Inactivation of Aerosolized Spores in Combustion Environments Using Filled Nano-composite Materials: Study with Two Surrogates of Bacillus Anthracis

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Bio-threat agents may be aerosolized should a bio-weapon facility be accidentally or intentionally targeted. Some aerosolized microorganisms (e.g., bacterial spores) may survive the associated heat and chemical stresses and pose a major threat. Novel halogen-containing reactive materials (referred to as Filled Nano-composite Materials, FNM) are being developed with the added capability to inactivate viable microorganisms during their release to the atmosphere. A state-of-the-art laboratory facility was designed and built in our earlier efforts to evaluate the biocidal effects of heat and various compositions released during combustion.

The objective of this research was to determine the efficiency of combustion products of existing and newly-developed materials to inactivate aerosolized spores of two well-established surrogates of *Bacillus anthracis*: *Bacillus subtilis var. niger* (also referred to as *Bacillus atrophaeus* or BG spores) as well as *Bacillus thuringiensis* (Bt spores). The spores dispersed in dry air flow were exposed for sub-second time intervals to hydrocarbon flames seeded with different reactive powders. The bioaerosol particles interacted with the combustion products in a controlled high-temperature environment. The concentrations were determined for viable spores exposed to combustion (C_{exp}) and non-exposed spores ($C_{control}$); the ratio of $C_{control}/C_{exp}$ defined as Inactivation Factor (IF) was calculated for each tested reactive material and each of the two *Bacillus* species. The tests were performed with Al powder (dispersion = 3-4.5 µm) regarded as the reference material and two novel iodine-containing FNMs, $Al{\cdot}I_2$ and $Al{\cdot}B{\cdot}I_2$, which release iodine when the base material (Al or Al·B) is melting in the powder combustion process.

The IF data are presented in Fig. 1 for BG and Bt exposed to combustion products at air temperatures of 192 to 210°C (above the iodine boiling point, 184°C). Both iodine-containing materials exhibited IFs higher than Al by two to three orders of magnitude, producing IF = 733 ($Al{\cdot}I_2$) and 2,654 ($Al{\cdot}B{\cdot}I_2$) for BG and IF = 918 ($Al{\cdot}I_2$) and 10,895 ($Al{\cdot}B{\cdot}I_2$) for Bt. The inactivation level provided by $Al{\cdot}B{\cdot}I_2$ was significantly higher than that of $Al{\cdot}I_2$ for both species. The species effect on IF was statistically significant only for $Al{\cdot}B{\cdot}I_2$. Similar tests performed at exposure temperatures slightly below 184°C also showed an iodine-enhanced inactivation although generating much lower IF-levels (because only a small fraction of the released iodine remained in the gaseous phase in the exposure chamber). Overall, the results suggest a great biocidal potential of combustion products generated by the two tested iodine-containing FNMs.

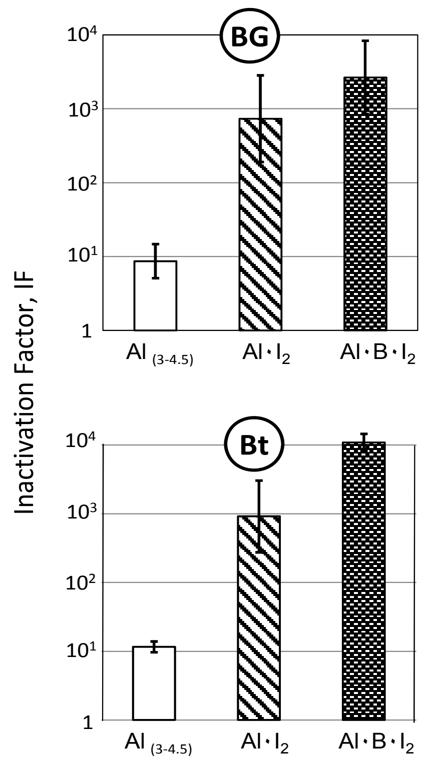

Figure 1. Inactivation factors for the aerosolized BG and Bt spores measured for $Al_{3\text{-}4.5}$ and two Al-based iodinated FNMs.

This study provided foundation for the hypothesis about a synergistic effect of dry heat and chemical products released during the FNM combustion. The heat-induced stress is considered as a tool to damage the spore protein coats and affect the spore outer membrane, cortex, and inner membrane, which, in turn, is expected to enhance the penetration of the "lethal" chemical products. This hypothesis is being tested in a separate investigation.

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