PROTECTION - SCIENCE AND TECHNOLOGY ADVANCES FOR CHEMICAL AND BIOLOGICAL PROTECTION

Nanocellulose Ionogels For CWA Protection

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Organophosphate compounds (OpCs) are commonly used as pesticides but are also the foundation of many known nerve agents developed during the early 20th century. Their ability to be readily synthesized and deployed as aerosols renders them a potential threat to Joint Forces due to their capability of causing mass harm with very little material. Current dermal protection against OpCs follows a dual threat strategy that relies on the coordinated efforts between a semi-permeable membrane, that limits penetration of chemical hazards to < 0.4%, and activated carbon, which adsorbs chemical agents, to prevent dermal exposure to Joint Forces. While this setup offers excellent protection against chemical threats, they have two significant areas of concern; (1) there is still an issue regarding the long-term wearability of the protective suit which limits the ability of Joint Forces to operate for prolonged periods under hazardous conditions and (2) dealing with contaminated clothing, whether it be for reuse or disposal, when they still contain potentially active OpCs renders them hazardous.

To address the limitations of current apparel, we are developing a new dynamic material – a nanocellulose ionogel – that can act as a protective layer to trap and destroy OpCs, and under scenarios of high exposure, will have the capability to shed contaminated layers and be actively refreshed. Ionic liquids (IL) have been proven to be an effective medium to attack OpCs and degrade them into less toxic products. These "liquids" offer various benefits including low vapor pressure, good thermal and chemical stability, and the flexibility to be tailored for specific applications by modifying the anion cation pair. By dispersing cellulose nanocrystals (CNC) into IL, we can create a gel matrix that will improve the mechanical durability and efficacy of the IL relative to neat IL. We anticipate that CNC's good moisture vapor transport properties will translate to the gel and enable the wearability of protective garments containing this ionogel layer. Furthermore, the CNC matrix will provide the means to incorporate self-delaminating properties to the ionogel by installing acid-sensitive crosslinkers that decompose as the pH decreases from the degradation process of the OpCs.

We will report the synthesis of amino acid-based IL from imidazolium precursors via a two-step ion exchange process in high yield and scale and demonstrate proof-of-concept ionogels using crosslinker analogs to test the compatibility of the systems. Current efforts include synthesizing new acetal crosslinkers that are incorporated into the CNC-IL pre-solution and using Surface Enhanced Ramen Spectroscopy (SERS) to monitor OpCs penetration and degradation. This work is an evolution from previously DTRA-funded research on acrylate-based self-exfoliating polymer networks (BA12PHM123 in the “Dynamic Multifunctional Materials for a Second Skin D[MS]2” program).

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