#### **Overview** of the Problem & Solutions

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#### U.S. EPA "State of VI\* Science" Workshop Reliable Ongoing Human Exposure Protection to Vapor Intrusion Using Cleanup as the Simplest Approach

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**<u>Disclaimer</u>**: The views expressed in this presentation are those of the author and do not necessarily represent the views or policies of the U.S. EPA. \*chlorinated Vapor Intrusion (cVI)

#### Prologue Are we ready to do something *more effective* for cVI?\*

We've tried a lot of less effective things for >25 years

- That 'more effective' is:
- Protect all people\*\* from cVI exposures
  - Equivalent to having a completed cleanup
  - High confidence of No Unacceptable exposures
    - Proposal: by keeping (haz.) waste a Safe Distance away for Occupied Bldgs.

#### • Until a complete cleanup\*\*\* is achieved

\*chlorinated Vapor Intrusion (hereafter just VI)

**\*\*Nearby** vapor contamination subject to our authority for cleanup

\*\*\*Of vapor contaminated soil gas media (before it becomes indoor air) & all sources of it

# Part 1 – The Problem

# The **Problem** – <u>Acceptability</u> of **VI** *exposure* is **very hard to know**, document & defend; *esp.* over time

- Particularly when sampling is FOCUSED on the POINT of Exposure
  - In Indoor Air
  - As (we now know) these **concentrations** there are **Highly Variable** over time
  - Typical\* Samples of indoor air rarely representative of the exposures of most concern
  - Subject to distracting indoor and outdoor 'background' sources
  - Disruptive to Occupants (Access issues)
  - LOW Access rates (1/4\*\* 1/10) & extrapolations can *multiple* errors
  - Expensive \$\$\$ > mitigation (& possibly > removal/cleanup since can end monitoring)
  - Reduce NOBODY's exposures (alone & most often provides misinformation of 'all safe')
- In summary Indoor Air samples\* < INEFFECTIVE, as commonly misinformation
  - & In Subsurface Samples
  - Screening Levels AF are often based on somebody's Indoor Air samples & the problems above are reflected/embedded in them – so this could use some improvement too

\*A few random- or convenience-timed samples

\*\*Redfield Rifle Scope, Colo. & other Bldg. authorities can approach ~1/2

### *Example* of **Problem** (w/VI): for Regulators **We Want Verifiable Results Showing Progress**

- Our 1999 (RCRA) Human Exposures Under Control GPRA metric required the assessment of VI at all '2005 Baseline' facilities
  - We never expected to have all site-wide investigations 100% complete by 2005, but:
- We expected we could make a defensible professional judgement call on the probability of unacceptable exposures in the unfinished parts of the Investigations\*
- But the **unending complexity** of assessing VI using models, & sampling techniques has led to *Analysis Paralysis* and a real '**barrier**' to confidence in progress
- & Programmatically, the Assessment of VI is still today a 'barrier' called
  - "Sitewide <u>Investigation</u> Not Complete"
  - We <u>need</u> readily recognizable, verifiable, achievable goals for VI 'safety'

\*that could, if new information shows Exposures are NOT under control, be changed

# So we should end the **Monitoring** game called 'catch (exposure) & fix'

- Expending significant amounts of Resources
- Trying to 'Catch' Unacceptable Exposures
  - In Samples at *Exposure point* (or *pathway* to it)
  - With high variations across both Space & Time
  - Which is very **difficult, costly, & challenging** technically & socially (e.g., access)
  - When 'practical' amounts of sampling typically Under-estimates risks/exposure
    - Mis-informing the public that they are 'safe' when they are as likely not to be
      - Commonly Odds are ~Flip of a Coin
         First at SDM, & now appearing common
- & On occasion we do 'catch' unacceptable exposures (if they are always or frequently present – that defines our success) but then we;
  - Typically, Only address/mitigate/reduce risks to the single (or few?) building(s)

We expect **Confidence** from **Monitoring**: But Assessing VI **Pathway** to a Building is **Complicated** 

- Many different Conceptual Site Models Source to Bldgs.
  - With many Naturally varying factors over both Space & Time
- Many sites with varying types of *Preferential Pathways* 
  - Natural
  - Human made (sewers, utility lines, other conduits, ... connecting bldgs.)
  - Human *influenced/enhanced* Natural pathways
- In sum: Many different paths from vapor sources to building(s)
  - These vary across Space and Time, as various conditions change and/or interact
  - Can we really monitor all Pathways to a building over all Times? (Not realistic)

## The effect of the *portal* of entry *into* a Building to the Indoor Exposure Point is Complicated

- Likely varies across both Space & Time
- & we don't often sample All rooms, &
  - Portion of the **building/room**(s) *impacted* by VI and Sampled can vary over time
    - Just by the active portal of entry alone & mixing, bldg. operations, ...
- So, indoor air **Concentrations** from **VI** result from
- A long list of Subsurface and Building factors,
- That each vary across Space and Time individually, and when they interact
- Such complexity often results in a log-normal distribution where the vast majority of conc. are very low and very few are much higher conc.





#### Temporal Variability of Indoor Air Concentrations Across 7 Sites

**Temporal Variability - Least to Most Data** 



Lutes' Key points: 1. The long-term mean is always above the median and sometimes above the 75<sup>th</sup> percentile.

2. Half the exposure often comes from only a small percentage of the days.

3. The more samples you take the more "outliers" you see. Note log axis – those outliers are really high!

Testing Effectiveness of Current Indoor Sampling In One-bldg. studies (No Spatial variability), i.e., Only Temporal variability with & w/o continuous Indicators & Tracers (I&T) guiding IA sampling times

Ranking Effectiveness of different Sample Scheduling strategies<sup>1</sup>

G <u>oals of sampling =</u>	<mark>90<sup>th</sup> %ile dist.</mark>	<mark>50<sup>th</sup>%ile</mark> of <mark>t</mark>	<mark>otal</mark> exposure <sup>3</sup>
Using <mark>Max. conc. # from 4</mark> samples <sup>2</sup>	Short-term	Long-term	Summary
<ul> <li>Low radon (Rn), Tracer, Do NOT sample Now</li> </ul>	19%	32%	Lowest <sup>4</sup>
<ul> <li>Random [commonly used method] Flip of a Coin 50</li> </ul>	<mark>)%</mark> 35%	<b>48%</b>	Low <sup>5</sup>
<ul> <li>Seasonal (ONLY winter/heating) – 'wait for it'</li> </ul>	67%	84%	Better
<ul> <li>I&amp;T (Rn) guided times (any season)</li> </ul>	65%	86%	Better
<ul> <li>I&amp;T (Rn) guided times (ONLY winter/heating)<sup>6</sup></li> </ul>	89%	98%	Best

<sup>1</sup> Ranking simplified ~results of sampling in 12 bldgs./zones in Fig. 2 & 3 Lutes et al. (Sample Scheduling ...) submitted for pub.
 <sup>2</sup> Using max. not in explicit in most guidance (but RAGS), typically too few samples to calculate 95UCL, so should be common?
 <sup>3</sup> Used in instead of 95UCL of Mean in our study, since better for VI, but Not in guidance, so how common?

<sup>4</sup> Two-edged sword – un-RP could use to avoid detection of VI (we recommend occupants be aware of/monitor their bldg. Rn)
 <sup>5</sup> Majority of cases provides *mis-information* reporting 'all safe' when they are Not

<sup>6</sup> Possibly due to longer pathway from source of VOC needing sustained period of high intrusion relative to nearby Rn<sub>12</sub> Can do better w/ ITS-timed,

# Part 2 – Solutions

### Preliminary Discussion of Solutions\*

- Typical\*\* Samples cannot predict the Future
  - They can only *represent* the **actual time of collection**
- If we want Samples to show Continuous Protection
  - At the highly variable Indoor Air point of exposure
    - It appears:
- We would need ~*Continuous* <u>Sampling</u> there
  - Remember, We want:
- Achievable, Readily Recognizable, Verifiable, Confident & Lasting Protection
  - Typical VI sampling does not appear to able to meet many of those criteria

\*Potential and proposed for discussion, comments & recommendations \*\*A few random/convenient indoor air samples

VI <b>Protection</b> - <i>At a fork in the Road Continuous</i> * on-going all Bldgs. @ Risk					
MonitoringOrIndoor or Outdoor Sampling		<b>Prevention</b> Control vapor migration <i>away</i> from Ocp. Bldgs			
• Technically • +	?		• Technically • +	Do-able	
<ul> <li>Economically</li> <li>+</li> </ul>	?		<ul> <li>Economically</li> <li>+</li> </ul>	Cost- <b>effective</b>	
<ul> <li>Socially</li> </ul>	?		<ul> <li>Socially</li> </ul>	Receptor-Acceptable	
= Un-realistic		= Realistic			

\*Continuous *Indicators/Tracers* to *time* COC monitoring **possible**, but ... Not 100% predictable (yet) so Technically?, Economically?, Socially?

#### A Working Hypothesis – Given: **Proximity & Inevitable Combinations** of Factors

- Given one or more long-lasting subsurface Vapor source(s), Near Bldgs.;
  - Over Time, as many factors/features that can, will Vary over Space & Time, (e.g., GW source conc., subsurface conditions, soil moisture, water tables falling, Bldg. conditions, pressures, winds, temperature ...) and can eventually & inevitably interact and combine to create 'shorter' and more effective VI entry pathways into some bldgs. at some time(s).
- It is Only a matter of (unpredictable) Time,
  - That *VI favorable conditions* can align and produce higher conc. (unacceptable) VI
    - And the evidence we have shows 'peak events' are 'rare' but important driver of Exposure
- It appears Impractical/incorrect to continue trying to Monitor/Catch VI in:
  - <u>Subsurface</u> (at All Locations & Times) along the many possible VI Migration Pathways or
  - Indoor air at All Bldgs. at risk of VI, at All Times, to catch unacceptable Exposure conc.
    - Both Short- & Long-term concerns even if only from peaks (e.g., only 3.5% of time in SDM)

We have used the <mark>Distance</mark> *from* Conc. Of Concern\* to Occupied Buildings to 'Screen <mark>/n</mark>'

- We believe there is some probability (~5%) of
  - Bldgs. < 100 ft of >VISL\* contamination (in the subsurface media)\*\*
- Could be unacceptably impacted by VI
  - Thus
- It should/could follow:
  - Bldgs. > 100 ft of >VISL\* contamination (in the same subsurface media)
- Should have some (~95%) probability of Not being impacted by VI
  - That is could Screen Out of concern for VI by a 'safe' Separation Distance
    - This could be a readily recognizable, verifiable, confident and achievable safety goal

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• Prioritizing Protection while supporting a complete cleanup

\* >VISL conc. (Vapor Intrusion Screening Level in Soil Gas) based on either Generic or Site/Community-specific Attenuation Factors (AF) \*\*vapors in sewers/piping/conduits will be discussed soon

## Conceptual Model Scenarios for the Vapor Intrusion Pathway (USEPA, 2012)

https://www.epa.gov/vaporintrusion/conceptual-modelscenarios-vapor-intrusion-pathway



#### Source Lateral Distance Deep Groundwater

 A 20 m (66 ft) lateral distance separation results in decrease in α by two orders of magnitude

Note: High vapor conc. can be significantly reduced (with confidence by dispersion and dilution) over a reasonable separation distance between the contamination & receptor building.



#### Lower Permeability at Ground Surface



separation distances between the contamination & receptor building are the same, e.g., here where the ground surface has an impermeable cover/cap that is not allowing the vapors to flux into outdoor air.

Note: Not all

# Part 3 – Example Proposal

# 1<sup>st</sup> Draft Proposal for Confident, Continuous & Verifiable Prevention of VI Exposure

By increasing Separation Distance to Occupied Buildings until Cleanup is Completed

1<sup>st</sup> draft concepts for comment & input

#### Scope

- At each hazardous cVOC release site
- subject to regulatory authority to take Corrective Action/Cleanup
- for the protection of human health and the environment
  - e.g., under the
  - Resource Conservation and Recovery Act (RCRA) of 1976
    - Including the
  - Hazardous and Solid Waste Amendments (HSWA) of 1984
- Note: Soil gas has been too often ~ignored
- For VI Soil Gas is the contaminated media that becomes indoor air & causes Exposure

1) Document # of Bldgs. known to <u>Overlie</u> or are <u>Proximate to</u> >VISL contaminated Soil- or Sewer Gas

- a) # of Bldgs. Known to Overlie >VISL contaminated Soil Gas (0 ft Lateral separation, w/o cap/cover) & <100 ft depth</li>
- b) # of Bldgs. in Proximity of >VISL contaminated Soil Gas (1-100 ft Lateral separation, w/o cap/cover) & <100 ft depth</li>
- c) # of Bldgs. connected to & in Proximity of (1-300 ft Lateral separation) to >VISL contaminated Sewer/pipe\* gas
- In communications Public needs some awareness that:
  - Soil gas gets into ~all bldgs. (like radon) and is part of indoor air
  - Sewer/pipe gas enters bldgs. with faulty plumbing or other leaks to indoors

\*Or other Preferential Pathway/Utility Conduit

### 2) Document Engineering or other Controls Preventing VI at all exposed\* Buildings

- Adequacy of any Engineering Controls to Prevent vapor-phase contamination – with ~continuous verification (e.g., by Rn levels)
  - From entering individual buildings at unacceptable levels (e.g., SSDS), or
  - Large areas with multiple occupied buildings by SVE, or other means
- All buildings Located
  - Overlying, or within 100 ft of, >VISL\*\* contaminated Soil Gas (Lateral & Vert.)
  - Within 300 ft of >VISL contam. in connected Pref. Pathway/Sewer/Conduits
- These engineering systems are considered Interim Exposure Controls
  - & Only needed until >VISL contamination can be removed as part of cleanup and bldgs. are no long Overlying or Proximate to Soil- or Sewer Gas >VISLs

\* Overlying & Proximate to >VISL conc. In Soil-/Sewer Gas

\*\*Generic or based on site/community-specific Attenuation Factors (AF)

# 3) Option out of Eng. Controls by Monitoring Exposures in Overlying & Proximate buildings

- Those seeking this Option for individual buildings within Lateral separation distances of 0-100/300 ft zones
  - Need to Demonstrate/document how Exposure Point sampling has characterized the full exposure distribution
    - By representative sampling Over >1 year initially, & semi-annually as long as 'Exposed'
    - In a way that can demonstrate and document the RME mid-pt (95<sup>th</sup>%ile) from the likely Log-Normal distribution
  - Or
    - USE (4) typical samples along with 10-100x lower threshold\* to account for the samples are highly likely to miss log-normal peak/RME conc. largely determining short- and longterm risks

# 4) Semi-annual Verification of Current Extent of vapor Contamination

- Conduct Semi-annual monitoring of the area with soil gas & sewerconduit gas with > VISL conc.
- Document the area of this contaminated media (that become indoor air) in ways similar to that used for contamination in groundwater
  - It is possible that only a small percentage (~20%?) of VI sites have well documented the extent of the >VISL concentration contaminated soi gas media
  - And there may be thousands of indoor air samples without context for the surrounding soil gas conc.

5) Semi-Annual Documentation of the Migration of Vapor-contaminated soil gas (media), expanding or receding?

- Beginning with comparison to historical documentation, if any.
- Plans on how to address newly 'exposed' buildings due to migration
- Plans on how to address soon to be 'exposed' buildings due to migration

### 6) Semi-annually document individual Bldgs.' Separation (Lateral & Vertical) Distances

• Provide a statistical summary of changes in Separation Distance for individual buildings and for the entire exposed community

## 7) Document full **Aerial Extent** of Soil-/Sewer Gas **contamination remaining** for Cleanup

- Including:
  - Accounting of the # buildings still Exposed (Overlying and Proximate to >VISL contamination)
    - # with Verified protection from Eng. Exposure Controls
    - # with Verified on-going exposure point Monitoring showing exposure is Acceptable
    - # with-OUT either form protection (if any)
      - and
  - Total # of Acres where Soil- and/or Sewer Gas is >VISL (& <100 ft deep)
- Summary statistics for all occupied bldgs. Site-wide.
- Highlighting those:
  - Closest to original vapor contamination Release site/location & work needed to:
- Complete the Cleanup

#### Schedule – Proposed

- Today up to mid-Jan. (~2 months prior to) Spring AEHS (Mar.) 2025;
- We are welcoming (informal/technical/staff):
  - **Comments** to improve the concepts and/or approach &
  - Recommendations on implementing ideas/details & measurements/metrics
    - Note ~2 months prior to next Workshop to incorporate them into a better proposal:
- USEPA cVI Workshop at Spring AEHS (Mar.) 2025
  - Operationalize cVI Protection with Confidence & Readily-Verifiable Results
    - Example of Basic Elements
  - 'Safety' via Distance between >VISL conc. in Soil-/Sewer Gas & Occupied bldgs.
    - Until Cleanup is Completed