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Fire Retardant Treatments and their Effect on Smoke Emission

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A few fire retardant compositions based on ammonium phosphates, borate salts, amides, polyhydric alcohols, antimony oxide and a halogenated copolymer along with a binder have been developed for imparting flame retardancy to cellulosic materials. Fire performance and emission of smoke have been evaluated employing standard methods. The treatments are quite effective in reducing fire hazards. Smoke production appears to be affected by characteristics of the material as well as the nature of fire retardants applied.

Introduction

Various natural and synthetic polymeric materials such as cellulose and its derivatives, plastics, rubbers and foams are generally used in buildings. These materials are combustible and hence pose great fire hazards. Smoke and toxic gases evolved by burning materials cause hindrance in protecting life by physical incapacity and reduced visibility. In order that these materials meet fire regulations, they are often treated with fire retardants. A large number of fire retardant treatments based on organo-phosphorus and halogenated compounds [1—3] are reported for cellulosic materials. However, they have not been widely accepted due to their toxicity, high cost and limited durability. Other fire retardants are inorganic salts [1&3] which are comparatively cheaper, readily available and non-toxic, but are not durable. Besides, a few fire retardant intumescent and non-intumescent coatings [1,4&5] have also been suggested to reduce the burning characteristics of wood. None of them, however, possesses good fire performance as well as requisite physical properties.

Although these treatments exhibit good fire retardance, they have not been found suitable for reducing smoke generation. In fact, most of the fire retardants generally increase smoke generation [6—7], which is quite hazardous. It was therefore considered worthwhile to carry out experiments with a view to obtain a few cheap, durable and more efficient fire retardant compositions which can also reduce generation of smoke.

The present communication reports on the efficacy of several fire retardant compositions and their effect on smoke emission.

Experimental

Materials

A) Fire retardants used in present study are given in Table 1.
B) The substrates that were treated are:

Fabrics: 100 percent cotton coloured check weave curtain fabric of average weight 198 gm/m^2 and 100 percent cotton white canvas fabric of average weight 354 gms/m^2 were used.

Wood and Panel Products: Mangowood (Mangifera indica) of density 500 kg/m^3, plywood BWR grade, density 690-750 kg/m^3 and fibre board of 305 kg/m^3 density were studied.

Table 3

Performance of Intumescent Coating
(Composition 5)

Material	PERFORMANCE AS PER						
	ASTM D-1360		BS 476 Part 7			BS 476 Pt.6	
	Weight Loss (gms)	Char Volume (cc)	Flame Spread at 1.5 min (mm)	Flame Spread at 10 min (mm)	Classification *	i_1 *	I *
COATED							
- Mangowood	2.25	4.25	0	0	Class 1	-	-
- Plywood	2.92	5.50	0	0	Class 1	2.002	12.77
- Fibreboard	3.36	6.40	0	0	Class 1	2.334	15.13
UNCOATED							
- Mangowood	21.12	50.40	230	715	Class 3	-	-
- Plywood	22.65	63.00	250	740	Class 3	10.342	30.59
- Fibreboard	Burnt completely		325	900	Class 4	37.291	69.20

* Class 1, 2, 3 & 4 represent that surface of 'very low', 'low', 'medium' and 'rapid' flame spread respectively.

I = index of performance

i_1 = Sub index (initial burning only).

The lower the numerical value of the indices the better a material is.

Table 4

Smoke Density Results in the (American) National Bureau of Standards Chamber [Smouldering Test Conditions]

Sl. No.	Material	Treated with Composition Numbers	D_m	$t_{90\%}$	D_{90s}	SON	V_{max}	SOI
			Values of*					
1.	Cotton Fabric 198 gm/m^2	1	2.0	12.8	00	00	0.5	0
2.	Cotton Fabric 198 gm/m^2	2	2.4	12.6	00	00	0.7	0
3.	Cotton Fabric 198 gm/m^2	3	6.0	13.0	2.0	10.0	2.0	0
4.	Cotton Fabric 198 gm/m^2	Untreated	7.5	12.0	2.0	10.5	1.0	0
5.	Cotton Fabric 354 gm/m^2	4	220.0	14.7	14.0	108.0	16.0	19.24
6.	Cotton Fabric 354 gm/m^2	Untreated	46.5	10.0	11.0	78.0	16.0	3.01
7.	Fibre Board	5	36.0	16.2	2.0	15.0	4.0	0.087
8.	Fibre Board	5+Synthetic enamel paint	47.0	16.2	2.5	29.0	6.0	0.385
9.	Fibre Board	Control	308.0	3.9	40.0	670.0	216.0	358.0

* Lower value of D_m, D_{90s}, SON, V_{max}, SOI and higher value of $t_{90\%}$ better the performance of a material.

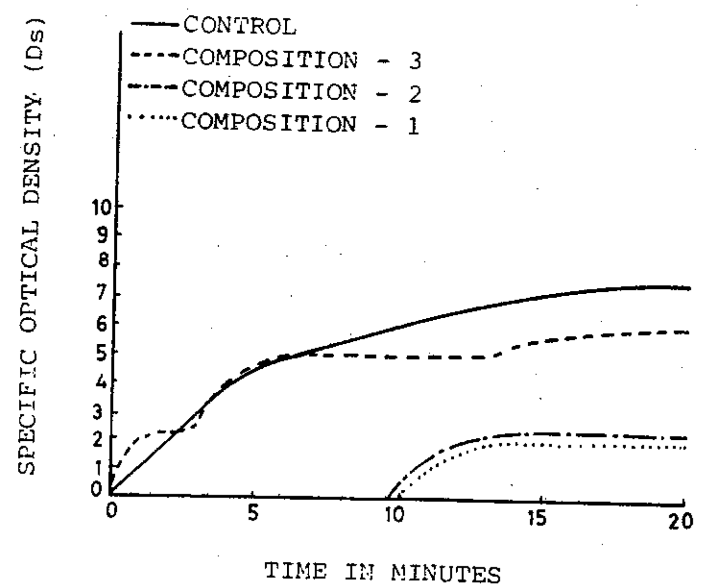

Figure 1: Effect of Chemical Composition on Smoke Generation (Compositions 1 to 3)

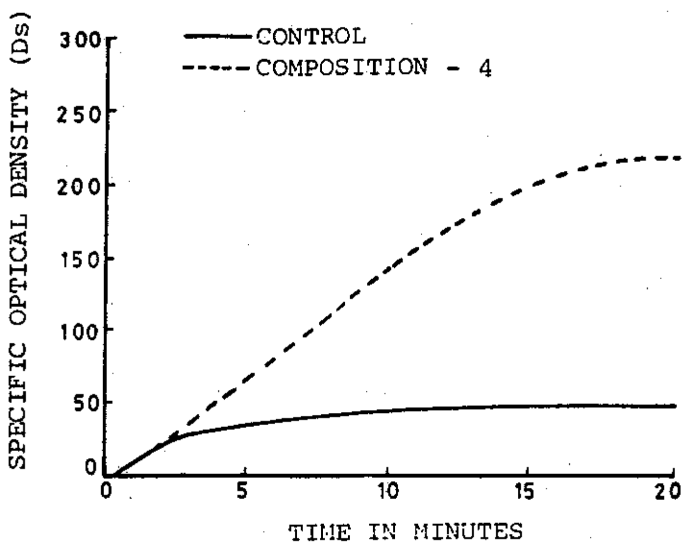

Figure 2: Effect of Chemical Composition on Smoke Generation (Composition 4)

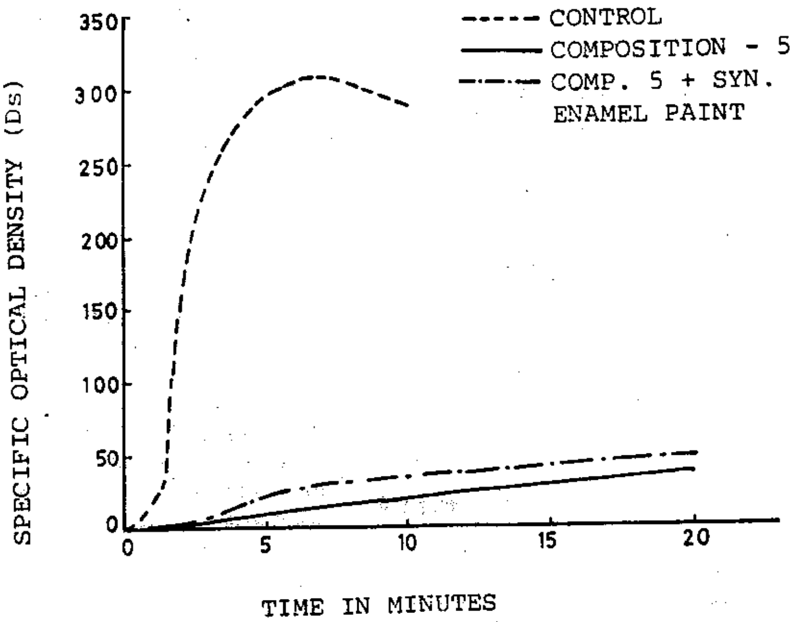

Figure 3: Effect of Chemical Composition on Smoke Generation (Composition 5)

Discussion

From Table 2, the fabric specimens treated with different compositions did not ignite and no flaming and afterglow were observed after removing the ignition source. The treated specimens remained self extinguished while the untreated samples burnt completely within a few seconds. The mixture of ammonium phosphate and sodium tetraborate (1:2, w/w) was quite effective in reducing the flammability of the fabric at dry chemical retention of 11 to 13% [9]. This combination was applied in case of fabrics which were not often washed.

The specimens of fabrics were treated with DAP-urea and UF resin combinations (2 and 3, Table 1) at various chemical retentions. They were then cured at different temperatures for different time intervals [9]. It was experimentally established that 15 to 18% dry chemical retentions or approximately 1.35 % phosphorus was found quite adequate for which specimens were treated with a 38% fire retardant solution for 1 hour and were cured at 160 deg. ± 2 deg. C for 18 minutes [9]. Fire performance of treated specimens did not change even after 15 washings.

The function of phosphorus-containing fire retardants appears to alter the course of decomposition of the cellulosic materials so that lower amounts of flammable volatiles and larger quantities of char are formed thereby reducing the flammable characteristics of cellulosic materials [16—18].

The combination of antimony oxide and halogenated copolymer (composition 4) was studied at different chemical retentions (17—100%). The specimens with higher chemical retentions (60—70%) showed no flame spread and afterglow observed was only for 3 to 4 seconds. After removing the ignition source the specimens remained unaffected except for the charred area.

Lower chemical retentions gave greater char length (18.5 cm) and afterglow up to 42 seconds [9—10]. The treatment increases the weight of the fabrics thereby rendering them unsuitable for apparel purposes. Although treatment may be useful in case of tents and pandals.

The reaction mechanism of the above chemical treatment is based on the synergistic effect of antimony oxide and halogenated copolymer binder [10]. When antimony oxide is associated with the halogenated copolymer which provides a source of hydrochloric acid at ignition temperature an excellent flame retardance is obtained. Hydrochloric acid reacts with antimony oxide to give antimony trichloride which functions as a catalyst for dehydration of cellulose to carbon and water [19].

It is clear from Table 3, that the combination of fire retardant intumescent paint and enamel paint is very effective in reducing the burning behaviour of wood and wood based products. The samples which were coated with this paint neither show any surface spread of flame nor afterglow on exposure. The burning test data from BS : 476 Part 7 show that the performance of coated mangowood and plywood improves from Class 3 to Class 1. The fibre boards can also be placed in Class 1, from Class 4. Significant improvement in the performance indicies are observed when coated specimens are tested by BS 476 Part 6.

The main constituents of fire retardant intumescent coating under study are pentaerythritol, ammonium phosphate and cyanoguanidine. When this combination is exposed to fire, it provides large amounts of carbonaceous char and non-flammable gases causing the carbon to produce a honey comb blanket resulting in a highly effective barrier for protecting the substrate [1&5].

It is evident from Table 4, Figures 1, 2 and 3, that emission of smoke is very much dependent upon the constituents of the material as well as types of fire retardants used. Maximum specific optical density (D_m) of three base materials, namely cotton fabrics of two different weights i.e. 198 gm/m^2 and 354 gms/m^2 and fibre board, was found to be 6.0, 46.5 and 308 respectively. The three materials used in the study are cellulosic in nature, however; difference in the values seems to be due to different weights in case of fabrics and constituents like resin, additives etc. in the fibre board.

The compositions employed to reduce the flammability of materials were also found effective in reducing the smoke generation except the composition 4. The effect of compositions 1 and 2 was found to be similar in reducing the smoke. No significant change in time to achieve 90% D_m ($t_{90\%}$) was noted. However, D_m was reduced up to 2.0 with compositions 1 and 2 and to 6.0 with composition 3 from 7.5 (Table 4, Figure 1). In case of fire retardant treatments based on antimony oxide and halogenated copolymer (Comp. 4) the amount of smoke had increased as compared to the untreated specimens (Table 4, Figure 2).

Fire retardant intumescent coating (Comp. 5) was found to be very effective in reducing the rate and amount of smoke. The value of $t_{90\%}$ was increased from 3.9 minutes to 16.2 indicating that the escape time is increased more than four time during fire. After the application of synthetic enamel paint the maximum optical density of smoke increased from 36 to 47, although it was negligible (3%) in comparison to that of control specimen (Table 4, Figure 3).

Conclusion

The fire retardant treatments under study are found to be quite effective in reducing burning and smoke generation characteristics of cellulosic materials. The treated specimens of fabrics neither show any surface spread of flame nor afterglow combustion on removing the ignition source. Charring is observed only where the flame is in contact with the specimen, while the untreated fabrics burn completely within few seconds. In the case of treated fabrics, maximum optical density of smoke is found to reduce from 7.5 to 2.0.

The fire retardant coating employed is also quite effective in reducing the flammability of wood and wood based panel products. Treated specimens satisfy class 1 characteristics while untreated ones are placed in class 3 and 4. It is also observed that the coating reduces smoke generation considerably.

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