Physical Removal Options for Porous/Permeable Materials Contaminated with a Persistent Chemical Warfare Agent

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Background

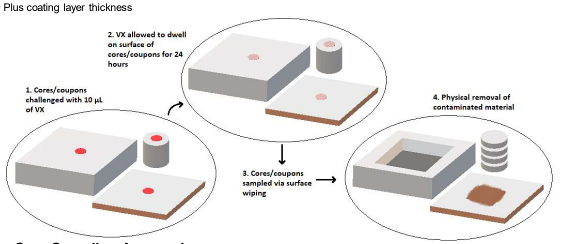
- Porous building materials and permeable coatings may become contaminated with chemical warfare agents (CWAs) that absorb irreversibly into these materials and coatings, becoming inaccessible to surface decontaminants.
- Remediation may require physical removal of contaminated materials or coatings.
- Literature searches were performed to identify technologies for physical removal of contamination that generate minimal waste and avoid irreparable damage.
- Two approaches were selected for bench-scale laboratory studies to experimentally evaluate physical removal efficacy: grinding and chemical stripping.
- Grinding involved application of an angle grinder to remove layers of VX-contaminated limestone and sealed concrete (porous materials) at successive 0.25-inch depths.
- Chemical stripper was applied to remove VX-contaminated paint (permeable coating) from low-carbon steel and hardwood.
- A method for dissection of porous materials to quantify VX depth penetration extent was also developed (referred to as the "core sampling approach").

Methods

Table 1. Physical removal methods and material types

Removal Approach	Material Type	Material Sample Dimensions
Core sampling approach	Sealed concrete	1.5"-dia. cylindrical cores (2" thick)
	Limestone	1.5"-dia. cylindrical cores (2" thick)
Grinding	Sealed concrete	5.75" L, 5.75" W, 2" thick
	Limestone	7.5" L, 7.5" W, 2.25" thick
Chemical stripping	Painted steel [A]	7.5" L, 7.5" W, 22-gauge thickness [B]
	Painted red oak hardwood [A]	5.5" L, 5.5" W, 0.75" thickness [B]

[A] Painted with an interior/exterior multi-surface white latex primer, followed by a white gloss oil-based interior/exterior paint.
[B] Plus coating layer thickness



- **Core Sampling Approach:**
  - Following contamination and post-dwell surface wipe sampling, sealed concrete and limestone core samples were dissected into discrete 0.25"-thick layer samples using a reciprocating saw equipped with a diamond-tipped blade (Fig. 1 and 2).
  - Dust created from dissection of the core samples was collected.
  - Core layer and cutting dust samples were extracted individually in isopropyl alcohol (IPA) and layer extracts were analyzed via LC-MS/MS (VR, Russian VX used as internal standard) to quantify VX and characterize the depth penetration of VX.

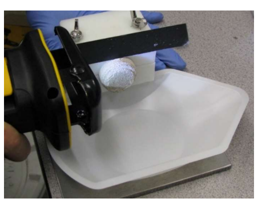


Figure 1. Saw, core sample in holder, and cutting dust collection tray.

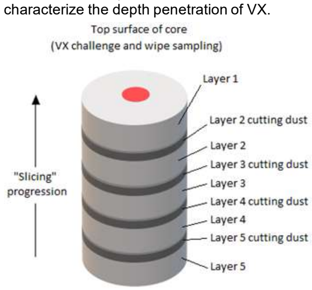


Figure 2. Core sample dissection

Methods (continued)

- **Grinding Approach:**
  - Following VX contamination and post-dwell surface wipe sampling, depth layer samples were collected from sealed concrete and limestone coupons using an angle grinder equipped with a fine-grit diamond grinding wheel (Fig. 3).
  - The grinder was applied to remove material to a target depth of 0.25" (Fig. 4) and the ground material that was removed was collected and extracted in IPA.
  - Grinding was repeated until four (4) depth layer samples were collected (1" total depth; Fig. 5).
  - Depth layer extracts were analyzed via LC-MS/MS to quantify VX and characterize the depth of VX penetration into the materials.

Figure 3. Grinder application

Figure 4. Ground limestone coupon

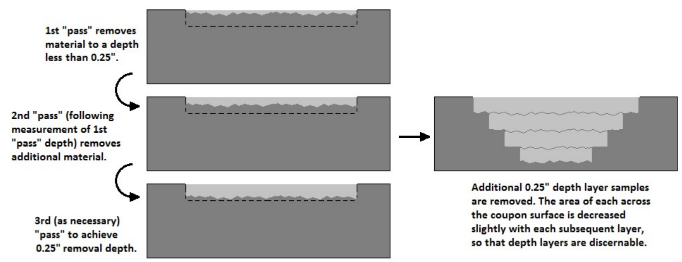


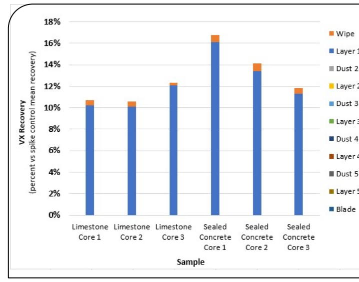
Figure 5. Approach for depth layer sample collection via grinding

- **Chemical Stripping Approach:**
  - Following VX contamination and post-dwell surface wipe sampling, a dichloromethane-based stripper (Klean-Strip® KS-3 Premium finish/paint stripper) was applied to the contaminated coupon area.
  - After 45 minutes, the coating was stripped using a plastic joint knife (Fig. 6).
  - The stripped coating was extracted in IPA and a repeat wipe sample was collected from the stripped substrate surface.
  - Wipe and stripped coating extracts were analyzed via LC-MS/MS to quantify VX and assess the efficacy of VX contamination removal through removal of the contaminated coating.

Figure 6. Coating removal

Figure 7. Coating stripped from steel

Results



Core Sampling Tests

- Average (total) VX mass recovery measured 11% (vs spike control means) from limestone cores and 14% from sealed concrete cores.
- The majority of VX recovered from the cores was obtained from the 1st layer sample (the "topmost" 0.25"-thick layer that was initially contaminated with VX).
- Next highest recoveries were obtained from the wipe samples taken from the top surface of the cores.
- Recoveries suggest that VX does not penetrate the materials past the topmost 0.25" depth (via gravity-driven diffusion), or VX becomes increasingly unrecoverable or degrades as it penetrates farther.

Figure 8 (left). VX depth penetration; mass recovery by core sample component

Grinding Tests

- Most VX recovered from porous materials via grinding was obtained in the 1st ground layer sample (topmost 0.25" of the material, to which the VX was applied).
- Recovery averaged 8.5% (vs spike control means) from sealed concrete.
- Average recovery from limestone was markedly higher at 47%.
- After the 1st ground layer sample, recoveries decreased sharply to less than 1% of control mean recovery in almost all cases.
- It cannot be discerned from the data whether lower detections in deeper layers were due to the absence of VX (i.e., VX did not penetrate past the topmost 0.25" layer), degradation of VX, or an inability to recover VX that was present.

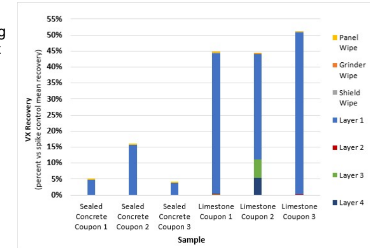
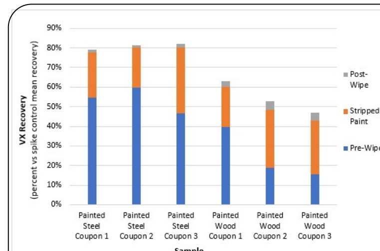


Figure 9. Contamination removal by grinding; VX mass recovery by sample component



Chemical Stripping

- Less VX was recovered from steel than from wood following removal of the coating layer by the chemical stripper.
- The majority of VX contamination was removed by the pre-stripping wipe and by removal of the permeable coating.
- Lower total recoveries from painted wood, as well as higher recoveries from post-stripping wipe, suggest that VX may have permeated through the coating layer and into the underlying permeable wood substrate.

Figure 10 (left). Contamination removal via chemical stripping; VX mass recovery by sample component

Conclusions

- Field-application of grinding to remove contamination would likely require physical removal to a greater depth than just the topmost 0.25" of material. Generally low total recoveries coupled with recoveries obtained from deeper layers from one replicate sample suggest that the depths necessary for removal of the contamination can be inconsistent and hard to predict.
- Remediation of VX-contaminated painted/coated steel via a combination of solvent wiping and removal of the coating via chemical stripping may be possible, though repeated wipes and applications of the stripper may be required depending on the necessary decontamination level.
- Residual VX contamination in porous materials such as wood could potentially pose contact or vapor hazards later if the VX diffuses back to the surface or if the material is cut, ground, or otherwise manipulated.

Disclaimer

The U.S. EPA, through its Office of Research and Development, funded and managed this investigation through Contract No. EP-C-15-002 Task Order 0020 with Battelle. This document has been subjected to the Agency's review and has been approved for presentation. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names or commercial products, or services does not constitute EPA approval, endorsement or recommendation for use.