US ARMY RDECOM

Laboratory to Field: Characterizing Decontamination Efficacy Through Exposure Assessments

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Outline

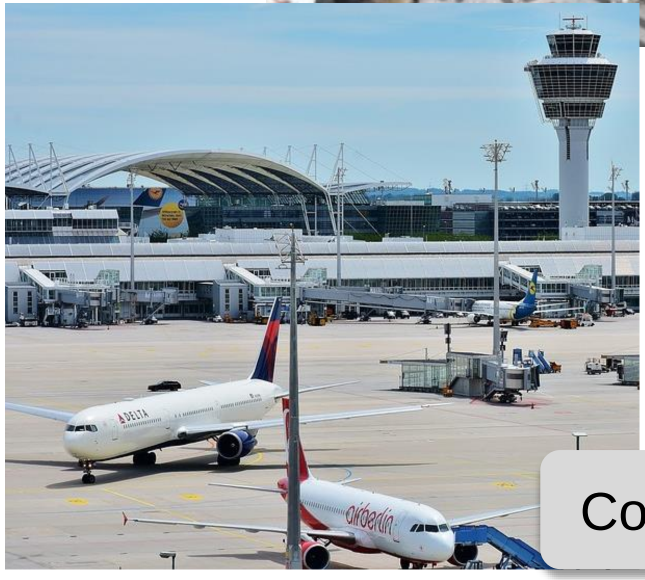
Objective: Compare the analysis of Efficacy with hazard mitigation for vapor exposure

- Identify the types of measurements to characterize decontaminants
- Demonstrate how to measure vapor source terms and conduct vapor exposure assessments
- Demonstrate correlation of efficacy to vapor source terms
- Through this process see how to progress from lab testing to understanding exposure in the field

Assessing Decontamination Efficacy Is it Clean Enough?

Example: Decontaminant with 99.7% efficacy used after chemical contamination (e.g., VX).

Would these personnel exhibit acute health effects during their mission if their vehicle, weapons, and radios were just decontaminated?



Could you return an airport to use?

Purpose of Measurements

Metric	Objective	Measurement & Analysis	Context
Material Efficacy 1- (How much Agent Remains after Decon) / (How much Agent you Started With)	Removal of Agent from a **Material**	Material Extraction 99.9% Efficacy!	**Laboratory** GD on CARC Panel
Health Effects Do not Exceed Health Effect Toxicity Levels e.g., toxicity levels: IDLH, AEGL 3 (4 hr, 0.0052 mg/m^3)	Returning asset to use will produce no negative health effects	• Measure source terms • Perform exposure assessments	**Operational**

GD on CARC Panel

Source Term Scale-up

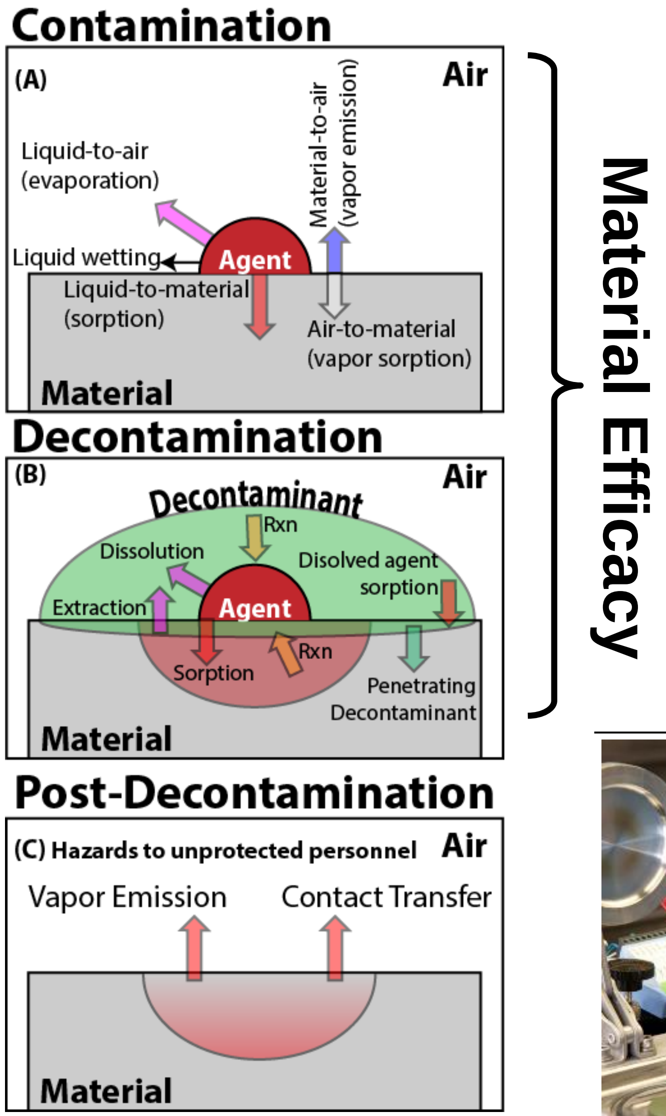
Exposure Assessment

What is the correlation of efficacy to preventing health effects?

How clean is clean enough?

…it depends on what you want to do with the decontaminated materials.

Challenges with Material Decontamination: Transport Limited Rates



- Longer duration contamination allows more absorption
- The decontaminant should remove the absorbed agent from the material to minimize vapor emission or contact transfer
- The decontamination process is rate limited by agent transport to the material surface, or the ability of the decontaminant to penetrate the material*
  - The rate limiting process is the primary difference between liquid reactor efficacy (reactivity) and material efficacy (transport)**

Vapor Test

Output: Vapor Source Term (mg agent m^{-2} min^{-1})

Enables health effect analysis

*Varady et al., *Ind. Eng. Chem. Res.*, **2016**, 55 (11), pp 3139

**ECBC-TR-1383 (available at www.dtic.mil)

Testing to Vapor Requirements

'Asset' in test chamber

Vapor Concentration (mg/m^3)

Measure Concentration in Test Apparatus

Decon Testing

Measure Source Term

Exposure Assessment

Dose ($mg\ min\ /m^3$)

ASTM D5116 shows that chamber concentrations ≠ exposure concentrations

Health Based Evaluation

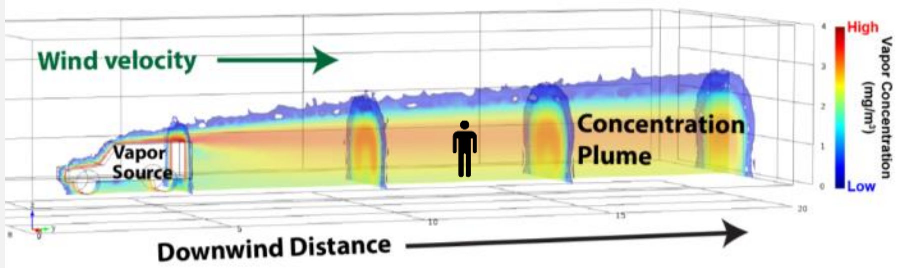
Vapor Concentration (mg/m^3)

Assume exposure duration

Toxicology Requirement

Health effect for specified population

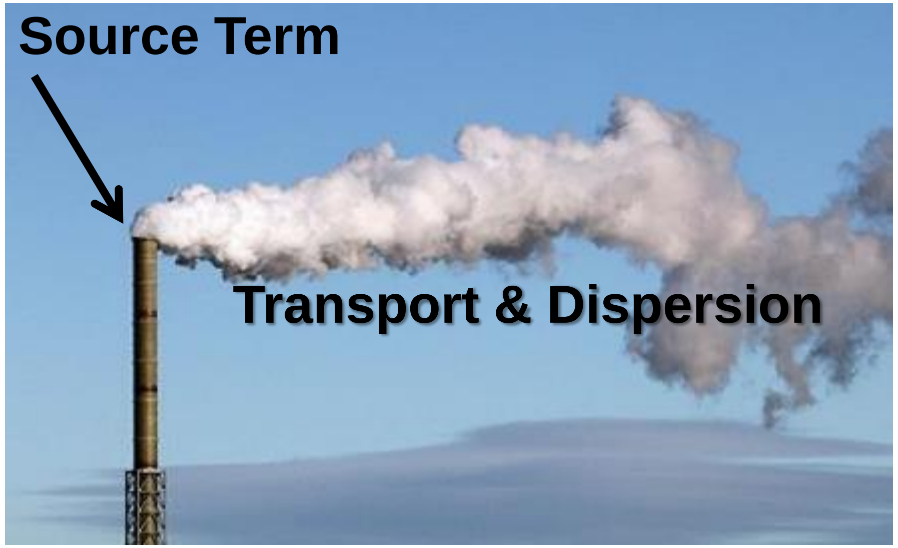
Dose ($mg\ min\ /m^3$)



Missing Component for 'Clean Enough?'

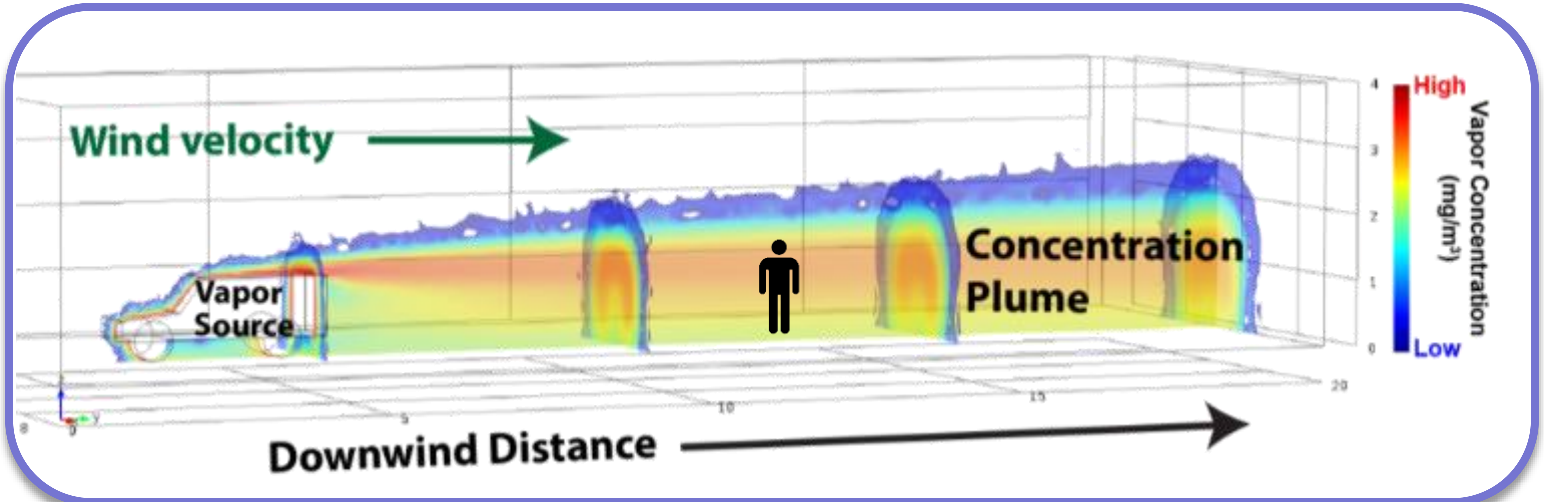
-Context of asset(s) in a specific environment

Vapor Source Terms & Dispersion Models



- The vapor source term is a description of how chemicals are introduced into an environment determined by testing* or modeling**
- Exposure is a result of how source terms are carried from asset to personnel via *transport & dispersion* in a vignette

Vignette – Description of environment, asset, and personnel during mission

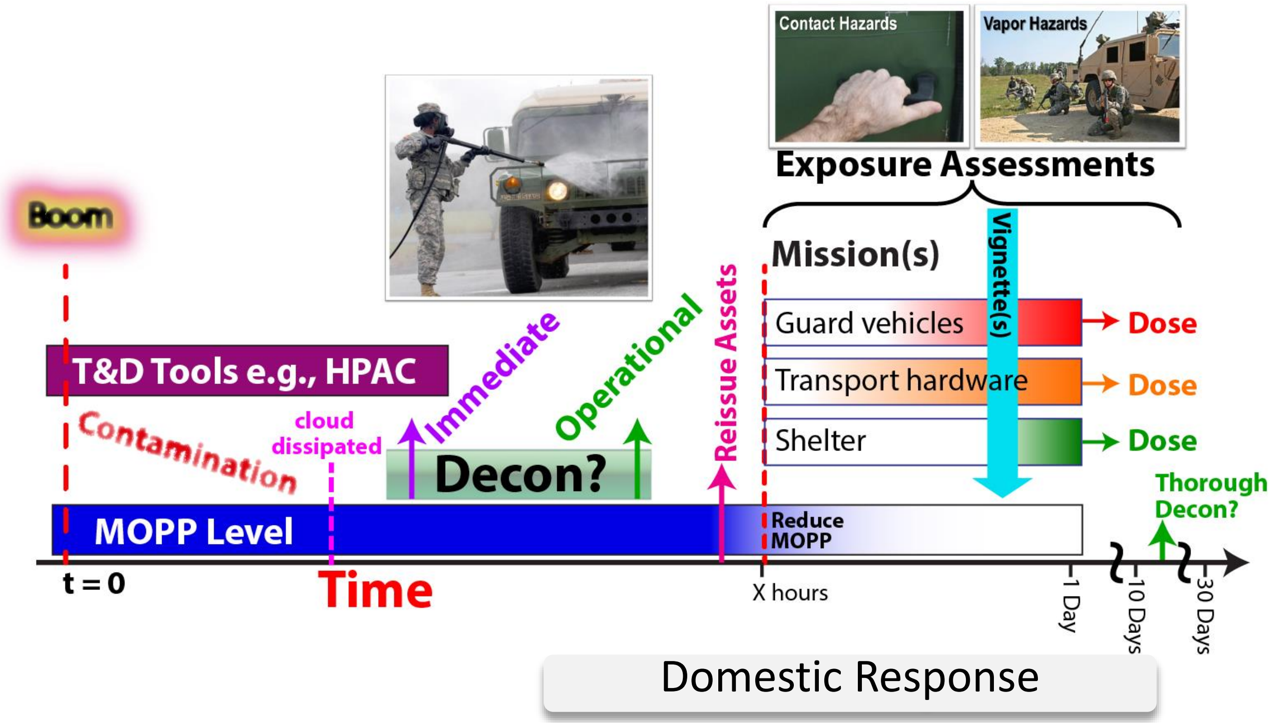


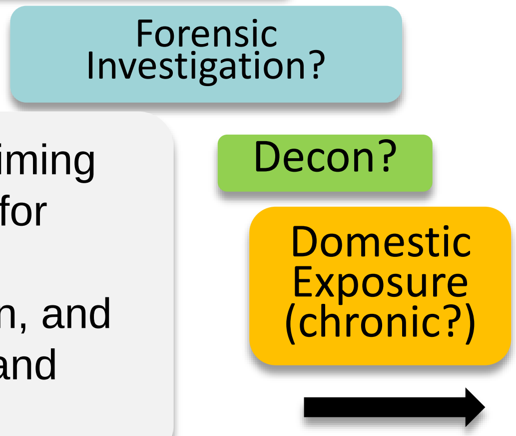
Vapor Source	Industrial - Smoke stack	Military - Vehicle
Source Emission Rate	1000 g/min H_2O	1 mg/min VX from vehicle
Source Flux (rate/area)	1 g m^{-2} min^{-1}	Paint: 1×10^{-3} mg VX m^{-2} min^{-1}

*ECBC-TR-980 (available at www.dtic.mil)

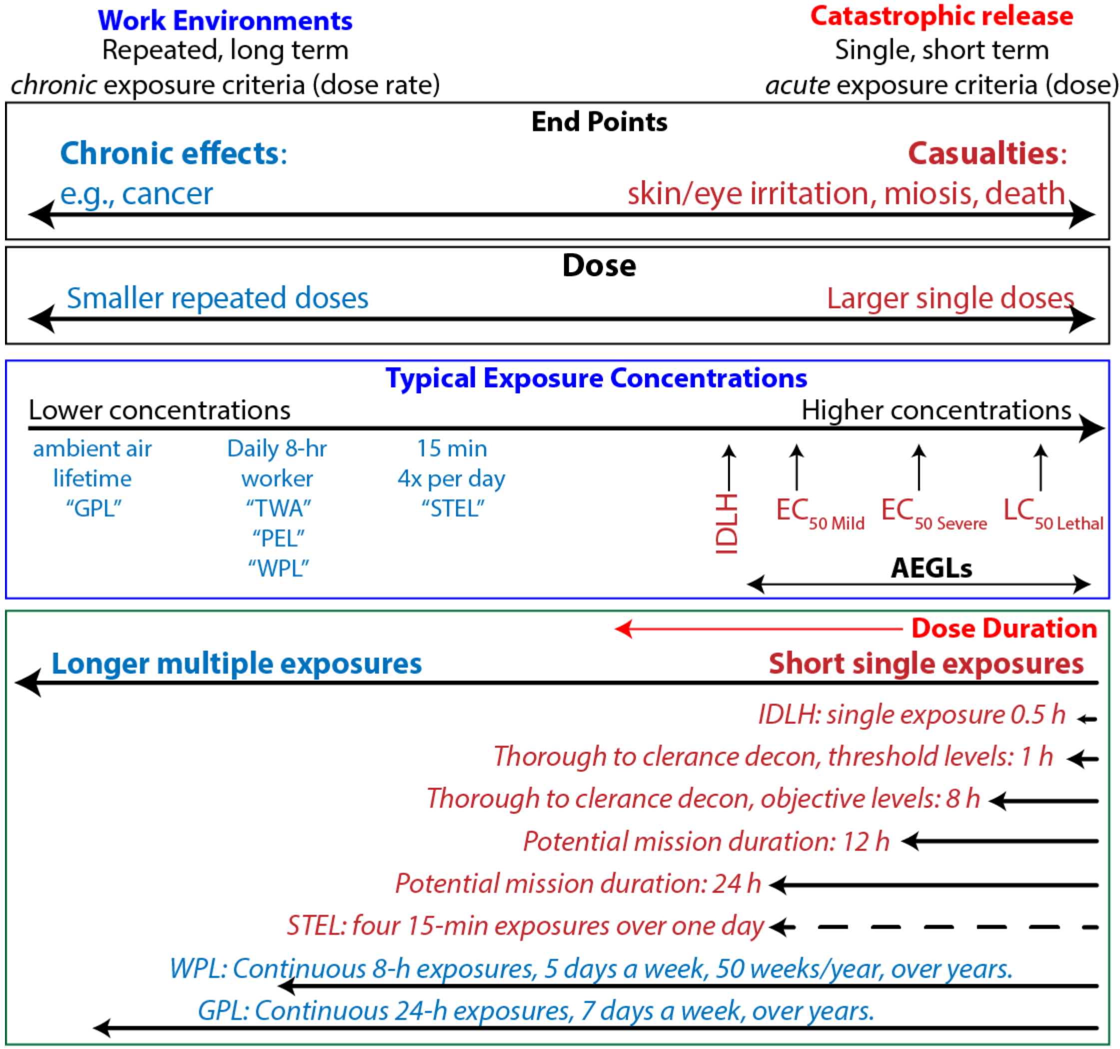
Varady et al. *Ind. Eng. Chem. Res.*, **2017, 56, 10911

Exposure Durations: Acute Through Chronic





- Toxicological endpoint of interest drives timing and approach to collecting source terms for exposure assessment
- Timing of contamination, decontamination, and exposure significantly influence efficacy and source terms



Focus: Asset/Material vs. Personnel

Communications

Vehicles

Fixed Sites

- Material Efficacy (e.g., 99.9%) focuses on a material response in a laboratory context
- Typically, decontamination assessments have focused on evaluating individual assets to toxicology-based levels
- Health effects result from the **aggregate dose** due to interacting with **all** contaminated materials in a vignette during the mission
- **Exposure** is a function of how *personnel interact* with all *contaminated items*
- **Key Change**: Move focus from assets to how personnel interact with multiple assets in the context of their use of the assets
- For simplicity, next demonstrations will focus on a single asset

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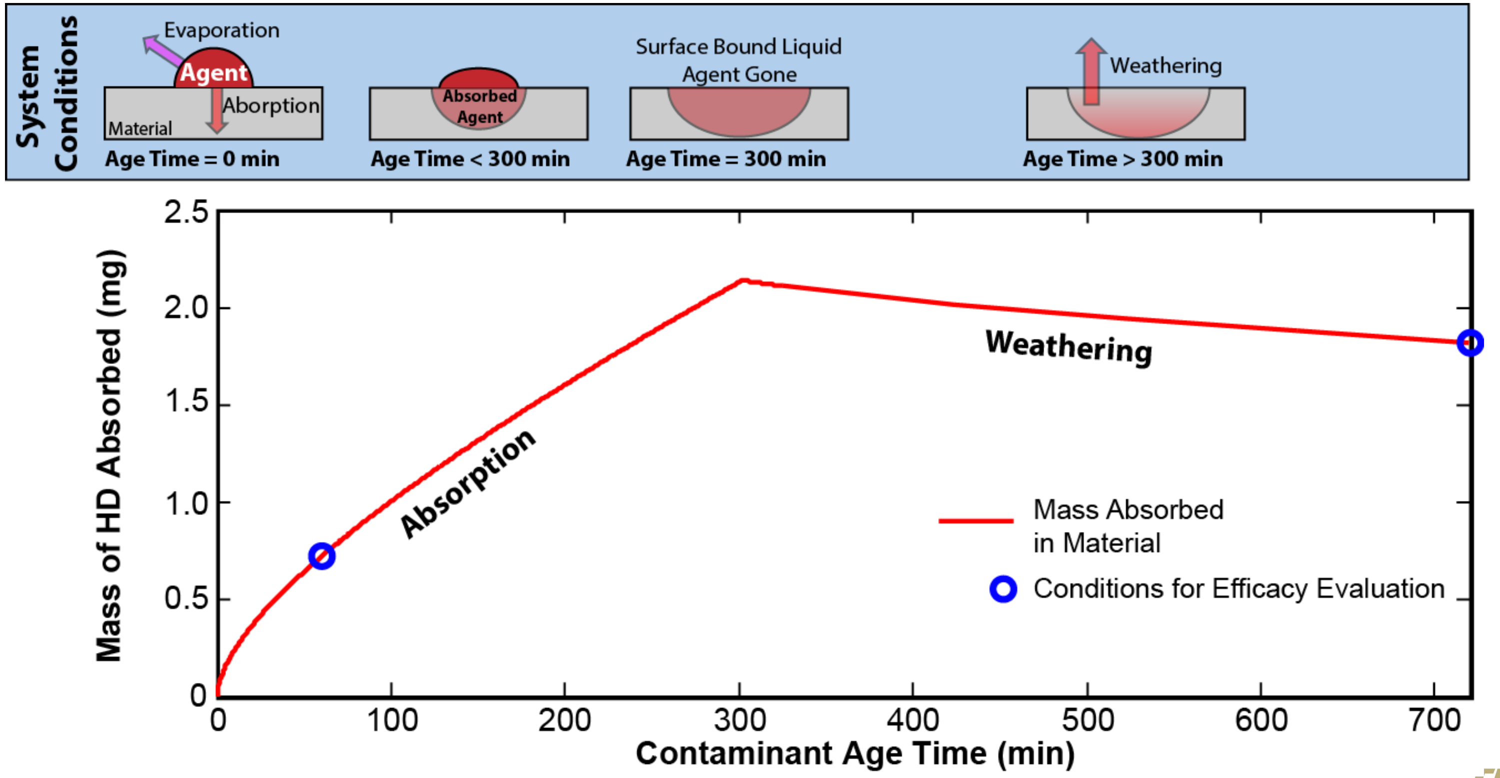
Efficacy – The Material Perspective

Agent: HD, 1 x 2 µL droplet applied to material (2.8 mg HD)
Contamination Age Time: 1 h, 12 h duration
Material: Polymer
Decontamination: Soapy Water Wash and immerse panel in decontaminant for 30 min

Contamination Duration establishes the *initial condition* for the agent distribution and how much agent is absorbed



Material Efficacy

$$1 - \frac{\text{How much Agent Remains after Decon}}{\text{How much Agent you Started With}}$$

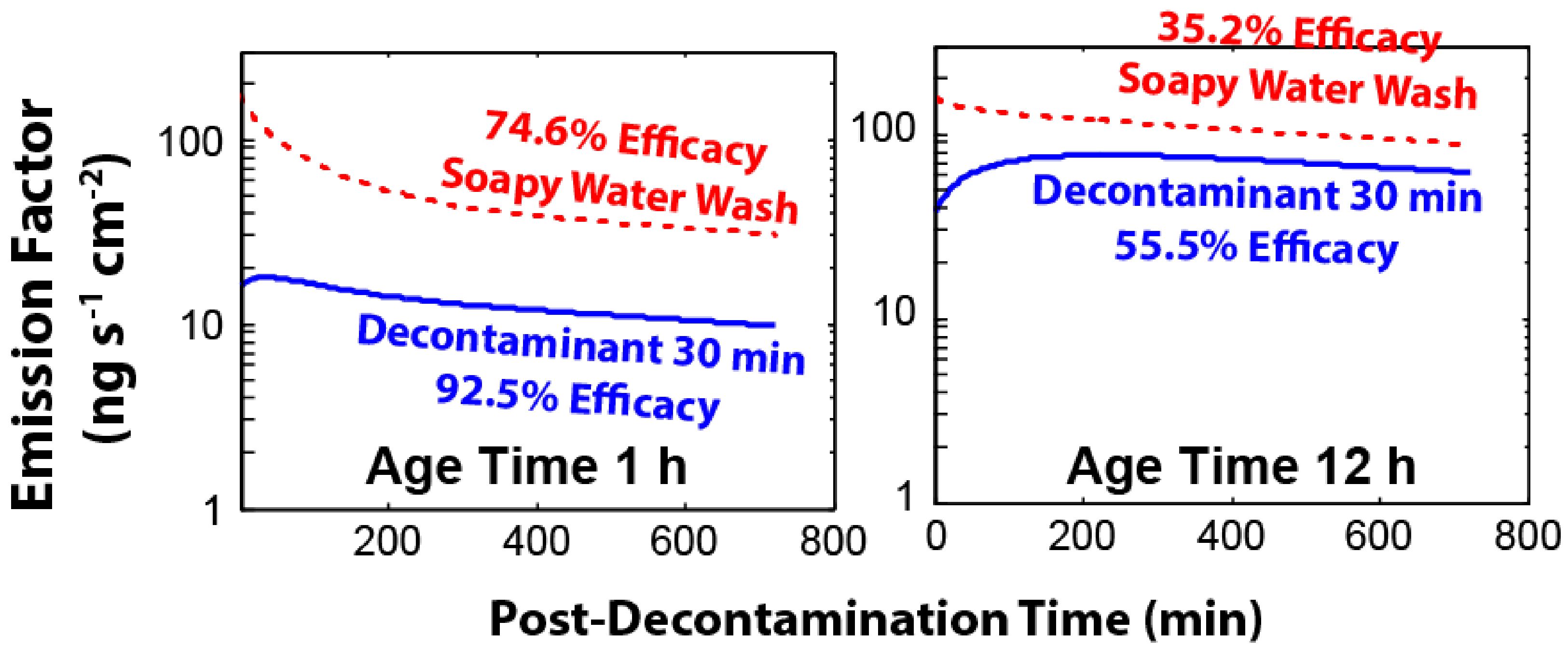
Applied Mass: 2.8 mg HD

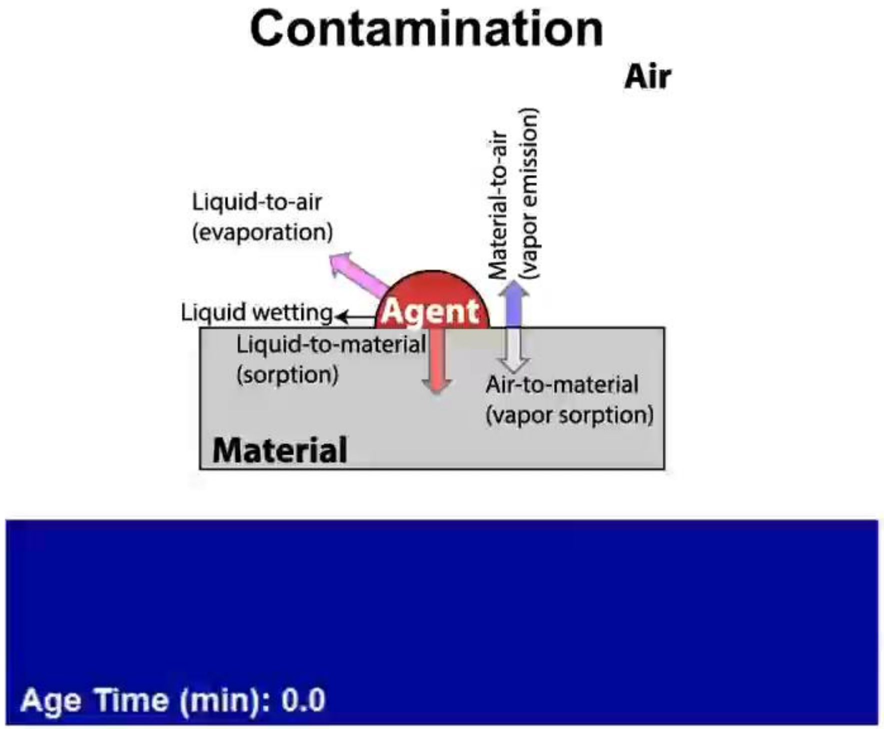
	Soapy Water Wash	**Efficacy**
1 h	0.712 mg HD	74.6%
12 h	1.815 mg HD	35.2%

	Decon 30 min	**Efficacy**
1 h	0.208 mg HD	92.5%
12 h	1.245 mg HD	55.5%

Efficacy vs. Vapor Source Terms

- Efficacy changes with age time and indicates how much agent remains
- Vapor source term **magnitude** and **time evolution** are influenced by the **distribution** of the agent in the material





From Testing To Health Effects: Source Term Measurement

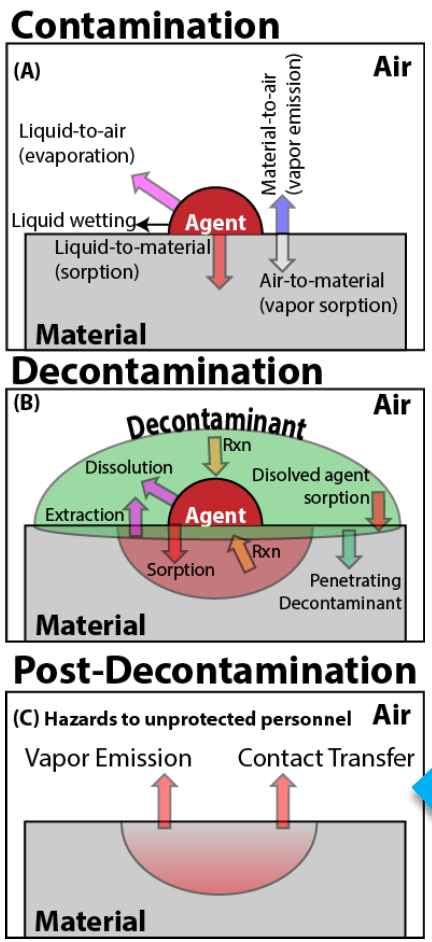
Test Methods
TOP 8-2-060
ECBC-TR-980

Testing: Measure Source Terms

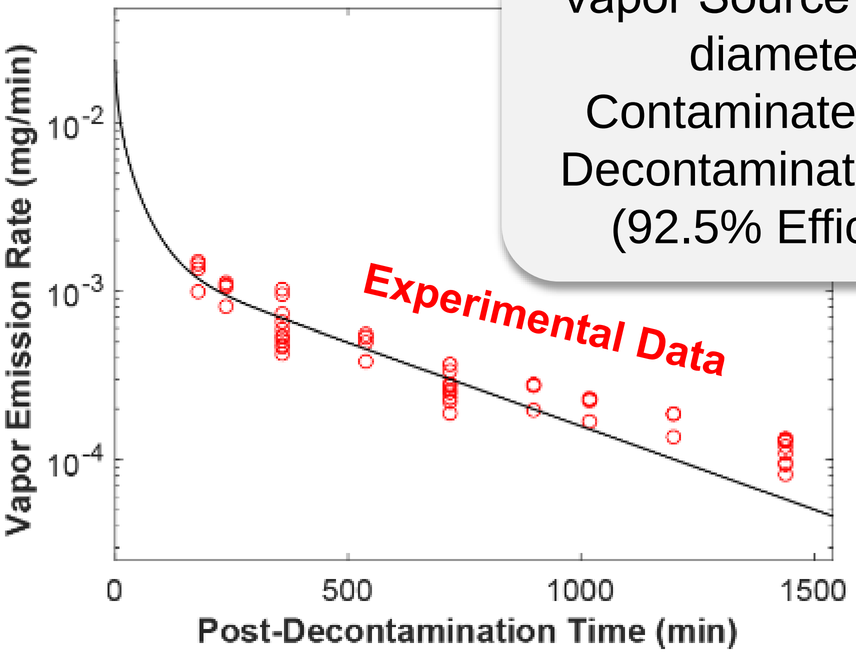
Source Term → Source Term Scale-Up → Transport & Dispersion Modeling → **Dose** → **Operational Health Effect**

Toxicity value → **Operational Health Effect**

Vignette → Transport & Dispersion Modeling



Vapor Microchamber



Vapor Source Term for a 2” diameter panel
Contaminated for 60 min
Decontaminated for 30 min
(92.5% Efficacy Case)

Scaling Laboratory Data

TOP 8-2-060
TOP 8-2-061
SD2ED (ECBC-TR-980)

Source Term → Source Term Scale-Up → Transport & Dispersion Modeling

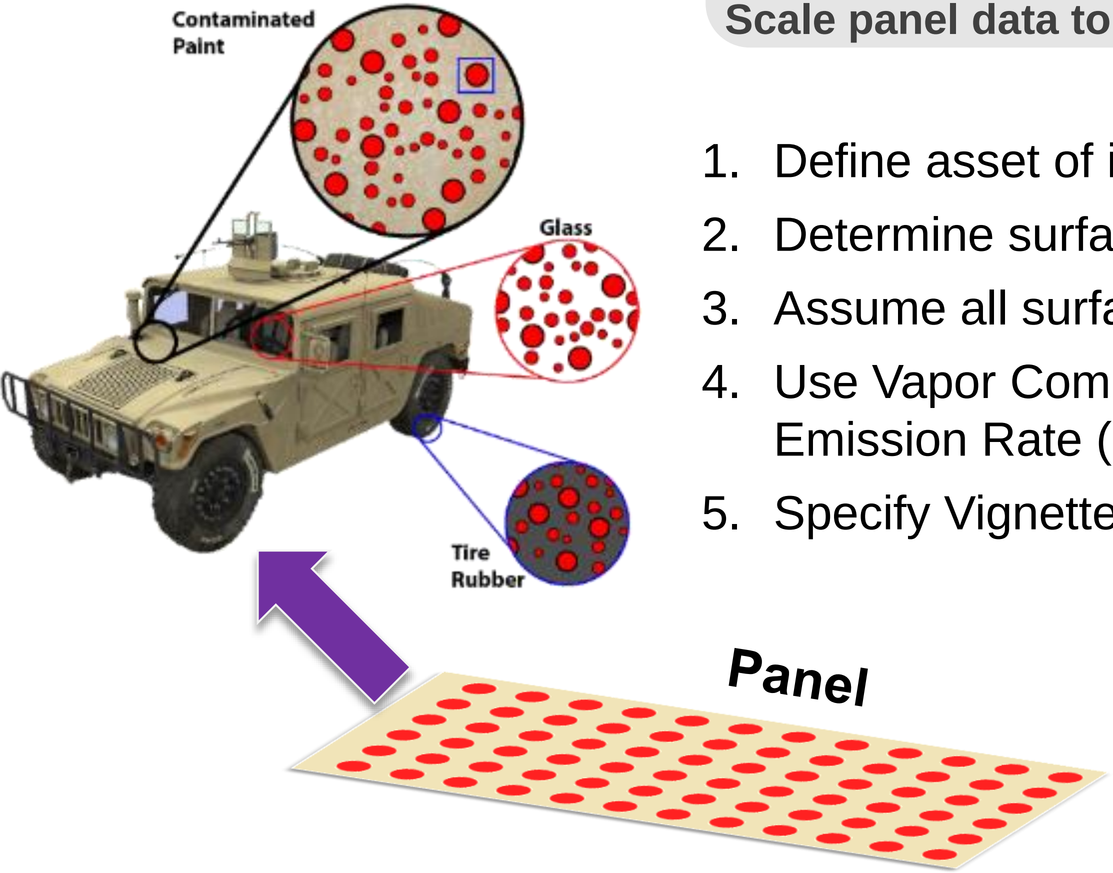
Scale panel data to Assets

Vignette

Toxicity value

Dose

Operational Health Effect

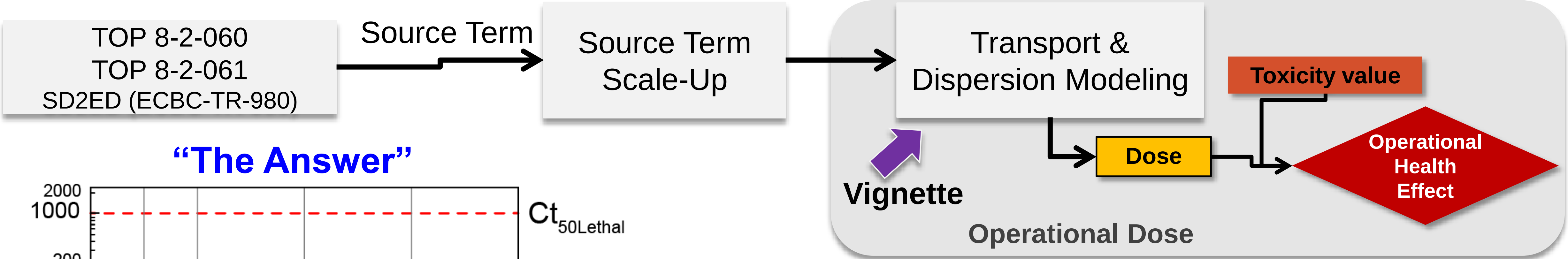


1. Define asset of interest (HMMWV)
2. Determine surface area of each material on HMMWV
3. Assume all surface area is contaminated to 10 g/m^2
4. Use Vapor Composite System Calculation in TOP 8-2-060 to calculate Asset Emission Rate (ER_{Asset})
5. Specify Vignettes

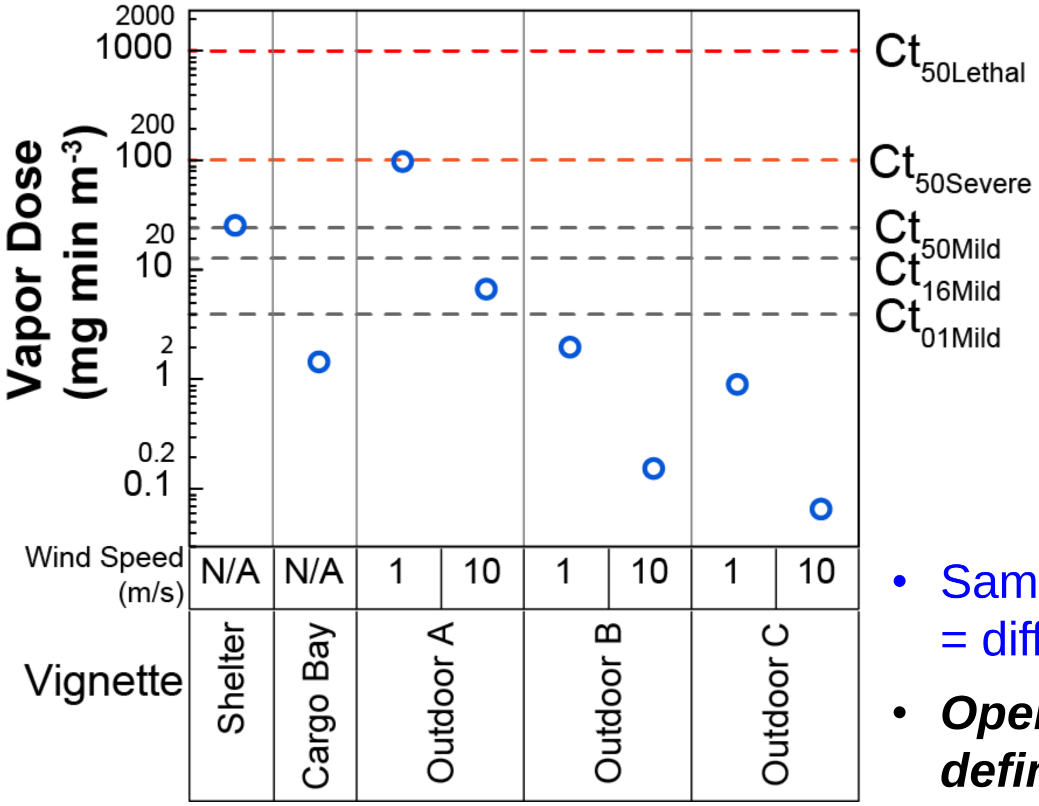
Scale-Up
How to convert laboratory vapor data from a 2 inch panel to represent a full-scale asset/vehicle

TOP methods available at NIST:
https://www.nist.gov/pml/radiation-physics/radioactivity/dod-test-operations-procedures-documents/decontamination

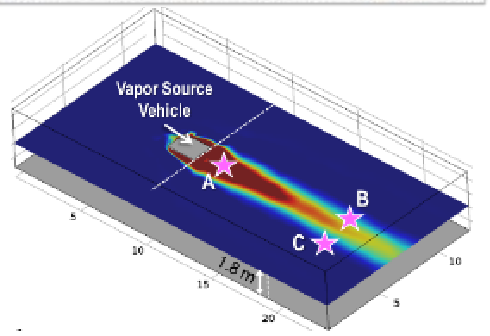
Exposure Dose Changes with Vignette



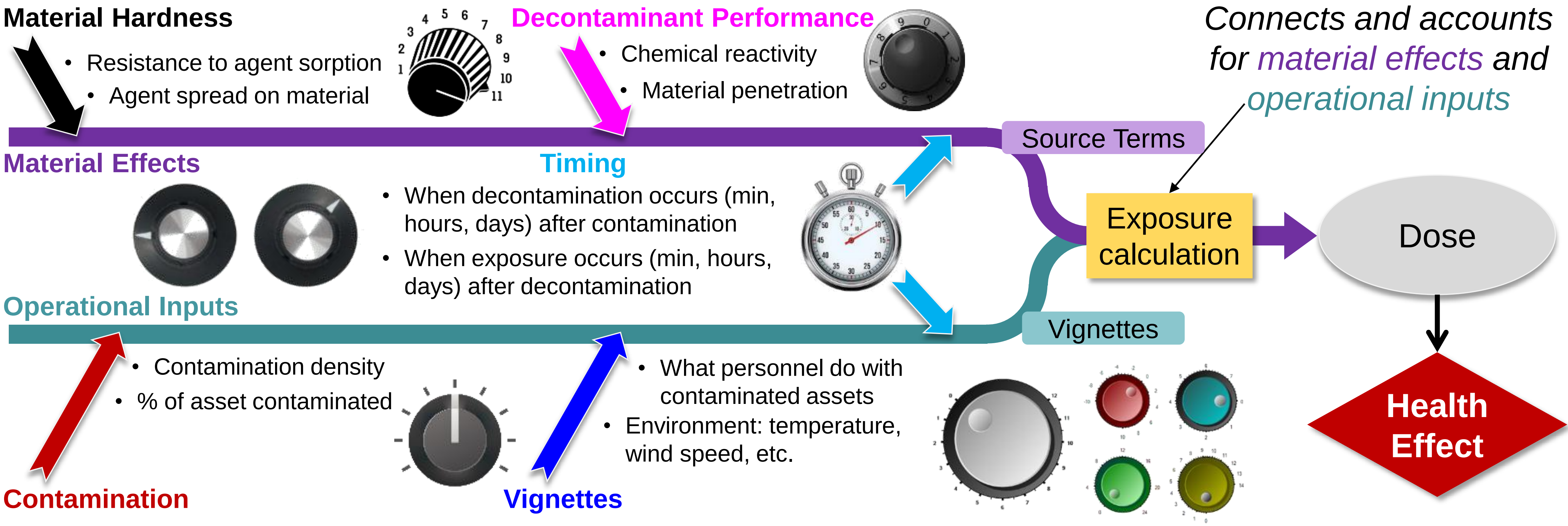
"The Answer"



- Same asset, same decon, different vignette = different dose, different health effect
- ***Operational health effects vary with the defined operation (combination of material effects and operational inputs)***



Exposure & Health Effects are a Response to Many Factors



- Exposure is a ‘systems’ level output and is influenced by multiple inputs
- Health effects are a convolution of decontaminant performance, material hardness, and operational inputs
- The only factor a decontamination technology/process influences is the ability to **Reduce** source terms

Conclusions

- Material decontamination is rate limited by transport, typically by rate of agent transport to material surface
- Efficacy changes with test conditions (such as contamination duration)
- The ability to determine health effects requires the measurement of source terms and exposure assessments
- The same assets used in a different vignette/context may produce different exposures
- Efficacy is a measure of decontaminant performance in the context of individual materials
- “Is it Clean Enough?” requires Source Term measurement and Exposure Assessments

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Relevant References

DoD Public Release Reports (available via https://www.dtic.mil)

- ECBC-TR-980 – Chemical Contaminant and Decontamination Source Document 2nd Edition Test Methodologies
- ECBC-TR-1384 - Interpretation of Liquid Reactor Results
- ECBC-TR-1383 - Relationship of Liquid Reactor to Material Testing

Peer Reviewed Literature

- *Journal of Physical Chemistry B*, **2018**, 122, 2155 – Multi-species transport related to removing contaminants from materials
- *Industrial & Engineering Chemistry Research,* **2017**, 56, 10911 - Agent to Simulant Relationships for vapor emission
- *Industrial & Engineering Chemistry Research*, **2016**, 55(11), 3139 – Material decontamination dynamics for VX from a polymer
- *ACS Appl. Mater. Interfaces,* **2014***,* 6, 16289 – Chemical depth profiling in coatings