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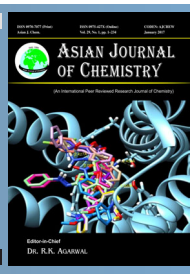

Investigation of Boric Acid and Sodium Borate Effect on Flame Retardancy of Cotton and Polyester Fabrics

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In this study, cotton and polyester fabrics were added non-flammability properties based on the padding method by using flame-retardant finishing (Ruco-Flam CK) in addition to boric acid and sodium borate. The purpose of the study is to investigate the effects of boric acid and sodium borate on flame-retardancy in cotton and polyester fabrics. The effects of these chemicals used in varying concentrations on cotton and polyester fabrics and after washing the permanence of flame retardant agents were investigated with vertical burning test standard.

Keywords: Flameretardancy, Polyester, Cotton, Boricacid, Sodium borate.

INTRODUCTION

Natural or synthetic textile products started to be used in all areas with the developed technology and industry. However, these textile products which often take place in our daily lives, in case of a possible situation like a fire, become serious risk factors that trigger fire, cause fire to spread. Especially for fabrics with cotton and polyester content that we use frequently in our daily lives, a need emerged to add flame-retardant or flame-resistant properties that let fire to die away when the burner agent is removed, or slowing down burning if the substance is ignited [1,2].

Thousands of people worldwide lose their lives each year due to house and enclosed space fires. Textile products used in various spaces such as flooring, drapes, bed sheets, beds or duvets play an important role in house fires and the spread of such fires [3-5]. Therefore, the importance of finishing textile products with flame-retardant properties has increased [6,7]. The compounds of various elements such as phosphorus, antimony, chlorine, bromine, boron and nitrogen are used as fire-retardant substances [7,8]. Numerous studies have been conducted with the purpose to add flame-retardant properties to cotton and polyester fabrics using various substances containing nitrogen, halogen, phosphorus, titanium and silicon [9-13]. Boron is an element with high affinity to oxygen and it establishes a strong covalent bond with oxygen. It is easily dissolved in water [14]. Boron is highly resistant to fire as it is an oxide itself and it has a melting point of 2300 °C. Because of this property, it is used as a flame-retardant substance or mixed into such substances in varying ratios. Similar studies conducted with boron compounds have been performed.

Flame-retardant properties were tried to be added by the processes of padding and exhaust on acrylic and wool blend fiber using chemicals with organophosphate structures and viscose fabric using boric acid and organophosphate chemicals. According to the results of determining the limit oxygen index (LOI), it has been found that using a combination of boric acid and padding drying method increases the value of limit oxygen [15-17].

It was aimed to increase the flame-retardant properties of cotton fabrics by adding boric acid, borax and zinc borate to a flame-retardant chemical named Alpha-X. Flame-retardancy of the samples was analyzed using the method of surface ignition and it was concluded that boron compounds increased the flame-retardant properties of the fabrics [3-5].

Flame-retardant substances' effects were analyzed by applying the Alpha-X substance and boric acid to cotton and polyester fabrics in varying ratios according to exhaust, padding and printing methods. When the flame-resistant behaviour is analyzed, the best flame-resistance performance was seen in samples that were applied finishing agents with the exhaust process and it was determined that the flame-resistance effect highly deteriorated after washing [18,19].

The effects of boron compounds and nitrogen on flame-retardancy in cotton-based fabrics were investigated. Synergic effects of boron and nitrogen elements were analyzed. The

experimental study was analyzed according to the LOI method. The finishing process including a mixture of boron and nitrogen showed a good flame-retardant effect in cotton fabrics [20]. 100 % polyester-based undyed textile fabrics with pre-finishing were exposed to a dying process using dye solutions which contained varying concentrations of boric acid and decahydrate borax [21].

Flame-resistant and thermal properties of the polyester fabric were analyzed by applying new flame-retardant agents. The water-based solution was synthesized with the addition of diammonium phosphate $(NH_4)_2HPO_4$ and boric acid, then sodium borate was added. It was observed that the flame-retardant property and the LOI value of polyester fabrics increased [22]. In this study, cotton and polyester fabrics were added non-flammability properties based on the padding method by using the Ruco-Flam CK flame-retardant agent in addition to boric acid and sodium borate in varying concentrations. The flame-retardancy effects before and after washing were investigated on cotton and polyester fabrics that were applied finishing.

EXPERIMENTAL

The samples used were 100 % cotton (196 knot/cm^2) knitted fabric and 100 Polyester (26 warp/cm, 15 weft/cm) woven fabric. The fabrics were supplied by Oz Tekstil. Ruco-Flame CK (Rudolf-Duraner) was used for the flame-resistant finishing. The chemical structure of this flame-retardant substance is a mixture of organic and inorganic salts and is slightly anionic. Ruco-Flam CK, applied in the concentration interval of 200-600 g/L, shows permanent flame-retardancy properties when used in high concentrations [23]. In the conducted experimental study, while decreasing the usage of Ruco-Flam CK, with additions of boric acid and sodium borate (Merck Group) were made in varying concentrations.

Method: Table-1 shows the chemicals used for the flame-retardant finishing and their ratios. Each prepared solution (bath) was applied on both cotton (C) and polyester (P) samples.

After the samples were padded based on the pad-dry method (80-100 % pick-up), they were dried in the drying-oven at 110°C and then fixed at 180°C for 2 min.

TABLE-1
FLAME-RETARDANT FINISHING AND THEIR RATIOS

Groups	Solution no.	100 % PES	100 % CO	Ruco-flam CK (g/L)	Boric acid (g/L)	Sodium borate (g/L)
	1	1P	1C	–	30	30
	2	2P	2C	600	–	–
1. Group	3	3P	3C	600	30	30
	4	4P	4C	600	–	30
	5	5P	5C	600	30	–
2. Group	6	6P	6C	300	30	30
	7	7P	7C	300	–	30
	8	8P	8C	300	30	–
3. Group	9	9P	9C	300	20	20
	10	10P	10C	300	–	20
	11	11P	11C	300	20	–
4. Group	12	12P	12C	300	10	10
	13	13P	13C	300	–	10
	14	14P	14C	300	10	–

ISO 6941 Vertical firing test was applied on the experiment samples that were fixed [24]. Each experiment was repeated 3 times and the arithmetic means of the data obtained as a result of the firing test were calculated. In order to analyze the flame-resistance effect after washing, ISO 6330 standard domestic type washing was applied [25]. They were washed for 50 min for 5 times in a domestic type washing machine at 40 °C, using 20 g of domestic detergent.

RESULTS AND DISCUSSION

The results regarding the cotton fabrics are given in Table-2, while Table-3 shows the results about the polyester fabrics. The tables show that the burning zone measurements used only sodium borate and boric acid are similar to those in cases where only the Ruco-Flam CK (600 g/L) substance was used (1C-2C/1P-2P). However, these samples did not show good resistance to washing.

TABLE-2
BURNING AREA OF COTTON FABRICS

Groups	Samples	Width of burned area (cm)	Length of burned area (cm)	Burned area (cm^2)
	1C	3.0	4.0	12.00
	2C	3.0	3.9	11.70
	3C	3.0	3.5	10.50
1. Group	4C	3.0	3.8	11.40
	5C	2.9	3.6	10.44
	6C	2.8	3.9	10.92
2. Group	7C	2.8	3.6	10.08
	8C	2.8	3.6	10.08
	9C	3.2	3.2	10.24
3. Group	10C	3.1	3.3	10.23
	11C	3.0	3.4	10.20
	12C	2.9	3.5	10.15
4. Group	13C	3.2	3.2	10.24
	14C	3.0	3.3	10.00

TABLE-3
BURNING AREA OF POLYESTER FABRICS

Groups	Samples	Width of burned area (cm)	Length of burned area (cm)	Burned area (cm^2)
	1P	1.6	2.4	3.84
	2P	1.6	2.5	4.00
	3P	1.5	2.6	3.90
1. Group	4P	1.5	2.4	3.60
	5P	1.5	2.5	3.75
	6P	1.5	2.5	3.75
2. Group	7P	1.3	2.5	3.25
	8P	1.4	2.6	3.64
	9P	1.4	2.3	3.22
3. Group	10P	1.3	2.4	3.12
	11P	1.5	2.4	3.60
	12P	1.5	2.6	3.90
4. Group	13P	1.4	2.4	3.36
	14P	1.6	2.3	3.68

In the 2nd group, the ratio of Ruco-Flam CK was decreased to half (300 g/L), the experiments were repeated and the 1st and 2nd groups were compared. No significant difference was found between the results of ignition area. Later, while holding

the 300 g/L Ruco-Flam CK concentration constant, the concentrations of boric acid and sodium borate were decreased (20 and 10 g/L – 3rd and 4th groups). The samples that showed the best flame-resistance performance in the 2nd, 3rd and 4th groups were determined and they were compared amongst each other (8C-11C-14C and 7P-10P-13P).

It was observed that the Ruco-Flam CK + boric acid solution showed the best flame-retardancy performance in cotton, while Ruco-Flam CK + sodium borate solution showed the best performance in polyester. In line with these results, it was observed that even if the boric acid and sodium borate were used in 10 g/L of concentration (minimum concentration), no significant change was seen in the area of ignition. Standard washing process was applied on all samples implemented with the finishing process and the samples were exposed to the firing test again. It was determined that the best-performing solutions were Ruco-Flam CK + boric acid for cotton, Ruco-Flam CK + sodium borate for polyester and that they did not lose their flame-resistant properties in low concentrations (10 g/L).

Conclusions

• No significant difference was found between the results when the 1st and 2nd groups were compared (sodium borate 30 g/L, boric acid 30 g/L, Ruco-Flam CK 600 and 300 g/L). Accordingly, it was observed that a 300 g/L concentration of Ruco-Flam CK was sufficient for all 3 fabrics.

• In both cotton and polyester fabrics, it was observed that there was no significant difference noticed in burning zone when 300 g/L of Ruco-Flam CK is used alongside different concentrations (30, 20, 10 g/L) of sodium borate and boric acid. As a result, it was determined that the same results can be achieved using the minimum amount of chemicals (10 g/L) and the flame-resistance effect persists after washing. In terms of using less chemicals and environmental responsibility, it was determined that using boric acid in the amount of 3-3.5 % of Ruco-Flam CK in cotton and sodium borate in the amount of 3-3.5 % of Ruco-Flam CK in polyester was sufficient for the finishing substance.

• It was observed that Ruco-Flam CK supported by boric acid and sodium borate showed permanent flame-resistance properties even in low concentrations.

• It was determined that boron compounds do not have high toxic effects and as a results of analyses, it was determined that waste water containing boron do not carry a significant environmental risk [26]. As they have positive contributions to the environment and economic benefits by using less chemicals, it is projected that boron compounds will be more preferable in the future.

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