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THE IMPARTATION OF FLAME–RETARDANCY TO COTTON FABRIC BY THE APPLICATION OF "CALGON"

SEYED MORTEZA MOSTASHARI* and A'ZAM DARSARAEI

Department of Chemistry, Faculty of science, Guilan University, RASHT, IRAN

ABSTRACT

The effect of calgon as a nondurable finish on the flammability of 100% cotton fabric has been investigated. The laundered bone–dried, weighed fabric were impregnated with suitable concentration of aqueous calgon solution by means of squeeze rolls and dried at 110°C for 30 minutes. Then they were cooled in a dessicator, re–weighed in an analytical balance and kept under ordinary conditions before the fulfillment of the vertical flame test. The optimum add–on value to impart flame and glow retardancy was about 21.3 g anhydrous calgon per 100 g fabric. The results comply with the "condensed phase retardation" ascribed in "Chemical Theory".

Key words : Calgon, Flame–retardancy, Chemical theory, Condensed phase retardation

INTRODUCTION

Textiles usually undergo flaming combustion when ignited by an open flame. Once an amount of the material is consumed by the flaming reaction, the charred residue will often continue to react through a solid–state glowing or smoldering oxidation. In general, all textiles, with few exceptions, are flammable and a fire hazard is probable. As far as the household environment is concerned, domestic fire kill between 15 and 20 thousand more in the United States annually[1]. It is mentionable that the elderly are at most risk of the fatalities due to ignition of clothing. While fatalities due to clothing fires are obviously linked with the inflammability of textiles, there are other hazards caused by fires including the effects of smoke and toxic gases. It is stated that over half of the deaths were due to the combined above–mentioned side effects[2]. The cost, both in human lives and in financial terms of textiles fires caused in pressure on the textile industry to develop flame–retardant fabric that meet minimum legislative safety standards[3]. Hence, the incorporation of flame–retardants into consumer products such as fibres, fabrics etc. have gained a great significance these days.

The aim of this study is to investigate the effect of deposited "Calgon" as a nondurable finish on the flame–retardancy impared to cotton fabric.

The commercial material, "Calgon" is sodium polymetaphosphate[4]. In industry it is incorrectly called sodium hexametaphosphate[5]. This nomination is wrong because it does not contain six $[PO_4]$ units and is a high molecular weight polymer $(NaPO_3)$, which usually has a mean 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 metaphosphates and a little cross–linked material[6]. In over–all, although this substance is in fact, more complex, the formula; $Na_6P_6O_{18}$ is generally ascribed to it[7]. Calgon is a sequestering agent, i.e. it react with metallic ions in such a way that it becomes part of complex anion, so it can be used to soften hard water[7]. It is also supplied in the treatment of textiles and in laundry work[5].

EXPERIMENTAL

Materials

All fabrics were a "plain" construction weighing 240 g/m^2 unfinished 100% cotton, laundered and dried. They were 22 cm by 8 cm strips cut along the warp direction and pre–washed in hot distilled water. The samples were dried at 110°C for 30 minutes in an oven, cooled in a dessicator and weighed in an analytical balance.

Bath treatment

With the exception of the first bunch, all other specimens were impregnated with suitable concentration of "Calgon" at 22°C. Then they were squeeze rolled and dried horizontally in an oven at 110°C for 30 minutes. Afterwards, they were cooled in a dessicator, reweighted with analytical precision, so as the suitable add–on presented into the fabrics were determinable.

Flammability test

Vertical flame test method similar to the procedure in DOC FF 3–71 was applied[8]. The conditions of the specimens and environment were in average between 20°C–22°C, and the average of relative humidity (RH) ranged between 65–67%.

The aforementioned tester has been also described in the previous investigations[9–11]. It is an aluminium frame: Two strips of 3mm aluminium double–sheet, 22.5 cm by 1.5 cm were cut, perforated and welded at right angles to a shorter 9 cm strip. The specimens were pinned tightly to the frame and held vertically in a retort stand by clamps with the lower edge 1.9 cm above the top of a three centimeter yellow flame of a Bunsen burner, so as the harsh ignition circumstances was avoided. Repeatability of burning time was ±5% for untreated samples. This repeatability for "Calgon" treated fabrics was much lower. In fact, the pad squeeze process results a certain amount of variability. After an ignition time of three seconds, the burning time at the nearest 0.1 second was determined with a stop–watch. The ignition time was subtracted from the total combustion duration, and the rest was reported as the burning time. The length of "Char" was also measured after the burning process to the nearest centimeter.

RESULTS AND DISCUSSION

The experimental results are listed synoptically in Table–1. Vertical flame test was carefully accomplished to measure the burning time in seconds (column 4). In column 5, the burning rates are calculated by means of dividing the length of the specimens (22 cm) by the burning times in seconds. In columns 6 and 7, the char lengths in centimeter and the states of samples (after the tests) are given, receptively. CB means Completely Burned and FR stands for Flame–Retarded.

Table 1.The effect of deposited "Calgon" on the flame–retardancy imparted to cotton fabric (plain 240 g/m^2)

Bunch*	Treating solution Formality	Percent (Add–on) drying at 110ºC and weighing	Burning time (Seconds)	Burning Rate cm/S	Char Length in cm	State of the Fabric**
A	Untreated	–	34.6	0.64	–	CB
B	0.175	19.80	26.6	0.82	–	CB
C	0.20	21.30	1	–	0.3	FR
D***	0.3	31.56	–	–	0.1	FR

* Average of 5 tests for each bunch; ** CB stands for completely burned, and FR stands for flame–retarded; *** Confirmatory tests applying excessive quantities of "Calgon".

The results of the third row show that inadequate amounts of "Calgon" as a flame–retardant, i.e. about 19.8% decreased the burning time and increased the burning rate. These results are in favour of the literature stated by Reeves and Hammons[12]. They distinguished that inefficient quantities of certain flame–retardant finishes accelerate the burning process of fabric i.e. by application of inadequate amounts of them. The imperfect rapid combustion, deformation occurs and a decrease in burning duration and increase in burning rate is the resultant. This can be also generalized for the action of numerous flame–retardants including the inefficient quantities of "Calgon" which has been deposited to cotton fabric. The experimental observations showed the black carbonaceous texture remained after the combustion process of fabrics with low add–ons of "Calgon". On the other hand, burning characteristics of the treated fabrics also indicated suitable effectiveness in suppressing the after–glow. The plausible mechanism of such flame and glow–retardancy is in favour of Chemical Theory stated by Little[13,14]. According to this theory, the action of certain flame and glow retardants is to promote the formation of solid char rather than volatile pyrolysis products, when the polymer is subjected to thermal degradation. Ideally the carbon presented in cellulose could be confined to the solid phase during the thermal decomposition, then the degradation could be pushed through the catalytic dehydration shown below:[13,14].

$$(C_6H_{10}O_5)_x \longrightarrow 6xC + 5xH_2O$$

Troitzch[15] stated that phosphorus containing flame–retardants mainly influence the reactions taking place in the condensed phase. They are particularly effective in materials with high oxy–content, such as cellulose and oxygen containing plastics. They are converted by thermal decomposition to phosphoric acid which in the condensed phase, extracts water from the pyrolysing substrate, causing it to char, i.e. the phosphoric acid formed, esterifies and dehydrates the oxygen–containing polymer and causes charring. However, Jolles and Jolles[16] suggested that phosphorus compounds forms phosphoric acid, then forms a polymeric metaphosphoric acid on heating which is a stable coating material and coats the surface of the polymer, causing it to a carbonaceous residue.

CONCLUSIONS

"Calgon" as a phosphorus containing compound deposited into cotton fabric demonstrated a tendency towards flame and glow retardancy. Its action is assigned due to the "Condensed Phase Retardation" ascribed in "Chemical Theory".

As a phosphorus containing flame and glow retardant, it may be converted to phosphoric acid by thermal decomposition, which extracts water from the pyrolysing substrate, causing it to char. The formation of a strong and thick char supports this suggestion.

The optimum add–on values to impart flame and glow retardancy was about 21.3 g anhydrous "Calgon" per 100 g cotton fabric. It can be recommended to apply "Calgon" in conjunction with other flame–retardants to achieve a better performance on the flame–retardants to achieve a better performance on the flame–retardancy. i.e. using the synergistic influence may be beneficial to improve the above–mentioned effect.

REFERENCES

1. M. Kesner and W. J. De Vos, J. Chem. Edu., **78(1)**, 41 (2001).
2. S. M. Mostashari, M. Phil. Thesis, University of Leeds, (1978). p. 3, 4 and 11.
3. D. Price, A. R. Horrocks and M. Tunc, Textile flammability, Chem. in Britain, **23**, 235 (1987).
4. A. K. De, "A Textbook of Inorganic Chemistry" Wiley Eastern Ltd. New Delhi, (1983) p. 454.
5. Chambers Dictionary of Science and Technology. W & R Chambers, Ltd., Pedinburgh, (1971) p. 177.
6. J. D. Lee, "Concise Inorganic Chemistry". Chapman & Hall. London, (1991) p. 516.
7. E. R. Trotman, "Dyeing and Chemical Technology of Textile Fibers". Charles Griffn & Company Ltd. London, (1970) p. 175.

8. U. S. Department of Commerce Standard for the Flammability of Children's Sleepwear (DOC FF 3–71), Federal Register, **36**, 146 (1971).

9. F. M. Farhan, S. M. Mostashari and G. Ghazi Moghaddam, Intern. J. Chem., **1(3)**, 117 (1990).

10. F. M. Farhan, S. M. Mostashari and G. Ghazi Moghaddam. Intern. J. Chem., **2(4)**, 163 (1991).

11. S. M. Mostashari, Intern. J. Chem., **13(2)**, 115 (2003).

12. W. A. Reeves and M. A. Hammons, Textile Res. J., **50**, 245 (1980).

13. R. W. Little, "Flame Proofing Textile Fabrics". American Chemical Society Monograph Series. No. 104. Reinhold publishing New York (1947).

14. R. W. Little, Textile Res. J., **21**, 901 (1951).

15. J. H. Troitzsch, Chimica Oggi/Chemistry Today, **16**, 14 (1998).

16. Z. E. Jolles and G. I. Jolles, Plastics and Polymers, **40**, 319 (1972).

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