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Research Article

FLAME RETARDANT EFFECTS ON FLEXIBLE POLYURETHANE FOAM TREATED WITH HALOGENATED PARAFFIN

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ABSTRACT

This work studies the effects of flame retardant on flexible polyether foam samples. Flexible polyurethane foam samples were prepared by mixing 5ml, 10ml, 16ml, 24ml and 30ml chlorinated paraffin with foam recipes. Fire characteristics and FTIR analyses of various foam samples produced were compared with that of foam sample without chlorinated paraffin (control). Results showed that flame propagation rate, flame duration and after glow decrease with increase in the volume of chlorinated paraffin while ignition time and char formation were observed to have increased with increase in volume of chlorinated paraffin. Fourier transform infrared (FTIR) analyses revealed shifts in intensities of functional groups of various foam samples from the intensity of the functional groups of control indicating that the chlorinated paraffin interacted with the foam recipes.

Keyword: Flame retardant, Halogenated, Polyurethane, FT-IR

INTRODUCTION

Polyurethane foam as well as all organic materials burn when sufficient heat is applied to them in the presence of oxygen. The physical state of polymer determines the extent of burning of materials, for instance, low-density open celled flexible polyurethane foams have a large surface area and high permeability to air and this will burn most easily. Increased emphasis on flame retardant properties in polymeric material is as a result of the safety consciousness of modern time.

A flame retardant is a material used as a coating on or incorporated in a combustible product to raise the ignition point or reduce the rate of burning of the product[1]. Flame retardant agents vary with the physical and chemical properties of the material to be protected. They include inorganic salts such as borates, antimony oxides, phosphates, chlorine compounds, for example, perchloro-pentacyclodecane. These agents can be classified as: non-durable, semi-durable and durable flame retardants[2]. Polymers can be protected from fire in any of the following ways[3]: by stabilizing the polymer against degradation at flame temperatures so that volatile fuel is not given off, by coating the polymer with noncombustible coatings. Other ways include excluding oxygen by incorporating additives which degrade to given non combustible gas and by adding free radical acceptor carriers to the resin which will react in the flame to interact the chain reaction [4].

The most widely used flame retardant in flexible polyurethane foams are the chlorinated phosphate esters. Chlorinated paraffin with low chlorine content, 35% are usually liquid, those with high degree of chlorination 40-60% are viscous oil while higher chlorinated paraffin are waxy solid with glassy appearance. The phosphorous compounds affect a catalytic splitting of the polyurethane and lead through dehydrogenation and degradation reactions to a carbonized protective surface. The presence of elements such as nitrogen, halogens, sulphur and phosphorous in a material reduce flammability of the materials [5]. Flexible polyurethane foam is used in mattresses, cushions of furniture, automobiles, general upholstery; clothe interling and packaging [6].

MATERIALS AND METHODS

Materials

The materials used were obtained from Winco Foam Nigeria Ltd., Awka, and the chlorinated paraffin was purchased from Onitsha Bridge Head Market, Anambra State, Nigeria.

Method

Formulation of Foam Samples

The formulations in Table 1 were used for the production of flexible polyether foam:

Table 1: Formulation of foam samples

Materials	Pph	FRF$_0$	FRF$_1$	FRF$_2$	FRF$_3$	FRF$_4$	FRF$_5$
Polyol	100	200	195	190	184	176	170
TDI(index=108)	53	106	106	106	106	106	106
Silicone	0.85	1.7	1.7	1.7	1.7	1.7	1.7
Stannous	0.3	0.6	0.6	0.6	0.6	0.6	0.6
Water	4.6	9.2	9.2	9.2	9.2	9.2	9.2
DMEA	0.3	0.6	0.6	0.6	0.6	0.6	0.6
Flame retardant(ml)	-	0	5	10	16	24	30

Note: FRF means Flame retarded foam and Pph = Part per hundred

Production of flexible polyurethane foam

Polyol and toluene diisocyanate were weighed into separate containers using triple beam balance. Chlorinated paraffin was measured using measuring cylinder. Other materials such as water, DMEA, silicone oil and stannous required in small quantities were measured using syringes so as to get accurate measurement. The measurement of raw materials was based on part per hundred of polyol [7]. The mixing of the raw material was as described in a number of articles [8,9]. The mixture was then poured into a mould made of kraft sheet lined with silicone paper for easy removal. The foam samples were removed and kept at a temperature of 25°C for 48hours before analyzing.

Characterization of the foam samples

The following fire characteristics of the foam samples were analyzed: flammability, afterglow, ignition time, char formation and flame duration [10,11]. Analyses of FTIR of the foam samples were also carried out.

RESULTS AND DISCUSSION

From the results in Fig. 1, it can be seen that the introduction of little quantity of chlorinated paraffin into the foam drastically reduce the rate of burning of the foam. Flammability of the foam can be described as follows: thermoplasticity is observed as shrinkage and often melting, when such materials are subjected to heat. Both melting and shrinkage have the effect of reducing apparent flammability. On approaching the ignition source, a thermoplast will shrink and drip away from the flame. The behaviour ensures energy removal, decrease in surface exposed and hence reduction in oxygen accessibility. The results of the investigation under review show that even the above inherent flame-retardant property of polyurethane foam is enhanced by the paraffin.

The results of the analyses in Fig. 2 and 3, showed that as the concentration of chlorinated paraffin increased the afterglow and flame duration decreased. Glow depends on factors such as availability of oxygen as well as the nature of the burnt materials [12], while the flame duration is the time between the onset of ignition and self extinguishment.

It is shown in Fig. 4 that ignition time increases as the concentration of chlorinated paraffin increases. As the material receives heat, there is increase in temperature when it receives and redistributes the heat by conduction. While the temperature becomes very high, volatiles are formed and proceeded to the surface but as the temperature of the materials increases decomposition reactions occur which release combustible product. Ignition occurs if sufficient heat is supplied. Chlorinated paraffin raises the ignition temperature of the foam.

In Fig. 5, it is seen that flame retardant promotes char formation which acts as a physical barrier to flame and inhibits the volatilization of flammable materials. The chlorinated paraffin provides inert gases that blanket the substrate, thus excluding oxygen and preventing flame spread.

FTIR is used in the monitoring of polymer interactions with the flame retardant, when new specie attaches itself on the group; the natural vibrational frequency of a functional group in a molecule is disturbed. The degree of disturbance depends on the extent of the deviation of the intensity of the functional group of retarded and unretarded foam. This deviation can be due to increase or decrease in the intensity at the sites of the functional group. The functional groups that give the wave number with maximum deviation indicate the point of interaction of the foam with the flame retardant. The interaction holds the foam recipes with the flame retardant.

From the results in Table 2, in all the functional groups present, foam samples FRF_2 (10ml of flame retardant) has the highest deviation of intensity from what is obtained in FRF_0, followed by FRF_5. There is a negative deviation of intensity for foam samples FRF_3 and FRF_4 from FRF_0. The ranges of the functional group with the highest deviation include: 500-598cm^{-1}, 1100-1120 cm^{-1} and 3450-3670 cm^{-1}. These ranges of wave numbers are likely the highest points of interaction. The FTIR results of flame retarded flexible polyether foam samples are shown in Table 2 below.

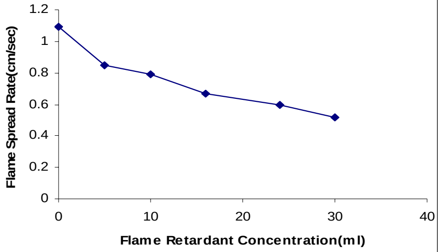

Fig.1: Effect of Chlorinated Paraffin on Flame Spread Rate

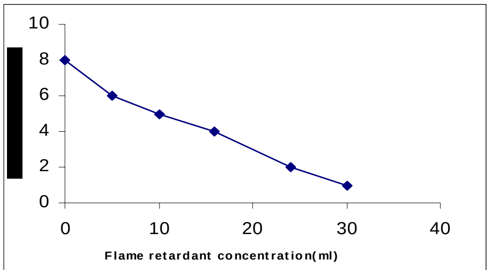

Fig.2: Effect of Chlorinated Paraffin on Afterglow Time

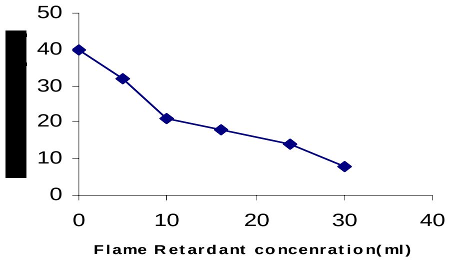

Fig.3: Effect Chlorinated Paraffin on Flame Duration

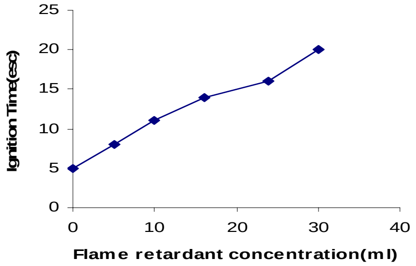

Fig.4: Effect of Chlorinated Paraffin on Ignition Time

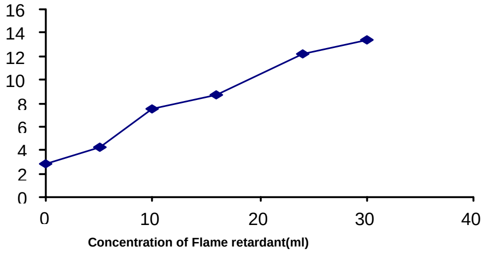

Fig. 5: Effect of Chlorinated paraffin on Char Formation

Table 2: Summary of deviation of vibration frequencies (cm^{-1})

Wave Number Ranges(cm^{-1})	Functional group	Deviation of intensities					
		FRF0 (0ml)	FRF1 (5ml)	FRF2 (10ml)	FRF3 (16ml)	FRF4 (24ml)	FRF5 (30ml)$_5$
400-499	C-H bond out of plane deformation	0.800	0.855	0	0.677	0	1.058
500-599	C-H bond out of plane deformation	0.851	0.829	1.183	0.668	1.357	1.057
600-699	C-H for the out of plane deformation	0	0.728	0	0.628	0	1.046
1100-1120	C=O stretch of secondary unsaturated alcohol	0	0.783	1.250	0.697	1.488	11.235
1600-1700	C=C stretch for conjugated alkene	1.178	1.024	1.375	0.794	1.802	1.184
2285-2350	Si-H stretch for silicone compounds	0	0.861	1.281	0.710	0	1.263
3450-3670	N-H stretch of primary amine	2.344	1.186	1.898	1.286	3.202	1.401
3700-3757	O-H free	0	1.254	0	0.953	0	1..276
38003899	O-H free	0	1.267	1.324	0.970	0	1.280

CONCLUSION

The results of the fire properties studied showed decrease in flame propagation rate and flame duration while char formation and ignition time increase with increase in concentration of flame retardant. The FTIR results revealed deviation in intensity of various foam samples from the untreated foam samples. It is concluded that chlorinated paraffin can be used as flame retardant in flexible polyether foam.

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