M-F2 Introduction to Exposure Assessment with Case Studies

Monday 10:00-11:45am

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25th California Unified Program Annual Training Conference
March 20 – 23, 2023

Overview

- Exposure concepts
  - e.g., exposure media, routes of exposure, pathways of exposure
- How do we estimate exposure to general population?
  - Approaches
  - Measurements vs modeling
- Understand how to quantify exposure for noncancer and cancer risk assessments: Examples

Introduction

Steps of Human Health Risk Assessment

Hazard Identification

Dose-Response Assessment

Exposure Assessment

Risk Characterization

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Exposure Assessment Defined:

The process of characterizing exposures of a population to one or more contaminants in environmental media

It involves determining the amount of chemical entering the body from an environmental media

Importance of Exposure Assessment

- To understand, characterize, and quantify human exposures to environmental chemicals
- To protect public health
- To determine risks to the general population using exposure data
- To understand risk to specific subpopulations and exposures that differ between groups
- To aid in cleanup decisions

Human health risk assessment is the evaluation of scientific information on:

Hazard Identification

- the hazardous properties of environmental agents

Dose-response Assessment

- the dose-response relationship, and

Exposure Assessment

- **the extent of human exposure to those agents.**

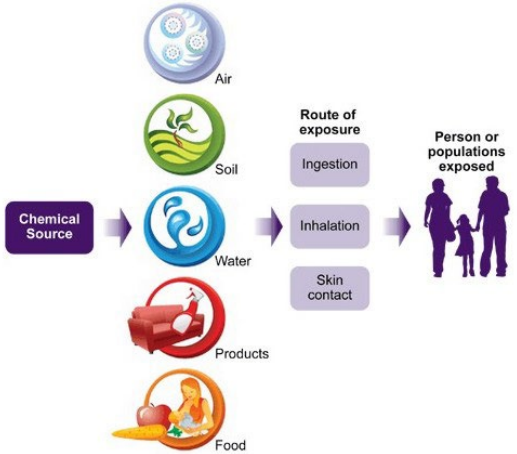
Risk Characterization

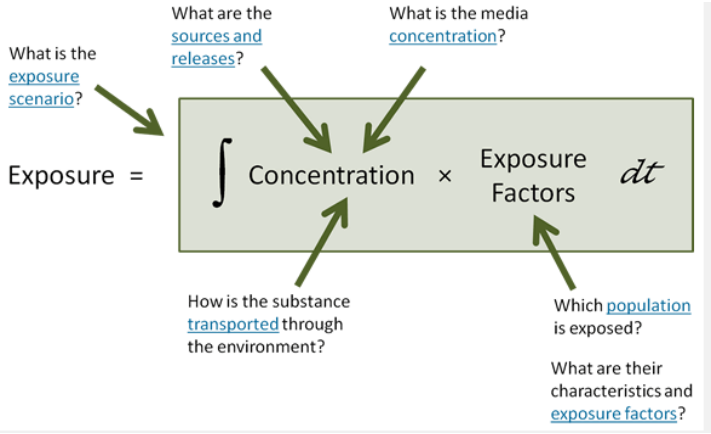
The **product** of the risk assessment is a statement regarding the probability that populations or individuals exposed will be harmed and to what degree

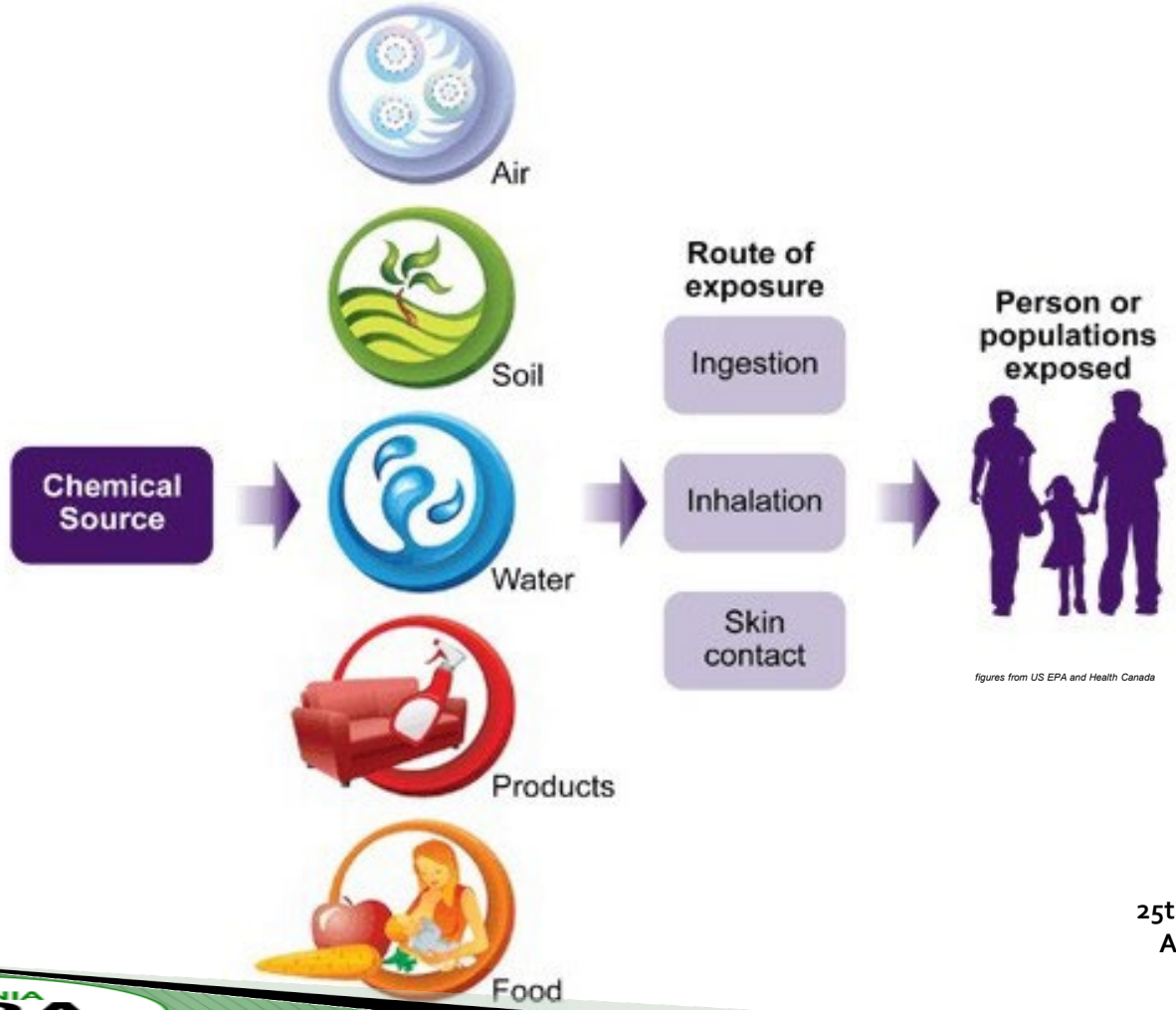
What is Exposure?

Exposure Assessment Definitions

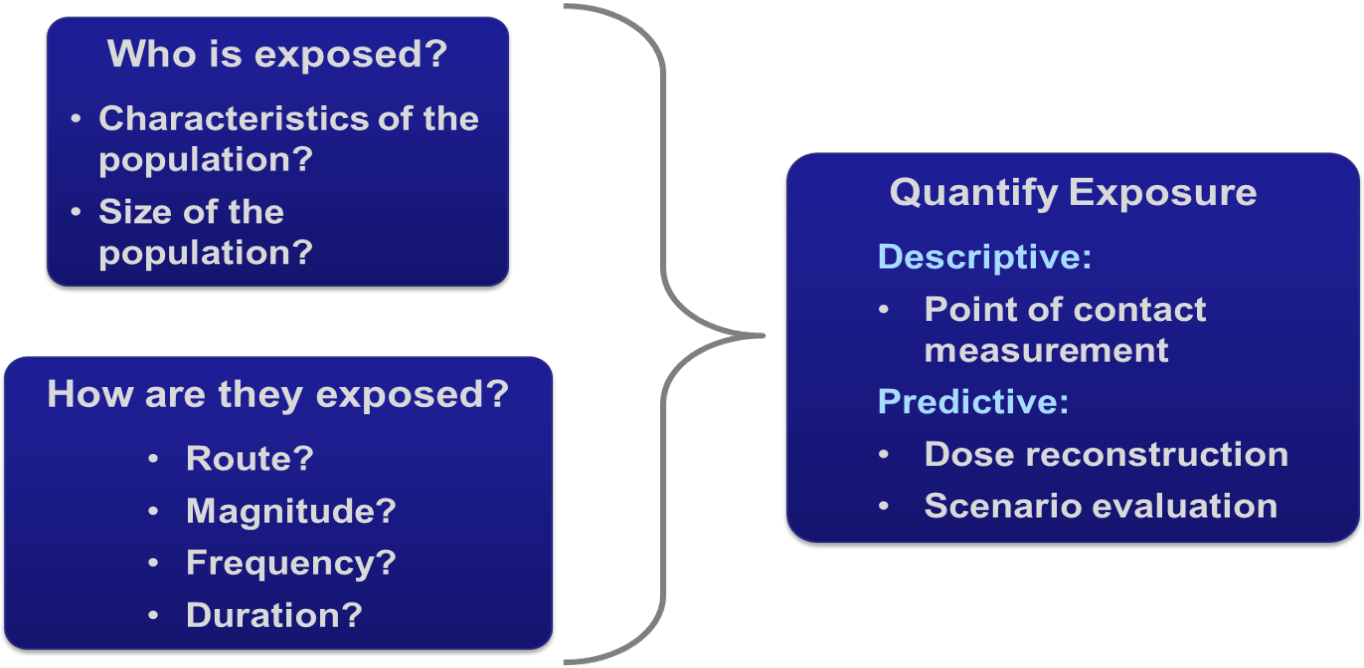
- **Exposure** is typically quantified as the amount of a chemical, physical, or biological agent available at the exchange boundaries of the organism (e.g., skin, lungs).
- Exposure Assessment involves Identifying the **pathways** by which toxicants may reach individuals,
- Estimating **how much** of a chemical an individual is likely to be exposed to, and
- Estimating the **number likely to be exposed**
- Basically, the determination or estimation (qualitative or quantitative) of the **magnitude, frequency, duration, and route** of exposure





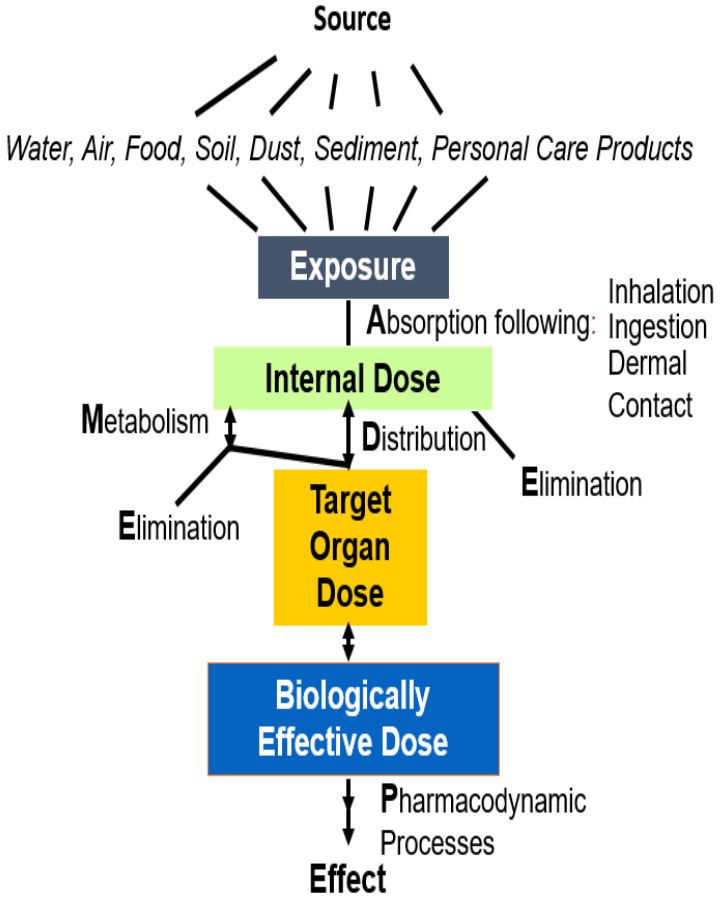


figures from US EPA and Health Canada


Who is exposed?
• Characteristics of the population?
• Size of the population?
How are they exposed?
• Route?
• Magnitude?
• Frequency?
• Duration?
Quantify Exposure
Descriptive:
• Point of contact measurement
Predictive:
• Dose reconstruction
• Scenario evaluation

Dose

The amount of substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism



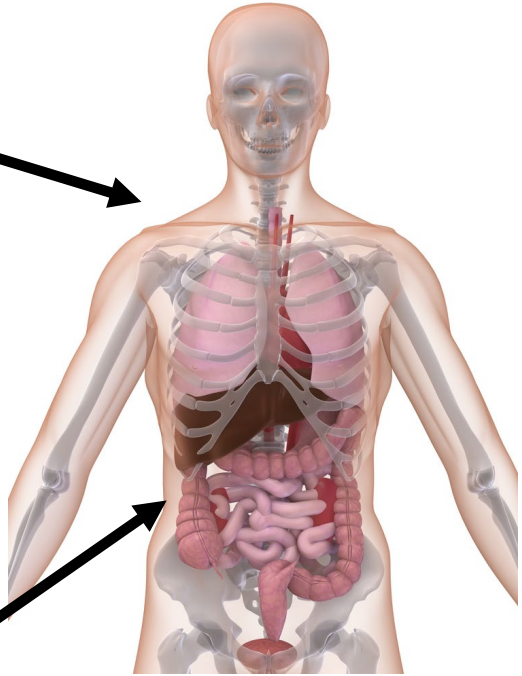
Exposure and Dose

On the topic of more specialized "dose" terminology…keep in mind that terms used may vary based on program / agency.

Potential dose:
Ingested, inhaled, applied to skin

Applied dose:
Present in exposure medium
(µg / m³)

Internal dose:
Amount absorbed and available for interaction
(µg / kg)



Why Conduct An Exposure Assessment?

- **Estimate an average dose for a risk assessment**
- Compare exposure / estimated dose to a standard
- Identify major sources / activities or pathways
- Assess status and trends of total exposure
- Classify members of an epidemiological study

Exposure Assessment: What do we need to determine?

Exposure Assessment involves determination or estimation (*qualitative or quantitative*) of several important aspects, including:

- **Nature of the agent**: Chemical, physical and biological properties
  How is it released? How is it transported through –and transformed in– the environment?
- **Intensity of exposure**: magnitude, concentration
  How much?
- **Exposure Factors**: characteristics of the receptor(s)
  How much of the exposure media are we taking in?
- **Exposure frequency**: *How often?*
- **Exposure duration**: *For how long?*

Exposure Concepts

Exposure pathway:

Connection between pollutant source and exposure including environmental media and **route of exposure**.

A **source of exposure:** origin of a substance: *such as a consumer product or a chemical spill*

An **environmental media** and **transport mechanism** —

environmental media include water, air, soil, and biota while transport mechanisms move contaminants from the source to points where human exposure can occur

such as movement of a substance through the indoor or outdoor air or through groundwater

A **point of exposure** — the point at which a person comes into contact with a substance in the environment

such as a person's house or a private well

Exposure Concepts

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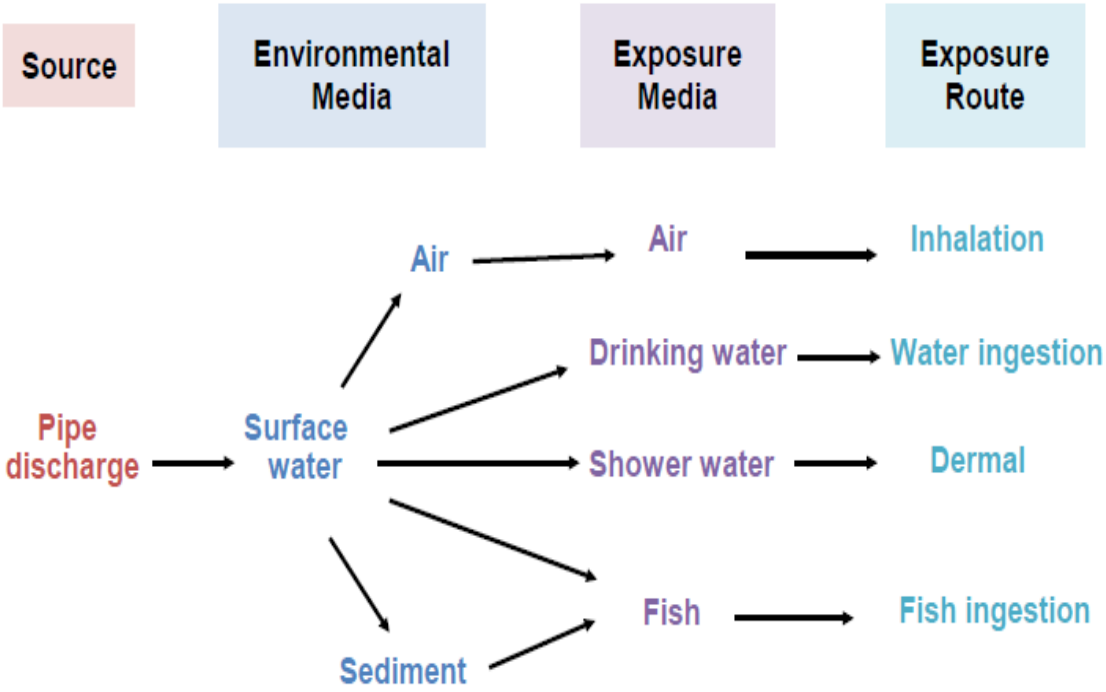
Exposure Concepts

- A **route of exposure** — how a person is exposed (ingestion/dermal contact/inhalation/injection)
  - *such as eating (ingestion), drinking (ingestion), breathing (inhalation), or touching (dermal contact)*

- A **receptor** population — a person or group of people (population) that is potentially or actually exposed
  - *such as children in a daycare next to a factory*

Exposure Pathway



Sources of Exposure





How is the contaminant released?

- Duration of release
- Quantity released
- Characteristics of source
- Area of contamination

Where is the contaminant discharged?

- Soil or sediment
- Surface water
- Ground water
- Biota
- Air

US EPA, 2014

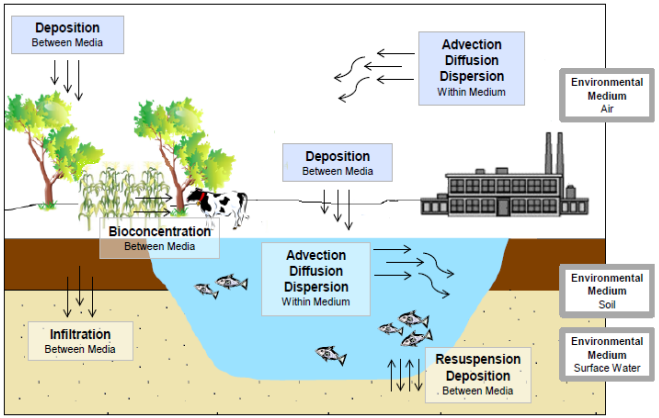
Environmental Media and Transport

- The environmental and exposure media (as well as transport and transformation) are influenced by chemical and physical properties, including:
  - vapor pressure, lipophilicity, water solubility, particle size

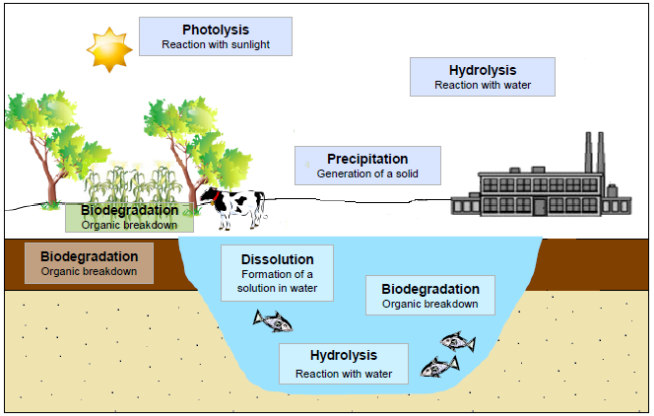
    - **Vapor pressure**: How likely a compound will evaporate, or convert from a liquid phase to a gaseous phase
      - ↑ Vapor pressure: more likely to be found in gas phase
    - **Water solubility**: Measure of the maximum amount of a chemical that will dissolve in pure water
      - ↑ Solubility: more likely to be mobile in environment
      - Less likely to sorb to other media or bioconcentrate
    - Both vapor pressure and water solubility are temperature dependent

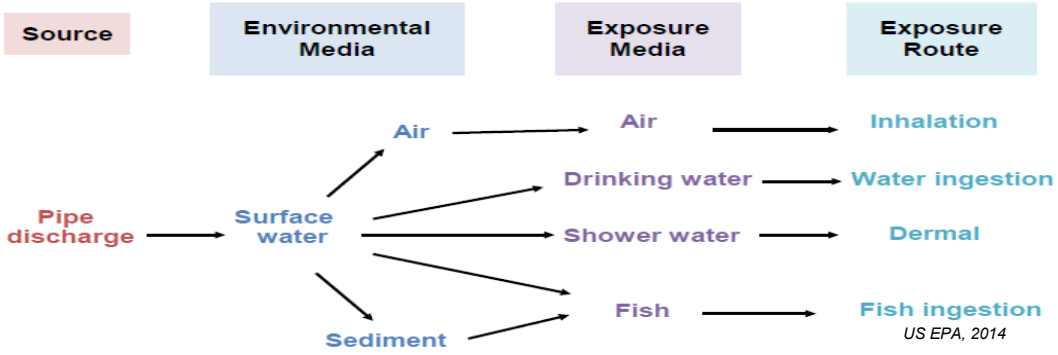
Environmental Media and Transport

Transport: Movement Within and Between Environmental Media



Transformation: Chemical Changes within a Medium





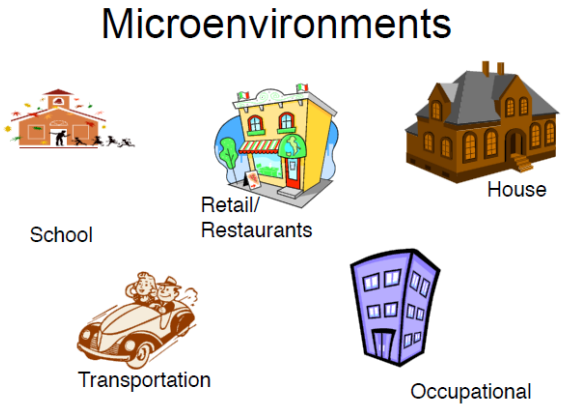
US EPA, 2014

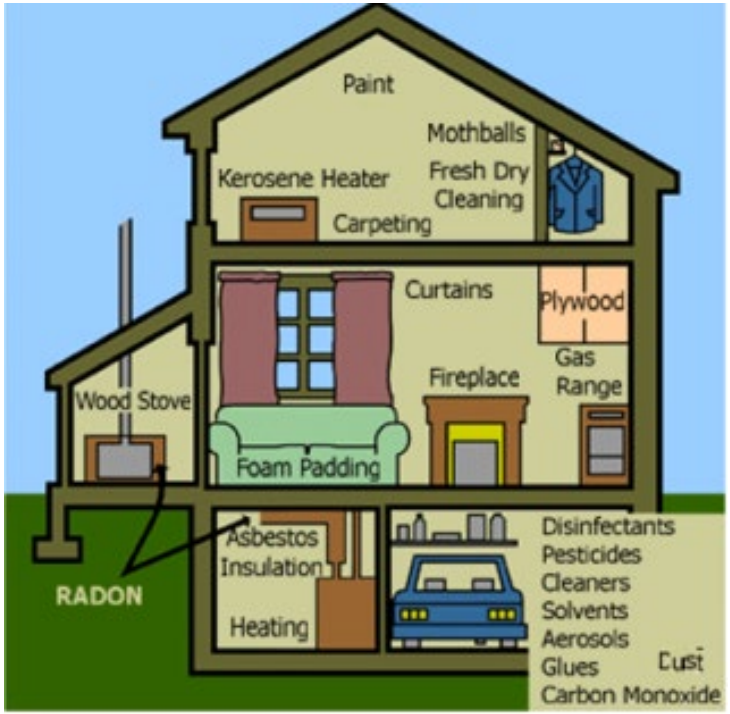
Point of Exposure

The point at which a person comes into contact with a substance in the environment

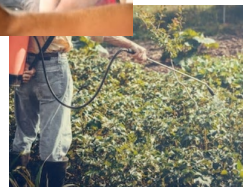
Example: Residential Indoor Air

Related Concept of the **Microenvironment**: **any *location or activity* in which a distinct exposure occurs**





Routes of Exposure



- **Inhalation**
  - Chemicals with higher vapor pressures
  - Aerosol bound particles and chemicals
  - Circulating dust particles
  - Particulate matter

- **Ingestion**
  - Dietary pathways
  - Non-dietary ingestion

- **Dermal absorption**
  - Accidental exposures
  - Intentional contact with the skin
- Ocular (eye) exposures, direct injection

Receptors (Individual or Population)

Individual- versus Population-Level Considerations!

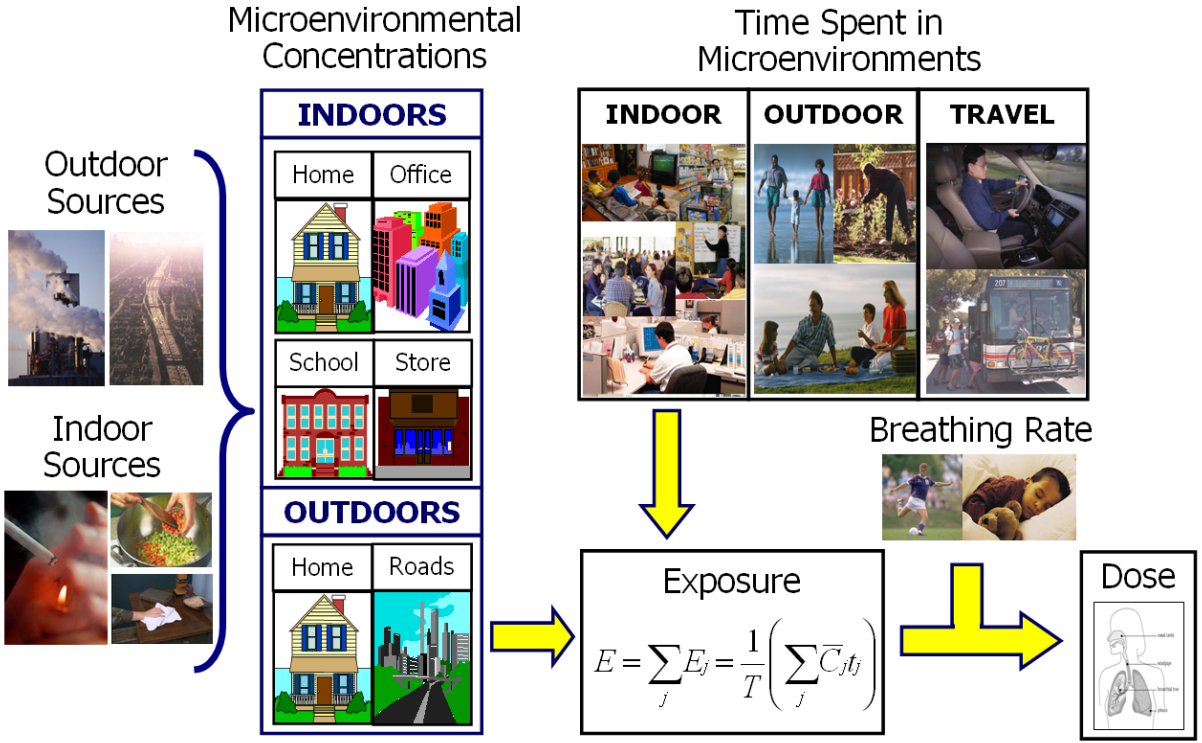
Exposure assessment are usually conducted for populations or groups

- **Exposure factors,** or characteristics of the population, are important to estimate exposure and risk that facilitate estimation of uptake or dose if the contaminant concentrations at the exposure surface is known.
- Examples include:
  - Food and water intake
  - Population behaviors
  - Inhalation rates
  - Other factors relevant to scenario

*__There are standardized factors available,__ e.g. the US EPA's Exposure Factors Handbook

Exposure Assessment:

A Visual Schematic for Inhalation Exposure to Air Contaminants

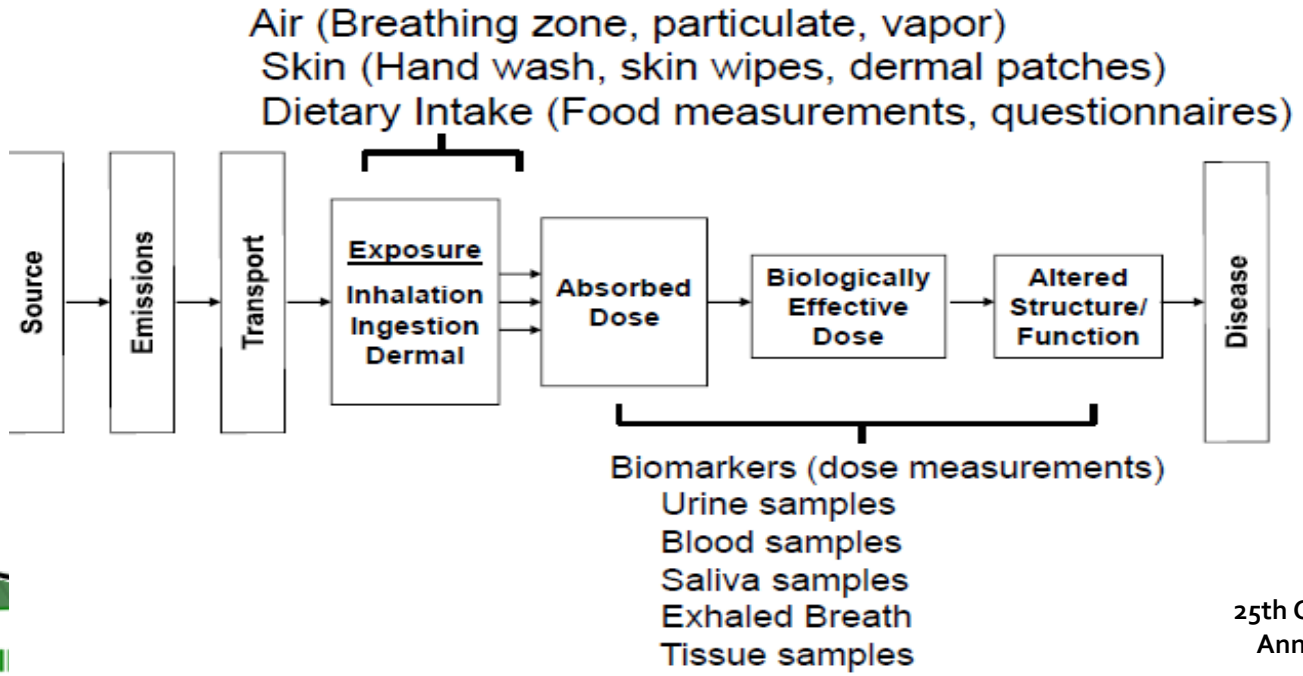


Data for Exposure Assessments:
Measurements and Estimates of Exposure (Concentration)

- In risk assessments where the substance is a more ubiquitous contaminant, we frequently have **measurements** (e.g., in air or water) to use to assess exposure.
- However, in most risk assessments:
  - the amount of chemical in contaminated environmental media is **modeled**

Data for Exposure Assessments:

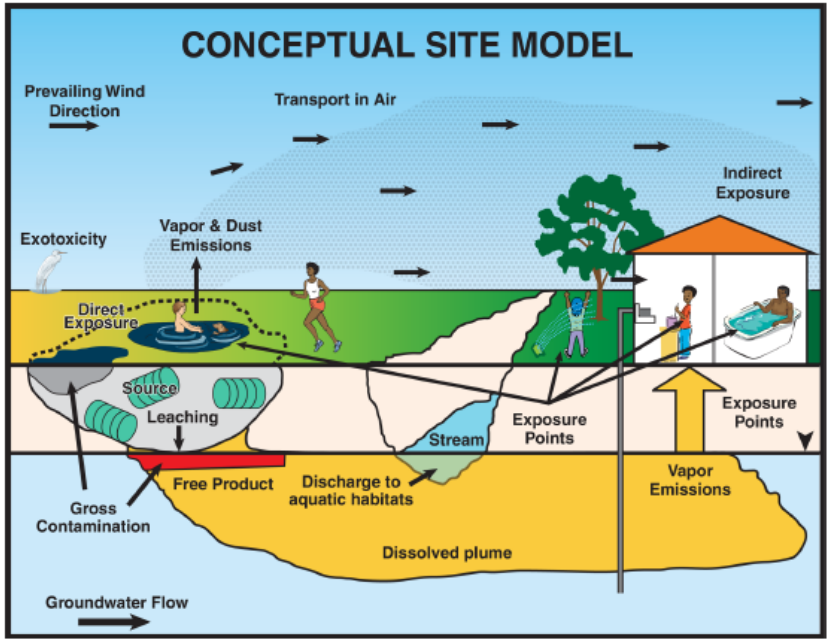
Measurements and Estimates of Exposure (Concentration)



Data for Exposure Assessments:
Considerations for Type of Exposure

- **Acute exposures** – short-term
  - Single point measurement on distribution may be adequate
  - Health-protective uses require many measurements
  - Evaluate frequency, magnitude of high concentrations
- **Chronic exposures** – long-term
  - Mean or median of data provides "typical" exposure
  - Tail of distribution might help estimate upper bound exposure

Data for Exposure Assessments:
Environmental Measures: Scenario Evaluation



- Measure or estimate the amount of substance contacted at a site
- Use equations and assumptions about behavior and exposure
- Mathematical estimation of exposure; predictive estimate

US EPA, 2014
ITRC, 2012

Types of Exposure Assessment and Data Considerations

	Screening Assessment	Refined Assessment
Measurements	• Readily available measured data • Release estimates based on generic emission factors	• Site-specific measured data • Emissions monitoring data
Inputs	• Generic or conservative model parameterization • Generic conservative exposure assumptions	• Site-specific parameterization
Models	• Simple models	• More complex models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Calculating Exposure

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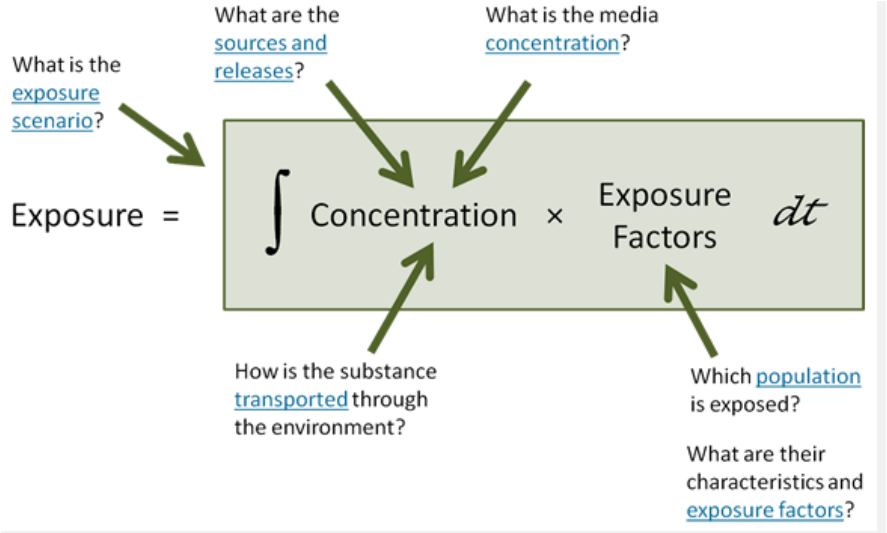
Calculating Exposure

Reminder: "Basic" Exposure Equation is

Exposure = f (Concentration, Time, Behavior)



Calculating Exposure

Example: Simplest Equation for Chemical Exposure from **Air Intake**

$$E_{inh} = (C_a)(IR)$$

where:

E_{inh} = inhalation exposure (mass per time)

C_a = airborne concentration of the chemical contacted by the exposed individual (mass of chemical per volume of air in breathing zone)

IR = inhalation rate (volume of air breathed per unit time)

Calculating Exposure

Example: Simplest Equation for Chemical Exposure **from Ingestion Intake**

$$E_{ing} = (C_{ing})(IR)$$

where:

E_{ing} = ingestion exposure (mass per time)

C_{ing} = concentration of the chemical in food or other exposure media (mass of chemical per mass of medium or mass of chemical per volume of medium)

IR = ingestion rate (mass of medium ingested during the exposure per time)

Calculating Exposure/Dose: Equations

$$\textbf{Potential Dose} = \frac{C \times IR \times CF \times ED \times EF}{AT \times BW}$$

Absorbed Dose = Potential Dose x AF

Absorbed Dose = Internal Dose

Where:

C = Contaminant Concentration

IR = Intake Rate

CF = Contact Fraction

ED = Exposure Duration

EF = Exposure Frequency

AT = Averaging Time

BW = Body Weight

AF = Fraction of Potential Dose Absorbed

General units for dose: $\frac{\text{Mass contaminant}}{\text{Average time x Body weight}}$

:

$$\frac{\text{Mass contaminant}}{\text{Average time x Body weight}}$$

Practice:
Exposure Assessment

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Conclusion

- Exposure concepts
- Ways to estimate exposure to general population
- Ways to quantify exposure for noncancer and cancer risk assessments
- Practice calculations for example scenarios