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Investigating The Efficacy Of Multiple Catalysts In Textiles For Protection Against Vaporous Threats

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Chemical Warfare Agents (CWAs) present complex challenges for protection and decontamination in battle theaters. In some instances, an impermeable barrier is sufficient to block contact with agents. Another approach integrates reactive catalysts and adsorbents into textiles to transform and neutralize the CWAs as they permeate. Some common examples include oxidative and hydrolytic reactants. The present work explores the concept by identifying appropriate catalysts, integrating the catalysts within fabrics, and then evaluating the performance of the functionalized materials. If successful, the vast majority of threat agents should be neutralized using this approach of oxidation plus hydrolysis.

Literature reports show trials using Metal Organic Frameworks (MOFs) to adsorb CWAs and using the MOF scaffold for catalytic neutralization. In other work, the strong nucleophilic character of zirconium hydroxide [Zr(OH)4] was applied to promote hydrolysis of CWAs and other toxins. However, while these catalysts show promise, they are not a panacea for the entire threat envelope. A third option may incorporate an oxidative catalyst (in this case, EcoCer™) alongside the hydrolytic catalysts. This combination expands the catalytic mechanisms of treated materials and, in some cases, might provide synergistic effects.

Bench-scale trials evaluated whether combinations of the noted catalysts yield a reactive air permeable barrier against chemical agents. Zr(OH)4, the MOF UiO-66-NH2, and EcoCer™ were bound to cotton textile swatches singly and in combination using aqueous tetraethyl orthosilicate (TEOS) followed by microwave irradiation to promote crosslinking. The treated textiles were analyzed using Fourier-Transform Infrared spectroscopy via Attenuated Total Reflectance (FTIR-ATR), X-ray Fluorescence (XRF), and Scanning Electron Microscopy (SEM). All methods indicated integration of the catalysts into the cotton via an interpenetrating siloxane network, as has been demonstrated in prior work. The SEM images show microparticles (5–20 μm diameter) of the catalyst(s) bound to the cotton fibrils. The reactivity of the treated textiles was evaluated using vial-in-vial vapor-permeation headspace analysis against two CWA simulants. The combination of catalysts effectively mitigated the breakthrough of 2-chloroethylethyl sulfide (2-CEES) and diisopropyl fluorophosphate (DFP) by up to two orders of magnitude after a 60-min exposure as compared to untreated controls. Wet-weight pickup values were used to calculate reagent consumption and evaluate production-scale potential.

Successful formulations are now being prepared and tested using a pilot-scale (24” width), reel-to-reel, textile treatment line with integrated 3 kW, 2.45 GHz microwave chamber. The methodology evaluates scalability of the process and chemistries, providing significant steps forward for the critical task of technology transition. This dual catalyst plus adsorbent approach could provide additional protection and potentially enable the Uniform Integrated Protective Fabric System to achieve the long sought after balance of threat agent protection, water vapor transport, and breathability.

The team would like to acknowledge Guild Associates, NuMat, and Nanoionix LLC for providing catalyst materials.