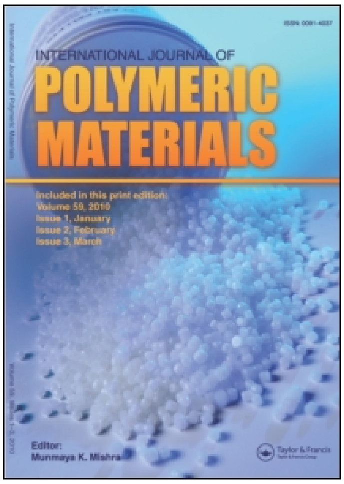

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The Effect of Selected Phosphates on the Flame Retardancy of Cotton and Polyester Fabrics

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The comparative effects of three selected phosphates on the flame retardancy of pure cotton and polyester fabrics have been chosen from the author's previous investigations. Earlier described procedure for the evaluation of flame retardancy were used. The optimum loading required to achieve flame retardancy indicated the inferiority of sodium polymetaphosphate as compared with the others.

Keywords: cotton fabric, dipotassium hydrogen phosphate, flammability, polyester fabric, sodium polymetaphosphate, trisodium phosphate

INTRODUCTION

Smoky fires generally result in the highest fatality rate and high injury rates for residential fires. As a result simply by being more attentive to the use of flammable materials a large number of fires and injuries could be prevented [1].

Each year in the United States and its protectorates, approximately 100 firefighters are killed on duty and tens of thousands of people are injured in fires. Although the number of firefighter fatalities has steadily decreased over the past 20 years, the firefighter fatalities per 100,000 incidents has actually risen [2].

Among flame retardants, phosphorus compounds are one of the most important groups of chemicals [3]. Actually one of the considerable uses of phosphates produced in the world is for flame-proofing fabrics [4].

The purpose of this investigation is to compare sodium polymetaphosphate (an inorganic polymeric phosphate) with two other selected

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phosphates with respect to their effectiveness as flame retardants for cotton polyester fabrics.

EXPERIMENTAL

Materials and Methods

All materials and procedures for the impregnation of salts have been described in previous published articles [5–7].

Flammability Test

A vertical flame-spread test method following the procedure described in DOC FF 3-71 [8] was originated to determine the flammability of thermoset fabrics. It was named Mostashari's Flammability Tester. The description of this tester has also been published in this journal [5,6].

RESULTS AND DISCUSSION

Data of several experiments on cotton and polyester fabrics are summarized synoptically in Table 1, reproduced from previous investigations [5,7].

Optimum add-on contents on the substrate, the burning time and rate are illustrated in columns 3–5, respectively.

Note that burning rate is in cm/s, calculated by means of dividing the length of the burned fabrics by their burning times.

In columns 6 and 7, Char length of specimens in cm and their status after the end of the tests are shown respectively. CB means completely burned and FR stands for flame-retarded. It can be deduced from the tabulated data concerning *cotton* fabric that it required 30 sec to burn completely, and its corresponding burning rate was 0.73 cm/s.

In the case of cotton fabric when impregnated with *optimum* concentration of phosphates, the efficient additive contents (wt%) were illustrated in Table 1.

The burning time and rate for pure *polyester* fabric were 12.0 sec and 1.83 cm/s respectively. The *optimum* content (wt%), of sodium polymetaphosphate needed to achieve flame retardancy compared to the other phosphates, either for cotton *or* polyester fabric, showed to be higher for both fabrics. In fact, these data could confirm the preference of cotton fabric over polyester textile in terms of flammability'. These outcomes plausibly correlate to the chemical structure of polyester fabric. It explains the low humidity content in polyester relative

TABLE 1 Effect of the Nature and Content of Some Inorganic Phosphates on the Flame Retardancy of Cotton and/or Polyester Fabrics

Set*	Treating solution optimum molarities and/or formalities	Additive content wt%	Burning time (sec)	Burning rate cm/s	Char length cm	State of the fabric***
1(C)**	Untreated	–	30.0	0.73	–	CB
2(C)	Sodium polymeta-phosphate (0.45)F	36.78	–	–	–	FR
3(C)	Dipotassium hydrogen phosphate (0.6)M	13.81	–	–	0.5	FR
4(C)	Trisodium phosphate (0.20)M	7.90	–	–	1.0	FR
5(P)**	Untreated	–	12.0	1.83	–	CB
6(P)	Sodium polymeta-phosphate (0.65)F	43.65	–	–	0.2	FR
7(P)	Dipotassium hydrogen phosphate (0.9)M	18.55	–	–	2	FR
8(P)	Trisodium phosphate (1.0)M	27.11	–	–	1.2	FR

Note: For flame-retarded (FRs) samples the char length ≤ 2.0 cm.
*Each experiment was repeated five times.
**C Stands for Cotton fabric and P for polyester fabric.
***CB means completely burned and FR stands for flame-retarded.

to cotton fabric. Actually, the standard humidity content, i.e. moisture regain for cotton fabric compared to polyester, is much higher. These figures are 8.5 and 0.5 respectively [9]. In fact, cellulose is a polymer of glucose and contains a large number of CH_2OH and CHOH groups. These make it hydrogen bond-forming to absorb moisture from the environment. Hence its hydroxyl units attract water from air, a significant contributed to the high moisture regain. On the contrary, polyester is a man-made fiber with a long-chain synthetic structure of at least 85% by weight of an ester of a substituted aromatic carboxylic acid and para substituted hydrobenzoate units [10]. Hence the polymer's resistibility towards weathering and its relative insensitivity to water. That is, textiles made from this fiber have low absorption of humidity in 100% applications and burn more vigorously. Concerning the inferiority of sodium polymetaphosphate relative to other phosphates to impart flame retardancy either to cotton fabric or to polyester, the chemical structure of these additives may explain their ability to impart flame retardancy. Sodium polymetaphosphate has a polymeric structure. In fact it has a high molecular weight of 12000–18000, and up to 200[PO_4] units in the chain. Though mainly made up of long chains, it does contain up to 10% of ring metaphosphate and a little cross-linked material [4]. Therefore, its efficiency to impart flame retardancy declines due to the involvement of phosphates with other elements in the polymeric chain. This polymeric compound illustrated only a tendency towards flame retardancy for both cotton and polyester substrates [5]. However, a better flame retardancy happens by using lower content of the other phosphates, such as trisodium phosphate, since the phosphates are not involved in the polymeric chain and may act rather freely and vigorously. So, higher efficiency could be gained to achieve flame retardancy by their application.

The mode of action concerning the flame retardancy of phosphorus compounds is discussed in the scientific literature [11–13].

Jolles and Jolles [11] stated that phosphorus compounds form phosphoric acid on heating which coat the surface of the polymer as a stable coating material and cause it to become a carbonaceous residue. Tohka and Zevenhoven [12] suggested the same pathway takes place in the solid phase by thermal decomposition, converting phosphorus compounds into phosphorus acid, which extracts water from the pyrolysing substrate, causing it to char. However Troitzsch [13] confirmed the occurrence of the reactions in the condensed phase and stated that they are particularly effective in materials with high oxy-content, and then converted by thermal decomposition to phosphoric acid which extracts water from the pyrolysing substrate, causing it to char. Therefore the esterification and dehydration of the oxygen-containing polymer result in charring.

CONCLUSIONS

This investigation has been devoted to the comparison of the efficiency and/or inefficiency of selected phosphates relative to each other in terms of combustibility by using cotton or polyester substrate. It is worthy to mention that the activity of phosphorus is limited when sodium polymetaphosphate, an inorganic polymeric material, is used, so higher amounts of this substance are required to achieve the same flame-retardancy performance compared to other phosphates. The optimum percentages of phosphates were obtained from the author's previous investigations. The above-mentioned data obtained by using cotton or polyester fabrics illustrated the preference of cotton fabric over polyester in terms of combustibility.

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