Chemical Hot Air Decontamination of Military-Relevant Materials and Sensitive Electronic Equipment using Elevated Relative Humidity

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Abstract

Funded by DTRA, Chemical Hot Air Decontamination has been shown to effectively remove chemical contaminants from a wide range of surfaces, including military coatings, polymers, fabrics, and adhesive-backed anti-skid patches using treatment times of 8 h or less with temperatures up to 170°F and up to 95% RH. CHAD treatment has also been shown to be effective for removing contaminant entrained in capillary features, where liquid decontaminants are less effective.

Chemical Hot Air Decontamination

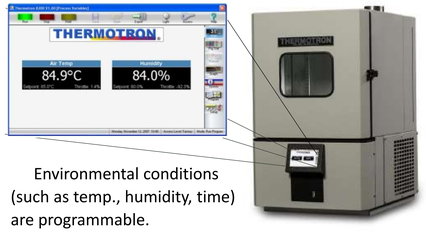
Chemical Hot Air Decon (CHAD) is the process of using heat and humidity to remove contaminants from items inside an enclosure. CHAD decontamination was conducted at a temperature of 170°F (76.7°C). Air was circulated throughout the chamber during treatment. External air was also supplied at a rate of 2 air changes/h.

Decontamination Challenge

The typical concept of operations for decontamination is to decontaminate assets after contamination occurs. In general, the faster a decontamination treatment can be applied, the more efficacy can be achieved. Given the logistics of setting up a CHAD enclosure, all experiments are performed with extended contamination aging times (~24 h) to maximize the absorption of contaminants into the substrates.

Apparatus

CHAD is applied using a Thermotron benchtop environmental chamber (model# S-1.0-8200). This unit has workspace dimensions of 14" x 8" x 14". Using standard 2" diameters test panels, up to 30 panels can be treated simultaneously.



Environmental conditions (such as temp., humidity, time) are programmable.

Humidification

Humidification of the air during CHAD has been shown to greatly increase the efficacy of the process by improving the heat transfer between the air and the contaminated substrate as well as hydrolyzing the contaminants on the surface of the materials.

Humidification is supplied as an integrated feature of the Thermotron environmental chamber. The unit can supply as much as 95% RH at CHAD temperature (76.7°C), which approximates 243 g H_2O/M^3 Air.

When CHAD begins, both the heat and humidification levels are increased. Near the end of the treatment, the humidity is reduced first, then the heat is reduced. This stepwise process reduced the likelihood of liquid water condensing on an asset, which could promote mold growth.

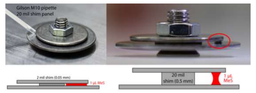
Treatment Sequence

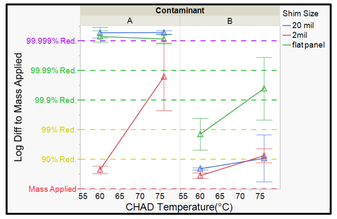
Test Substrates

The test substrates for CHAD include sorptive coatings (2), silicone elastomer, nylon webbing, adhesive backed anti-skid patch, and stainless steel as a non-sorptive control.

Complex features have also been evaluated with CHAD, where contaminant droplets can absorb into spaces through capillary action. Shim sizes of 2 mil and 20 mil were investigated.

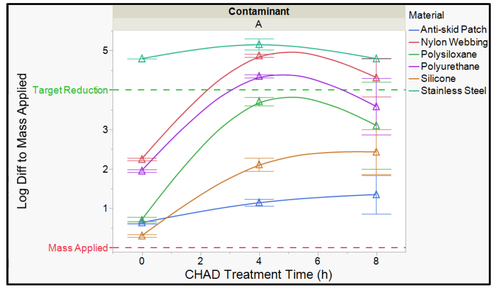
Shim Panel (pictured) developed under DTRA funded CB10409: Complex Systems



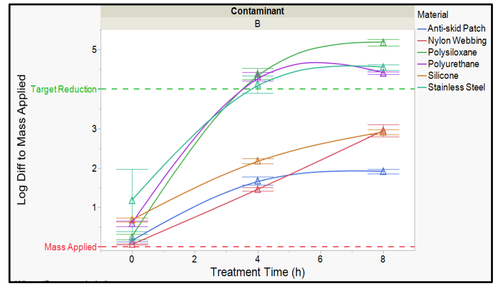


A 4 h treatment of Shim panels showed a substantial degree of contaminant removal for A at both 76°C and 60°C temperatures. The different temperatures produced a different result only for the small Shim size (2 mil). For B, higher temperature produced more removal for all tested materials including the flat panel.

Results



For contaminant A, weathering (treatment time = 0) reduced the contaminant by >1 log for 3/6 of the materials (Nylon, Polyurethane, and Stainless). Silicone, Anti-skid and Polysiloxane retained most of the contamination through the 24 h aging time. 4 h of CHAD treatment removed a significant amount of contaminant, achieving the 4-log target reduction for Polyurethane and Nylon. Additional treatment time increased the removal of the contaminant as well as variability across the replicates.



For contaminant B, a more persistent contaminant, weathering (treatment time = 0) reduced the contaminant by >1 log for only 1/6 of the materials, on average (Stainless). However, 4 h of CHAD treatment reduced the contamination for Silicone, Anti-skid and Nylon by ~2 log. 4 h of CHAD treatment removed a more significant amount of contaminant, achieving the 4-log target reduction for Polyurethane, Polysiloxane, and Stainless. Additional treatment time (to 8 h) further increased the removal of the contaminant.

Conclusions

- Chemical hot air decontamination (76.7°C with an air change rate of 2/h) effectively removes contamination from a wide range of absorptive materials, including paints, polymers, fabrics, and complex features.
- Humidity increases the rate of removal by improving the heat transfer and providing the opportunity to detoxify the contaminants (hydrolysis).
- CHAD can remove contamination from materials at lower temperatures (60°C) which may be more appropriate for sensitive electronic equipment functionality.
- CHAD experiments with increased humidity (95% RH) showed high levels of contaminant removal from substrates with treatment times as short as 4 h.

Next Steps

Sensitive Equipment may be comprised of absorptive materials and capillary features where contamination may become entrained. CHAD is an ideal decontaminant for such items because it removes contamination without the use of harsh chemicals, such as bleach or caustic. CHAD has shown the ability to remove contamination from absorptive materials and capillary features. Proof of concept studies will be performed on real assets.

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