

N-Methylol Dimethyl Phosphonopropion Amide (MDPA) and Zinc Oxide Nanoparticles (ZnO NPs) coated Flame Retardant Cotton Fabrics

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Abstract: In this study a durable flame retardant fabric along with antibacterial properties was developed without use of halogen and formaldehyde compounds.. Within this study, the application of zinc oxide nanoparticles (ZnO NPs) onto 100% cotton fabric was carried out through the sonochemical technique. Zinc acetate dihydrate ($\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$) and sodium hydroxide (NaOH) were utilized as precursor materials. Subsequent to the growth of ZnO NPs, N-Methylol dimethyl phosphonopropion amide (MDPA) flame retardant was applied in conjunction with 1, 2, 3, 4-butanetetracarboxylic acid (BTCA) as cross-linkers employing the traditional pad-dry-cure method. Additionally, assessments were conducted for vertical flame retardant test, Limiting Oxygen Index (LOI), and antibacterial properties of the samples. The fabricated specimens exhibited remarkable performance in flame retardancy (39 mm char length, 0 s after flame time, 0 s after glow time), 32.2 LOI, and 100% antibacterial efficacy

.Keywords: Flame retardants, antibacterial, ZnO, nanoparticles, metal oxide

1 EXPERIMENTAL

Zinc Oxide nanoparticles (NPs) were prepared and anchored onto the cotton material simultaneously. The zinc acetate dihydrate precursors ($\text{Zn}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$) 0.1 M and sodium hydroxide (NaOH) 0.3 M were individually dissolved in deionized water under vigorous magnetic stirring conditions at 300 rpm. Subsequently, the cotton fabric segment was immersed in the zinc acetate dihydrate solution. After that, the NaOH solution was gradually added drop by drop. To ensure the complete progression of the reaction mechanism, the resultant solution containing the cotton fabric piece was subjected to sonication for durations of 90 minutes using the Branson sonication probe. A hot plate was used to maintain the reaction temperature at 80 °C. The treated fabric samples were then meticulously rinsed with deionized water to eliminate any contaminants. Finally, the treated fabric pieces were dried in an air oven at 90 °C for 120 minutes. The MDPA application was conducted utilizing a laboratory padder with 80% wet pick up. The formulation in the bath consisted of 300 g/L MDPA, 60 g/L BTCA crosslinker, and 50 g/L SHP catalyst. The ZnO NPs loaded samples were immersed in MDPA and BTCA solution, padded, dried at 110 °C for 3 minutes, and cured at 150 °C for 2 minutes. To evaluate the significant role of ZnO NPs in enhancing flame retardancy, a cotton fabric specimen was prepared with MDPA and BTCA excluding ZnO NPs treatment.

2 RESULTS AND DISCUSSIONS

The findings related to the flammability test, limiting oxygen index, and antibacterial efficacy are displayed in Table 1 and Table 2. Analysis of Table 1 reveals that MDPA positively influences the flame retardancy of cotton fabric. The results clearly demonstrate that the flame retardant characteristics, such as after flame time, after

glow time, and char length, exhibit enhancement following the application of ZnO NPs. In contrast, the untreated sample exhibited vigorous burning upon contact with the flame, continuing until complete combustion without char formation post-flame detachment. Conversely, all treated samples displayed self-extinguishing behavior, accompanied by char formation. Specifically, the MDPA+ ZnO NPs-treated sample self-extinguished immediately after the combustion source was removed, showing zero seconds after flame time, zero seconds after glow time, and a char length of 39 mm. The data in Table 2 indicates that the untreated sample had an LOI of 17.6, which increased to 23.8 following MDPA treatment. Conversely, the MDPA+ZnO NPs-treated sample exhibited an LOI value of 32.2, along with 100% reduction in bacterial presence for E.coli and S.aureus strains.

Table 1 Experimental results for flammability test

Sample	Flammability test		
	After flame time (s)	After glow time (s)	Char length (mm)
Untreated	19.34	9.62	Completely burned
MDPA treated	8.04	5.21	127
ZnO NPs+MDPA Treated	0	0	39

Table 2 Experimental results for LOI, and bacterial reduction %

Sample	LOI	Bacterial reduction	
		E.coli (R%)	S.aureus (R%)
Untreated	17.6	-	-
MDPA treated	23.8	-	-
ZnO NPs+MDPA Treated	32.2	100	100