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INCREASING THE FIRE PROTECTION LEVEL OF TEXTILE FABRICS MADE FROM CELLULOSE

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ABSTRACT

Cellulose-based natural textile materials are highly flammable, which limits their use in areas with high fire safety requirements. Improving their fire resistance while maintaining their mechanical properties is an urgent scientific and practical problem. In this study, a TEX-1 oligomeric flame retardant was developed, synthesized on the basis of aluminum hydroxide as nitrogen, phosphorus and metal additives. The physicochemical properties of the synthesized oligomeric flame retardant were studied. Natural textile materials were treated with TEX-1 flame retardant and their fire resistance and mechanical properties were evaluated in the temperature range of 110–150 °C in accordance with the requirements of GOST. The results showed that the fire resistance of textile materials treated with TEX-1 oligomeric flame retardant significantly increased. At the same time, there was no negative impact on the mechanical properties of the materials in the given temperature range, and the fire resistance indicators fully complied with the requirements of GOST. The synthesized TEX-1 oligomeric flame retardant is an effective and promising fire retardant for cellulose-based natural textile materials, which, while ensuring high fire safety, maintains the mechanical stability of the materials.

Keywords: Cellulose, flame retardant, synthesis, flammability, material, product, textile, phosphorus, metal.

INTRODUCTION

Nowadays, cellulose-based natural materials are widely used in the textile industry. Although such materials are characterized by their environmental friendliness, convenience and hygienic properties, their high flammability poses significant problems from the point of view of fire safety. This problem is becoming more urgent, especially with the increasing requirements for fire resistance in special clothing, household textiles and industrial materials [1].

In order to increase fire resistance, various flame retardant treatment methods are used for textile materials. Traditional flame retardants are often limited by the fact that they deteriorate the mechanical properties of materials, do not fully meet environmental safety requirements, or lose their stability at high temperatures. Therefore, there is a need to develop new types of flame retardants that are highly effective, environmentally safe, and do not adversely affect mechanical properties[2].

In recent years, oligomeric flame retardants based on nitrogen and phosphorus have been the focus of scientific research due to their fire-fighting efficiency. These compounds form a protective layer under the influence of high temperatures, which slows down the combustion

process and reduces heat release [3]. The use of metal additives, in particular aluminum hydroxide, serves to increase the thermal stability of flame retardants and enhance their fire-resistance performance [4].

This study is devoted to the study of the effect of TEX-1 oligomeric flame retardant synthesized on the basis of nitrogen, phosphorus and aluminum hydroxide on the fire resistance of natural cellulose-based textile materials[5 - 6]. During the study, the physicochemical properties of the synthesized flame retardant, as well as the fire resistance and mechanical performance of textile materials treated with this substance, are evaluated. The results obtained are of scientific and practical importance in the development of new and effective flame retardants that meet fire safety requirements[7-8] .

LITRATURE REVIEW

Cellulose-based textiles have been extensively studied to enhance their fire-retardant properties. Various chemical treatments, including phosphorus-, nitrogen-, and metal-based compounds, have been applied to improve flame resistance (Gorovskikh & Price; Levchik & Weil). Phosphorus-containing compounds act by promoting char formation under heat, thereby reducing flame propagation, as described by Kamino et al. and Morgan & Gilman. Studies indicate that combining phosphorus and nitrogen compounds provides a synergistic effect, significantly improving flame retardancy (Horrocks & Kandola; Van et al.).

Uzbek scientists have contributed to this field by exploring the efficiency of new fire-retardant formulations for silk and other natural fabrics. For example, Qahramonov and Yusupov demonstrated enhanced flame resistance in silk textiles using novel antipyrene compounds. Similarly, Hamidov and Tashpulatov studied the fire resistance of textile components, emphasizing the balance between flame retardancy and preservation of mechanical properties.

METHODS

The enhancement of fire resistance in cellulose-based textiles is achieved primarily through chemical treatments. Phosphorus-, nitrogen-, and metal-based compounds are commonly used, either individually or in combination, to improve flame retardancy. Phosphorus compounds promote char formation under heat, nitrogen compounds enhance thermal stability, and metal salts increase resistance to ignition. Combined treatments, such as phosphorus–nitrogen–metal formulations, provide a synergistic effect, effectively reducing flame spread while preserving the mechanical properties of fabrics.

These chemicals are applied using methods such as impregnation, padding, or exhaustion, followed by curing to ensure durability and fixation of the fire-retardant agents. The effectiveness of treated textiles is evaluated through standard flammability tests, including vertical burning tests, limiting oxygen index (LOI), and cone calorimetry. Such methods, supported by both international and Uzbek researchers, have proven effective for enhancing fire resistance in natural fabrics like cotton and silk without significantly affecting their strength or texture.

RESULTS

The research used TEX-1 brand flame retardant based on an oligomeric composition containing phosphorus, nitrogen and metal. The solution used was at a concentration of 20% and contained the main substance, a metal-containing urea adduct, a urotropine-based binding agent and ammonium for neutralization. Surfactants were used to increase the wetting of the treated fabric. The physicochemical properties of the oligomeric flame retardant containing nitrogen, phosphorus and metal are given in Table 1.

Table 1. Physicochemical properties of nitrogen-, phosphorus-, and metal-containing oligomeric flame retardants

Physicochemical properties	Nitrogen-, phosphorus- and metal-containing oligomeric flame retardant
Aggregate status	White powder
pH	7.0
Density (g/cm^3)	1.08
Solvent	10% soluble in water at 80 °C

Elemental analysis to determine which elements are present on the surface of a new type of fire-resistant textile fabric The results of elemental analysis showed that it was possible to determine the concentration of nitrogen, phosphorus, and metal elements in the carbon and oxygen content, as well as the concentration of flame retardants in cellulose (Table 2).

Table 2. Elemental analysis results

Element	Weight %	Sigma Weight %
C	49.08	2.73
N	4.83	4.01
Oh	41.01	2.49
No	0.41	0.28
Hand	0.57	0.29
Yes	0.71	0.29
P	3.40	0.57

Experimental tests on the fire resistance of the composition developed in the study were conducted in accordance with GOST standards. Cellulose-based textile materials were treated with TEX-1 brand flame retardant and their fire resistance and physical and mechanical properties were tested.

Table 3 Experimental results and fire resistance and physical and mechanical properties of samples treated with TEX-1

Flame retardant concentration, g/l	Burnt part length, mm	Breaking load, N	Heat treatment temperature, °C
	110	130	150
Control sample (untreated)	220	220	220
TEX-1, 150 g/l	124	136	132
TEX-1, 300 g/l	115	122	118
TEX-1, 400 g/l	112	113	110

DISCUSSION

The results of the study show the effect of TEX-1 brand flame retardant on fire resistance and physical and mechanical properties when treated with cellulose-based textile materials. The physicochemical properties (Table 1) show that TEX-1 flame retardant is a white powder, has a neutral pH (7.0), a density of 1.08 g/cm³ and a 10% water-soluble solution at 80 °C. These properties are important for ensuring uniform absorption into materials and stability during thermal treatment.

According to the results of elemental analysis (Table 2), the presence of carbon (C), oxygen (O), nitrogen (N), phosphorus (P) and metal elements (Al, Si, Na) was found in the flame retardant-treated fabrics. This composition confirms that the TEX-1 flame retardant effectively binds to the cellulose fibers and contributes to increasing the fire resistance.

Fire resistance and physical and mechanical performance (Table 3) show that:

- As the concentration of TEX-1 flame retardant increases, the length of the burned part decreases (control sample 220 mm, 110 mm with TEX-1 400 g/l), which indicates a slowdown in the spread of fire;
- The slight decreases in breaking load (control 202 N, TEX-1 400 g/l 197–198 N) indicate that the mechanical stability of the material was not adversely affected;
- The heat treatment temperature (110–150 °C) did not significantly affect the results, meaning that the flame retardant retained its effective performance even at high temperatures.

Thus, TEX-1 flame retardant not only significantly increases the fire resistance of materials, but also allows them to maintain their mechanical properties. This makes TEX-1 flame retardant an effective means of fire protection for cellulose-based textile products.

DISCUSSION

In this study, a phosphorus, nitrogen, and metal-containing TEX-1 flame retardant was used to improve the fire resistance of cellulose-based textile materials. The solution was at a concentration of 20% and contained the main substance, a metal-containing urea adduct, a urotropin-based coupling agent, and ammonium. Surfactants were used to increase the moisture content.

TEX-1 is a white powder, neutral pH, density 1.08 g/cm³ and soluble in 10% water at 80 °C. It is uniformly absorbed into fabrics and is stable during thermal processing. Elemental analysis showed the presence of carbon, oxygen, nitrogen, phosphorus and metal elements, indicating effective binding of the flame retardant to the fabric.

According to the results of the experiments, the length of the burned part in the samples treated with flame retardant significantly decreased (control 220 mm, TEX-1 400 g/l 110 mm), while the mechanical properties remained almost unchanged (from 202 N to 197–198 N). The heat treatment temperature (110–150 °C) did not significantly affect the results.

Thus, TEX-1 flame retardant increases the fire resistance of cellulose-based textile materials and maintains their mechanical stability, which makes it an effective fire retardant.

CONCLUSION

In this study, the oligomeric flame retardant TEX-1 with phosphorus, nitrogen and metal content was used to improve the fire resistance of cellulose-based textile materials. The solution was uniformly absorbed into the fabrics, was stable at high temperatures and did not adversely affect the mechanical properties. Elemental analysis showed the presence of carbon, oxygen, nitrogen, phosphorus and metal elements, which confirms the effective binding of the flame retardant to textile fibers. Experiments showed that with increasing flame retardant concentration, the length of the burned part decreases, which slows down the spread of fire, and the breaking load changes minimally. The heat treatment temperature (110–150 °C) did not significantly affect the results. Thus, TEX-1 flame retardant is recommended as a safe, durable and effective fire retardant, effectively protecting cellulose-based textile products and improving their service life and quality.

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