



# Evaluation of Surface Applied Decontamination Methodologies for Partially Permeated Persistent Chemicals in Permeable Layers and Underlying Porous Subsurfaces

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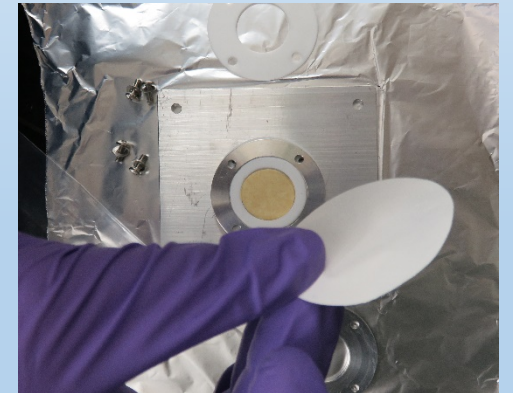
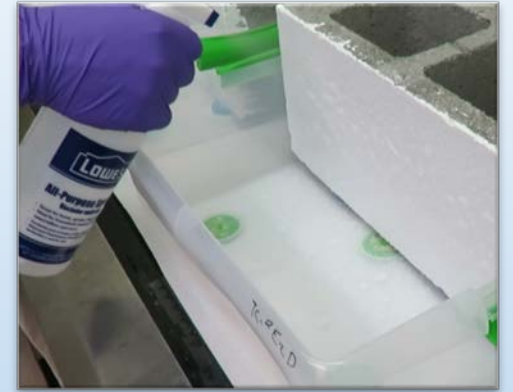
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# Background

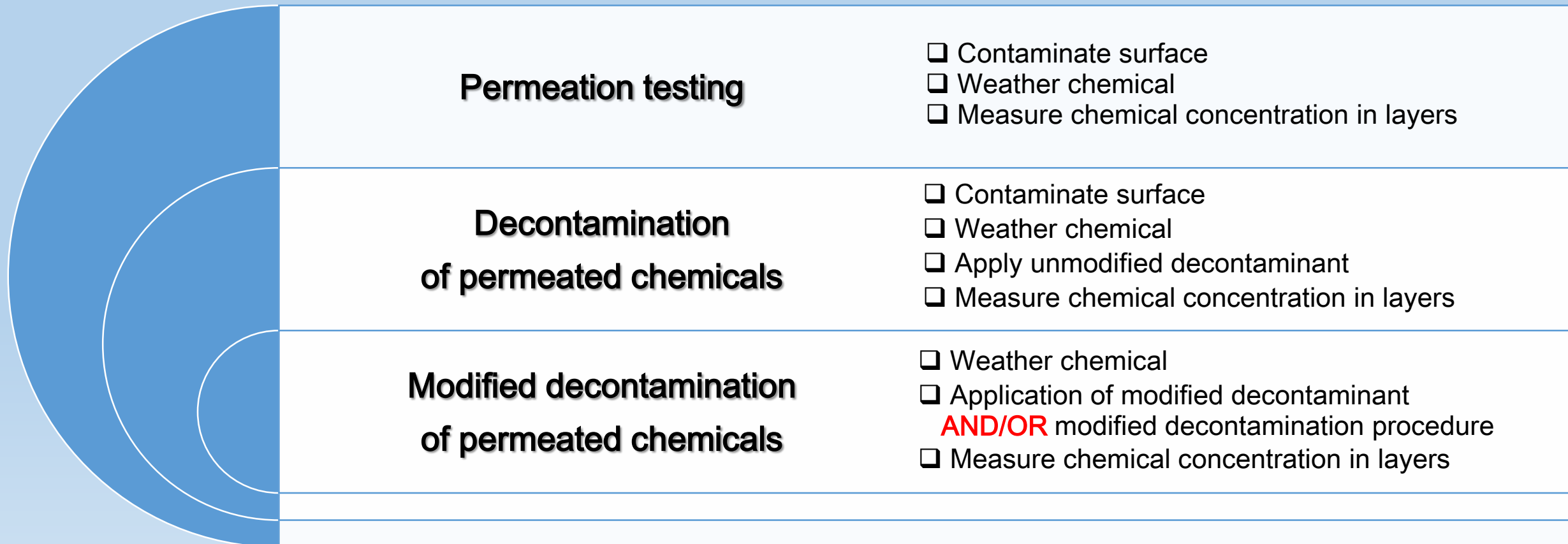
- Most *in situ* chemical decontamination technologies using aqueous decontaminants (e.g., bleach, liquid hydrogen peroxide, etc.) typically yield high neutralization efficacies for nonporous materials.
- However, decontamination procedures generally have limited efficacy if the contaminant migrates into a permeable surface or further into an underlying porous sublayer.
- This work determined the permeation of two CWA surrogates – malathion and 2-chloroethyl phenyl sulfide (2-CEPS) – into and through free standing paint (FSP) and free-standing sealant (FSS) layers placed on top of a porous solid phase extraction disk (SPE).
- Outcomes from permeation studies were used to design laboratory-scale decontamination approaches of permeated chemical using a common decontaminant (concentrated germicidal bleach)
- The results contribute to understanding on how to remediate challenging types of permeable building materials.



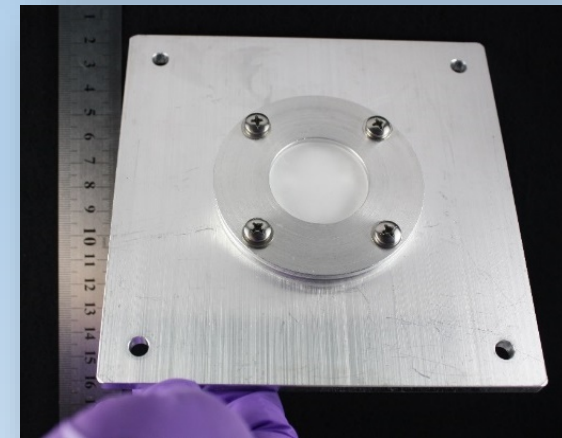
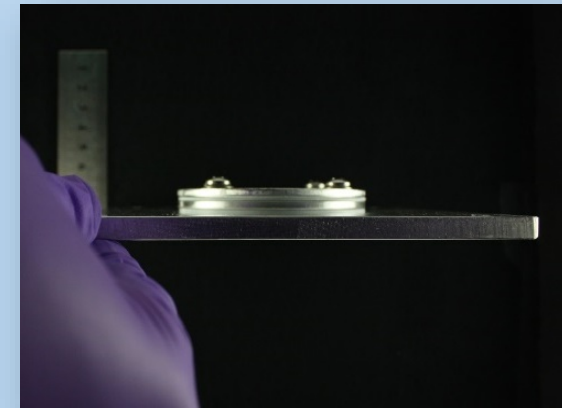
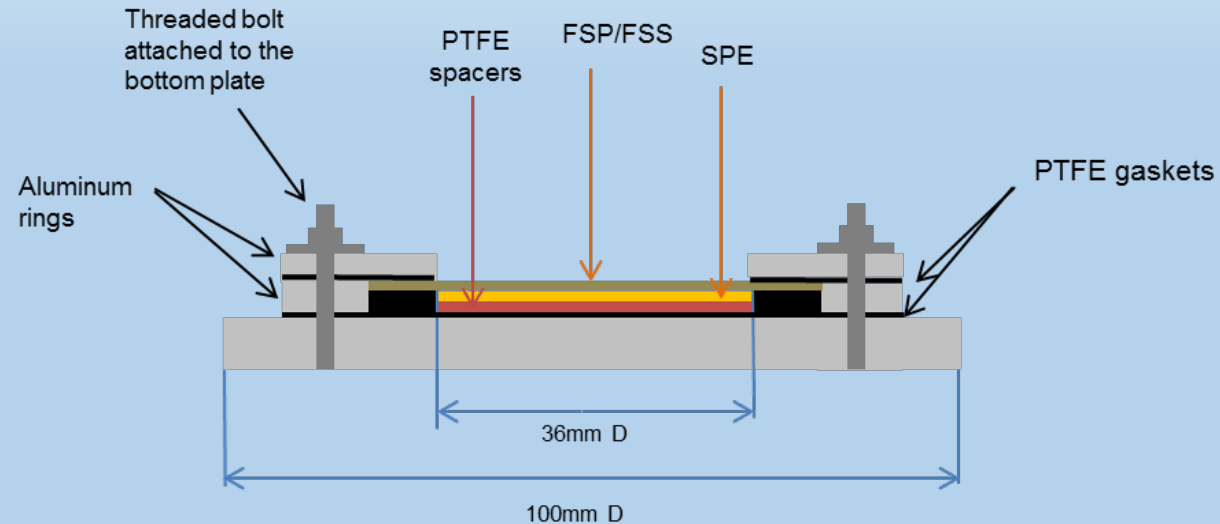
# Experimental approach

## Questions to answer:

- Do target chemicals permeate through common surface coatings, e.g., into underlying porous material?
- Can we decontaminate permeated chemicals?
- Is modification of decontamination approaches warranted for porous materials?



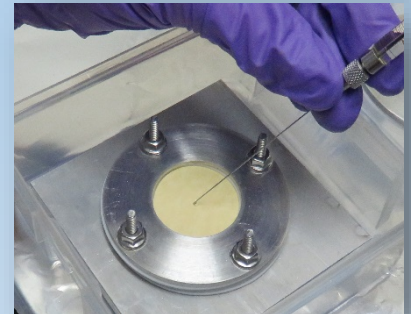
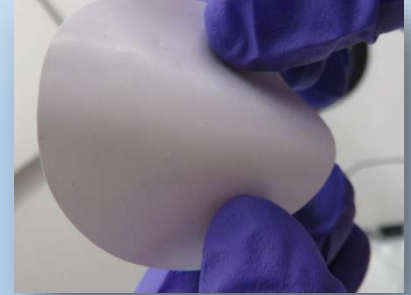
# Low volatility agent permeation (LVAP) cell



The use of this **compartmentalized system** permitted a distinct surface sampling of the top surface of a free layer of paint or sealant (FSP or FSS), followed by extraction of the entire layer, and extraction of the porous media underneath (represented by solid phase extraction, SPE disk) for assessment of the surface-specific permeation of chemicals.

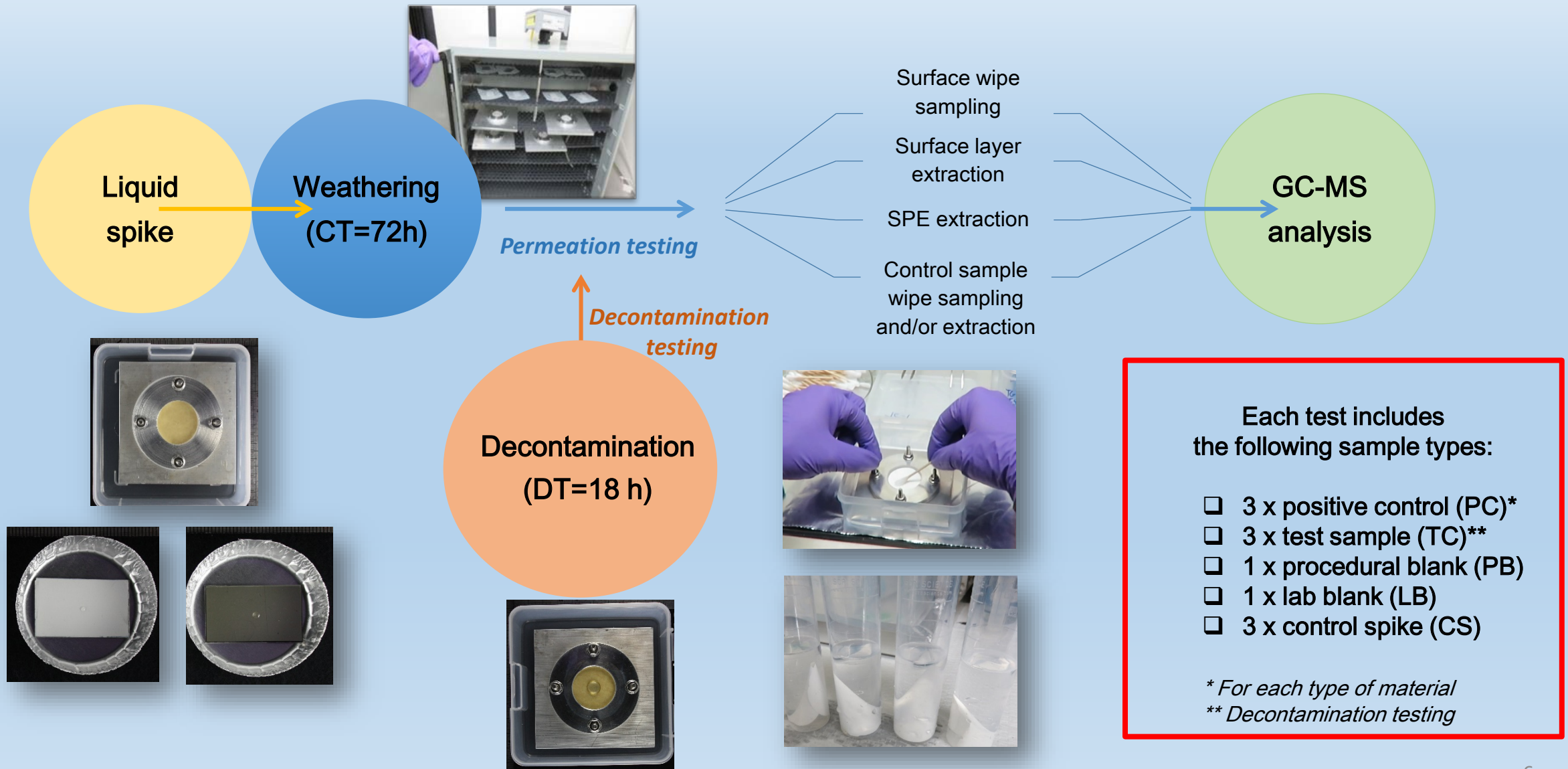
# Test design

- Two chemicals (malathion – pesticide and surrogate of VX nerve agent, 2-CEPS – surrogate of sulfur mustard, HD); applied onto surfaces using a direct liquid spike technique
- Two types of permeable surface layers (acrylic latex interior flat paint and water-based polyurethane sealant) prepared using ASTM methods; target thickness 0.051 mm (FSS) to 0.076 mm (FSP)
- SDB-XC (polystyrene-divinylbenzene copolymer) SPE disk used as a porous material surrogate
- Permeation period up to 72 hours under controlled environmental conditions ( $24^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ,  $50 \pm 5\%$  RH, 1 air exchange per hour)
- Concentrated germicidal bleach (8.25% sodium hypochlorite) used for decontamination (1 application, overnight processing, no rinse)
- Additional reference and control samples to check for non-permeation related losses, efficacy of analytical procedures (surface application of chemicals, wipe sampling, extraction and instrumental analysis)





# Process



# Information outputs

Surface layer wipe

- Chemical amount left on the surface (paint or sealant)

Surface layer extraction

- Chemical amount permeated into the (paint or sealant) layer

SPE extraction

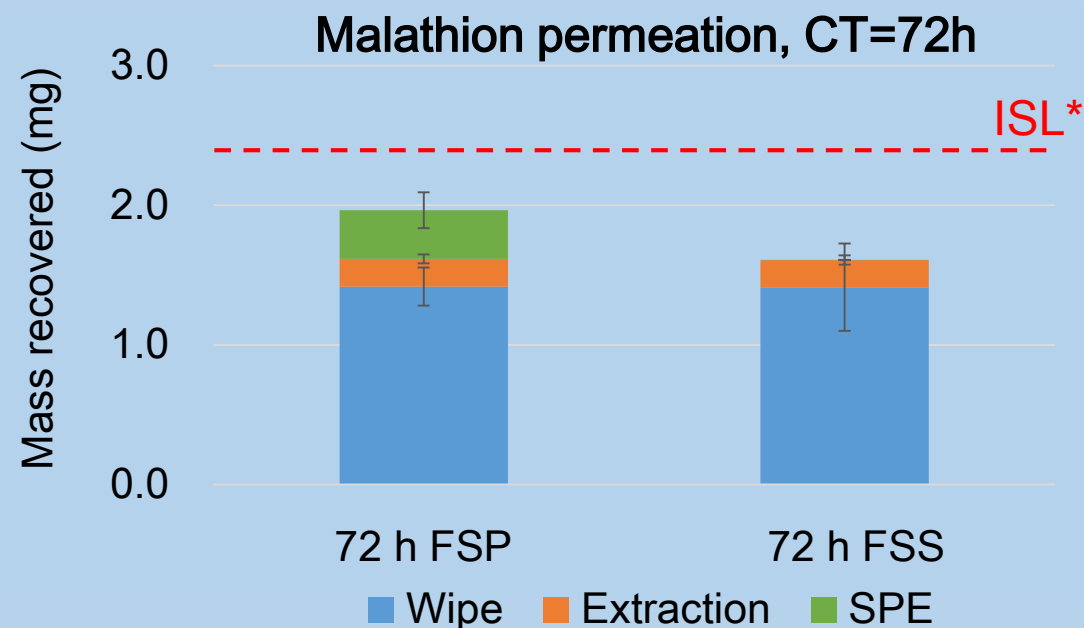
- Chemical amount permeated into the porous sublayer surrogate (SPE)

Control samples

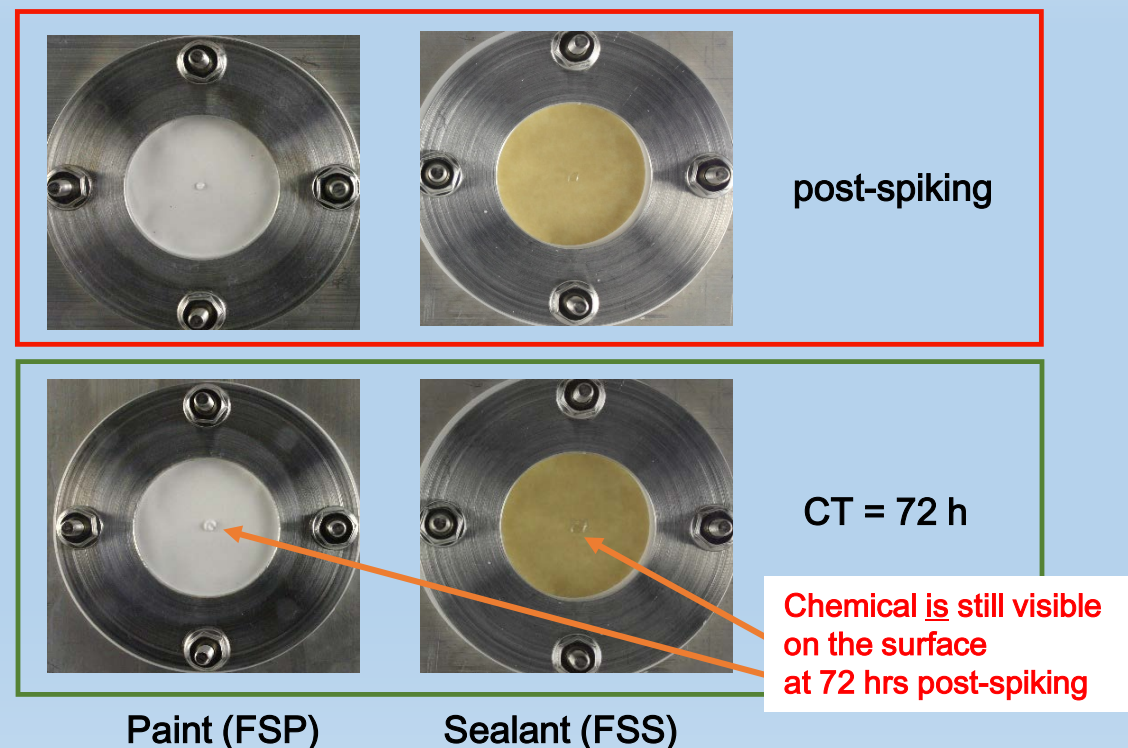
- Precision and accuracy of chemical application
- Chemical amounts for surface layers (on/in) with no porous sublayer (no SPE)
- Chemical amounts on the surface of non-porous material (stainless steel)

# Do target chemicals permeate?

Scenario # 1: Permeation transfer of less volatile (more surface-persistent) chemical; malathion  $V_p_{25^\circ\text{C}} = 0.0024 \text{ Pa}$



\* ISL - initial surface loading



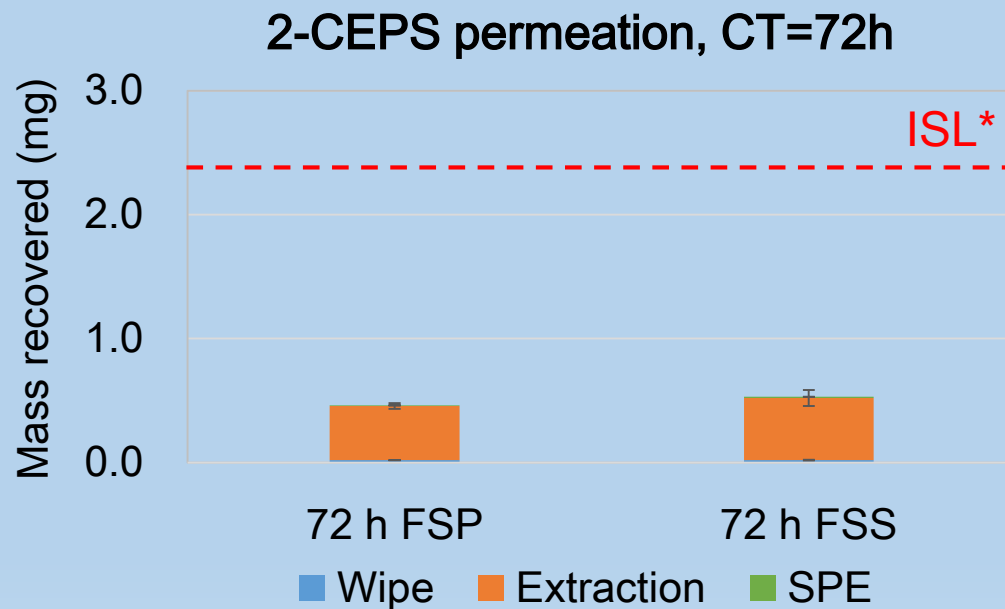
After 3 days post-application onto paint surface (contact time, CT = 72h) ~ 20% of malathion recovered was detected in SPE, ~10% in the FSP layer, and ~70% was still on the surface; the corresponding ratios for sealant were as follows: ~0.1% (SPE):10%(FSS layer):90%(FSS surface).

$V_p_{25^\circ\text{C}}$  - vapor pressure at 25°C

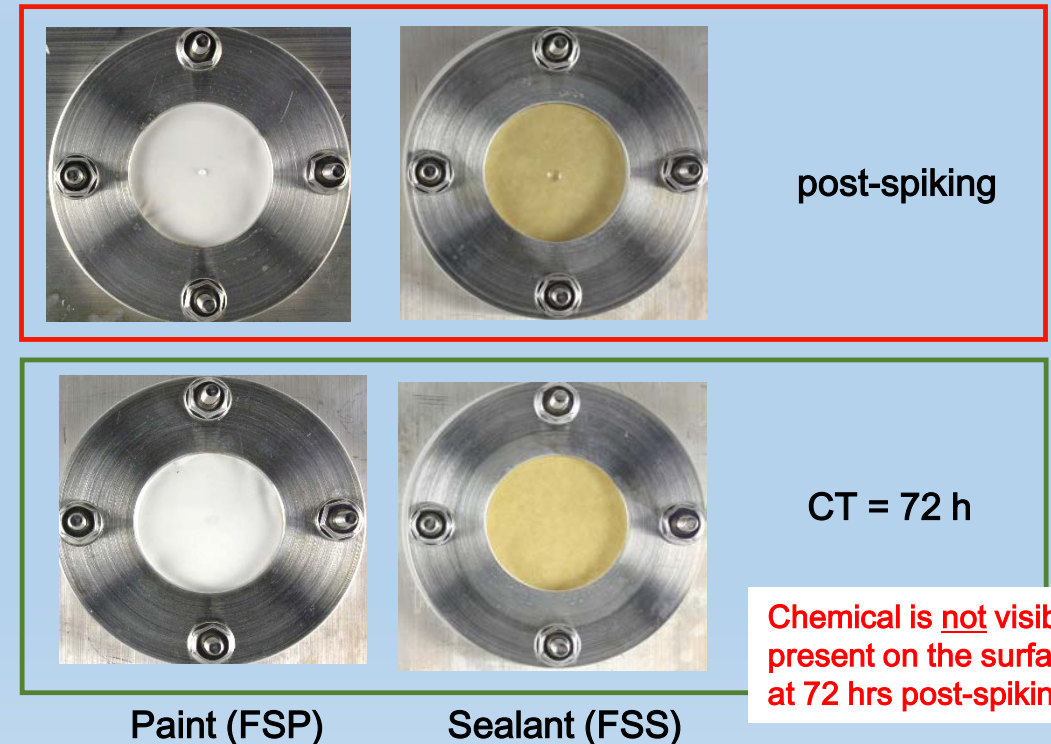


# Do target chemicals permeate? (*continued*)

Scenario # 2: Permeation transfer of more volatile (less surface-persistent) chemical; 2-CEPS  $V_{p_{25^{\circ}\text{C}}} = 2.53 \text{ Pa}$



\* ISL – initial surface loading

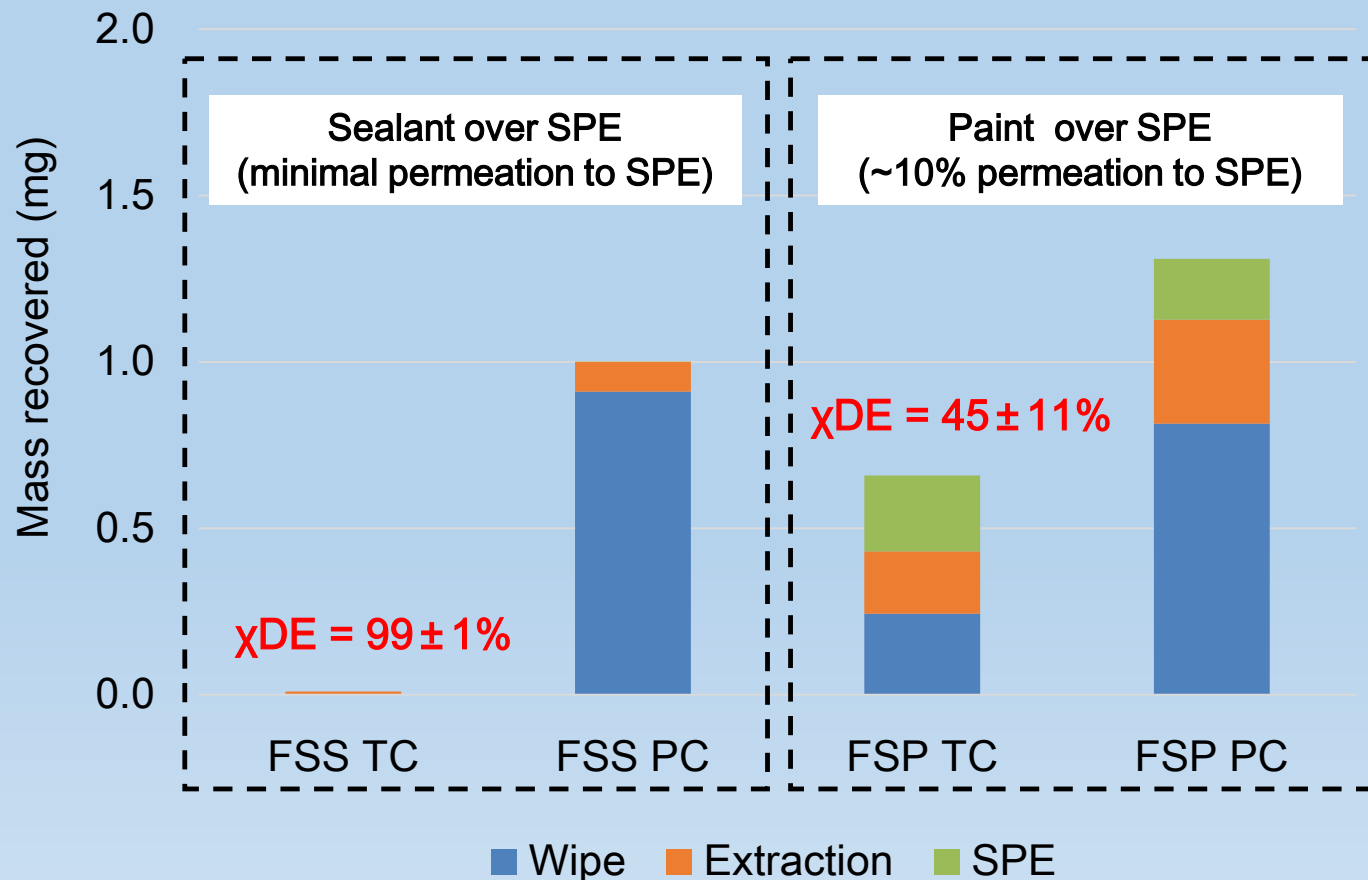


After 3 days post-application onto paint surface (contact time, CT = 72h) ~ 1 to 2 % of 2-CEPS recovered was detected in SPE, ~95% in the FSP or FSS layers, and ~4% the surface; the overall chemical recovery was < 25% suggesting that natural attenuation (due to evaporation) was occurring in parallel to permeation

$V_{p_{25^{\circ}\text{C}}}$  – vapor pressure at 25°C

# Can we decontaminate permeated chemicals?

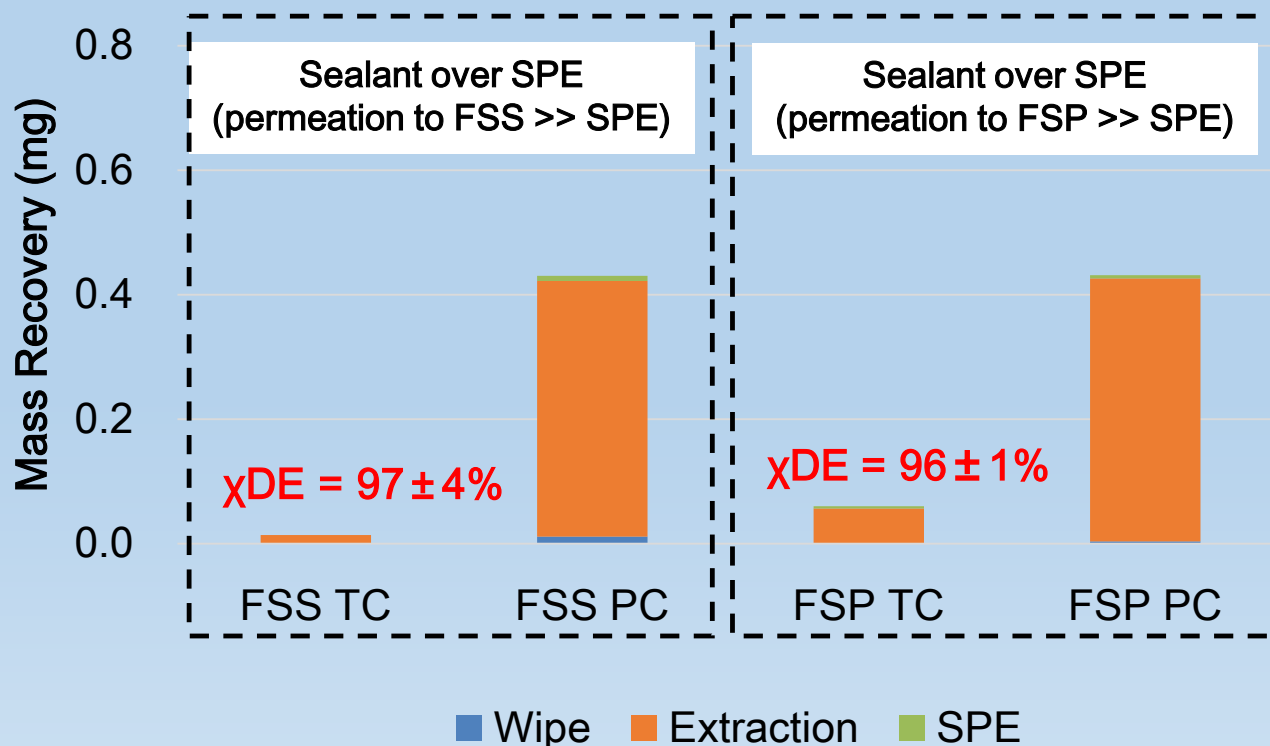
Decontamination of malathion using concentrated germicidal bleach (1 application, DT = 18h)



- Decontamination of malathion permeated (through paint layer) into SPE **was not effective when using one application of concentrated germicidal bleach (dwell time, DT = 18 h, no rinse)**
- Total chemical mass reduction of < 50% (mostly from the paint surface), compared to 99% total reduction in the sealant test for which no appreciable permeation of malathion to SPE was observed

# How about more volatile chemicals that quickly dissipate from the surface but do permeate into paint or sealant layers (and minimally to porous substrate)?

Decontamination of 2-CEPS using concentrated germicidal bleach (1 application, DT = 18h)

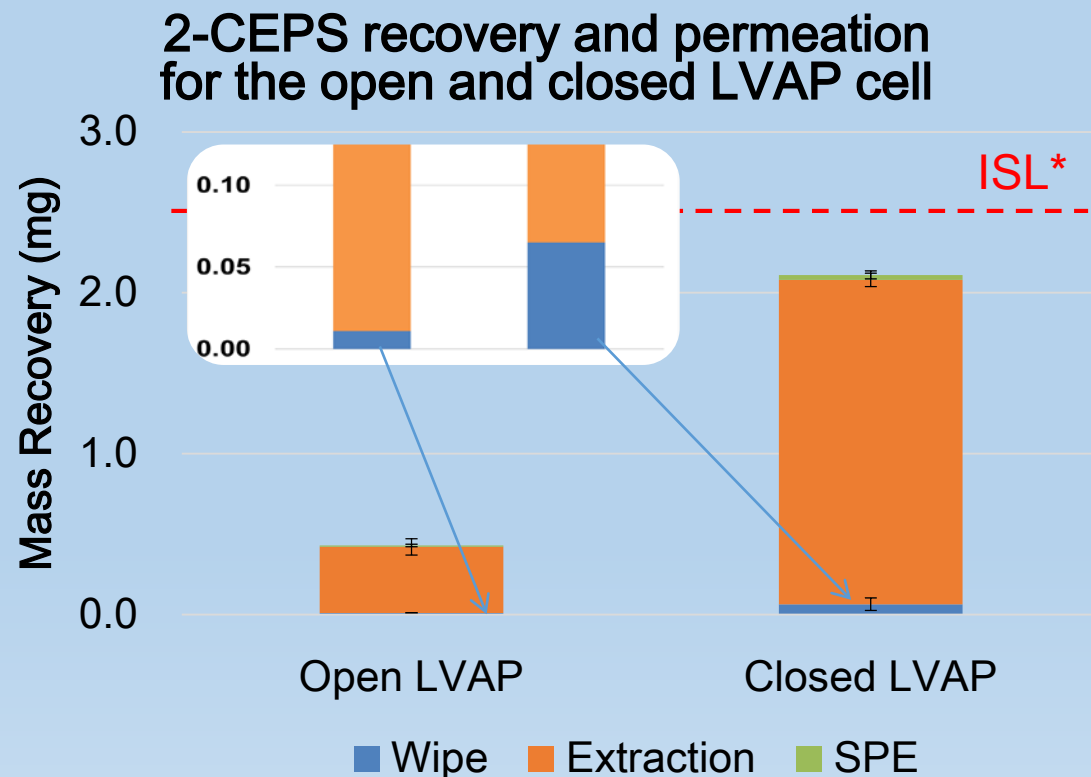


After prolonged CTs, the surface levels will be low (or non-detectable), but chemicals can be trapped in the paint or sealant layers.

- Very good overall decontamination efficacy; > 95% average reduction of the initial 2-CEPS surface loading for both paint and sealant tests
- Evaporation contributes significantly to the overall reduction of 2-CEPS. Evaporated amount can depend on air flow or volume above the surface.

# Permeation of volatile chemicals in the simulated confined space

## – preliminary results



- Special consideration should be given to decontamination conditions when the surface volatilization is limited (e.g. small confined spaces with no ventilation)
- Initial results for closed LVAP (tested only with sealant layer, FSS) suggest that for 'no-ventilation' scenario, the surface evaporation decreases, yielding good (~ 90%) total recovery of 2-CEPS and ~ 6x higher surface concentration of chemical.
- The sealant layer effectively absorbs the evaporated agent, and the relative distribution of the total permeated chemical (FSS:SPE) is similar for both closed and open LVAP systems (~ 95% and <2% of total recovered chemical was detected in FSS and SPE, respectively).

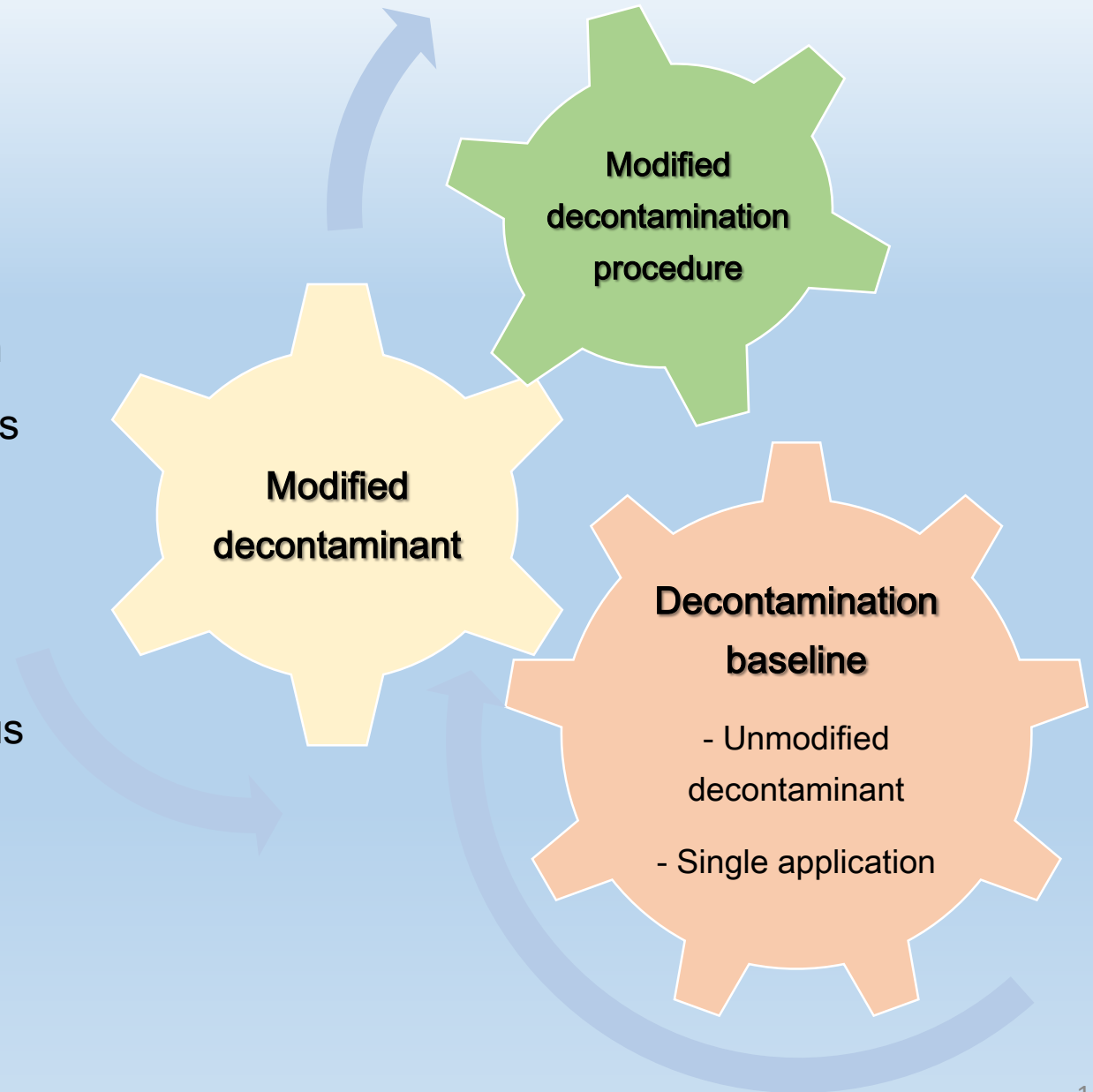
# Conclusions

- **Permeation** into surface layers and porous sublayers **is both chemical- and surface layer-type dependent**
- **Decontamination of chemicals permeated into porous substrate was not effective** when using a simple liquid-based procedure (1 application of concentrated germicidal bleach-overnight processing-no rinse)
- Therefore, **studying of different decontaminants and/or modified decontamination approaches is warranted** for chemicals that permeate to surface layers and porous sublayers
- Surface levels and permeation of chemicals can be affected by environmental conditions, therefore **decontamination approaches should be always studied in a realistic setting** that mimics potential field conditions



# Next steps

- Further investigate the efficacy of various decontamination approaches for neutralization of chemicals permeated into thin surface layers and porous sublayers, using both non-modified (no additives) and – when warranted – modified (with additives, e.g. surfactants, solvents) decontaminants applied using various decontamination procedures (e.g. with and without decontaminant re-application step).



# Disclaimer

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