

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?

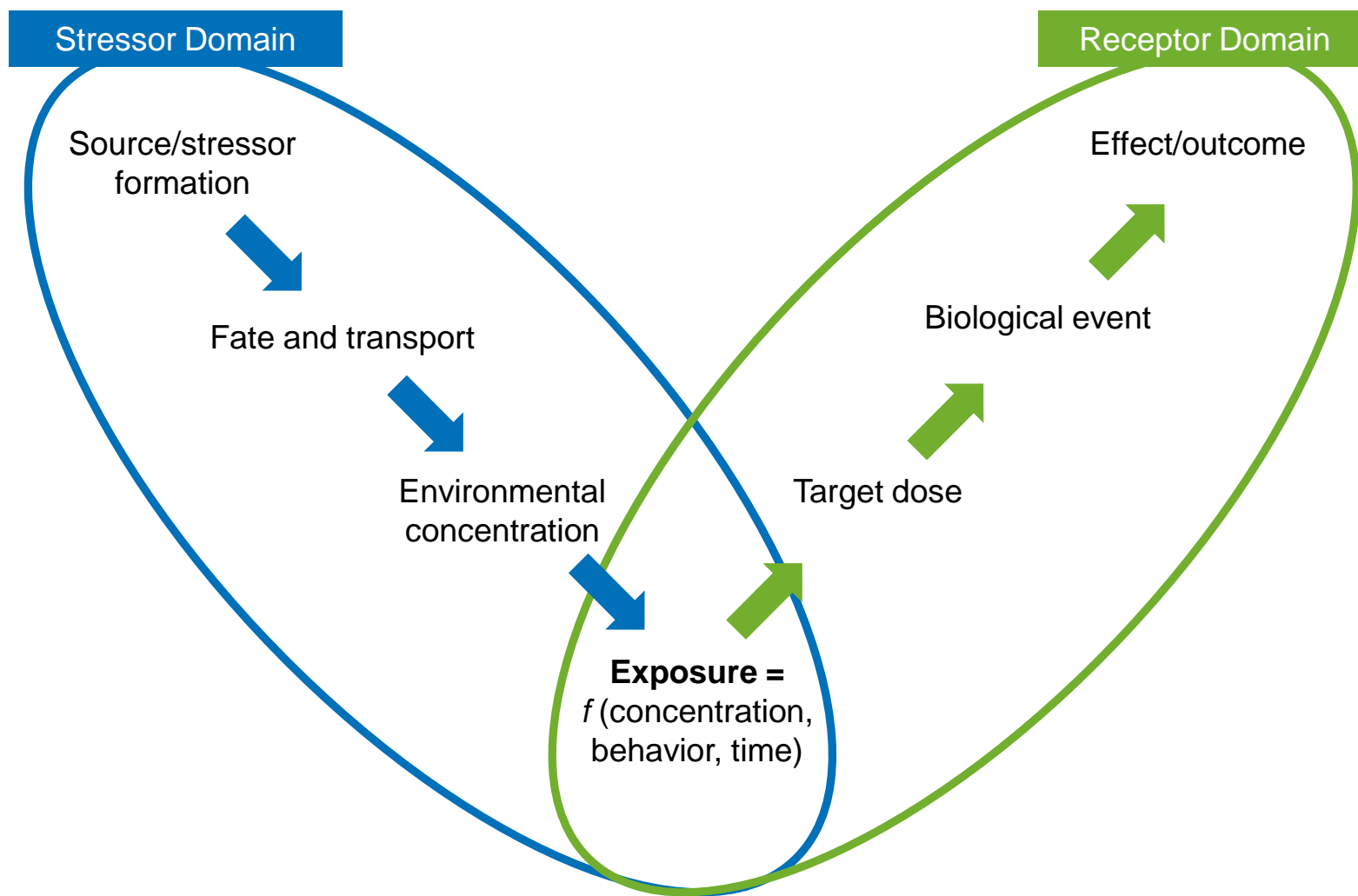
- To picture how exposure might take place
- To provide a framework for quantifying potential exposures for a risk assessment
- To follow fate of a chemical from source to exposure (and beyond)



Example Exposure Scenario

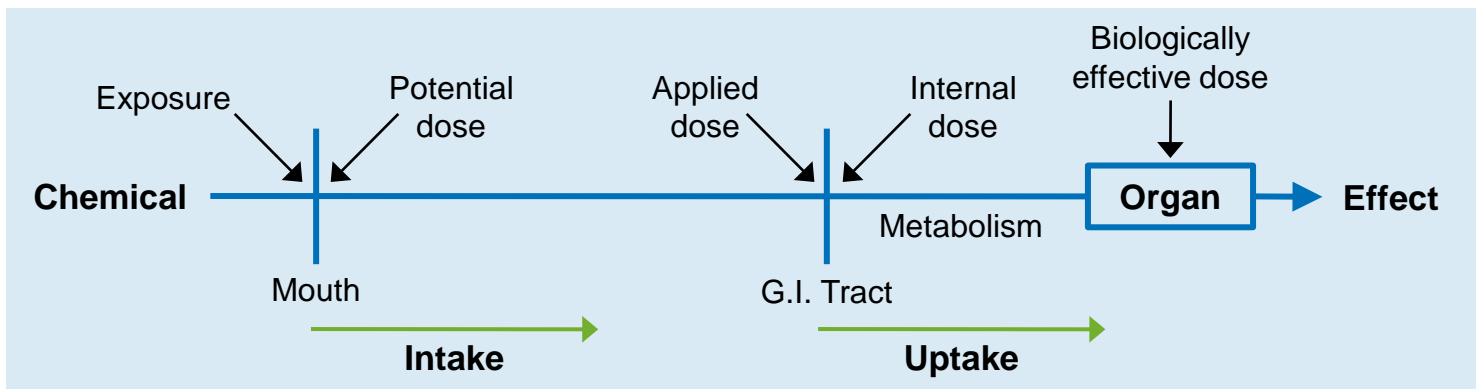


Overview of Source to Dose to Outcome

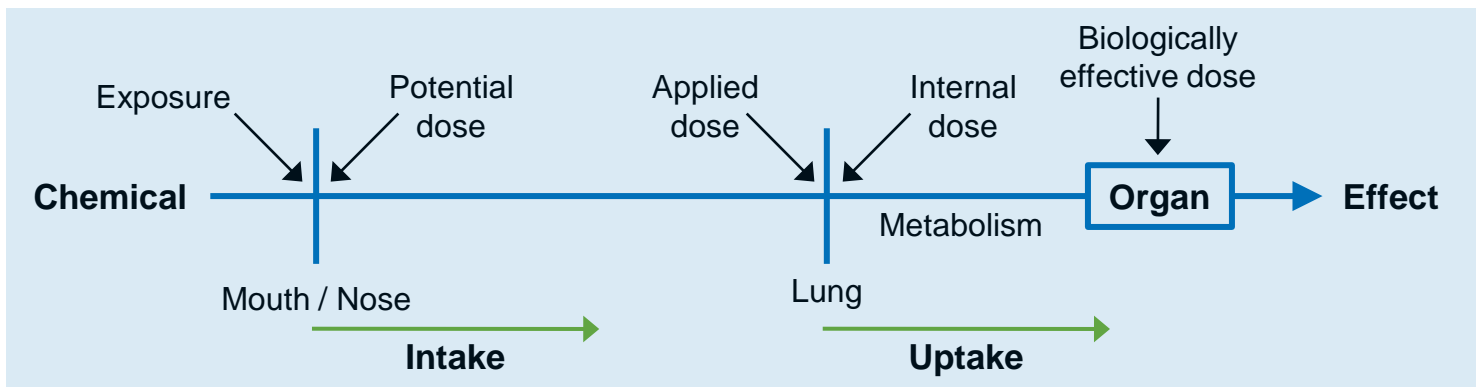


Dose Concepts

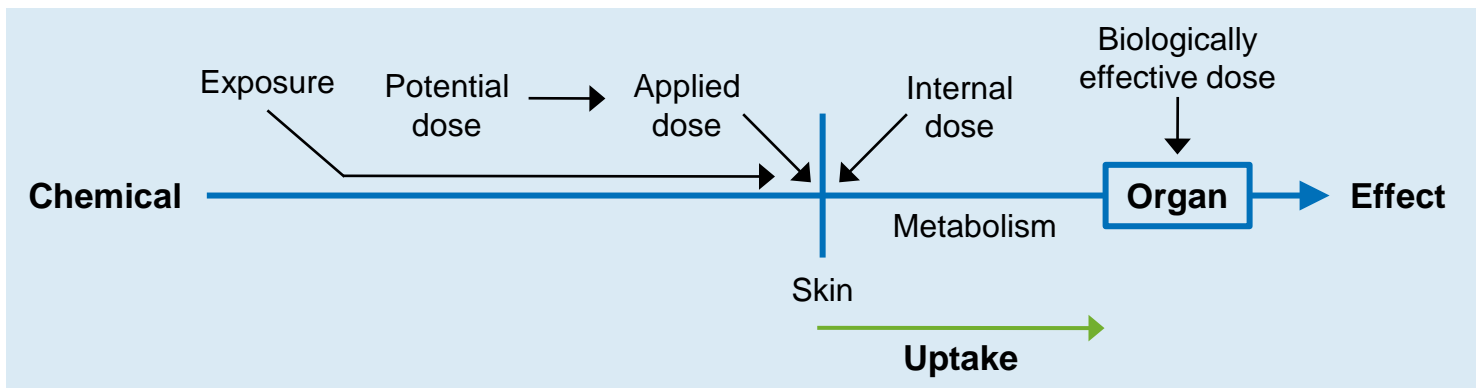
Oral Route



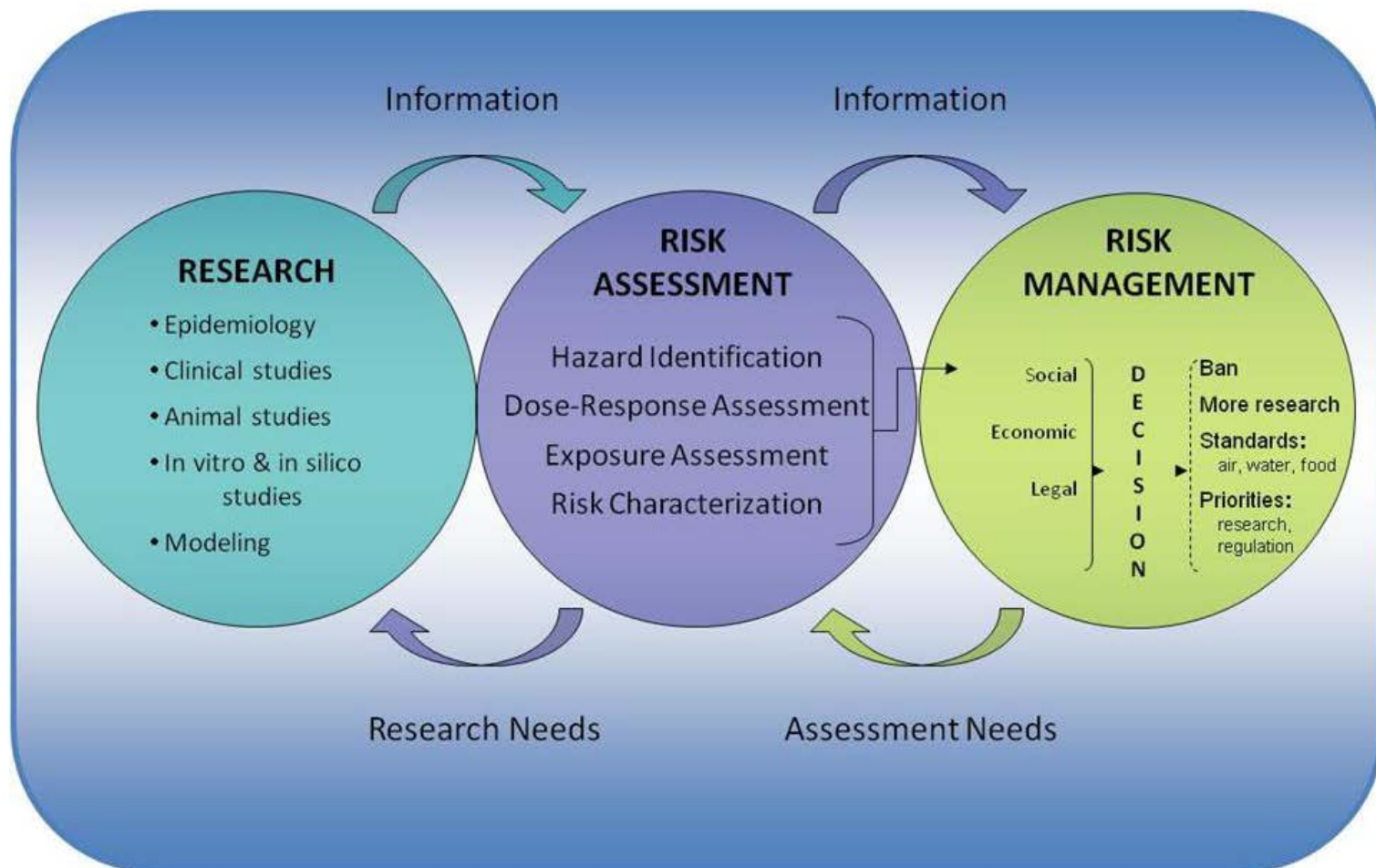
Respiratory Route



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)**

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

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 ³ , mg/kg
Contact fraction (CF)	unitless
Intake rate (IR)	mg/day, L/day
Body weight (BW)	kg

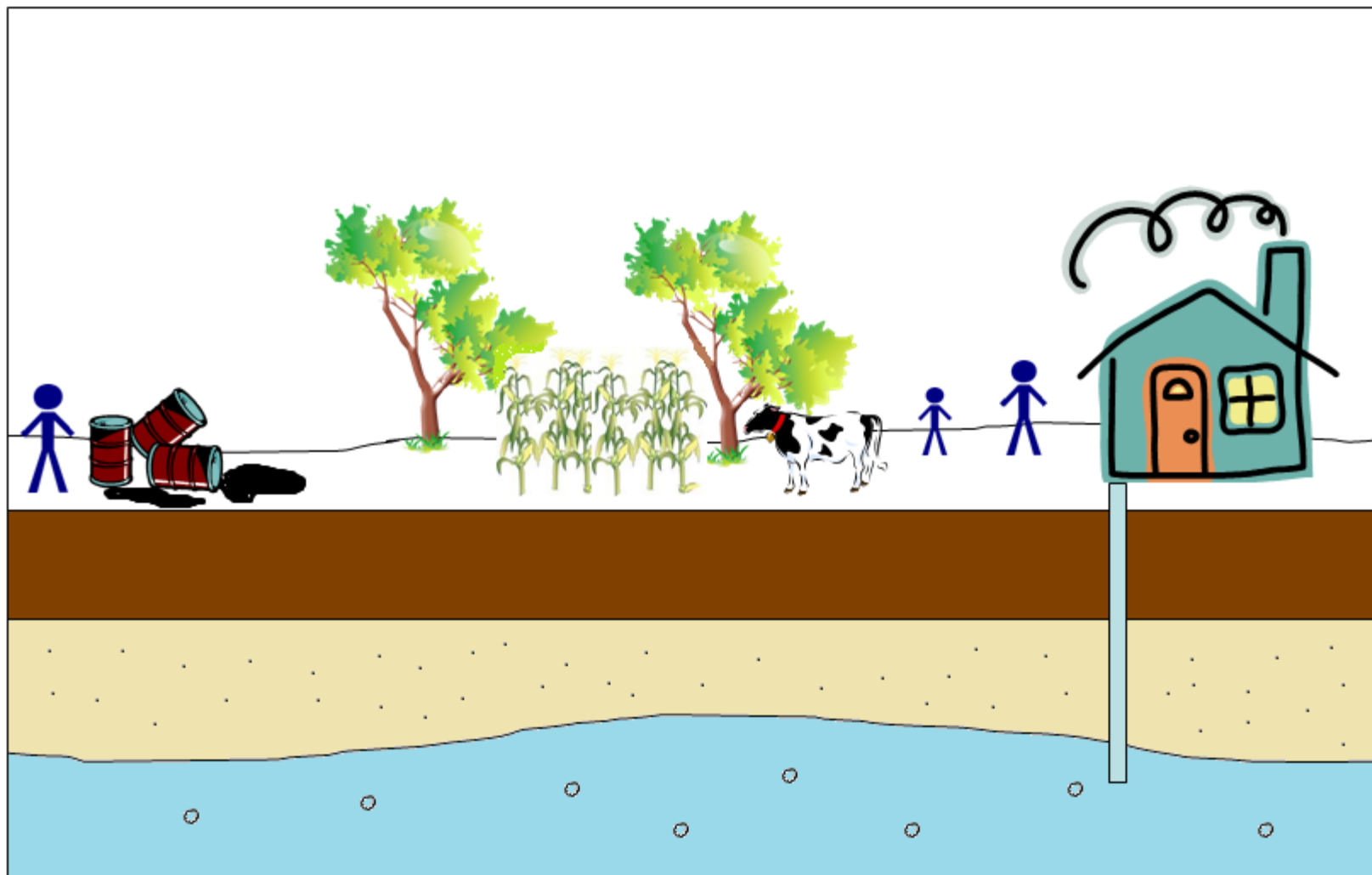
Temporal Parameters in Dose

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

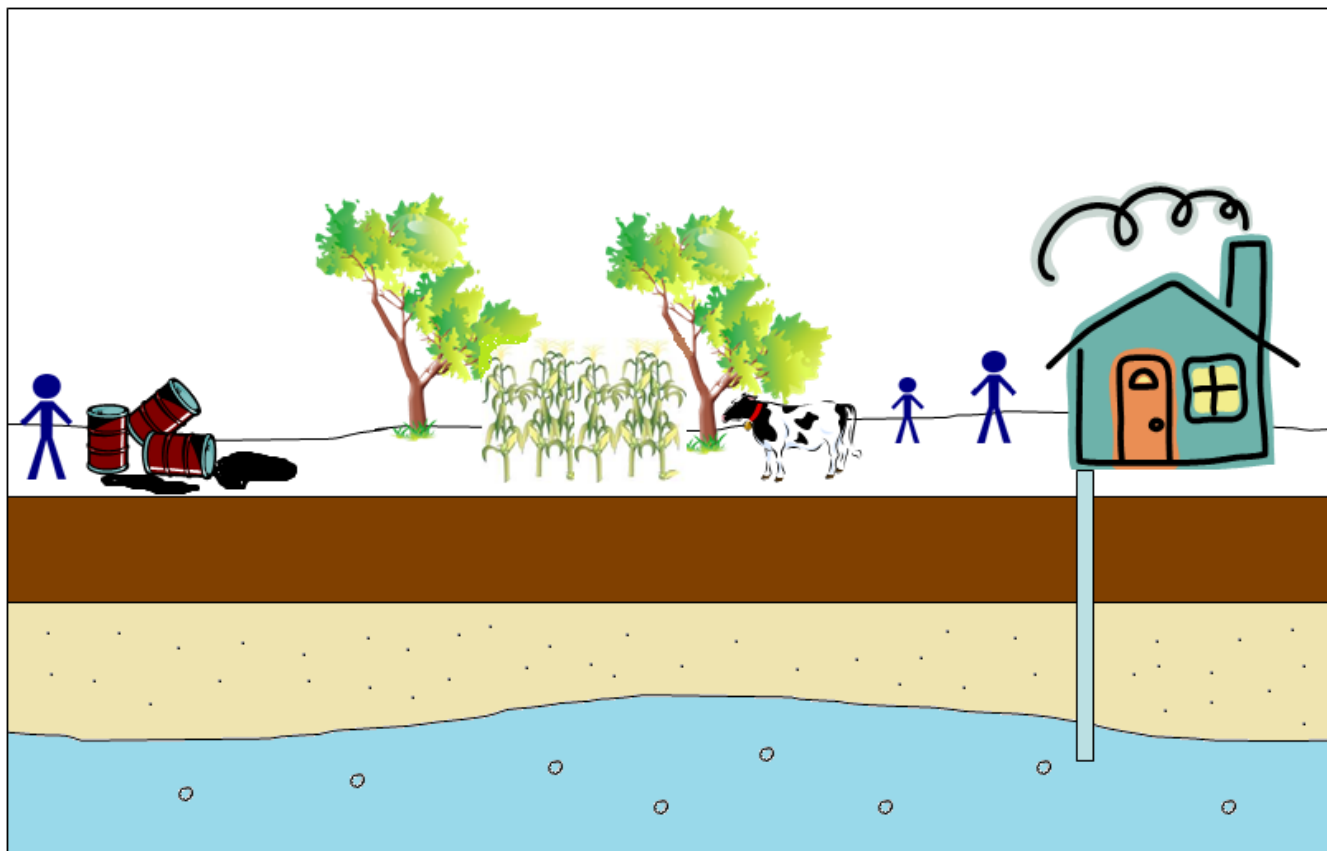
Variable	Common Units
Exposure duration (ED)	minutes, hours, days, years
Exposure frequency (EF)	days/yr, events/day
Averaging time (AT)	minutes, hours, days, years

CHARACTERISTICS OF AN EXPOSURE SCENARIO

Case Study



Exposure Setting



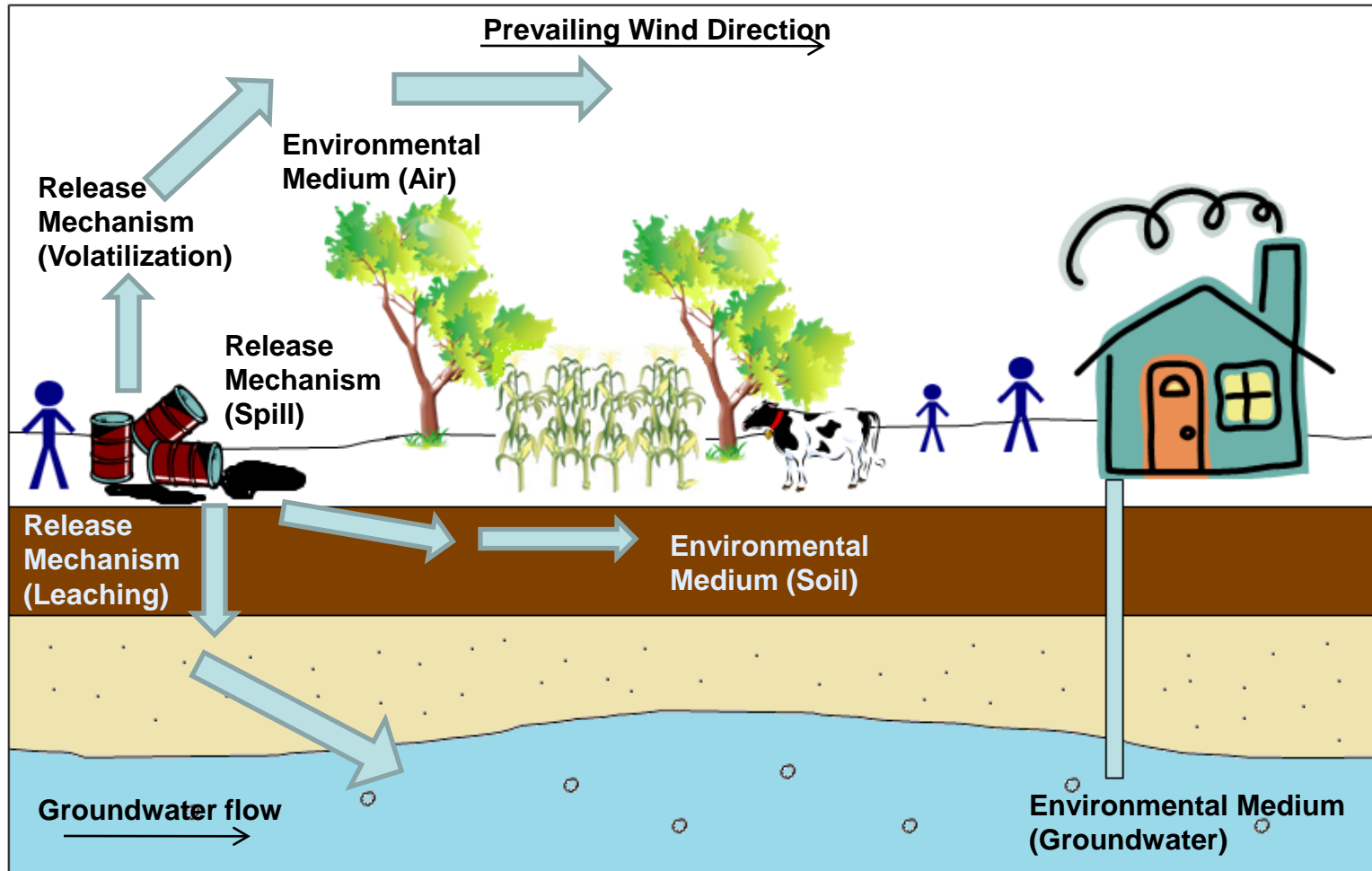
Exposure setting: the physical setting where the exposure occurs

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



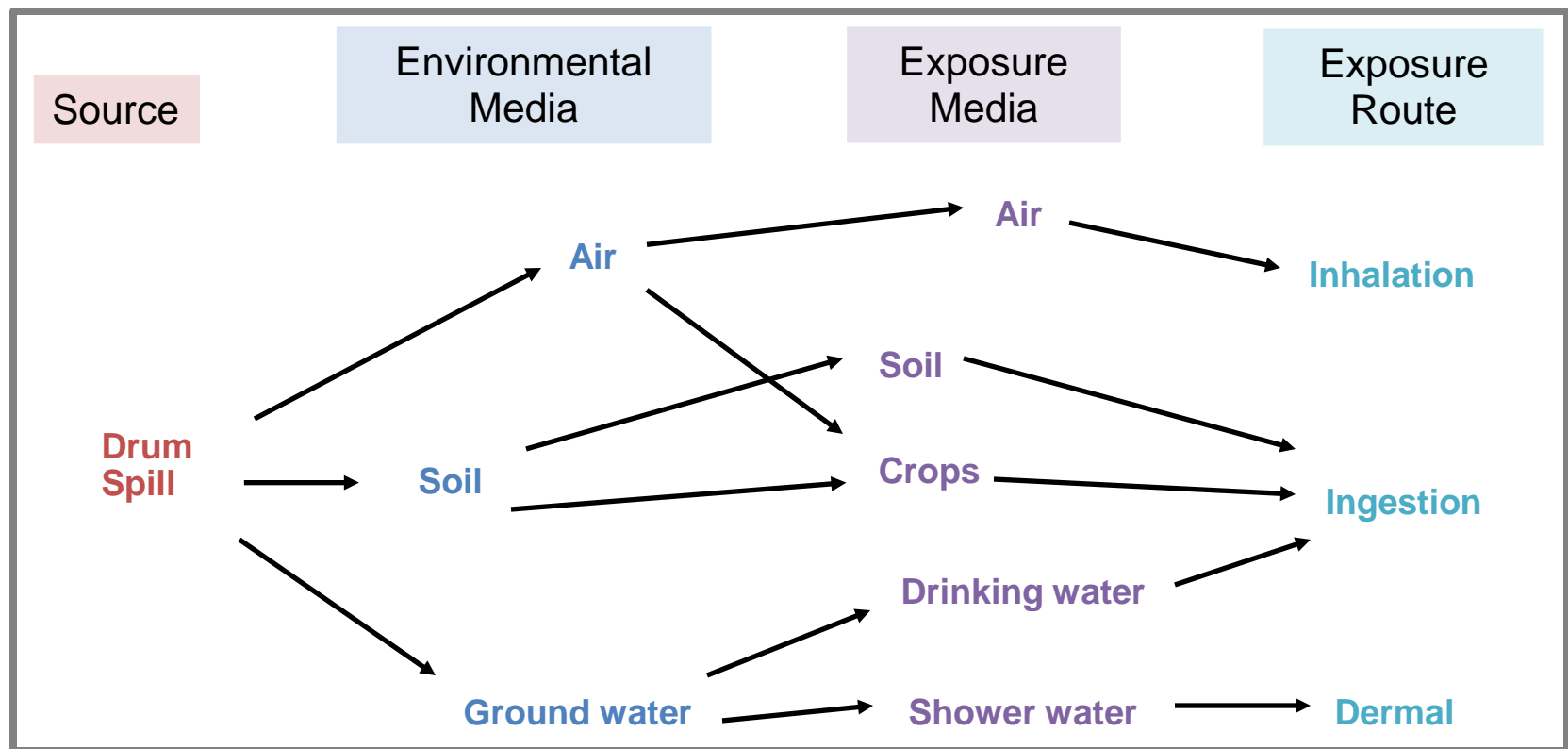
Direct exposure



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



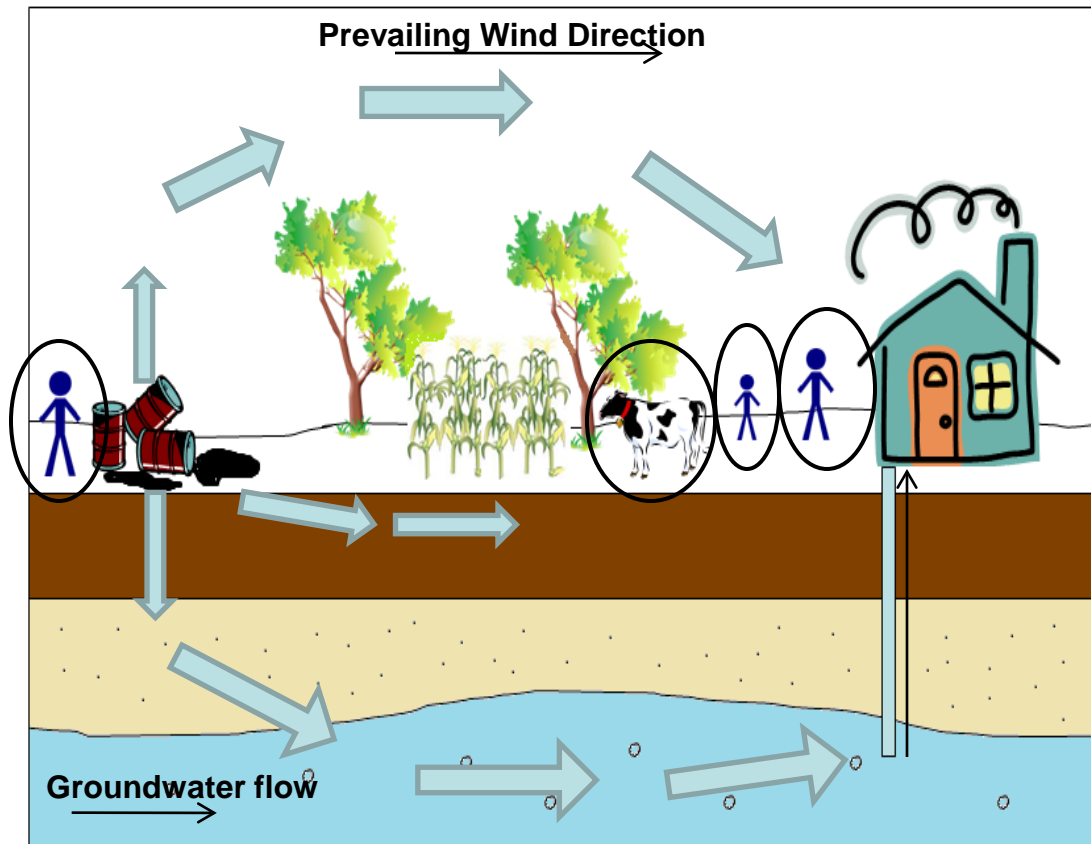
- **Inhalation:** rate of inhalation of contaminated air



- **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

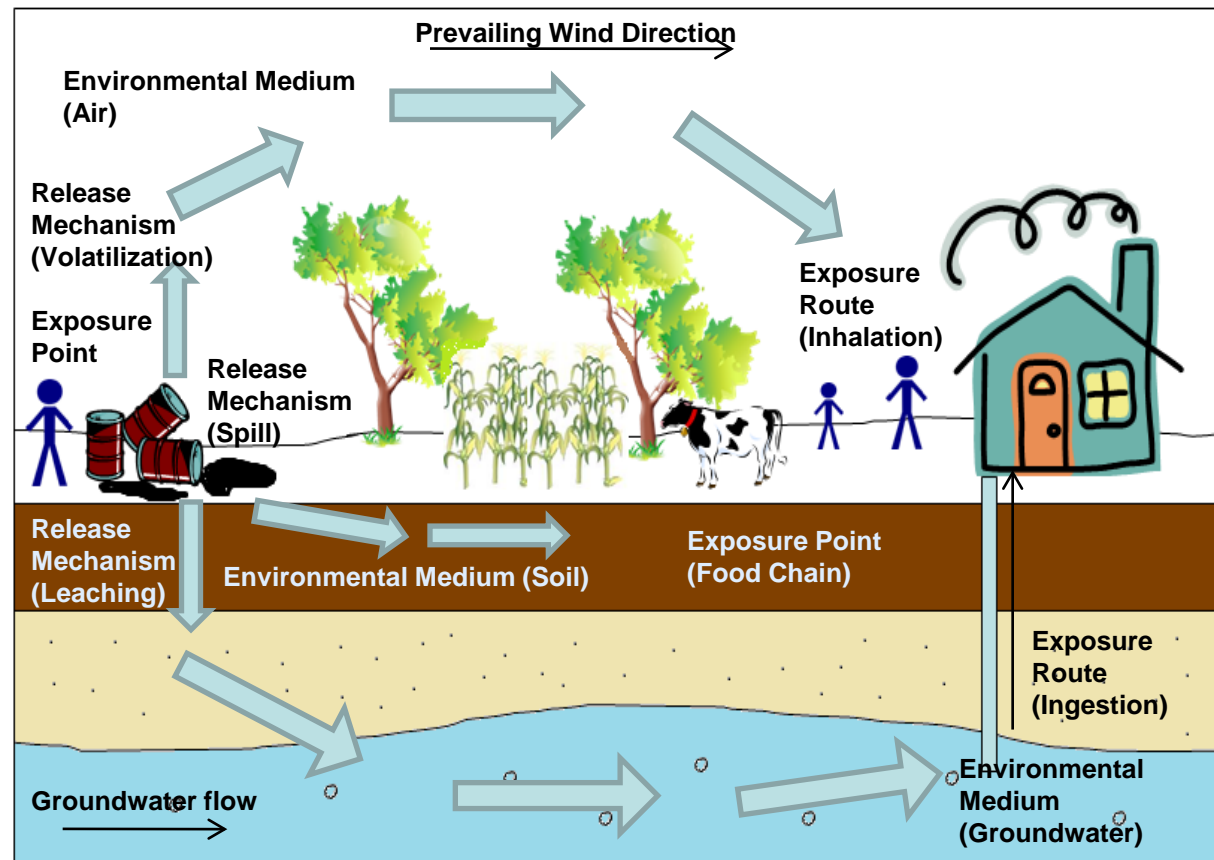
Variability and Uncertainty in Exposed Populations

- **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



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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.