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EVALUATION OF SMOKE FROM FIRE RETARDED CELLULOSIC MATERIALS

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Introduction

Cellulosic materials, in various forms. are most commonly used in construction and furnishings. Building materials such as plywood, wood and wood based products, cotton textiles etc. are increasingly being used for different purposes in buildings. These materials are intrinsically combustible due to their cellulosic nature and hence pose great fire hazards. To retard burning characteristics of cellulosic materials several chemical treatments and surface coatings have been suggested by various workers from time to time. Most of the flame retardants used for cellulosic materials are based on ammonium salts of sulfamic acid, phosphoric acid; boron compounds; chlorides, bromides and sulphates of aluminium, copper, zinc, chromium and antimony (Lyons 1970, Lewin 1975). A large number of fire retardant treatments based on amino resins, organophosphorous and halogenated compounds are also reported (Lyons 1970, Sharma *et al.* 1977, Bailur *et al.* 1986). Besides, a few fire retardant intumescent and non-intumescent coatings have also been suggested to reduce the burning characteristics of wood and wood-based products (Lyons 1970, Smith 1982, Bhatnagar and Vergnaud 1983).

Although these treatments exhibit good fire retardance, their effect on smoke generation is not very much known. In fact, smoke and toxic gases; which are quite hazardous; evolved by burning materials cause hinderance in protecting life by physical incapacitance and reduced visibility. Therefore, it was considered worthwhile to carry out experiments to determine the effect of fire retardant treatments on the emission of smoke.

The present communication reports the smoke generation characteristic of a few cellulosic materials and efficient fire retardant treatments.

Experimental

Materials

1. Fire retardants used in present study are of commercial grade (Table 1).
2. The subtrates that were treated are : Textiles : 100 percent sotton, undyed fablics of average weight 198 g/m² and 354 g/m².

   Wood based products : Fibre board of 305 kg/m³ density.

Table 1

Fire retardant chemicals and compositions

Composition No.	Chemicals & Compositions	Chemical Retention %	Material
1	Monoammonium Phosphate (MAP)	8 — 10	Fabric wt. 198 g/m²
2	Diammonium Phosphate (DAP)	8 — 10	-do-
3	MAP-Borax (1: 2, w/w)	10 — 13	-do-
4	MAP-Borax-Boric acid (1 : 2 : 1.5, w/w)	12 — 15	-do-
5	Boric acid–Borax (1 : 2.5, w/w)	11 — 13	-do-
6	DAP-Urea (1 : 2, w/w)	14 — 17	-do-
7	Antimony oxide (6-8%) Chlorinated rubber (9-11%), Borate (4-6%), Phosphate salt (4-6%) Phthalate (0.5-1%), Ethyl Acetate (65-70%)	35 – 42	Fabric wt 354 g/m²
8	Same as composition no. 7 except VC-VA copolymer used instead of Chlorinated Rubber	33 — 42	-do-
9	Non intumescent coating; Antimony oxide (16-18%), Zinc oxide (12-15%), Mica (12-15%), Chlorowax (25-30%), Ammonium Phosphate (10-15%) Bincer (25-28%) Solvent (100-110%)	2.8 m²/lit.	Fibre board
10	Intumescent coating : Ammonium Phosphate (24-30%), Amide (16-20%). Polyol (8-12%), Pigment (3-5%), Thickening agent (20-22%), Binder (16-20%), Solvent (15-20%)	2.8m²/lit	-do-

Methods

FABRIC TREATMENT : Fabrics were treated with different fire retardants (Table 1). Fire retardants and compositions were selected on the basis of past experiments (Jain *et al.* 1984 & 1985, Gupta and Saxena 1989). For treatment, fabric specimens were immersed in aqueous solutions of predetermined concentration containing monoammonium phospate (MAP), diammonium phosphate (DAP), mixtures of MAP—Borax, MAP—Borax-Boric acid, DAP— Urea Borax–Boric acid for one hour followed by squeezing and drying.

Solvent suspensions containig borate salts, antimony trioxide, chlorinated rubber, vinyl chloride-vinyl acetate copolymer, phosphate salt, phthalate and ethyl acetate were prepared and applied with the help of knife edge type applicator on the fabric specimens. Thereafter, specimens were dried in an electric dryer at 55±2°c.

Table 2

Results of smoke generation test

Compositions	Values of*					
	Dm	t 90%	D90 m	SON	V max	SOI
1	9.1	9.4	3.2	16.8	2.6	0.00
2	10.5	8.4	4.8	21.4	3.0	0 00
3	2.0	12.8	0.0	0.0	0 5	0.00
4	3.2	11.0	1.2	6.6	0.8	0 00
5	4.0	10.8	2.0	6.1	0 8	0 00
6	2.4	12.6	0.0	0.0	0.7	0.00
7	318.0	9.8	17.2	124.0	30.0	22 40
8	220.0	14.7	14.0	205.0	35.0	35.14
9	168.4	5.2	26.5	128.0	89.4	112.58
10	36.0	16.2	2.0	24.5	4.0	0.13
CONTROLS						
Fabric weight 198 g/m²	7.5	12.0	2.0	10.5	1.0	0.00
Fabric weight 354 g/m²	46.5	10.0	11.0	78.0	16.0	3.01
Fibre Eoard	308.0	3.9	40 0	670.0	216.0	358.00

*Lower values of Dm. D 90 m, SON, Vmax, SOI and higher values of t 90 indicate better performance of a material.

FIBRE BOARD TREATMENT : Fibre board was treated with fire retardant intumescent and non intumescent type coatings (Table 1). Coatings were applied with the brush at the rateof 2.8 m²/lit. on the fibre board.

Evalaution of Smoke Generation

Generation of smoke was evaluated according to ASTM E-662 method (Anon. 1979). Test specimens of 76 × 76 mm were cut and affixed to 6 mm asbestos board in accordance with the standard procedure. They were subjected to non flaming (smouldering) exposure conditions. Irradiance level of 2.5 W/cm² averaged over the central 38.1 mm diameter area of vertically mounted specimens was used. The following parameters were determined :

D_m = maximum specific optical density

$t_{90}\%$ = moment where upon 90% of D_m is reached, time in minutes.

D_{90m} = Optical density at 90 seconds.

SON = Sum of the specific optical densities at 1 min., 2 min., 3 min. and 4 min., a measure for the rate of smoke development.

V_{max} = maximum rate of smoke development estimated every 30 seconds and expressed as D_m/min.

SOI = smoke obscuration index calculated as :

$$SOI = \frac{D_m^2}{2000 \times t_{16}} \left[\frac{1}{t_{0\cdot9} - t_{0\cdot7}} + \frac{1}{t_{0\cdot7} - t_{0\cdot5}} + \frac{1}{t_{0\cdot5} - t_{0\cdot3}} \frac{1}{t_{0\cdot3} - t_{0\cdot1}} \right]$$

Where t_{16} is the time to reach $D_m = 16$, $t_{0\cdot9}$, $t_{0\cdot7}$, $t_{0\cdot5}$, $t_{0\cdot3}$, $t_{0\cdot1}$ are time to reach 90%, 70%, 50%, 30% and 10% of D_m

Results and Discussion

Smoke generation characteristics of different fire retardants are reported in Table 2. It is evident from Table 2 that emission of smoke is very much dependent upon the constituents of the material as well as the type of fire retardants used. Maximum specific optical density (Dm) of three base materials namely, cotton fabrics of two different weights i.e. 198 g/m², 354 g/m² and fibre board was found to be 7.5, 46.5 and 308 respectively. The three materials used in the study are cellulosic in nature, however, difference in the values seem to be due to different weights in case of the fabrics and constituents e.g. resin, filler etc. in case of the fibre board.

The compositions (MAP-Borax, MAP-Borax-Boric acid, Borax-Boric acid and DAP-Urea) generally employed to reduce the flammability of cellulosic materials were also found effective in reducing smoke generation. In case of MAP, DAP and treatments based on antimony oxide and chlorinated rubber or VC-VA copolymer the amount of smoke had increased as compared to the untreated specimens.

Fire retardant intumescent coating (Comp. 10) was found to be very effective in reducing the rate and amount of smoke in comparison to that of the control specimen.

Summary

A few fire retardant treatments generally used to improve the fire resisting characteristics of cellulosic materials have been evaluated for smoke generation behaviour using ASTM E-662 method. Smoke production appears to be affected by characteristics of the materials as well as the nature of fire retardant used. The amount of smoke is increased with antimony oxide and halogenated copolymer based treatments. Fire retardant intumescent coating applied on wood based products was found quite effective in reducing the rate and amount of smoke release.

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