Abstract

Subslab Depressurization (SSD) is the most widely used engineering control and is considered the most effective available technology in reducing indoor air concentrations attributable to VI. SSD systems work with the general principal of changing the pressure differential across the slab in order to prevent vapors from entering the occupied space of a building. The current design, commissioning and operational criteria for SSD systems to address VI have largely been adapted from radon industry experience and guidance. Radon mitigation systems have been shown to be effective at reducing concentrations over long periods of time. As a result, numerical criteria for an acceptable degree of depressurization have also been adapted from radon guidance documents.

This presentation will focus on re-evaluating the radon guidance recommendations to determine an acceptable pressure differential for addressing VI. Many regulatory agencies currently misuse the recommendations provided in historical USEPA radon guidance documents. This misuse has led to the adoption of unnecessarily high depressurization requirements. Excessive depressurization can potentially pull soil gas concentrations towards buildings as well as lead to back drafting (induced spillage of combustion gases) of combustion appliances, causing carbon monoxide exposure to occupants. Specifically, this presentation will (1) compare the factors that affect SSD design for Volatile Organic Compounds (VOCs) compared to radon; (2) identify additional criteria for determining the effectiveness of a SSD system; and (3) document a new design approach based on risk mitigation considerations specific to VOCs, which utilizes the concept of "adaptive design" and leads to an energy efficient "green" design.

Conceptually, any additional implementing criteria, such as a specific numerical depressurization target for SSD, should be strictly secondary to the primary criteria of achievement of acceptable indoor air quality and maximizing net environmental benefit. Practically, it will still often be necessary to design and control systems with reference to differential pressure across the slab. However, it is only necessary to minimally remove the driving force for VI, for a sufficient percentage of the operating time, to address the chronic risks normally posed by VOCs. Rather than attempting to over compensate for variability in buildings, a system should be implemented on an interim basis, and adjusted based on operating data – an approach referred to as adaptive design (Payne et al. 2008).

Optimal Design of Sub-slab Depressurization Systems for Volatile Organic Compound Vapor Intrusion (VI) Mitigation

Chris Lutes, ARCADIS, Durham, North Carolina, USA • Ric Studebaker, PE, ARCADIS, Milwaukee, Wisconsin, USA
• Nadine Weinberg, ARCADIS, Portland, Maine, USA

Objective

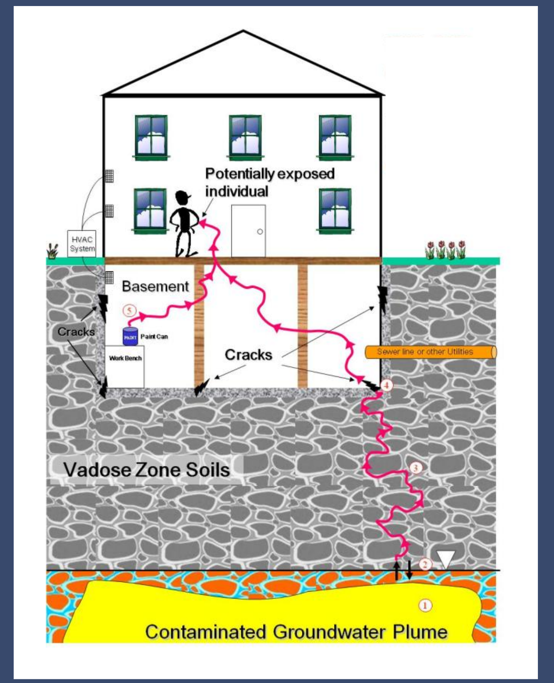
Develop a cost effective, energy efficient design strategy for sub-slab depressurization (SSD) systems.

Design Elements of Sub-Slab Depressurization (SSD)

- Sealing - A Key Element
  - Cracks/Seams
  - Block Walls
  - Sumps
  - Utility openings
- Sub-Slab Depressurization
  - Active Blower
  - Passive Wind turbines

Sub-slab depressurization (SSD) is the most commonly used mitigation technology

- Design of active systems involves selecting the right blower to provide the desired suction and flow.
- Systems can be high flow/low suction or low flow/high suction



Understanding the Guidance in Context

- SSD Engineering Design Guidance Used for VOC VI has been Based Heavily on 1990s Radon Program Guidance
  - 1993: Radon Reduction Techniques for Existing Detached Houses - Technical Guidance for Active Soil Depressurization Systems (EPA)
  - 1994: Radon Prevention in the Design and Construction of Schools and other Large Buildings (EPA)
  - 2003: Standard Practice for Installing Radon Mitigation in Existing Low Rise Buildings E-2121 (ASTM)
  - 2007: Vapor Intrusion Pathway: A Practical Guideline (ITRC)
  - 2008: Engineering Issue: Indoor Air Vapor Intrusion Mitigation Approaches (EPA)
- Radon Based Design Recommendations
  - A pressure differential of 0.025-0.035" w.c. sufficient to maintain downward flow. This is 6 – 9 pascals
  - This is a conservative number only necessary when all exhaust appliances (e.g. central furnace fans, clothes driers and exhaust fans) are turned off or installation takes place in summer.
  - When SSD systems are installed under worst case conditions (i.e., fans on, winter heating season), USEPA (1993a) acknowledges that "any measurable sub-slab depressurization should be sufficient (0.001 to 0.002 in. [wc])." This is < 1 pascal
- Historical Radon Criteria Has Been Misapplied Today
  - Numerical criteria divorced from the original context
  - Lack of design flexibility for situations in which achieving this numerical criteria is impractical
  - Not allowing indoor air concentration to be used as clearer evidence of mitigation effectiveness.
  - Fails to account for the differences between VOC and radon VI
  - Making a conservative criteria even more conservative with additional safety factors
- Often Overlooked Quotes from Original Guidance
  - "other mechanisms…, including soil gas dilution and perhaps air-barrier shielding… These other mechanisms could explain why good radon reductions are often achieved by SSD systems even in cases where portions of the sub-slab are only marginally depressurized, to an extent far less than the nominally required 0.025 to 0.035 in [wc]." This is 6 – 9 pascals
  - "there may not necessarily be a significant impact on long-term average indoor concentration if the pressure differential across some portion of the slab is occasionally reversed."

Proposed New Design Criteria (Qualitative)

- Provide depressurization and thus remove the driving force for vapor intrusion, for a sufficient percentage of the operating time to address the chronic risks posed by VOCs. Through depressurization achieve an acceptable time averaged indoor air concentration.

To Make the Proposed Criteria Quantitative

- Begin by measuring the average indoor concentration of the constituent of concern (C_{avg}) by:
  - sequential extractive samples (i.e., Summa canister TO-15)
  - real time instrumentation providing continuous monitoring

  OR
  - passive samplers that provide long term time-integrated concentrations
- Then let C_{std} be an acceptable risk-based concentration in indoor air and $p_{average\ required}$ the target average differential pressure during SSD operation the engineer needs to achieve
- Assume the concentration in the indoor space is solely attributable to vapor intrusion. The rate of vapor intrusion flow is proportional to the square root of the long-term representative differential pressure (ASHRAE, 1993):

$$\frac{C_{std}}{C_{avg.pretreatment}} = k\sqrt{\frac{p_{avg.required}}{p_{avg.pretreatment}}}$$

K is a proportionality constant.

Note average differential pressure during treatment can be small, but not negative, and still achieve acceptable indoor air concentrations.

Given:

Pretreatment indoor air C_{avg} = 3 ug/m^3
30 year chronic standard (Indiana's) C_{std} = 1.2 ug/m^3
Avg. pressure diff. before treatment: p_{avg} = +3 pascals into building
K = 1

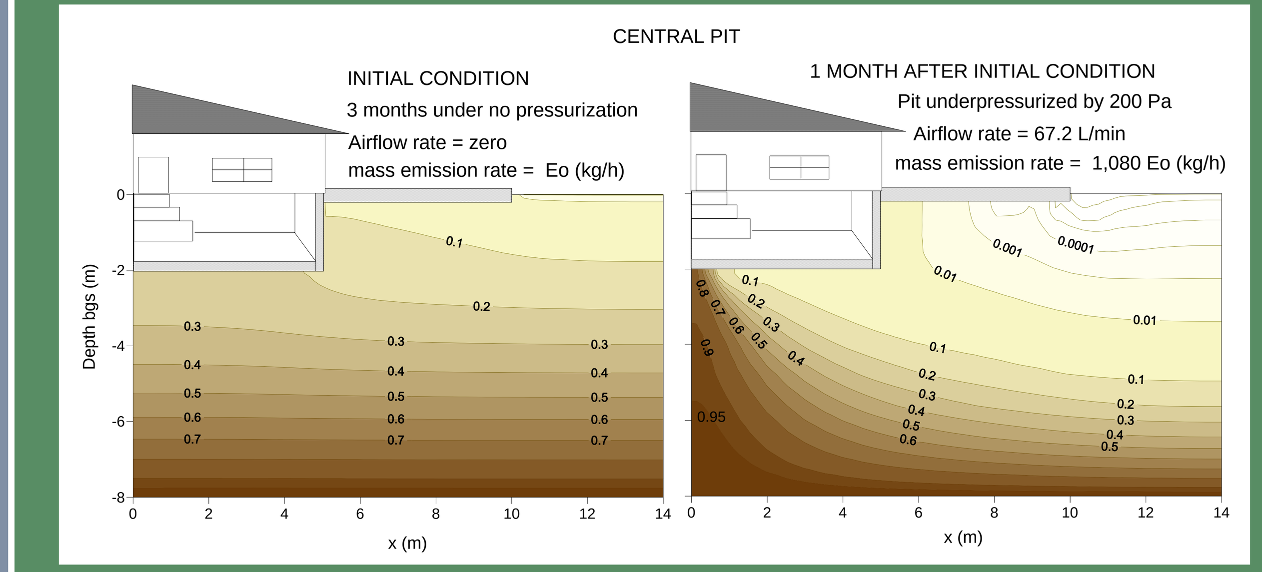
Result:

Maximum average pressure differential after treatment p_{avg} = +0.48 pascals into building. Thus any average depressurization in the other direction (for example: - 0.5 pascal = 0.002" w.c. will be sufficient.

Radon and VOC VI: Two Big Differences

One	Two
Radon sources are diffuse – 3.8-day half life soil sources close to the building are the biggest concern	Radon is naturally occurring and so systems have minimal design and ongoing monitoring – commoditized
versus	*versus*
VOC sources are often discrete concentrated source zones vertically separated from the building – such as groundwater	VOC sources are often discrete concentrated source zones vertically separated from the building – such as groundwater

A 3D Model of a Month of SSD Operation



Contour lines show relative soil gas concentrations

Goal: Minimize Mass Movement toward the Building from Plume while Still Protecting Occupants

How Do We Get There: Design Philosophy

- Adaptive Design – get system installed quickly, and then adjust it to achieve adequate depressurization and indoor air quality without excessive energy use.
- Focus SSD systems on building occupant protection, not mass removal. If you want mass removal, use a separate SVE system that doesn't pull contaminant mass toward the building for mass removal. This is especially important for making the system resilient to power failures (Hurricanes!)

Benefits of Revised Green Remediation Design Approach

- EPA defines green remediation as "considering all environmental effects of remedy implementation and incorporating options to maximize the net environmental benefit of cleanup actions." (EPA 2008).
- Minimization of energy requirements and air emissions are two of the six core elements
- This approach also reduces capital cost, operating cost and noise. Cost reductions typically 25-75%.
- Our field experiences show that reductions in VOC concentrations indoors can be achieved even with differential pressures of <0.004" w.c. = 1 Pascal.

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