Prioritizing Buildings/Zones Using a Quantitative Decision Framework and Incorporating Indicators/Tracers into Vapor Intrusion Building Assessments

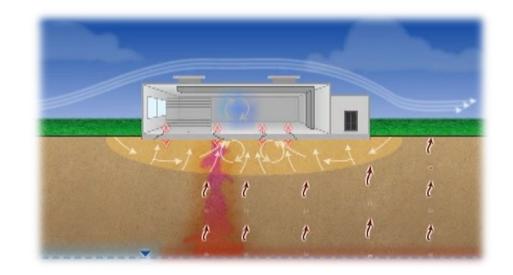
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Agenda

- Introduction
- DoD Industrial Building VI Database
 - Background
 - Types of data
 - Data Analysis
- Quantitative Decision Framework
- Practical Indicator & Tracer Protocol
- VI Matrix of Technologies
- Conclusions
- Q&A
- DoD = Department of Defense





DoD Industrial Building Vapor Intrusion Database

RITS 2016: EPA's 2015 Final VI Guidance

DoD Industrial Building VI Database

- Objectives
 - Create DoD-specific VI database for industrial/commercial buildings
 - Evaluate relationships between factors affecting VI
 - Use data analysis to create framework to assist in VI decisionmaking
- Initially created in 2015 under NESDI Project #476
 - 12 installations 13 sites, and 49 buildings
- Updated in 2018
 - 22 installations, 27 sites and 79 buildings
 - Number of VOC indoor air results increased from 1,870 to 5,323
 - 2,989 VOC results in EPA (2012) database
 - Large (47%), medium (37%), small (16%) buildings



NESDI Project #476: Quantitative Decision Framework for Assessing Navy Vapor Intrusion Sites <u>http://www.nesdi.navy.mil/Files/</u> <u>FinalReports/FR_476.pdf</u>

Types of Data

- Chlorinated VOCs concentrations
 GW, SSSG, IA/OA
- HVAC type
- Area and volume of sampling zones/buildings
- Building/Zone Use
- Flooring type
- Presence of exterior wall

GW = Groundwater SSSG =Subslab Soil Gas IA = indoor air OA =outdoor air

- Preferential pathways
- Soil type
- Depth to groundwater
- Distance to primary release
- Open/closed doors
- Construction Date



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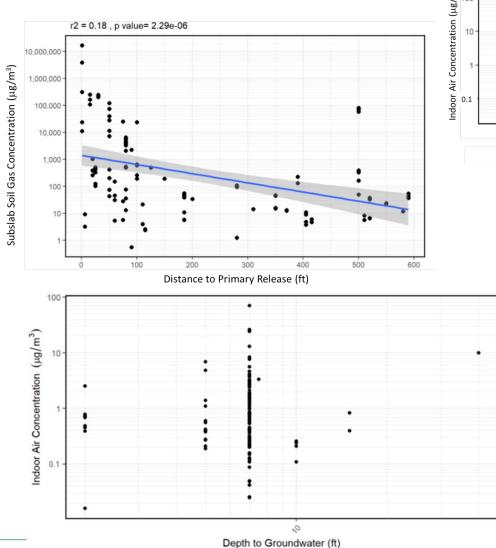
Data Analysis

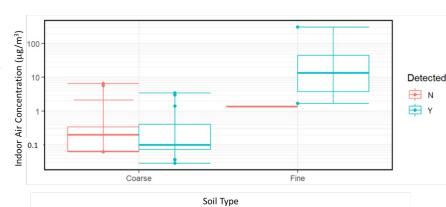
- Conducted statistical analysis using screening methods consistent with USEPA (2012) in analysis of their (primarily residential) database.
- Single Variate Analysis
 - GW Concentration
 - SSSG Concentration
 - Building Area
 - Soil Type
 - Distance to Primary Release
 - Depth to GW
 - Exterior Wall Presence
 - Building Characteristics
 - Building/Zone Use
 - HVAC presence
 - Flooring type
 - Construction date
- Atypical Preferential Pathway

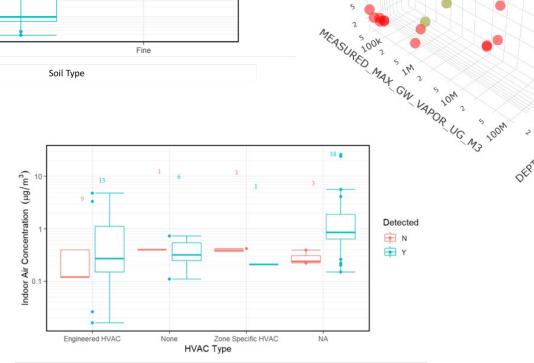
- Multivariate Analysis
 - Transport from GW to IA
 - Soil Type and GW Depth
 - Transport from GW to SSSG
 - Soil Type and GW Depth
 - Transport and Dilution from SSSG to IA
 - Sample Zone Area and Presumed Open Doors
 - Transport and Dilution from SSSG to IA
 - Sample Zone Area and Zone Use
 - Transport and Dilution from SSSG to IA
 - Building Area and Building Use
 - Transport and Dilution from SSSG
 - Building Volume and Building Use



Data Analysis







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DEPTH-TO_GROUNDWATER

Significant Findings

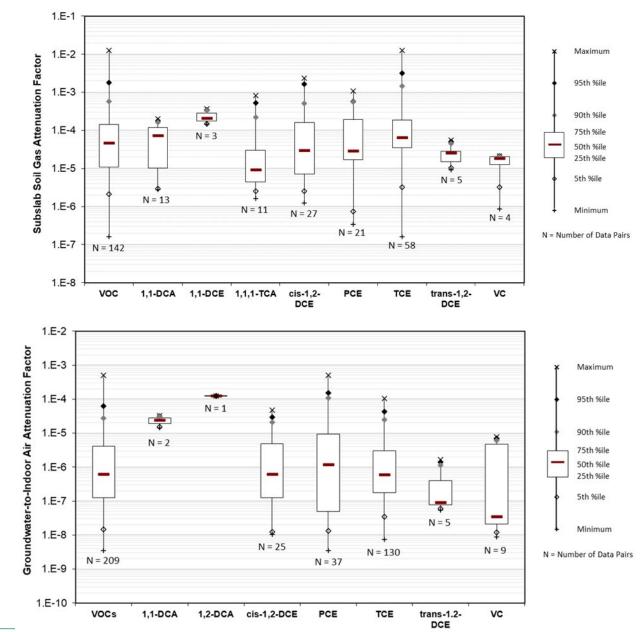
- USEPA Default AFs of 0.03 for SSSG and 0.001 for GW not appropriate for commercial/industrial buildings
- 95th Percentile for DoD Industrial Buildings:
 - SSSG to IA = 0.001
 - GW to IA = 0.0001
- Journal of the Air & Waste Management Association:

"An Alternative Generic Groundwater-to-Indoor Air
 Attenuation Factor for Application in Commercial,
 Industrial, and Other Nonresidential Settings"
 (2023)

https://doi.org/10.1080/10962247.2023.2175740

- "An Alternative Generic Subslab Soil Gas-to-Indoor
 Air Attenuation Factor for Application in
- Commercial, Industrial Other Nonresidential Settings" (2021)

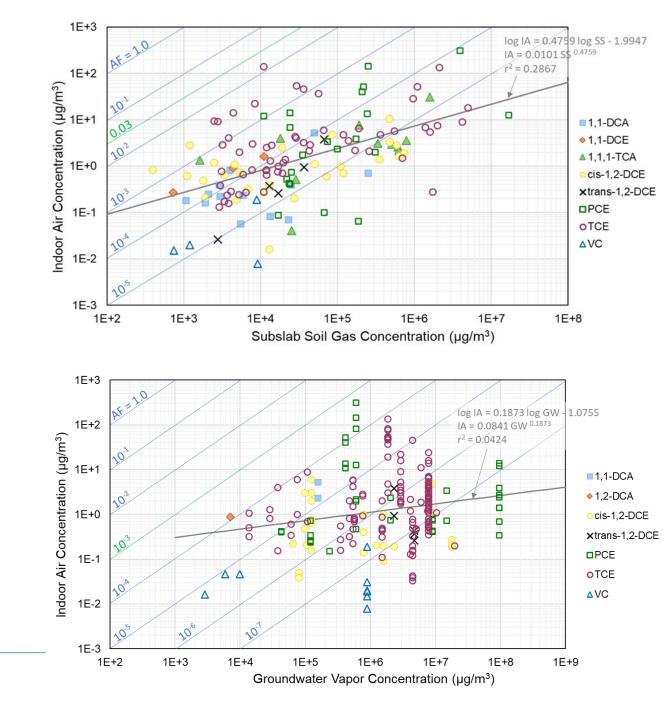
https://doi.org/10.1080/10962247.2021.193028



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Significant Findings (cont)

- Analysis indicated IA concentration does not rise linearly with the SSSG or GW vapor concentration
- For SSSG, the slope or exponent is 0.4759 (versus 1 if the increase was linear)
- For groundwater vapor, the slope or exponent is 0.1873 (versus 1)
- Linkage between GW concentrations and SSSG concentrations found to be relatively weak

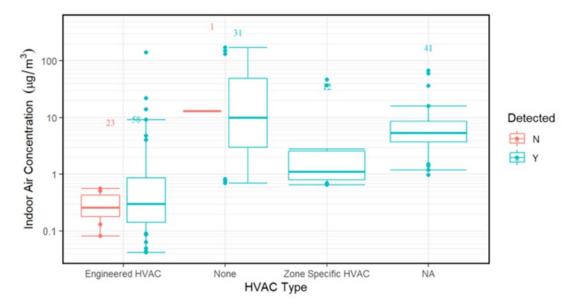


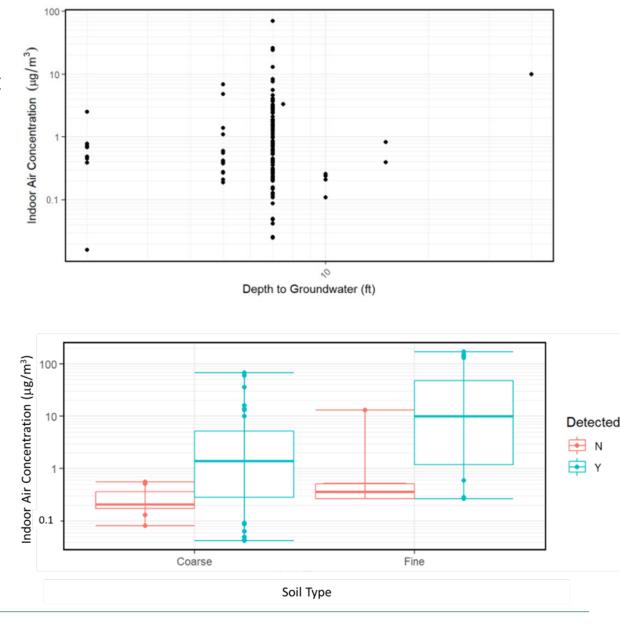
Significant Findings (cont)

- Other statistically significant factors influencing VI:
 - Soil Type and Solvent Use History
 - Atypical Preferential Pathways
 - Distance to Primary Release Point*
 - Depth to Impacted Groundwater

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- Presence of Engineered HVAC System
- Year of Building's Original Construction



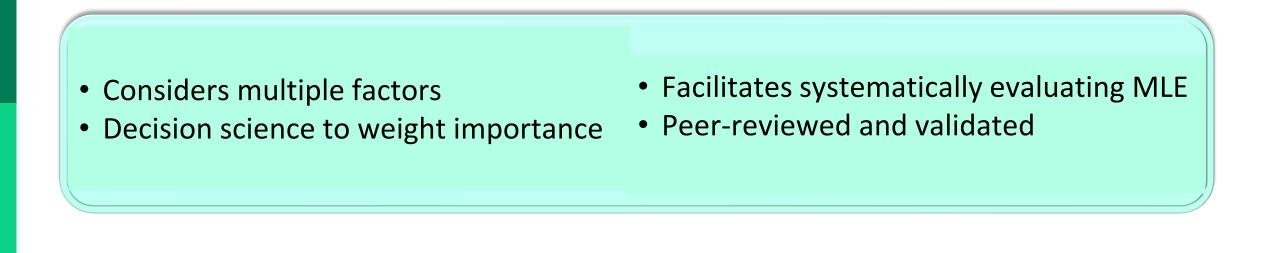


Quantitative Decision Framework

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Quantitative Decision Framework (QDF)

- QDF developed based on the results of the analysis of the DoD Industrial Building VI database
- Designed to assist project team in prioritizing and evaluating VI at industrial/commercial buildings
 - Multiple lines of evidence (MLE) (analytical and non-analytical)



QDF (cont)

- QDF (flowchart/scoring system) has similar format to ITRC 2014 petroleum VI guidance:
 - Provides "off ramps" for clear-cut cases
 - Harder cases lead to scoring
- Allows more in-depth evaluation using MLE leading to a VI prioritization score
- Range of weights emphasize the importance of predictor variables
- Separate scorecards available for groundwater only and groundwater/subslab soil gas data

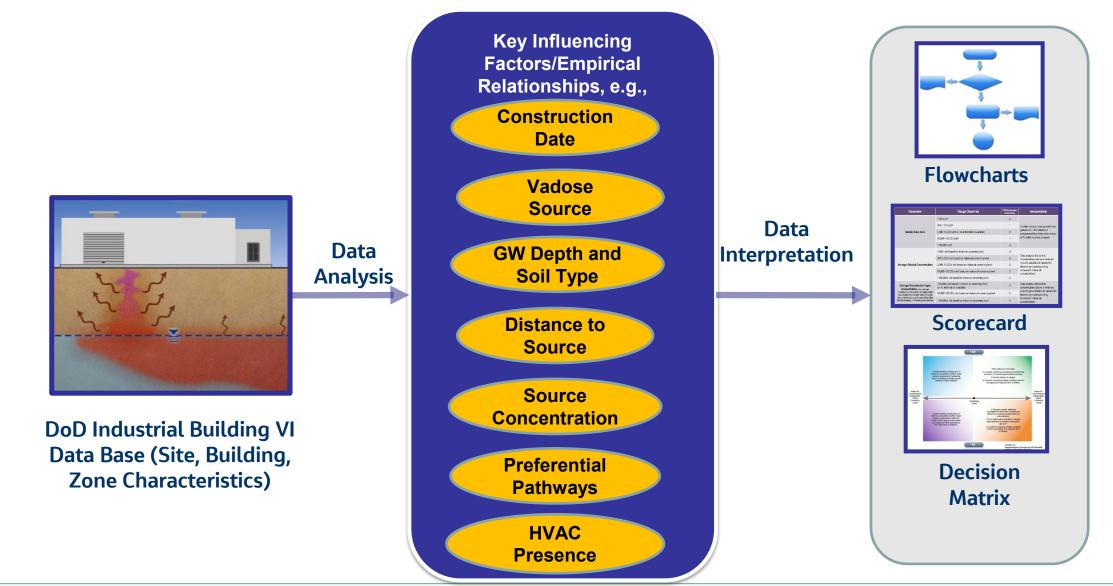
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BUILDING 1 SCORECARD

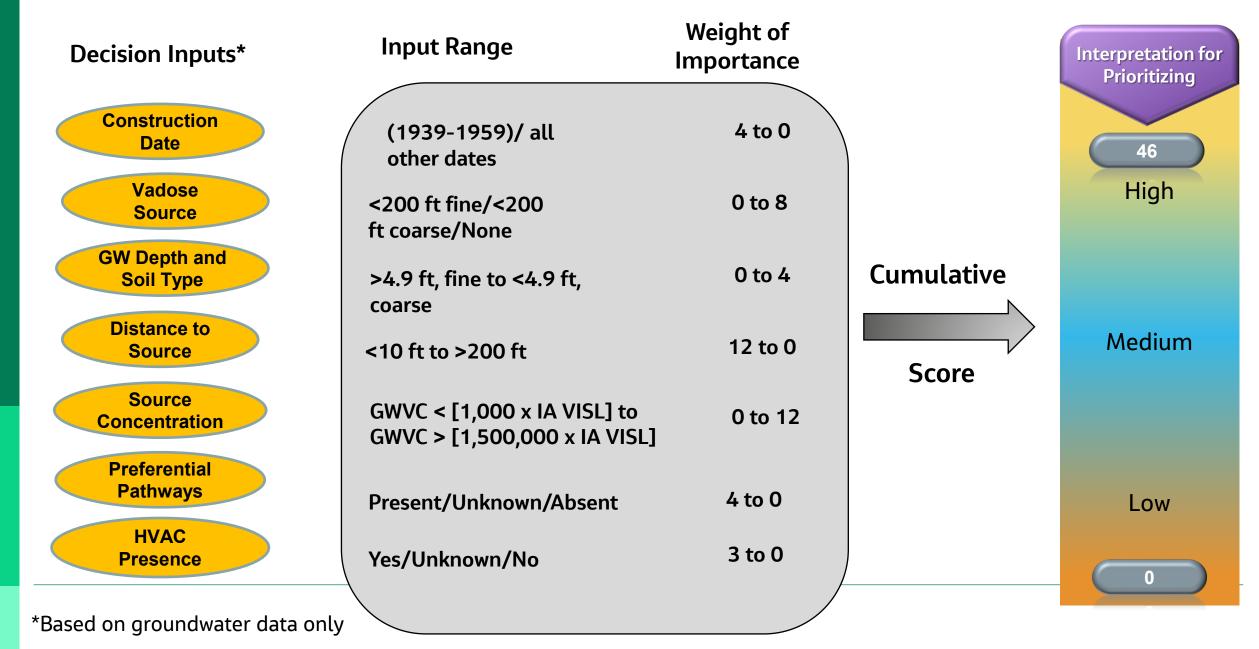
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ITRC = Interstate Technology and Regulatory Council MLE = Multiple lines of Evidence

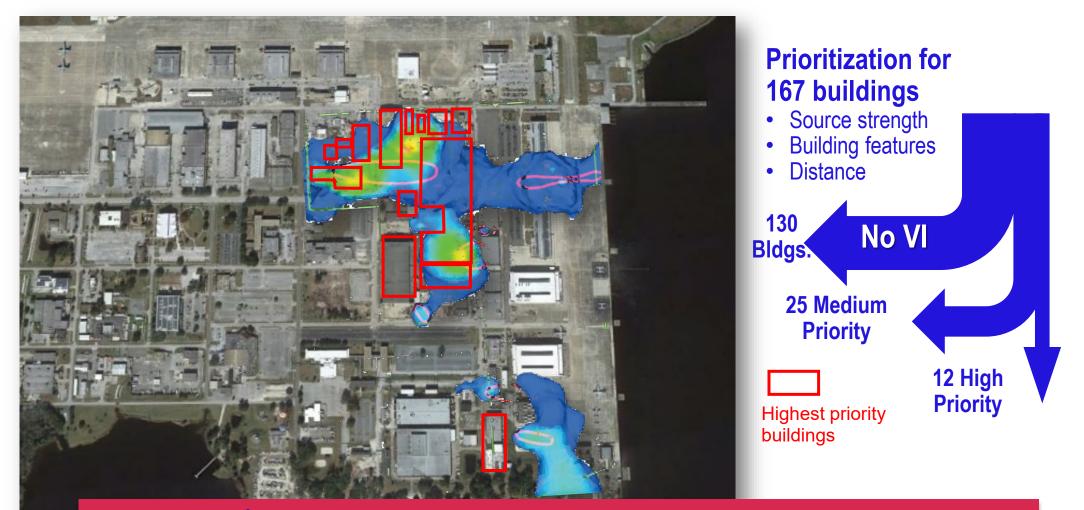
QDF (cont)



Applying the QDF - Prioritization



Prioritization

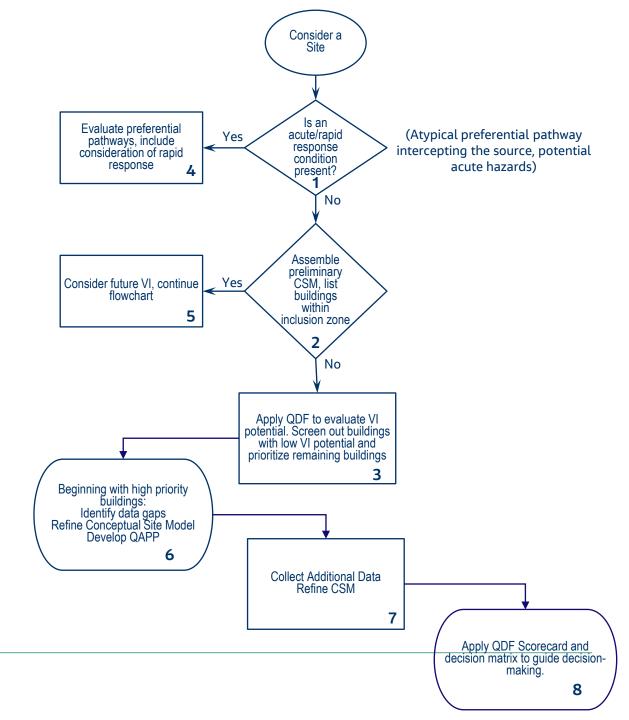


Saved >\$1M by limiting investigation to only a few buildings

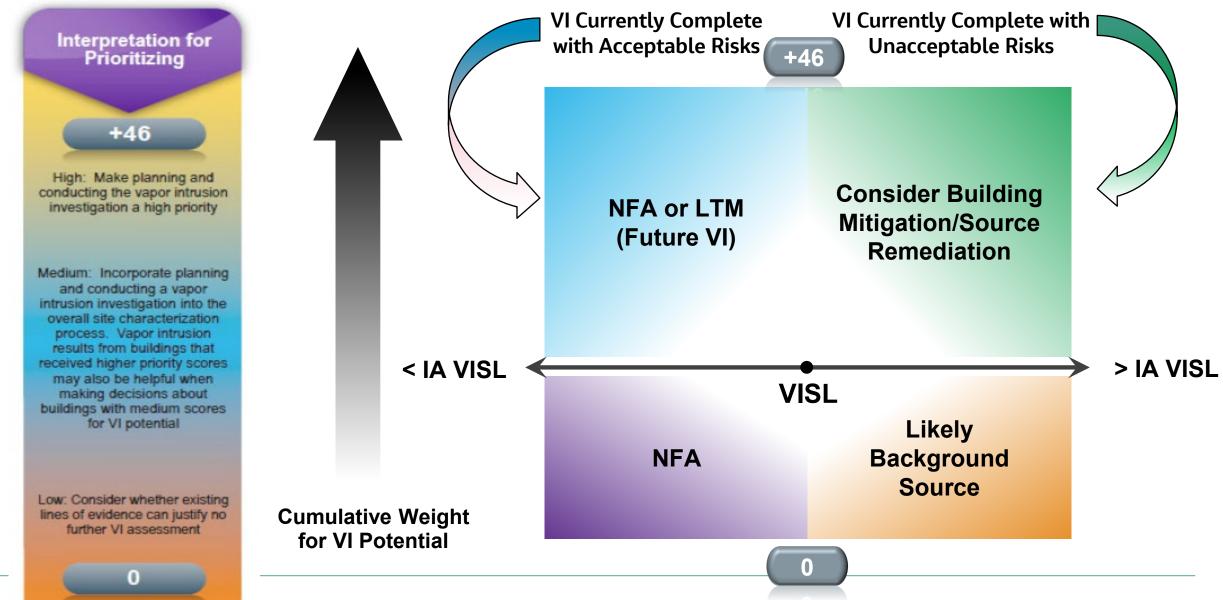
Applying the QDF – Project Lifecycle

Steps for applying the QDF:

- Identify presence of known atypical preferential pathways
- Screen out buildings with very low VI potential using GW Vapor Concentrations and/or SSSG Concentrations
- Calculate VI prioritization scores using multiple lines of evidence
- Interpret VI prioritization scores
- Collect additional data and refine the CSM
- Update the QDF Scorecard and use the decision matrix

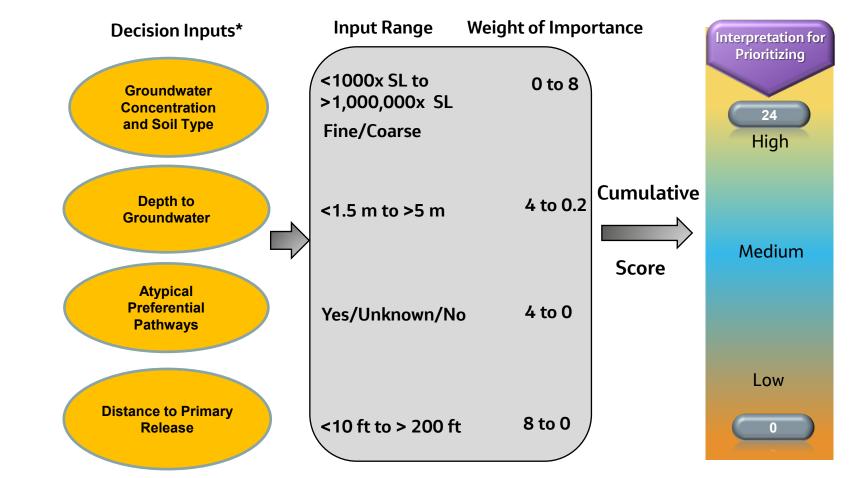


Interpreting Industrial QDF Cumulative Weights & Indoor Air Data



Residential QDF

- Residential Version of the QDF developed in 2018
- Based on literature review
- Designed to be used with 1 to 4 family detached residential housing for chlorinated solvents
- Additional materials available upon request



Incorporating Indicators and Tracers into VI Assessments

Indicators and Tracers (I&T)

Following prioritization, I&T can be used to reduce uncertainties and in VI investigations and should be incorporated into planning.

VI uncertainties can be reduced using I&T measurements (Schuver, USEPA, March 2021 VI Workshop) I&T = Non-VOC metric used to assess/predict VI

Potential I&Ts:

- Radon
- Pressure
- Temperature

Objective

Present an evidence-based practical protocol for integrating I&T data collection/analyses into VI assessments

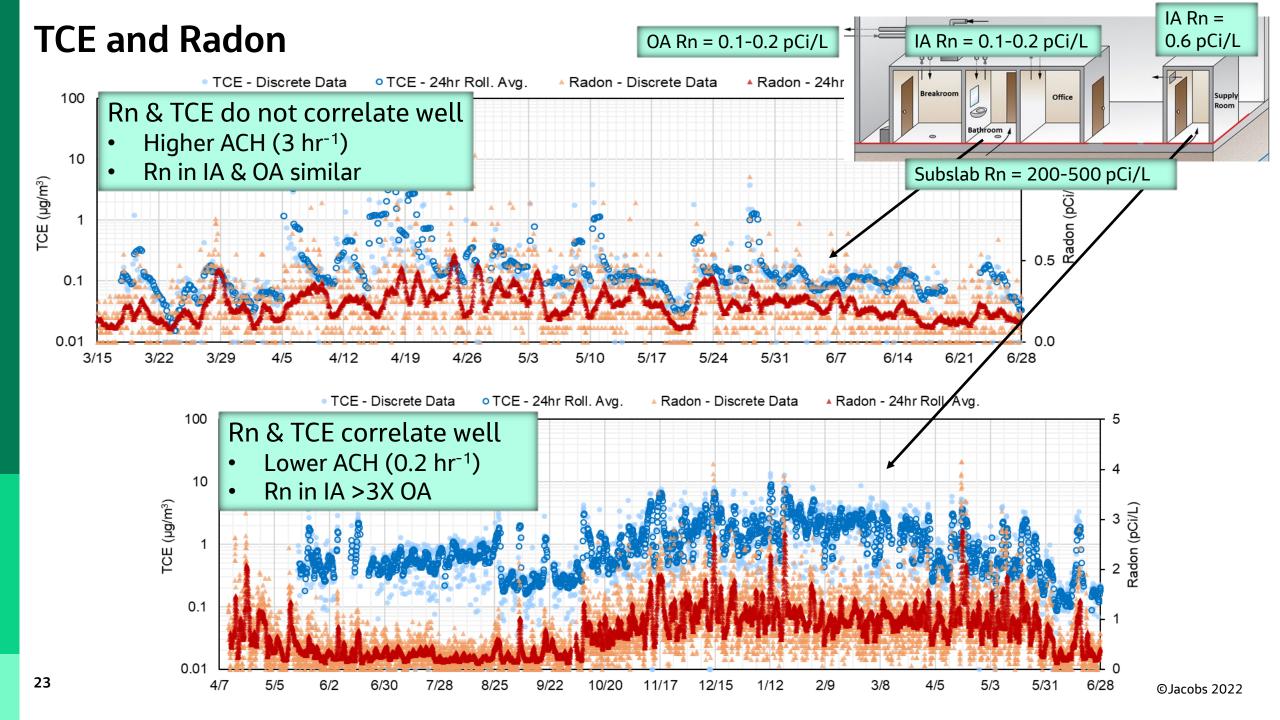
Practical I&T Protocol Development

- Results from NESDI Project 554 used to help develop I&T practical protocol
- Building located in Mid-Atlantic region
 - Subsurface source & documented VI
 - ~120,000 ft² slab-on-grade & 3 large bays
 - Steam heat & overhead fans
 - No centralized cooling; bay doors open in summer
 - Interior office areas with separate HVACs
 - "Enclosed spaces within larger building"

Beneath/Near Building

CVOC	Max GW (µg/L)
1,1-DCE	644
1,2-dichloroetha	ne 7.4
Cis-1,2-DCE	474,000
Trans-1,2-DCE	67,700
TCE	898 <mark>,</mark> 000
VC	639,000

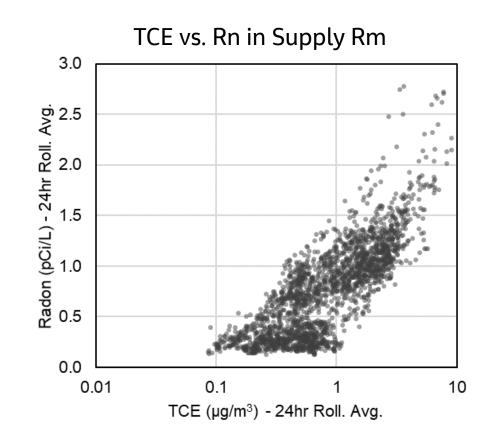




Radon as a Predictor of VI

Radon is good predictor of VI when:

- IA radon is >2-3X OA
- Air exchange rate is low (e.g., <1 hr⁻¹)
- Note:
 - Need to understand subslab radon and VOC levels
 - Rn was best I&T for predicting VI



Practical I&T Protocol for VI Investigations

- Step 1: Identify, prioritize, & select indoor sampling zones, using:
 QDF
 - Information about areas with significant VOC subsurface sources
 - Bldg drawings & surveys for areas more susceptible to vapor entry
 - Zones with lower ACH rates &/or high negative dP potential
- Step 2: Collect continuous IA & OA radon data for at least one week prior to VOC sampling
 - Consider collecting other I&T data (e.g., dP & dT) as supplemental
- Step 3: Continue collecting radon/I&T data and collect subslab, IA, and OA VOC samples (during heating season)
 - Collect subslab radon samples



Practical I&T Protocol for VI Investigations (Cont'd)

- Step 4: Evaluate data to assess if I&T can predict VI
 - Radon is best I&T predictor of VI when:
 - IA radon is >2-3X OA
 - Air exchange rate is low (e.g., <1 hr-1)

- Effectiveness depends on Rn source strength and dilution upon entry
- Step 5: Continue monitoring radon in place of VOCs, unless
 - Indoor Rn increases significantly; and
 - Subsurface VOC x bldg-specific AF suggests VI may be potential concern

Note: Building pressure control (BPC) testing can be considered when:

- Radon is not a suitable tracer for monitoring VI
- Long-term radon monitoring is not feasible
- VI investigation is time-sensitive & needs to be expedited

I&T Protocol Advantages

- Radon as I&T to greatly increase defensibility of VI assessments at most buildings
 - Return to "status quo" if Rn not effective and opt not to use BPC
- Uses and benefits of radon as an I&T* include:
 - Prioritizing & selecting indoor sampling locations
 - Predicting VI of VOCs
 - Guiding when to sample for VOCs and better estimating exposure
 - Minimizing VOC sampling (saves money)
 - Increasing confidence when assessing VI multiple lines of evidence



²⁷ *Need information about IA/OA (Rn) and subslab (Rn & VOC) levels to decide

Matrix of Technologies for VI Investigations

- DoD Vapor Intrusion Handbook Fact Sheet Update No: 007, titled "Matrix for Selecting Vapor Intrusion Investigation Technologies"
 - Matrix created to provide a tool to select the most effective technologies for investigating VI, broken down by study question
 - Includes technologies for investigating soil sources, soil vapor, and indoor air, I&T, and forensic tools
 - Publicly available at: <u>https://www.denix.osd.mil/irp/denix-files/sites/48/2019/09/Matrix-of-VI-</u> <u>Technologies-Fact-Sheet_Revised-Final-July-2019.pdf</u>

			Soil Screening			Soil Vapor & Indoor Air Field Screening				Soil Vapor & Indoor Air Sampling				Forensic Tools					
			1	2	3	4	5	6	7		9	10	11	12	13	14	15	16	17
VI Pathway Assessment	Investigation Objective	Sub-objectives	Discrete soil samples for VOC analysis with microwave extraction	Continuous coring or profiling (MIP, Dye LIF)	Soil Physical Properties (core logging, geotech analysis)	Handheld PID (VOCs)	Portable GC/PID (Tediar bags)	Mobile GC/ECD (Tediar bags, glass syringes, Tefion tubing)	Portable GC/MS (HAPSITE) & MS/MS (TAGA)	Evacuated Canister with analysis by EPA Method TO-15	Active Sorbent Sampler with analysis by EPA Method TO-17	Passive Sorbent Sampler	Flux Chambers	Compound Ratio Analysis	Compound Specific Isotope Analysis	Building Pressure Differential Monitoring	rogates & Tracers Other R= Radon, TD = Temperature Differential; Tr= Introduced Tracers	Building Pressure Cycling	High olume Soil Gas Sampling
Are VOCs/SVOCs associated with	Characterize vapor sources	Delineate vadose aone vapor sources		+++ (LIF and MIP)									1	•					•
subsurface sources underneath or near the building(s) present at concentrations	Characterize near source vapor concentrations	Characterize spatial distribution	•	++ (MIP)				•••			•••								
above screening levels?		Characterize temporal variability		-										-	-	-			
	Identify vapor migration pathways in the subsurface	Characterize soil migration pathways		+ (MIP)		•		•••									***		•
Are VOC/SVOC vapors migrating from the source towards the		Characterize utility conduits pathways	•	-		•								•		-	*		•
building?	Characterize near foundation vapor concentrations	Characteriae spatial distribution											•			-			

Conclusions

- Commercial/Industrial AFs derived from robust statistical analysis of the DoD Industrial Building VI database
 - More representative than USEPA defaults based on analysis of primarily residential buildings
- Use QDF to prioritize buildings/sampling zones for data collection
 - Based on analysis of the DoD Industrial Building VI database
 - Can also be used through the project life-cycle to interpret data and evaluate MLE
- Matrix of Technologies can assist in selecting investigation strategy
- VI practice will significantly benefit if use radon as I&T



Thank You! Q&A

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