ABSTRACT

Fire is a worldwide issue that claims lives and causes significant damages to the properties. Due to the stricter fire regulations, the fire hazards have been reduced. This substantiates that flame retardancy is very important. The addition of flame retardants into the materials causes the delaying or extinguishing of flame growth and decreasing the flame spread time. Their inclusion can prevent the loss of life and destruction of properties. It has been observed that flame retardants made of phosphorous and halogens are very effective.

The use of non-halogen based flame retardants in textile products is becoming more important because of the close contact that textiles have with humans and the potential risks connected with halogen-based flame retardants. Due to worries about eco-toxicity and associated regulatory pressures, the development of novel flame retardants is gaining interest. In recent years, it has become clear that phosphorous-based flame retardants are an effective alternative to halogen-based flame retardants. The numerous studies have shown that the combination of nitrogen and phosphorous-based compounds enhances the flame retardancy of cellulosic textiles. The wool, silk, nylon 6, and acrylic are among the fibres that are rich in nitrogen. The nylon 6 and acrylic are synthetic fibres, while wool and silk are natural fibres made of proteins. Although these fibres are rich in nitrogen but they burn quickly. Interestingly, among these four fibres, wool is considerably more flame retardant. The disulphide linkages between molecules are present in the wool. However, there are few reports on the use of sulphate-based flame retardants to textiles. This makes it interesting to investigate and conduct research on the mechanisms applicable in the flame retardant finishing of such nitrogen-rich textile fabrics and studying their burning behaviour particularly after finishing with sulphur and phosphorous-based chemicals. This research work is divided into four parts.

The first part of the research covers the flame retardant finishing of wool fabric. The limiting oxygen index (LOI) of wool is 25. In the vertical flammability test, it ignites and burns entirely. The efficacy of the phosphorous and sulphur-based flame chemicals was investigated in this study. The impact of concentration of phosphorous and sulphur-based chemicals on flame retardancy was also assessed. It was discovered that at around 20 percent w/v concentration in the pad bath, limiting oxygen index of 30 or higher could be obtained. To test the durability of compounds after drying and curing, the treated samples were washed. Wool responded well to phytic acid, phosphoric acid, sulphamic acid, ammonium sulphate, and ammonium peroxydisulphate. Wool has not shown good efficiency with aluminiun sulphate. The limiting oxygen index of wool was not significantly impacted by thiourea. The sulphamic acid and 1,2,3,4-butane tetracarboxylic acid (BTCA) were used in the development of the durable flame-retardant wool.

The second part of the research presents the outcomes of treating a silk cloth with various phosphorous and sulphur-based chemicals. Studies have been done on the impact of concentration. At the appropriate concentration, a limiting oxygen index of 30 or higher was attained. The analysis of the effect of washing on the limiting oxygen index of dried and cured samples has been reported. A potential method for flame retardancy has been developed. Aluminium sulphate and thiourea were ineffective even on silk. The chemicals that showed the promise were phosphoric acid, ammonium sulphate, aluminium peroxadisulphate, and sulphamic acid. The sulphamic acid and BTCA were used to develop the flame retardant silk.

The third part of the research presents studies on the flame retardancy of nylon 6 fabric. Upon burning, the untreated fibre melts and drips. The chemicals based on phosphorous and sulphur were applied. The LOI of at least 30 was obtained. The nylon 6 stopped dripping. The phosphate salts showed good results. With the exception of aluminium sulphate, the sulphate salts were similarly found to be quite effective. Thiourea that was shown to be ineffective in earlier on wool and silk, however, thiourea worked nice on nylon 6. Thiourea was used in the development of the durable flame retardant nylon 6. It is challenging to conduct the test successfully in order to evaluate the effectiveness of different chemicals because nylon 6 drips during bottom burning. A top burning method was investigated as an alternative, which produces more reliable results because the fabric does not drip. This chapter also explored in depth the flame retardancy mechanism of the thiourea. According to the findings, thiourea dispersed and became confined into nylon 6 while it predominately existing on the surface of wool and silk. Thiourea degrades first and is unable to give wool and silk flame retardancy because flame retardancy is a bulk property.

This fourth part of the research presents the results of experiments performed for the flame retardancy of acrylic fabric. The chemical diffusion is difficult in acrylic fibre and Tg is significantly high than that of nylon 6. The diffusion of chemicals was analysed using the exhaust method and combined two-step procedures. The different amines were used to perform the amination. This was followed by the treatment of phosphoric acid, phytic acid, and sulphamic acid. It was found that the cationization process utilising amines was inefficient in terms of flame retardancy. The modification of acrylic by amino oximation, followed by treatments with phosphoric acid, phytic acid and sulphamic acid was however successful, and greatly improved flame retardancy. This treated acrylic fabric was durable to wash as well.