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technical BRIEF
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SURFACE DECONTAMINATION EFFICACY STUDIES FOR CHEMICAL WARFARE BLISTER AGENTS

PURPOSE

Blister agents, or vesicants, are contaminants of concern due to their recent suspected use in the Middle East [1]. Because these agents persist on surfaces, it is critical to have effective decontamination methods. This brief provides a summary of recent U.S. Environmental Protection Agency (EPA) studies evaluating the efficacy of various decontamination methods against blister agents on surfaces. Results of bench-scale tests that assessed four decontamination solutions against three blister agents applied to building materials are discussed. This overview provides decision-makers with practical information on surface decontaminations options during a blister agent response.

INTRODUCTION

EPA is the primary federal agency responsible for remediation of indoor and outdoor areas in which chemical agents are released. Therefore, in support of EPA's mission in this area, EPA's Homeland Security Research Program conducts research to help responders and decision-makers minimize environmental impacts and human health effects following the release of a chemical agent. Limited data exist on decontamination approaches that neutralize the vesicant properties of blister agents. EPA conducted bench-scale studies to evaluate several decontaminants for their efficacy against the chemical warfare blister agents Lewisite (L), sulfur mustard (HD), and Agent Yellow (HL) (a mixture of L and HD) on a variety of building materials. Some of the studies also evaluated the formation of residual vesicant decontamination by-products that remained after decontamination.

PERSISTENCE OF BLISTER AGENTS

Sulfur mustard and Lewisite are semi- and low to moderate- persistent chemical warfare agents, respectively [2,3] with liquids on surfaces likely to last hours to days for both agents. Persistence of the neat agents is known to be dependent on material type and environmental conditions and should be considered in the overall remediation objectives. The studies in this brief measured agent amounts removed through natural attenuation processes (e.g., evaporation, degradation and other physical or chemical interactions) at 60 or 90 min following contamination and those results are reported as "No Decon".

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EXPERIMENTAL METHODS

Decontamination studies were conducted using approximately 10 cm^2 coupon materials (i.e., an excised sample) held at room temperature. For each study, a 30 min contact time between the surface material and the blister agent prior to decontamination solution application was included. Residual amounts of blister agent HD as extracted from coupons were determined by gas chromatography/mass spectrometry (GC/MS). Quantification of residual amounts of L required a derivatization step to allow detection by conventional GC/MS [3,4].

DECONTAMINATION PRODUCTS AND APPLICATION PROCEDURES

The bench-scale studies reviewed in this brief tested four decontaminants with varying contact times. All decontamination studies summarized in this brief started at 2-5 g/m^2 surface concentrations.

- Bleach (full strength): K-O-K® Regular Bleach (5.25% sodium hypochlorite; Columbus, OH) for HD decontamination testing; Clorox® (4–6% sodium hypochlorite; Oakland, California) for L decontamination testing; and Fisher Scientific sodium hypochlorite (5.65–6%; Pittsburgh, PA) for HL decontamination testing
- Dilute bleach: 1/10 dilution of Fisher Scientific sodium hypochlorite with deionized water
- Hydrogen peroxide solution - 3% (HP3%): Fisher Scientific
- EasyDecon® DF200 (DF200): prepared per manufacturer's instructions; ingredients listed in manufacturer's Safety Data Sheet that are mixed to produce DF200 include benzyl-C12-C16 alkyl dimethyl chlorides, hydrogen peroxide, and diacetin

The decontaminants were applied to building materials including wood (fir or pine plywood), clear (uncoated) window glass, galvanized metal (industry HVAC standard 24 gauge; 0.7 millimeter [mm] thickness), and epoxy sealed concrete. It is important to note that multiple studies were performed and not all combinations of material, decontaminant, and reaction time could be compared between neat and mixed blister agents.

Figures 1 and 2 show the percent of blister agent (measured as HD or L) that is removed through natural attenuation only ("No decon") and by neutralization on the surface through chemical interaction with the decontaminant. Two interaction (dwell) times (30 min and 60 min) between chemical agent on surface and decontaminant were considered.

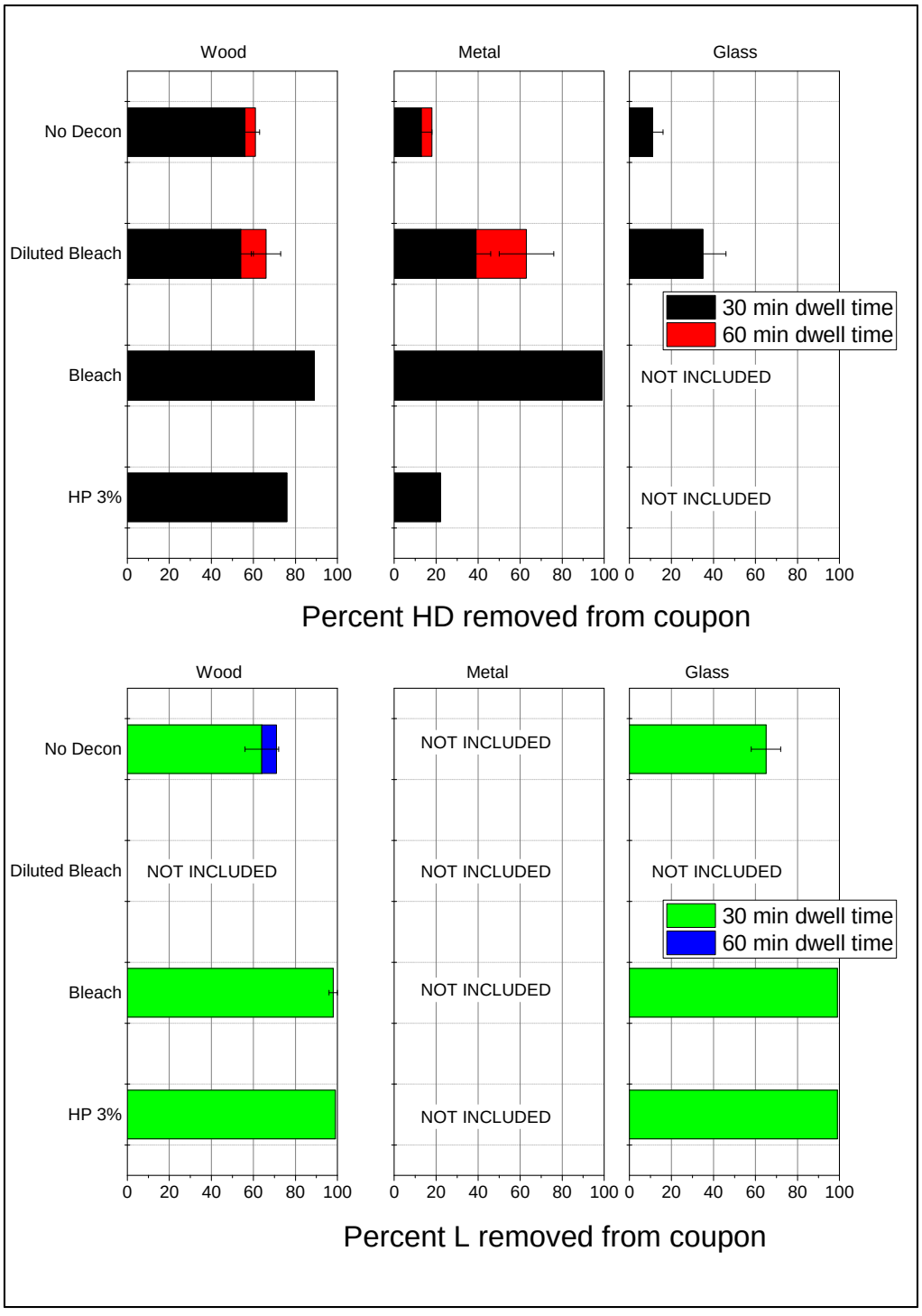

Figure 1: Natural attenuation (no decontamination activity) and decontamination solution results against blister agents on building materials for two dwell times (30 and 60 min). Top panel: HD; Bottom panel: L, when applied as neat agent. (DF200 and sealed concrete were not part of the test matrices for neat HD and L.

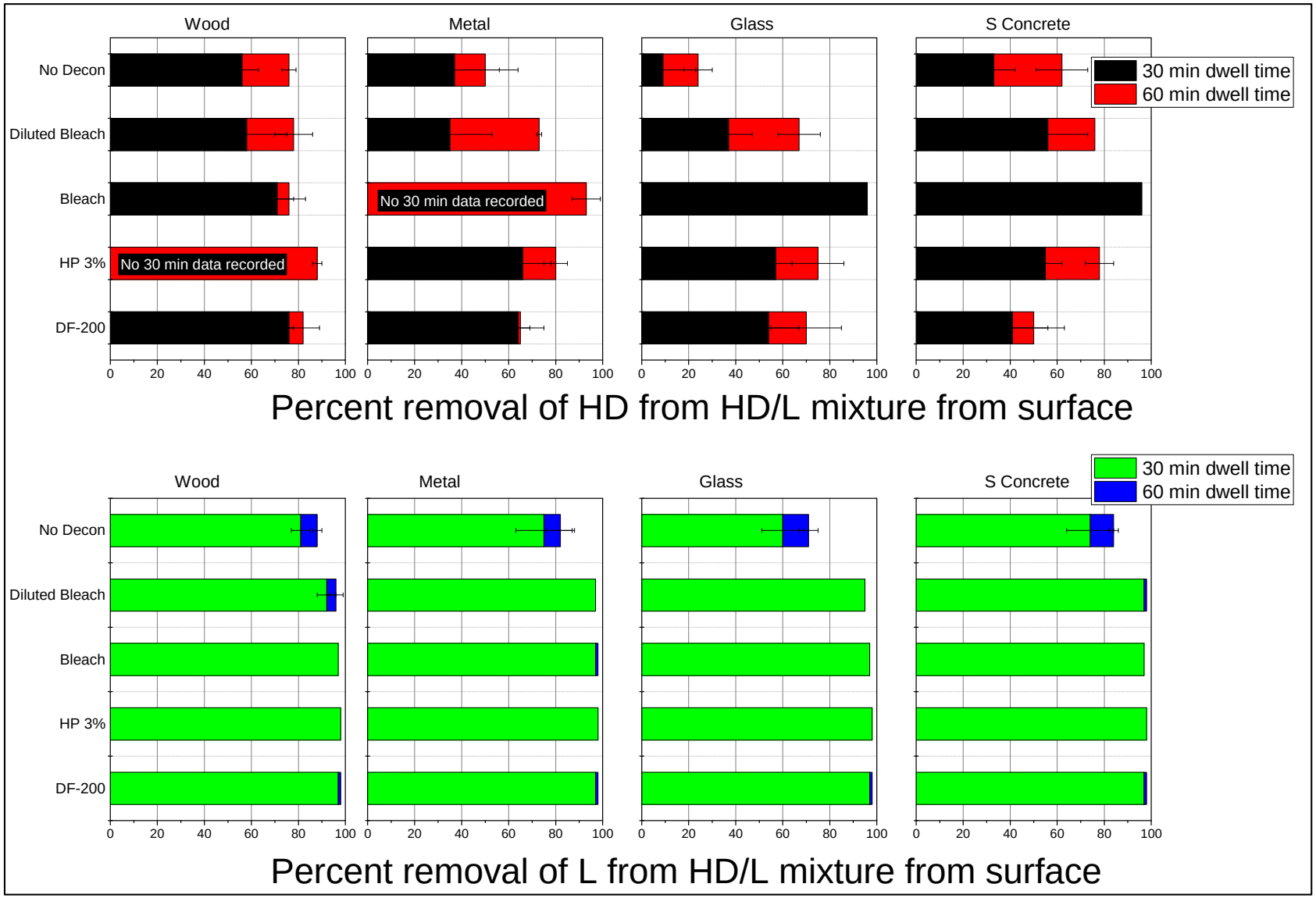

Figure 2: Natural attenuation (no decontamination activity) and decontamination solution results against blister agent mixture HL for two dwell times (30 and 60 min) on building materials. Top panel: Amounts of HD recovered. Bottom panel: Amounts of L recovered

SUMMARY

Table 1 lists a summary of surface decontamination technologies evaluated by EPA. The table reviews the decontamination efficacy findings associated with each decontaminant, and several elements that should be considered such as availability of the decontaminant, ease of use/application of the decontaminant, and material compatibility (damage such a corrosion due to application of the decontaminant). Lewisite is an organoarsenic compound. Any L degradation or attenuation will require removal of toxic residual arsenic from any surface.

Table 1. Chemical Warfare Blister Agent Surface Decontamination Technologies evaluated by EPA.

Decontaminant	Availability and Ease of Use	Findings/Results	Material Compatibility	Reference #(s)
Natural Attenuation	Requires (long term) monitoring of contaminated area. Entails less effort to implement than surface decontamination options. Personal protection equipment (PPE) required.	Amounts recovered vary with time and by material, both for HD and L with L more persistent than HD. Degradation of HD in air on the tested surfaces does not result in formation of toxic HD by-products.	No material incompatibility	2, 3, 4, 5
Bleach (full strength)	Readily available as household bleach. Relatively easy application when using low pressure off the shelf commercial sprayer; PPE required.	Full-strength bleach was the most effective of four decontaminants at reducing the amount of HD (both applied as neat and as part of HL) from coupons. Wood is more difficult to decontaminate with bleach. No toxic HD degradation products were detected. Amounts of L recovered following bleach application was near or below detection limit for L.	Showed slight discoloration (lightening) of the wood. [3] There were no other obvious visible changes to any of the coupons. [4,5]	2, 3, 4, 5
Dilute Bleach	Readily available as household bleach. Relatively easy application when using low pressure off the shelf commercial sprayer; PPE required.	Limited or no efficacy against HD from HL after a 30-min dwell time on wood, glass, and metal when compared to natural attenuation. Not evaluated for decon of neat L. Reduced recovered amount of L from HL by more than 92% after a 30-min reaction time on wood, glass, and metal. A longer reaction time did not improve efficacy appreciably. After decontamination of metal, a small amount of toxic HD	There were no obvious visible changes to any of the coupons. [3]	2, 3

Decontaminant	Availability and Ease of Use	Findings/Results	Material Compatibility	Reference #(s)
		degradation by-product mustard sulfone was detected. More residual L was observed after treatment with dilute bleach than with the other three decontaminants.		
HP3%	Readily available. Relatively easy application when using low pressure off the shelf commercial sprayer; PPE required.	HP3% did decrease the amount of HD recovered from coupons more than natural attenuation, but substantial amounts of HD remained on all materials. Toxic HD by-products (mustard sulfone) were generated by hydrogen peroxide treatment. HP3% does reduce L to levels near detection limit, both when applied as neat L and as L from HL.	There were no obvious visible changes to any of the coupons. [4]	2, 3, 4
DF200	Available from multiple sources in the U.S. Follow vendor specifications for application procedures. Can be applied as liquid and as foam (not evaluated).	DF200 did decrease the amount of HD (applied as HL) recovered from wood and glass coupons more than natural attenuation (did not decrease the amount on metal), but substantial amounts of HD remained on some materials. No toxic HD degradation products were detected. Amounts of L recovered following DF200 application was near or below detection limit for L (applied as HL).	There were no obvious visible changes to any of the coupons. [3,4]	2, 3, 4

DF200: EasyDecon®; HP3%: 3% hydrogen peroxide solution; N/A: Not Applicable

CONCLUSIONS

The effectiveness of the tested surface decontaminants was found to depend on agent, material, and decontaminant. **Table 1** summarizes findings for the four decontaminants tested: full strength bleach, dilute bleach, HP3%, and DF200. Below are additional general findings and decontamination cautions.

General Findings for HD

- An increased decontaminant reaction time (60 min rather than 30 min) resulted in increased efficacy for HP3%. Generally minimal or no impact on efficacy as a function of reaction time was observed for the other decontaminants tested.

- Only very low levels of toxic by-products were observed with the decontaminants tested. The observed HD oxidation by-product is susceptible to further degradation by hydrolysis with water and should not be a persistent hazard [2]. Formation of toxic by-products may be further reduced when sufficient decontaminant is available.

General Finding for L

- All four decontaminants were effective at eliminating L to the detection limit level from all tested surfaces.
- Decontamination of L or HL will always leave arsenic as a toxic metal on a surface, which must be dealt with as to minimize its adverse health effects.

General Decontamination Cautions

- Decontamination reaction rates are in general temperature dependent. Application of any of these decontaminants at lower temperatures, for example, are likely to result in different (lower) efficacies.
- Presence of dirt or grime can impact the performance of a decontaminant due to the possible degradation of the neutralizing active ingredient with the dirt and/or grime.
- The material that is contaminated has a significant effect on observed decontamination efficacy. The porosity of the material is likely to be an important characteristic, as in wood. Any possible reactivity of the surface material with the decontaminant may also impact the overall efficacy.
- Hypochlorite in bleach degrades over time. This should be considered in an actual response where bleach products may be applied without verification of actual hypochlorite concentration.

While EPA studies were conducted on a bench-scale, the tactical procedures for decontaminating a wide- area contaminated with blister agents are limited and knowledge gaps exist. However, recommendations can be made by extrapolating experimental findings from the lab to the field. The decontamination approach chosen for a particular surface may need to be evaluated in the field (at pilot scale or within a small zone) and refined as necessary during the course of the response until the desired effectiveness and process-knowledge is established for wide-scale applications. Additionally, decision makers will need to consider the available resources, cost, waste production, and the available waste management options before selecting a method.

DISCLAIMER

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has been approved for publication. Note that approval does not signify that the contents reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

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CONTACT INFORMATION

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