

# Developing Exposure Scenarios and Calculating Dose



**RISK ASSESSMENT TRAINING AND EXPERIENCE**  
**Exposure Assessment Course Series – EXA 403**

# What You Can Expect to Learn from this Course



- What is an exposure scenario?
- What are important elements to consider when developing an exposure scenario?
- How are exposure scenarios used in risk assessment?



# INTRODUCTION AND BASIC CONCEPTS

# What is an Exposure Scenario?

An **exposure scenario** is a set of facts, assumptions, and inferences about how exposure takes place that aids the exposure assessor in evaluating, estimating, or quantifying exposure.

Source: EPA's Example Exposure Scenarios Guide (2004)

# What Elements are Encompassed by an Exposure Scenario?

- Exposure setting
- Chemical of concern
- Source of contamination
- Exposure pathway and exposure route
- Environmental and exposure media
- Intake and uptake rates
- Population of concern

# Why Do We Develop Exposure Scenarios?

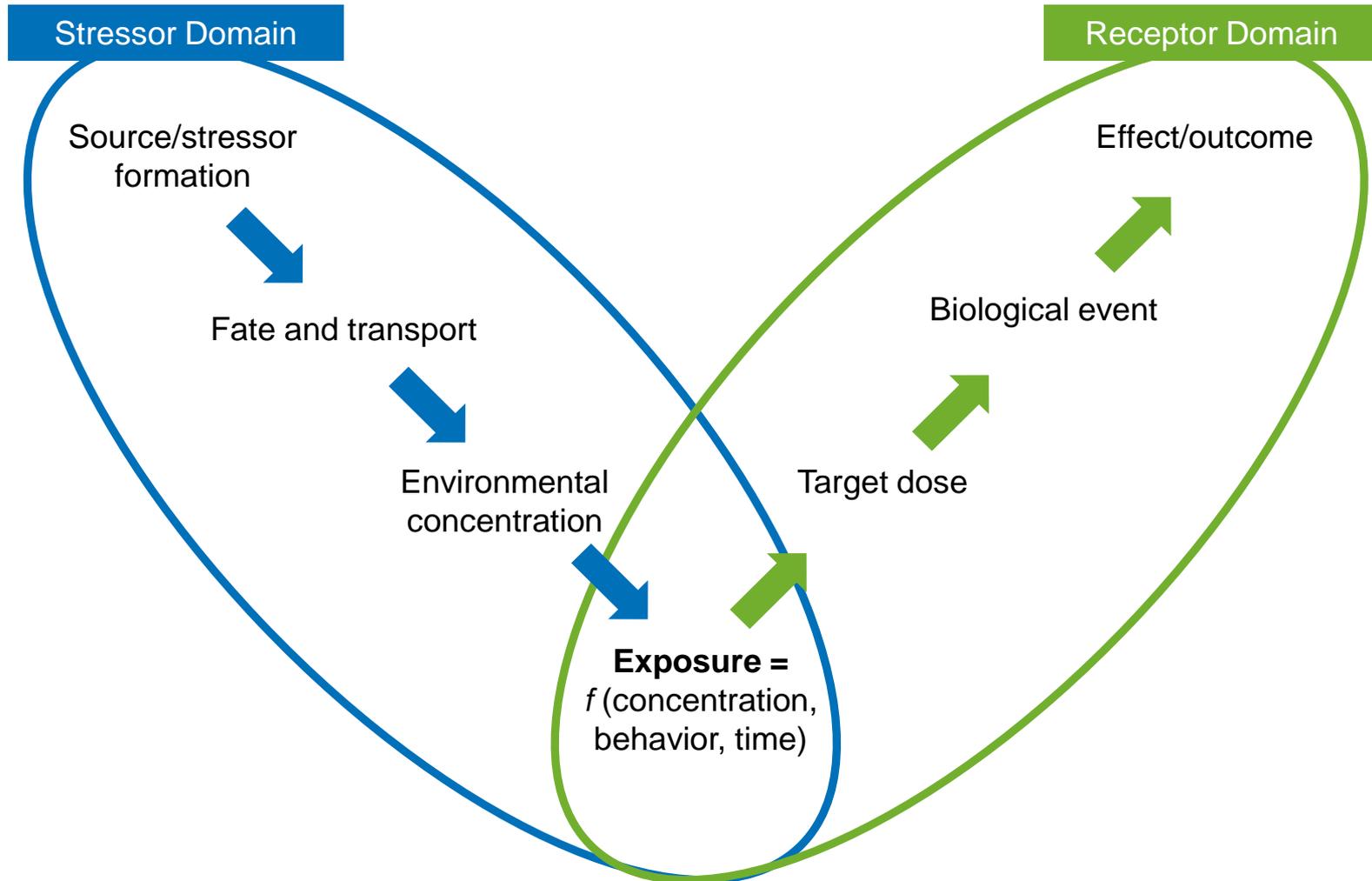
- To picture how exposure might take place
- To provide a framework for quantifying potential exposures for a risk assessment
- To follow fate of a chemical from source to exposure (and beyond)



# Example Exposure Scenario

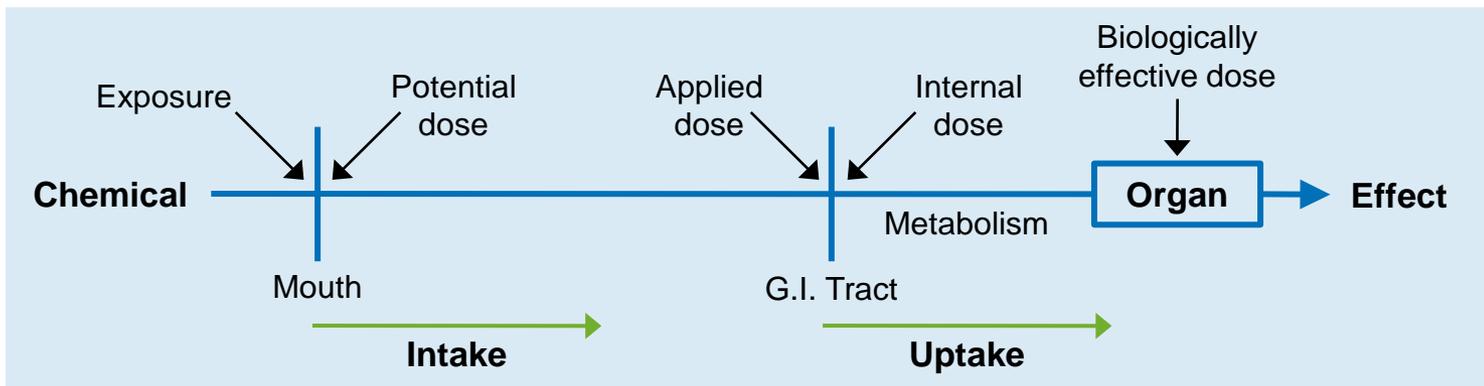


# Overview of Source to Dose to Outcome

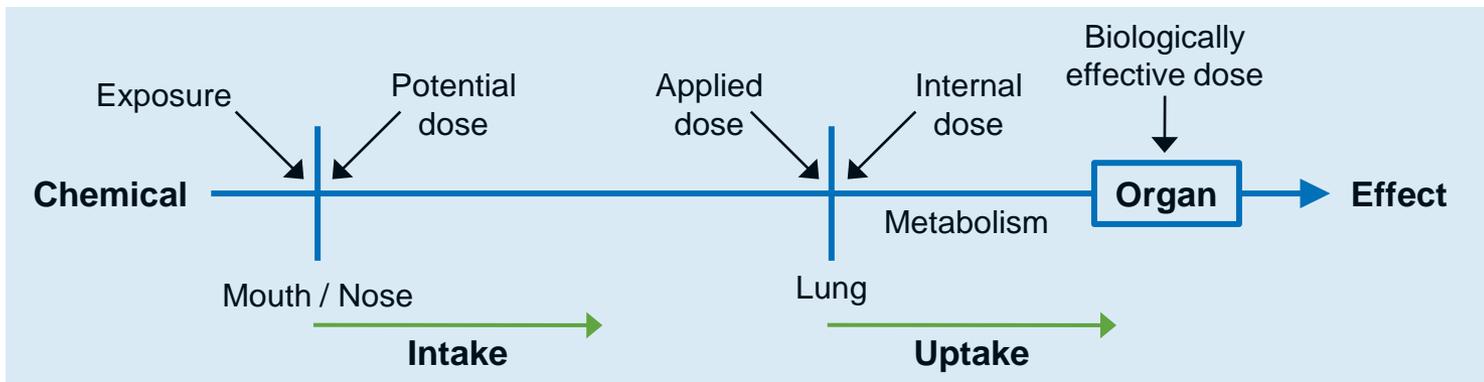


# Dose Concepts

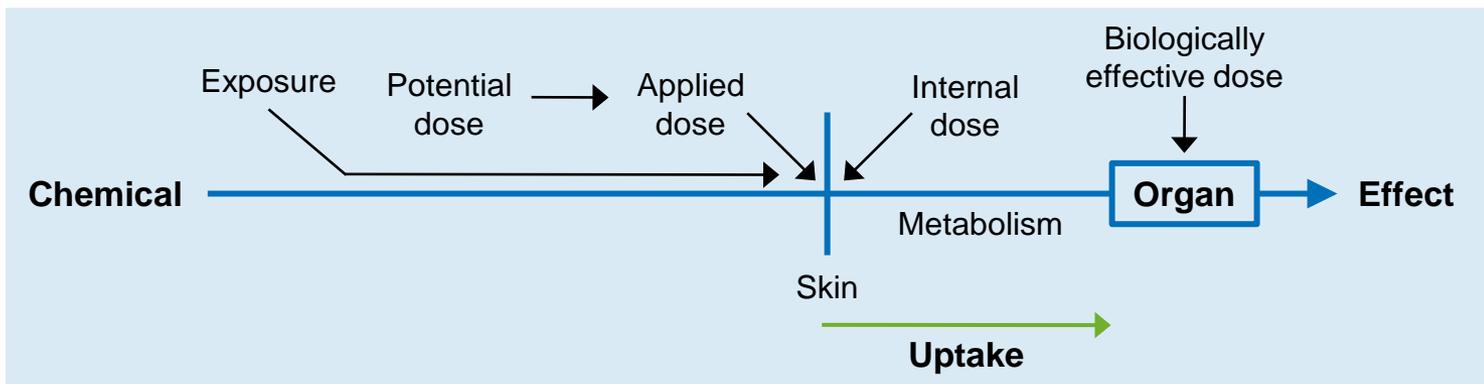
## Oral Route



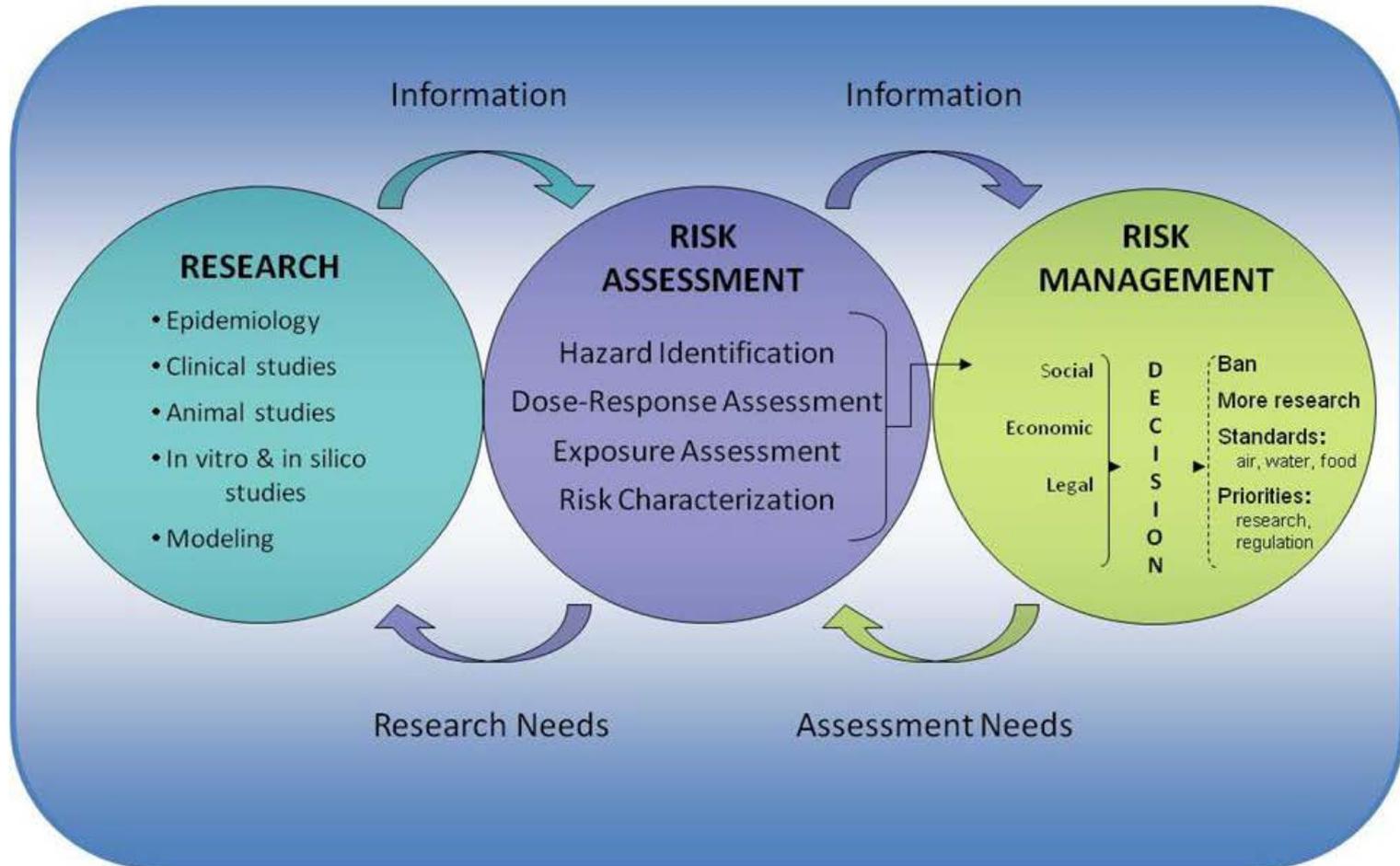
## Respiratory Route



## Dermal Route



# Exposure is a Critical Component of the Risk Assessment Paradigm



# Use of Dose in Quantitative Risk Characterization

- Desired units of dose will depend on:
  - What “type” of risk is being evaluated
  - Units of available toxicity reference values

**Cancer risk  
(Inhalation)**

$$\text{air concentration} \left( \frac{\mu\text{g}}{\text{m}^3} \right) \times \text{inhalation unit risk estimate} \left( \frac{\mu\text{g}}{\text{m}^3} \right)^{-1}$$

**Non-cancer  
hazard quotient  
(Ingestion)**

$$\frac{\text{Dose via ingestion} \left( \frac{\text{mg [chem]}}{\text{kg [BW]} - \text{day}} \right)}{\text{RfD} \left( \frac{\text{mg [chem]}}{\text{kg [BW]} - \text{day}} \right)}$$

# Dose Equation

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

$$\text{Absorbed Dose} = \text{Potential Dose} \times AF$$

$$\text{Absorbed Dose} = \text{Internal Dose}$$

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

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

# Dose Parameters that Can Vary Over Time

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

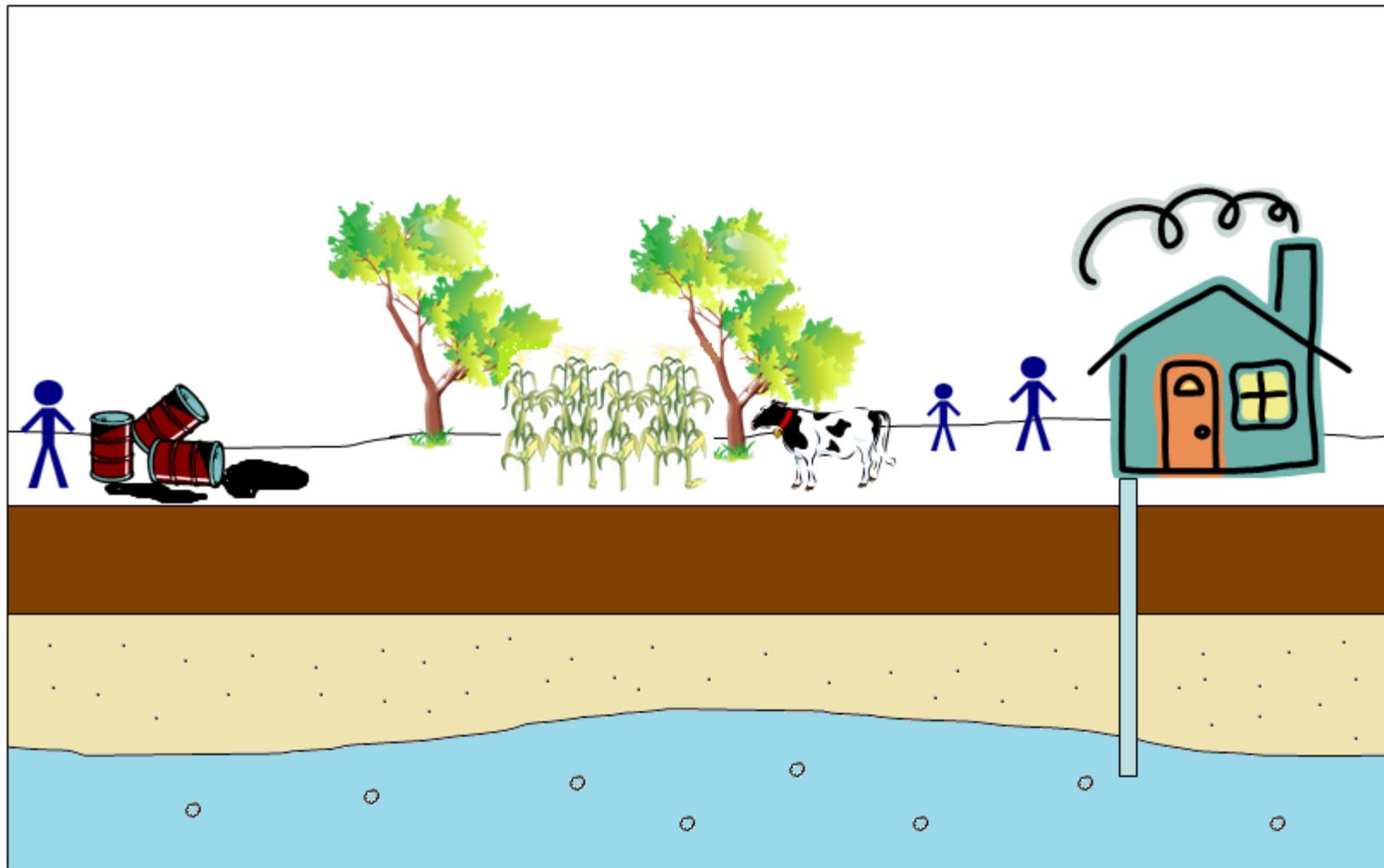
Variable	Common Units
Contaminant concentration (C)	mg/m <sup>3</sup> , mg/kg
Contact fraction (CF)	unitless
Intake rate (IR)	mg/day, L/day
Body weight (BW)	kg

# Temporal Parameters in Dose

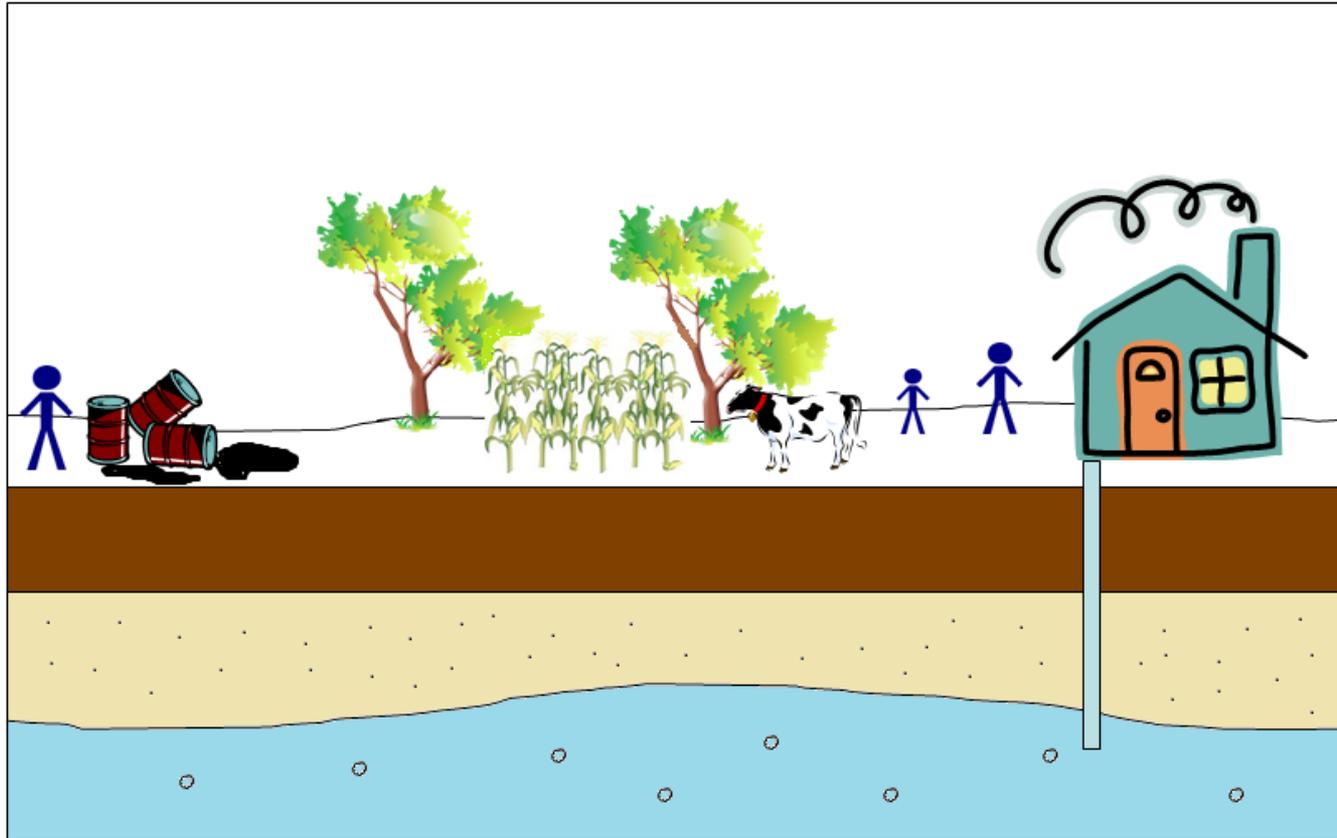
$$\text{Potential Dose} = \frac{C \times IR \times CF \times ED \times EF}{AT \times BW}$$

Variable	Common Units
Exposure duration (ED)	minutes, hours, days, years
Exposure frequency (EF)	days/yr, events/day
Averaging time (AT)	minutes, hours, days, years

# CHARACTERISTICS OF AN EXPOSURE SCENARIO



# Exposure Setting



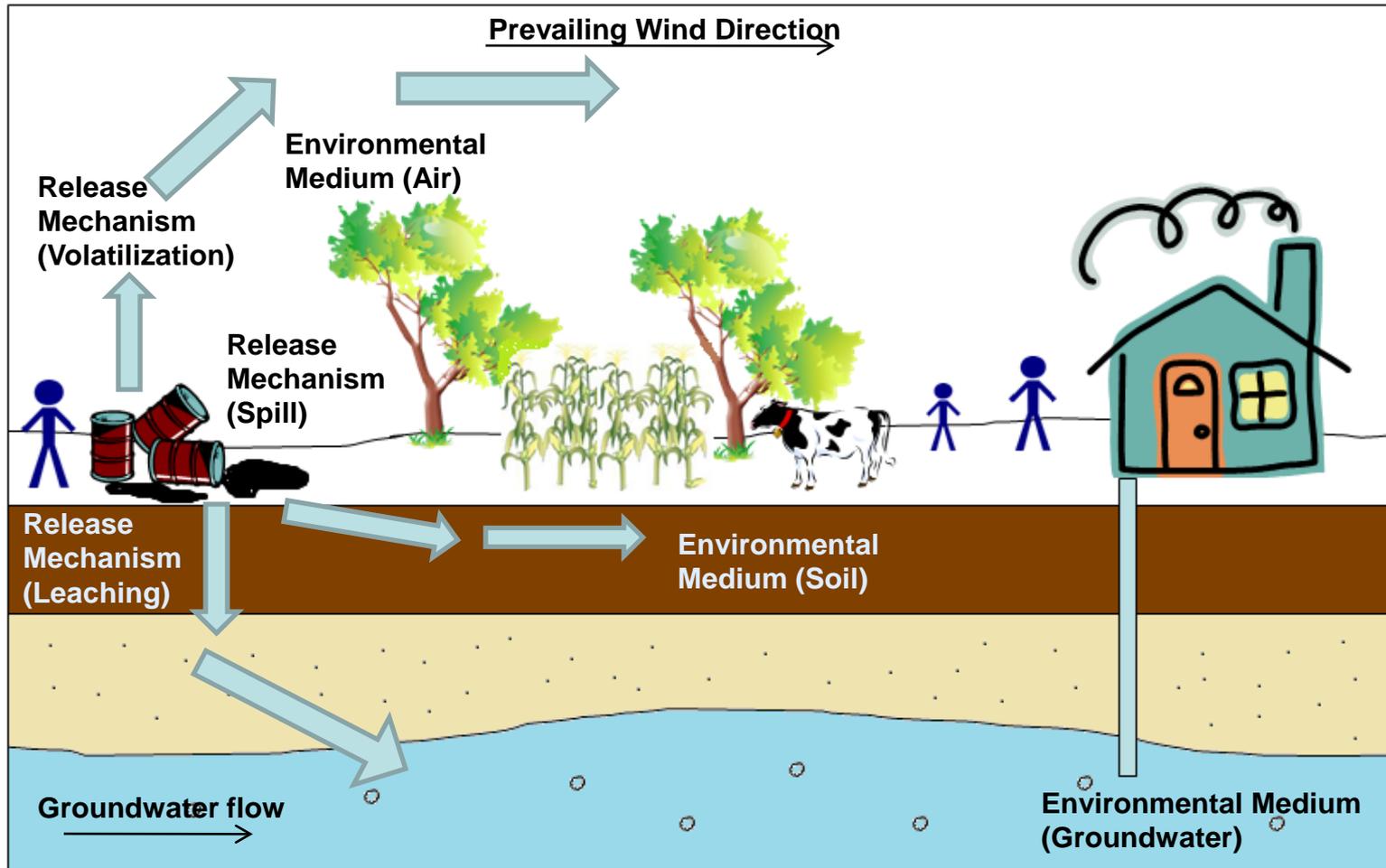
**Exposure setting:** the physical setting where the exposure occurs

# Chemical of Concern

- **Chemical of concern:** a chemical to which a person is exposed
- **Properties of interest of a chemical of concern:**
  - Physiochemical properties
  - Pathway from source to receptor
  - Amount and location of release (source characteristics)
  - Release rate or concentration



# Fate and Transport



- Upon its release into the environment, a chemical can be transported and transformed.

# Environmental and Exposure Media



Environmental media



Exposure media



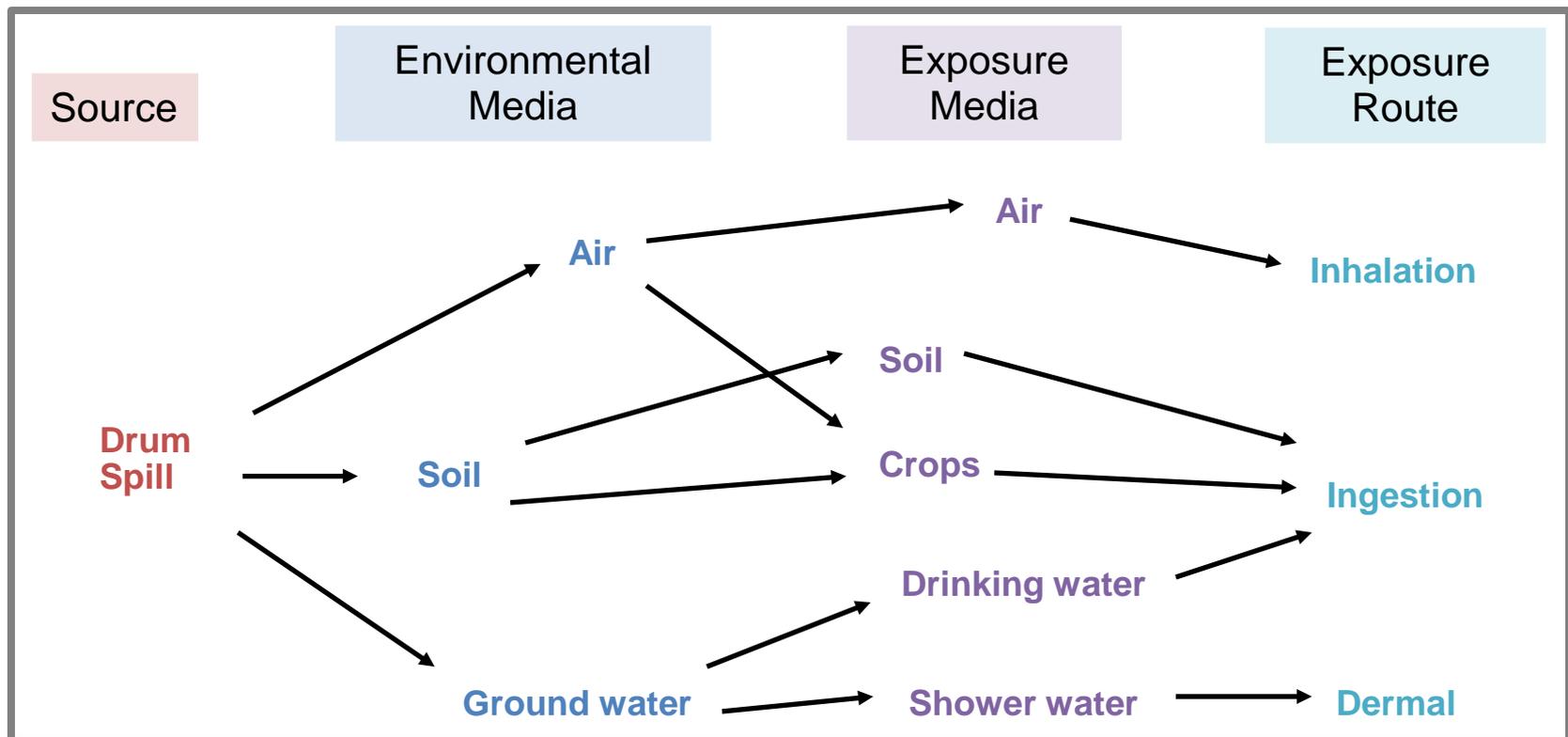
Direct exposure



Indirect exposure

# Exposure Pathway and Exposure Route

- **Exposure pathway:** the physical course a chemical takes from the source of the chemical to the exposed individual
- **Exposure route:** the way a chemical enters an individual upon contact



# Intake and Uptake Rates

- **The intake rate** is the rate of ingestion, inhalation, and dermal contact
- **The uptake rate** is the rate at which a substance crosses an absorption barrier and is absorbed into an organism

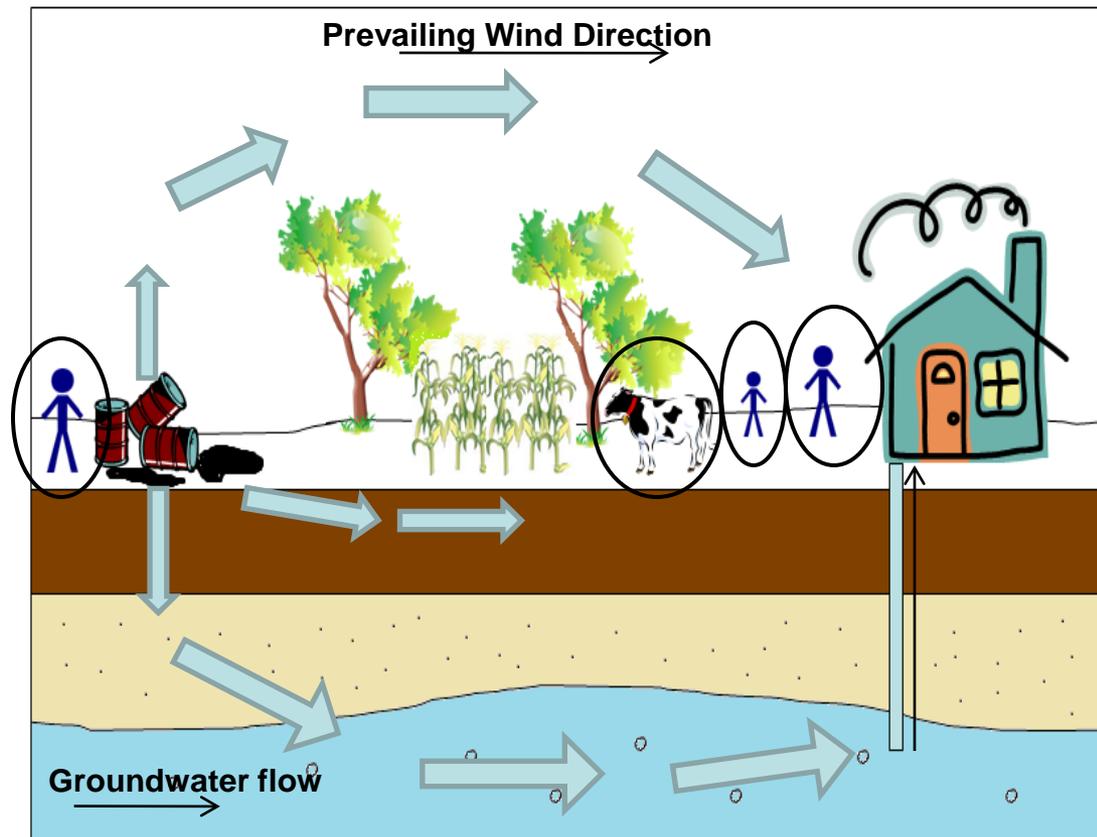
# More on Intake and Uptake Rates



- **Ingestion:** rate of ingestion of contaminated food or water
- **Inhalation:** rate of inhalation of contaminated air
- **Dermal:** rate of dermal contact with contaminated media

# Population of Concern

- The **population of concern** is the population exposed to the chemical
  - Human and/or wildlife
  - Characteristics
  - Activity and location during exposure



# Special Considerations for Human Populations



- General population vs. workers
- Children vs. adults
- Infants
- Consumers
- Fishermen and subsistence farmers
- Racial and ethnic groups
- Socioeconomic status
- Healthy vs. disease state

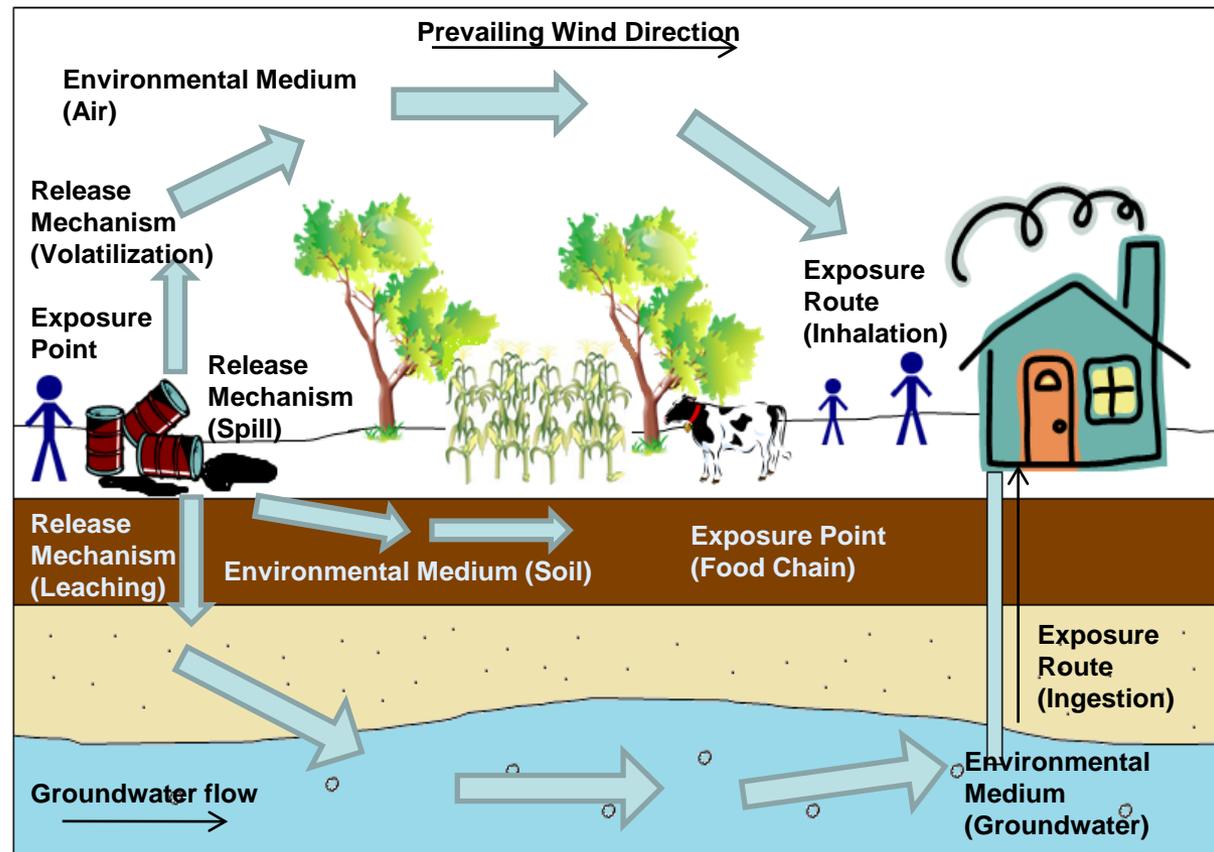
# Variability and Uncertainty in Exposed Populations

- **Variability:** true heterogeneity or diversity in a population
- **Uncertainty:** lack of knowledge due to incomplete data or incomplete understanding of a process



# Putting It All Together

- **Exposure setting:** drum spill in uncontained outdoor setting inhabited by humans and wildlife
- **Exposure pathways:** air, soil, water
- **Exposure media:** air, soil, water, plants, animals
- **Exposure routes:** inhalation, ingestion, dermal contact
- **Chemical of concern:** physical chemical properties, amount and location of release, concentration
- **Exposed population:** humans (adults and children) and wildlife



# USING EXPOSURE SCENARIOS

# Example Exposure Scenarios

- Guidance documentation:
  - NCEA Example Exposure Scenarios
  - Office of Solid Waste and Emergency Response
    - RAGS – Risk Assessment Guidance for Superfund
  - Office of Air Quality Planning and Standards
    - ATRA – Air Toxics Risk Assessment Reference Library
  - Office of Water
    - AWQC – Ambient water quality criteria

## Exposure routes:

- Ingestion
- Inhalation
- Dermal

# Example Ingestion Scenarios



- Homegrown vegetables
- Beef
- Fish
- Dairy
- Drinking water
- Dust/soil and surface residues
- Breast milk



# Example Inhalation Scenarios

- Ambient air, residential
- Indoor air, occupational
- Indoor air, residential



# Example Dermal Scenarios



- Contaminated soil
- Consumer products
- Surface water



# Common Exposure Scenarios for a Human Health Risk Assessment

Exposure Pathways	Farmer	Resident with Garden	Fisher
Inhalation of Vapors and Particulates	●	●	●
Incidental Ingestion of Soil	●	●	●
Ingestion of Drinking Water from Local Sources	●	●	●
Ingestion of Homegrown Produce	●	●	●
Ingestion of Homegrown Beef, Dairy, Chicken, and Pork	●	--	--
Ingestion of Self-Caught Fish	--	--	●
Ingestion of Breast Milk	--	--	--

# CONCLUSION

- Exposure scenarios are a tool for risk assessment; they provide a framework for quantifying exposures.
- An exposure scenario includes information on at least these seven elements:
  - Exposure setting
  - Chemical of concern
  - Source of contamination
  - Exposure pathway and exposure route
  - Environmental and exposure media
  - Intake and uptake rates
  - Population of concern
- EPA has developed various example and “typical” exposure scenarios that can be used to evaluate ingestion, inhalation, and dermal exposures.