ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
PROPOSED AMENDMENTS TO TIERED	)	R09-9
APPROACH TO CORRECTIVE ACTION	)	(Rulemaking – Land)
OBJECTIVES (35 ILL. ADM. CODE 742)	)	

EXHIBIT LIST

First Hearing: January 27, 2009, Springfield

Exhibit 1: *Errata* Sheet Number 1 of the Illinois Environmental Protection Agency (Agency)

Exhibit 2: *Errata* Sheet Number 2 of the Agency

Exhibit 3: Prefiled Testimony of Gary King of the Agency

Exhibit 4: Color Hardcopy of Slide Presentation of Dr. Atul Salhotra on behalf of the Agency

Exhibit 5: Prefiled Testimony of Dr. Thomas Hornshaw of the Agency

Exhibit 6: Prefiled Testimony of Tracey Hurley of the Agency

Exhibit 7: Prefiled Questions of Gail Artrip, Carlson Environmental

Exhibit 8: Prefiled Questions of the Illinois Environmental Regulatory Group

Exhibit 9: Prefiled Responses of the Agency

INDOOR INHALATION PATHWAY

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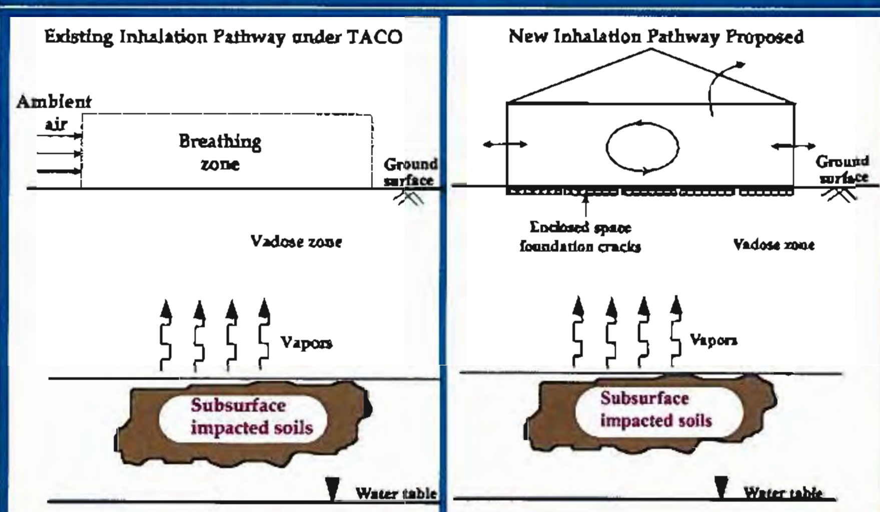
Agenda

- Introduction to the Indoor Inhalation Pathway
- Movement of Volatile Chemicals in Soil (Fate and Transport Mechanisms)
- Methods to Evaluate Indoor Inhalation Pathway

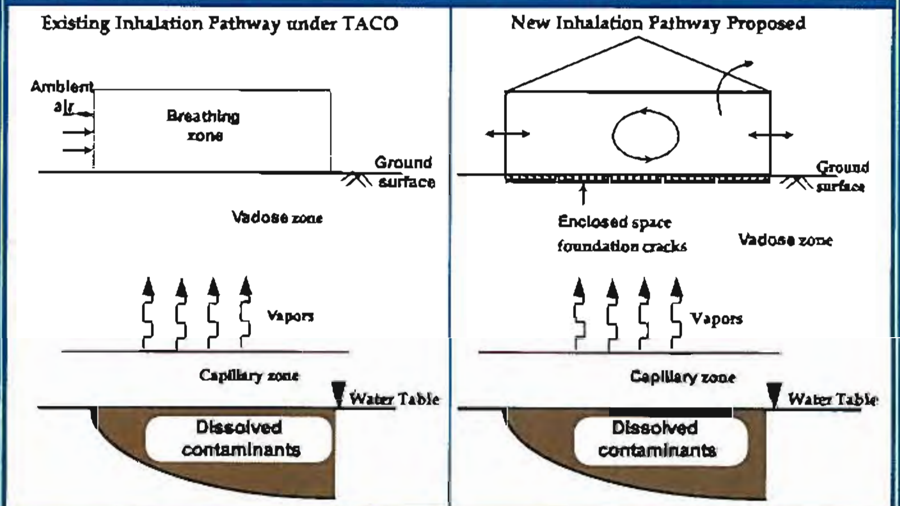
R09-9 Jan. 27, '09
Hrg. Exh. 4

Introduction to Indoor Inhalation

Subsurface Soil Volatilization Pathways



Groundwater Volatilization Pathways



Process of Indoor Inhalation
Six Steps

Step 1: Volatilization of chemicals from soil or groundwater

Step 2: Migration of chemicals from the point of volatilization to the building

Step 3: Entry of vapors into the building

Step 4: Mixing of vapors with the air inside the building

Step 5: Inhalation of air by a human being (receptor)

Step 6: Potential health risk to the receptor

These steps are quantitatively evaluated using a model.
We will discuss Step 2 in detail and also the model!

Factors that Affect Migration of Volatile Chemicals into a Building

- Characteristics of the source
  - Chemical of concern
  - Variability in the concentrations
  - Depth to contaminated soil and groundwater
- Media through which chemicals migrate
  - Capillary fringe
  - Vadose zone
  - Building material
  - Material that fills the cracks
- Characteristics of each medium
  - Porosity
  - Water content
  - Soil vapor permeability
  - Organic carbon content

Factors that Affect Vapors in a Building (continued...)

- Characteristics of the building
  - HVAC System/ Pressure/ Air exchange rate
  - Basements, crawl space, slab on grade
  - Size
  - Elevators
  - Preferential pathways
  - Current and potential future receptors
  - Cracks in buildings floor or basement walls
- Climatic factors
  - Temperature
  - Atmospheric Pressure

Assessment of Indoor Inhalation Pathway

- Assessment of this pathway is complex because:
  - Many factors affect the intrusion of vapors into a building.
  - These factors have strong spatial and temporal variability.
  - Factors are site-specific but cannot be easily measured.
  - Many of the chemicals of concern have indoor sources.
  - Elevated indoor air concentrations do not necessarily imply a subsurface source.

Necessary Conditions for Pathway to be Complete

- Presence of volatile chemical (s)
- Presence of a building
- Presence of a human receptor inside the building
- Absence of a barrier that prevents migration to the receptor

History of Pathway

- Radon accumulation (1980s)
- Methane migration from landfills
- Two solvents plumes in Colorado DOT Materials Testing Laboratory Redfield Rifle Site indicated indoor air impacts (late 1990s)
- Draft vapor intrusion guidance (EPA, 2002)
- ASTM standard (E2600-08) published in 2008

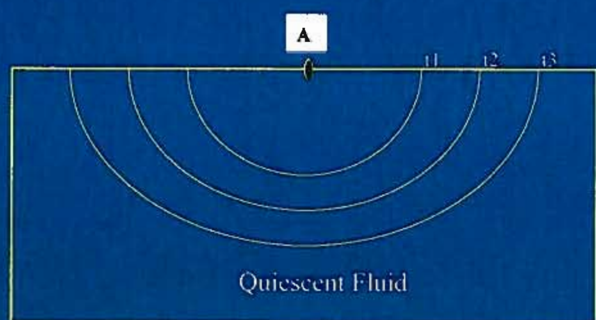
Movement of Vapors in Soil (Fate and Transport Processes)

Two Processes Cause Movement of Vapors

- Diffusion (Primary)
  - Molecular vibrations
- Advection (Variable)
  - Pressure Differences

Of these, advection may or may not occur.
We will briefly review each process.

Molecular Diffusion: Qualitative



Molecular Diffusion: Qualitative

- Occurs due to molecular vibrations
- Causes mass to move from area of high concentration to area of low concentration (concentration gradient)
- Mathematically, the mass that migrates is quantified using Fick's law

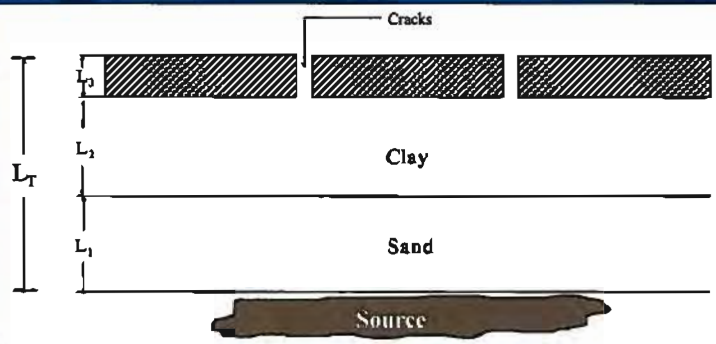
Diffusive mass transfer occurs in all situations where there is a concentration gradient

Transport of Mass by Diffusion Depends on

- Diffusion coefficient which is chemical specific
- Porosity of the soil
- Water content of the soil
- Variations in porosity and water content in different soil horizons

Above factors are combined to estimate the effective diffusion coefficient of soil below building

Schematic of Layered System



L_T = Thickness of all layers [cm] (For groundwater, capillary fringe is a separate layer)

L_1 = Sand layer thickness [cm]

L_2 = Clay layer thickness [cm]

L_3 = Slab thickness [cm]

Advection

- Migration of chemicals due to the bulk movement of air
- Bulk movement of air caused by pressure difference
- Vapor flow occurs from high pressure to low pressure areas
- Complicated analytical and numerical models used to estimate migration due to advection

Methods to Evaluate Indoor Inhalation Pathway

Two Methods to Evaluate Risks to Persons for Indoor Inhalation Pathway

1. Collect indoor air samples and compare to acceptable indoor air concentrations.
2. Collect soil and groundwater or soil gas samples and calculate soil and groundwater or soil gas remediation objectives based on acceptable indoor air concentrations.

Evaluation Based on Indoor Air Measurements
Two Step Process

Step 1: Measure **representative** indoor air concentrations

Step 2: Evaluate the measured concentrations

Simple method but has many issues.

Issues with Indoor Air Measurements

- Numerous indoor air sources (cooking, washing, smoking)
- Difficult to attribute the portion coming in from subsurface sources vs. indoor or ambient air
- Considerable temporal and spatial variability: difficult to explain
- One snapshot may not be enough: repeat measurements necessary
- May cause unnecessary alarm and inconvenience

Avoid indoor air concentration measurements unless absolutely Necessary.

JOHNSON & ETTINGER MODEL

JOHNSON & ETTINGER MODEL

- First published in peer reviewed journal in 1992
- Used by many states and USEPA
- Key technical components
  - Emission model that includes
    - Dispersive transport in vadose zone
    - Dispersive & advective transport within building zone of influence
    - Finite source and infinite source
  - Indoor air mixing model
  - Dose and risk calculations
- Numerous inputs and assumptions

JOHNSON & ETTINGER MODEL

The risk-based ROs for indoor inhalation pathway are derived from J&E equations using the following four steps:

Step 1: Calculate target or acceptable indoor air concentration

Step 2: Calculate attenuation factor

Step 3: Calculate target or acceptable soil gas concentration

Step 4: Calculate target or acceptable soil and/or groundwater concentration

Each of the steps is briefly explained in next slides.

Step 1: Calculate Target or Acceptable Indoor Air Concentration

Acceptable indoor air concentrations are calculated to be adequately protects humans who inhale this air (i.e., meets the risk criteria of one-in-a-million individual excess lifetime cancer risk and a hazard quotient of one).

Calculation uses:

- Target risks
- Exposure factors
- Toxicity values

Step 2: Attenuation Factor Definition

The ratio of the concentration in the indoor air (Step 1) to the soil gas concentration is called the attenuation factor.

$$\text{Attenuation Factor } (\alpha) = \frac{\text{Indoor Air Concentration}}{\text{Soil Gas Concentration at Source}}$$

(α always ≤ 1)

Higher $\alpha \rightarrow$ Less attenuation or higher indoor air concentration

$\alpha = 0.5$, implies a factor of 2 reduction in concentration
$\alpha = 0.01$, implies a factor of 100 reduction in concentration

$1/\alpha$ is the concentration reduction factor.

Step 2: Attenuation Factor Calculation

Calculation of attenuation factor is based on J&E model and required following inputs:

- Source parameters
- Geotechnical parameters
- Building parameters

Step 2: Attenuation Factor General

The attenuation factor accounts for the following processes:

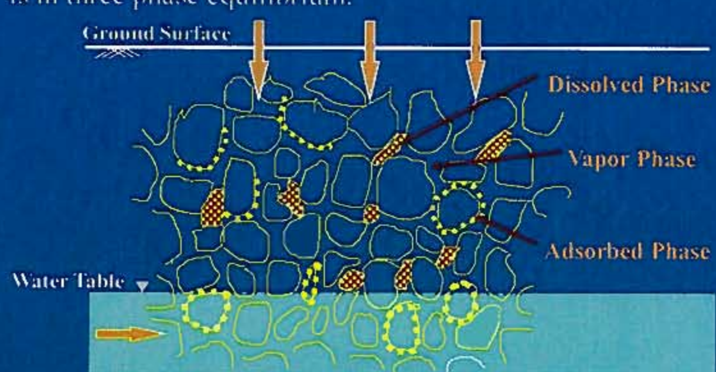
- Migration of contaminants from the source upwards through the vadose zone. The source of contaminant concentrations in the subsurface may be either soil or groundwater. If the source is groundwater, the attenuation factor considers the initial migration of contaminants through the capillary fringe.
- Migration of contaminants through cracks in the slab-on-grade or basement floor.
- Mixing of the contaminants with air inside the building.

Step 3: Calculate Target or Acceptable Soil Gas Concentration

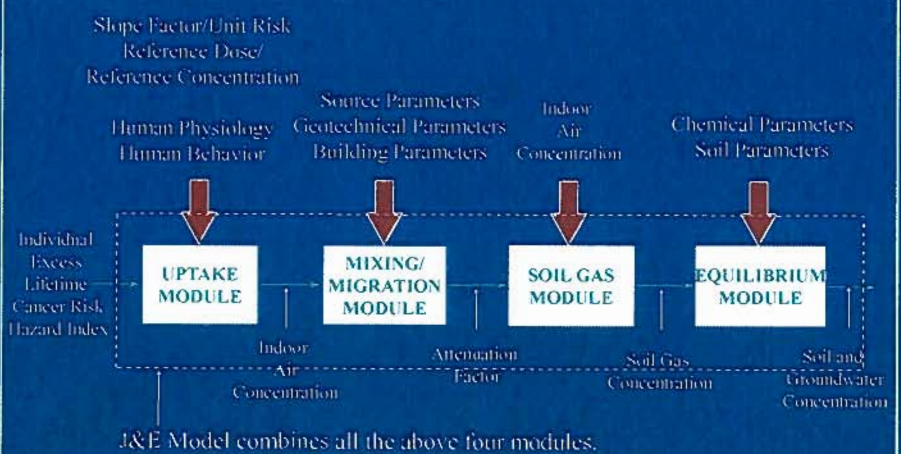
Calculate an acceptable concentration of the contaminant of concern in the soil gas at the source of contamination. This concentration will not cause the contaminant in indoor air to exceed the concentration calculated in Step 1. This calculation was made using an attenuation factor derived from the modified J&E model.

Step 4: Calculated Target or Acceptable Soil and Groundwater Concentration

Calculate acceptable soil and groundwater ROs using the soil gas RO calculated in Step 2, with the assumption that this contaminant is in three phase equilibrium.



Estimation of Tier 1 ROs



Summary of Indoor Inhalation Models

Indoor inhalation depends on:

1. Source vapor concentration
2. Media parameters
3. Building parameters
4. Environmental parameters

Summary of Indoor Inhalation Pathway

- Indoor inhalation pathway is conceptually simple
- Pathway risk depends on numerous inputs
- Data necessary to evaluate pathway can be collected and analyzed in a timely and cost-effective way
- Conceptually simple methods can be used to make the pathway incomplete
- Mitigation measures (Building Control Technologies) ought to be evaluated as a part of the site conceptual model