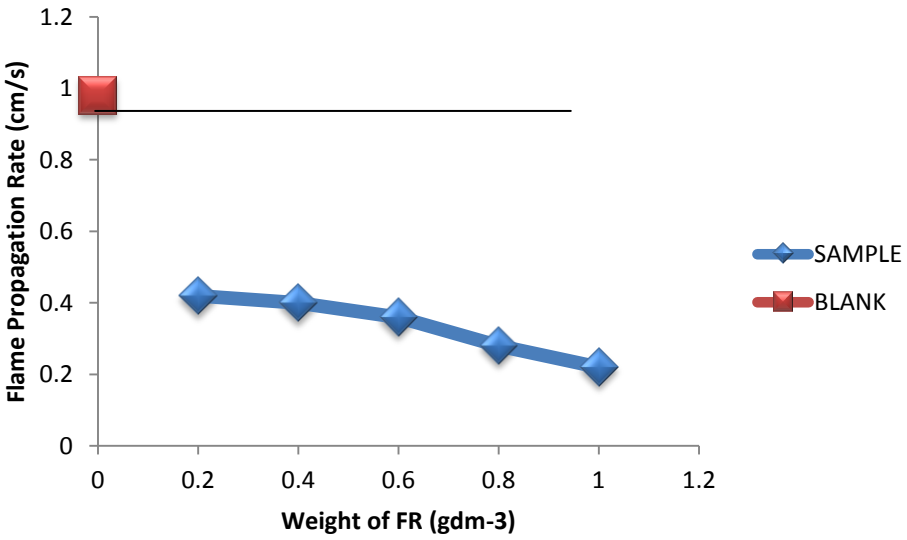

Fig. 3: Effect of Weight of Flame Retardant on Flame Propagation Rate

Fig. 4 showed the after glow times for all the extracts analysed. *Trichlia emetica* leaf extract has a good after glow time. The lowest after glow time was 2 seconds and the highest was 12 seconds while the blank sample took 30 seconds before the glowing stopped Glow is a heterogeneous oxidative surface reaction and depends on the amount of burnt material and oxygen available (Garba and Eboatu, 1990; Garba *et al.*, 1993; Abdulrahman *et al., 2001*). Therefore, it can be seen that the treatment decreases the after glow time as you go up the series. For all the materials investigated, there are definite after glow times.

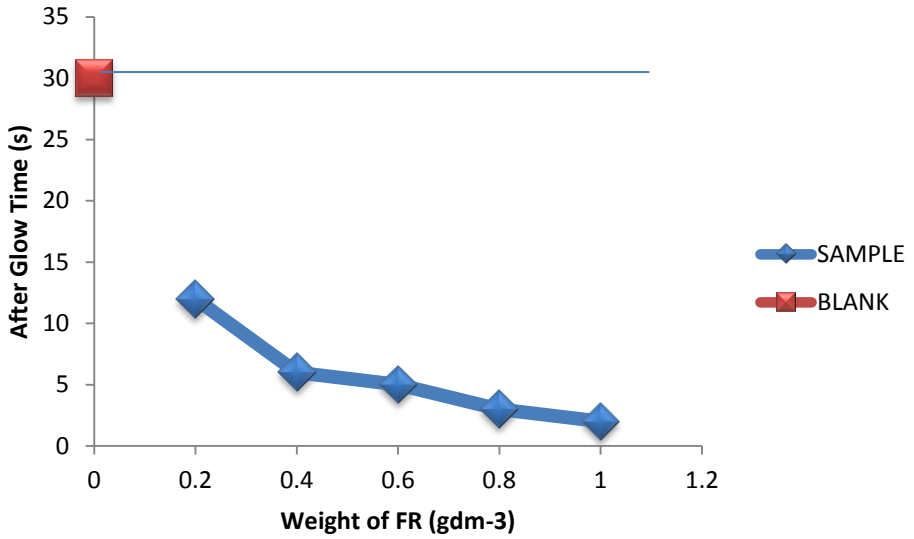

Fig. 4: Effect of Weight of Flame Retardant on After Glow Time

The char % of *Trichlia emetica* leaf extract as shown in Fig. 5 has a good char forming ability. The lowest char formation was 18% and the highest was 26%.The char formed by the blank sample was 10%. Char formation is the formation of an impervious layer between the burning and the unburned part turning the material into a carboneceous char. The formation of an insulating barrier between these parts is brought about by dehydrating agents or char forming agents which hinder heat transfer to unburned parts thereby reducing the reaction rate. The difference in char percentage between the cited literature and the present work is significant although it is higher than the blank sample which may indicate that the sample analysed has char forming ability.

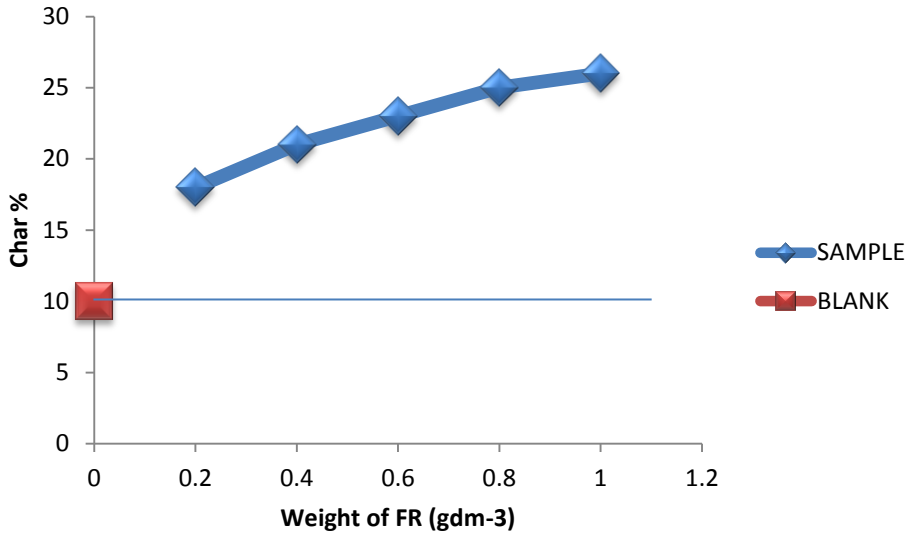

Fig. 5: Effect of Weight of Flame Retardant on Char %

Conclusion

Flame suppressant treatment is aimed at delaying the spontaneous spread of fire when it does occur, that is, increases escape time, such that reasonable lives and properties may be saved. The thermal properties of flexible polyurethane foam were modified by the controlled addition of *Trichlia emetica* leaf extract. Tthe result showed the effect of these treatments was more pronounced in after glow and char formation which may indicate a condensed phase mechanism.

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