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General Concepts of Exposure Assessment



Abdel-Razak Kadry, DVM, PhD, DABT
Center of Computational Toxicology and Exposure, ORD, USEPA, Washington, DC, USA

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What You Can Expect to Learn from this Course

- How exposure assessment relates to human health risk assessment
- Important elements of exposure assessment
- How to handle uncertainty and variability in exposure assessment
- What EPA resources are available for exposure assessors

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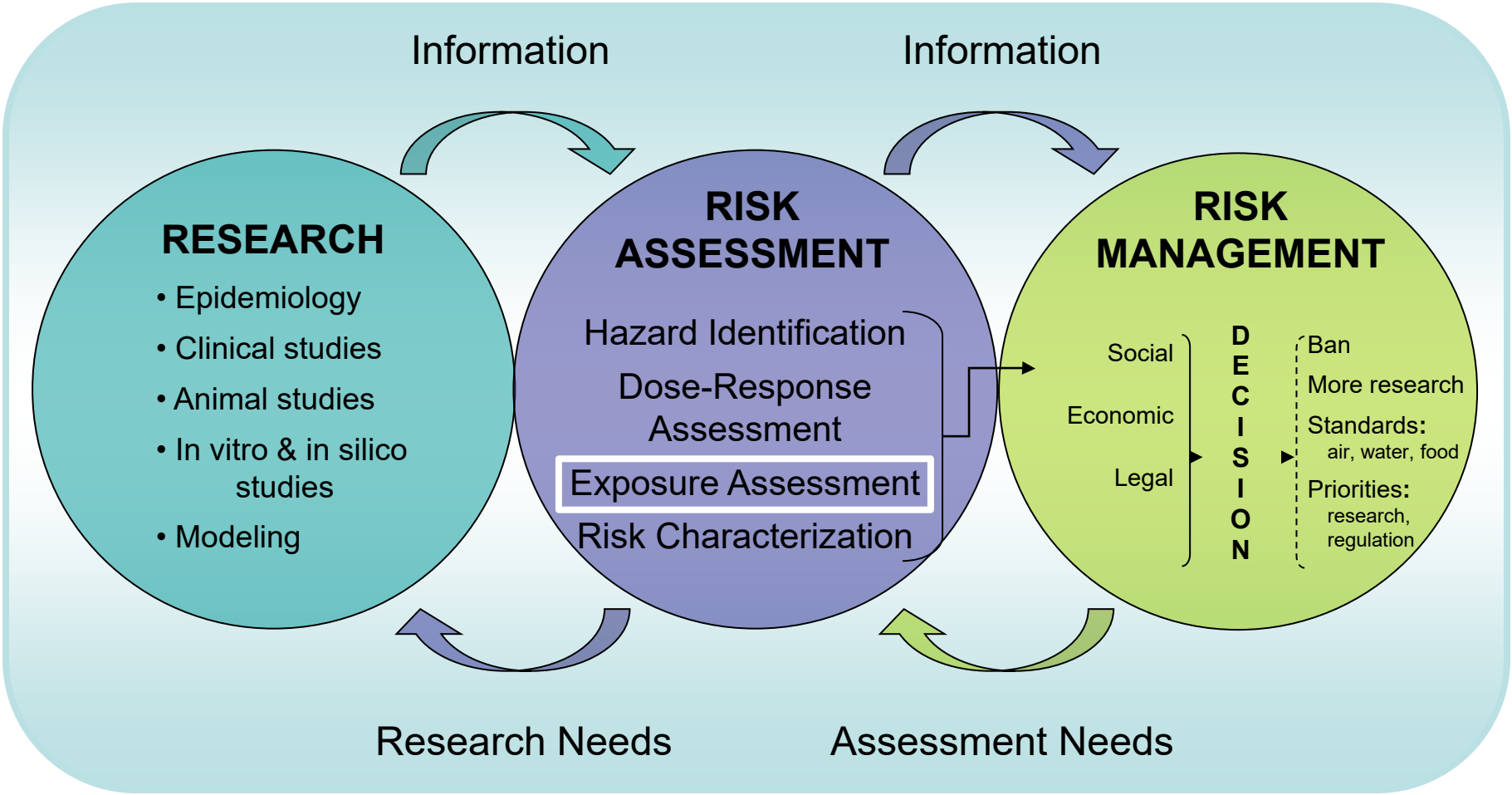
INTRODUCTION AND BACKGROUND CONCEPTS

The Risk Analysis Paradigm and the Role of Exposure Assessment



The Dose Makes the Poison

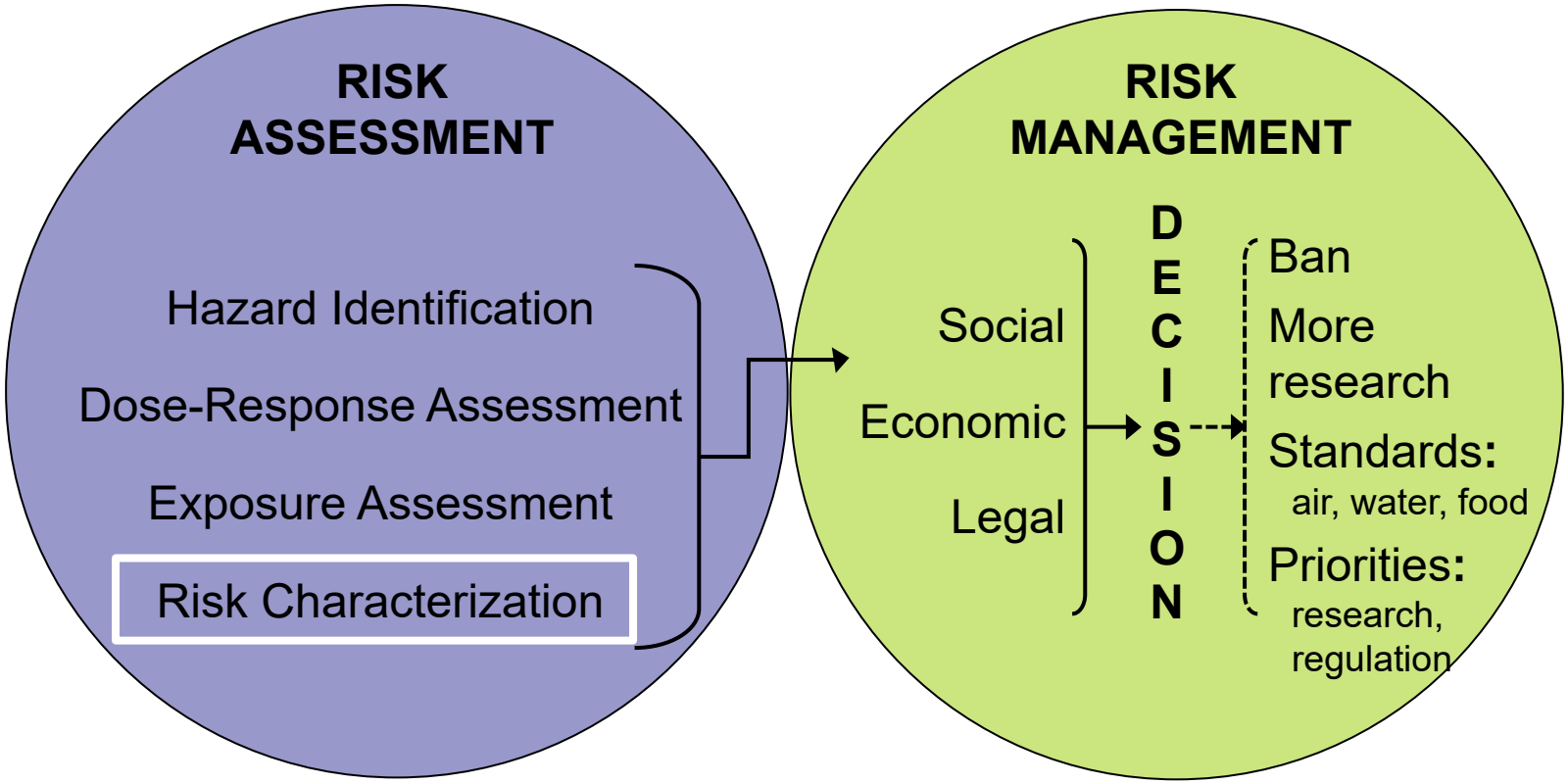
– Attributed to Paracelsus, 16th c. Swiss physician & chemist

- Exposure is a critical element of risk

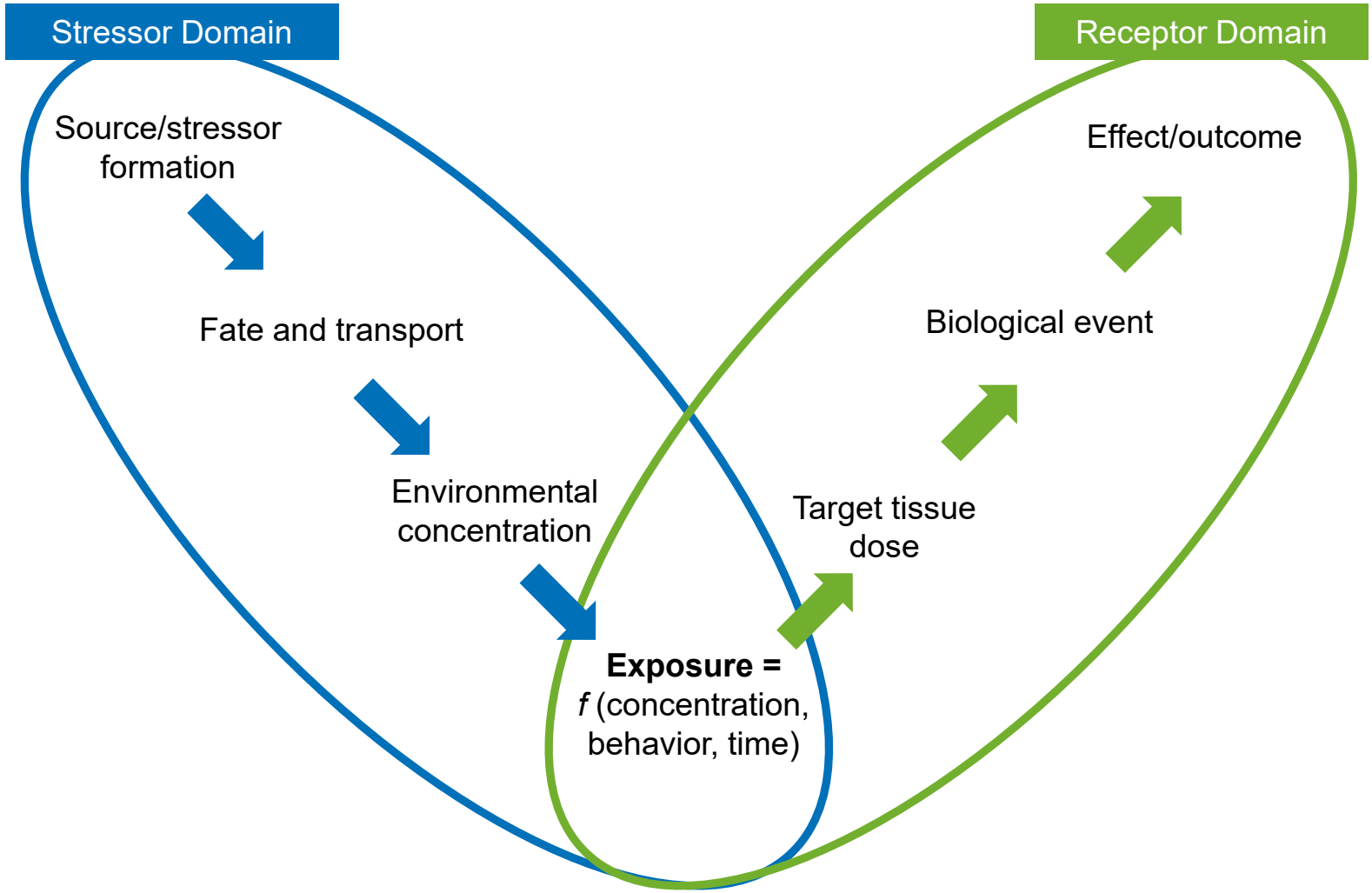
Hazard × Exposure = Risk

- A hazardous chemical release does not *necessarily* mean a high-risk situation
- Exposure assessment used to evaluate risk for future and past decision-making
  - **Future:** More uncertainty, but can prevent health impacts
  - **Past:** Less uncertainty, accurately quantify population health impacts and mitigation

The Utility of Risk Assessment in Environmental Decision-Making



Source-to-Effect Continuum



What is Exposure?

Exposure is contact made between a chemical, physical, or biological agent and the outer boundary of an organism.

- Two-step process

1. Contact
   - Inhalation, ingestion, or dermal contact
2. Absorption
   - Skin, respiratory tract, gut

Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, respiratory tract, gut).

The Exposure Equation

Exposure = *f* (Concentration, Time, Behavior)

EPA Guidelines for Exposure Assessment (1992)

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What is Dose?

- **Dose:** The amount of substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism
  - **Applied dose** is the amount of substance at an absorption barrier (skin, respiratory tract, gut) that can be absorbed by the body.
  - **Potential dose** is the amount of substance ingested, inhaled, or applied to skin, not all of which will be absorbed.
  - **Internal dose** is the amount of substance absorbed and available for interaction with biological receptors.

Dose Equation

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

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

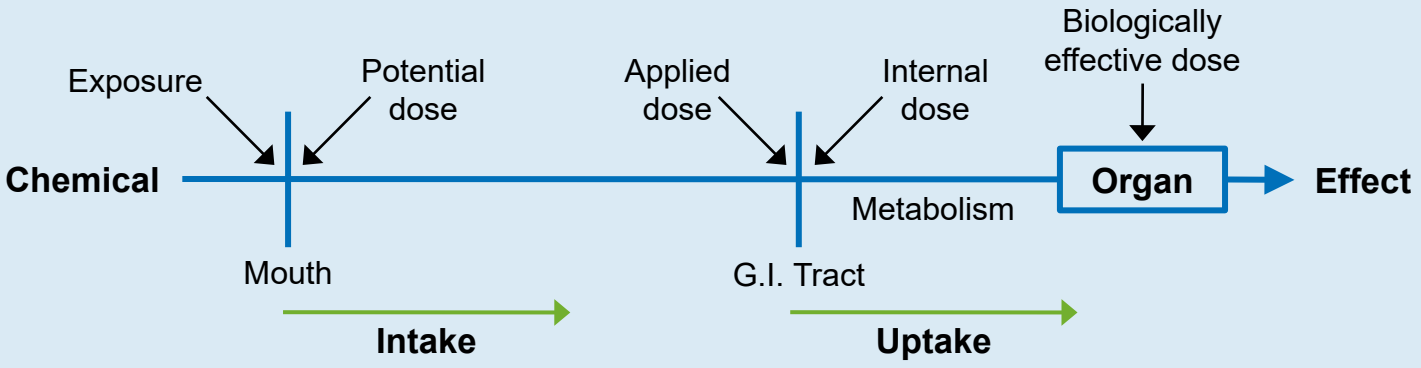
BW = Body Weight

AF = Fraction of Potential Dose Absorbed

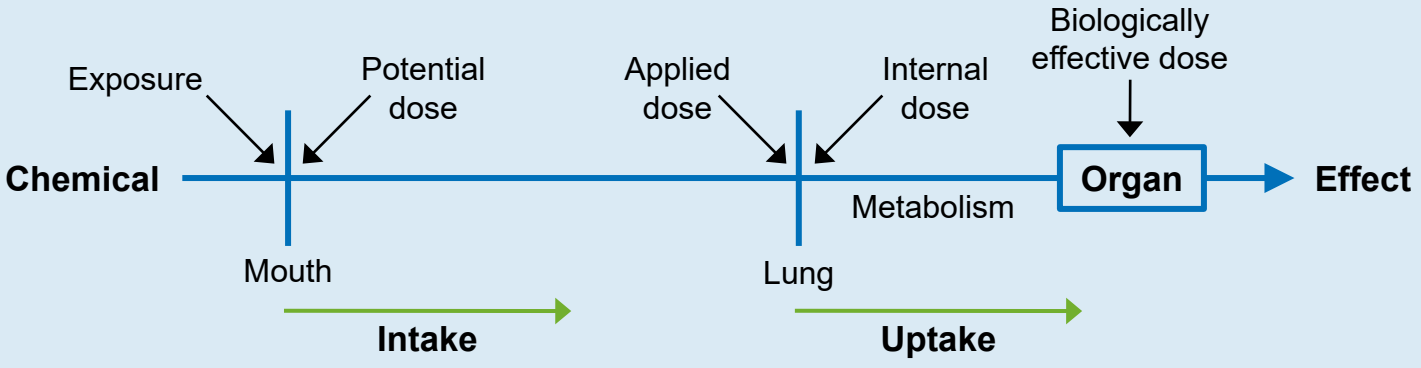
$$\textbf{General units for dose:} \quad \frac{\text{Mass contaminant}}{\text{Averaging time} \times \text{Body weight}}$$

Dose Illustrated

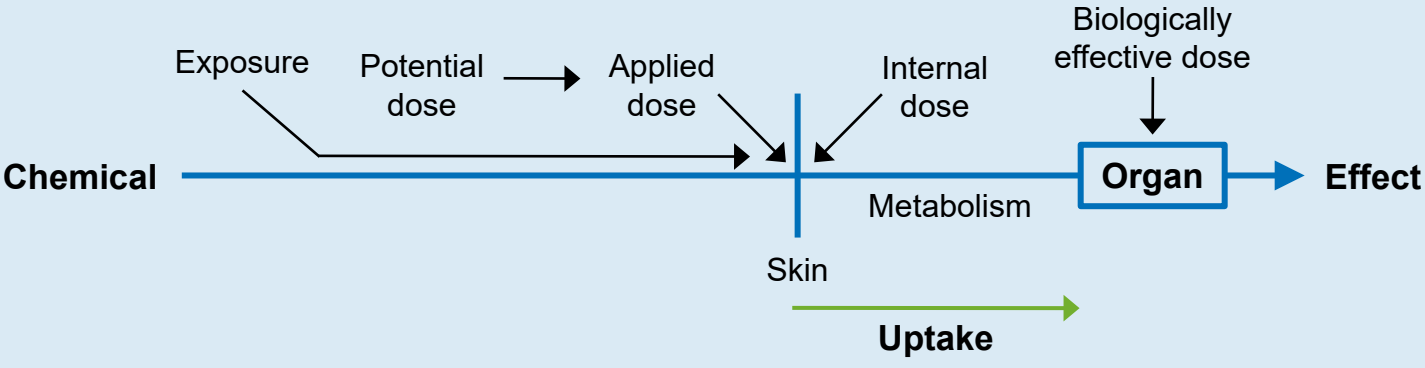
Oral Route



Respiratory Route



Dermal Route



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EXPOSURE ASSESSMENT: EXAMPLES OF EXPOSURE

Four Exposure Examples

- Meet Jim
- Four hazards in and around Jim's home
  - Benzene in drinking water
  - Nickel and lead in garden soil
  - Smoke in the kitchen
  - Pesticide residue on garden vegetables
- Four different routes of exposure
  - Consumption of drinking water, skin absorption, inhalation, eating

Exposure Example 1: Benzene in Drinking Water

- Jim has a well and drinks 2L of water/day
- Old, leaking underground storage tank in adjoining lot

Exposure: Occurs when a chemical or agent contacts the visible exterior of the person, making contact with the skin or openings into the body such as the mouth or the nose

- Benzene in Jim's water: >5 ppb

Intake: The substance enters Jim's body without passing through a barrier – for ingestion and inhalation

- Intake versus uptake, discussed more later in the course

Exposure Example 1: Benzene in Drinking Water

Chronic Exposure: Repeated exposures by either ingestion, inhalation, or skin exposure for more than about 10 percent of a person's lifespan

- How much benzene was Jim exposed to, on average?
  - Average Daily Dose (ADD)
- Estimate average daily dose based on assumptions

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Exposure Example 1: Average Daily Dose

$$ADD = \frac{C \times IR \times ED \times EF}{BW \times AT}$$

$$\text{Jim's ADD} = \frac{\left[\begin{array}{c}\text{levels of}\\ \text{benzene in}\\ \text{Jim's water}\end{array}\right] \times \left[\begin{array}{c}\text{how much}\\ \text{water}\\ \text{Jim drinks}\end{array}\right] \times \left[\begin{array}{c}\text{how long Jim}\\ \text{has been drinking}\\ \text{the water}\end{array}\right] \times \left[\begin{array}{c}\text{how often}\\ \text{Jim drinks}\\ \text{water}\end{array}\right]}{\left[\begin{array}{c}\text{Jim's weight}\\ \text{in kg}\end{array}\right] \times \left[\begin{array}{c}\text{number of}\\ \text{years to}\\ \text{average over}\end{array}\right]}$$

Exposure Example 1: Lifetime Average Daily Dose

- Lifetime Average Daily Dose (LADD)

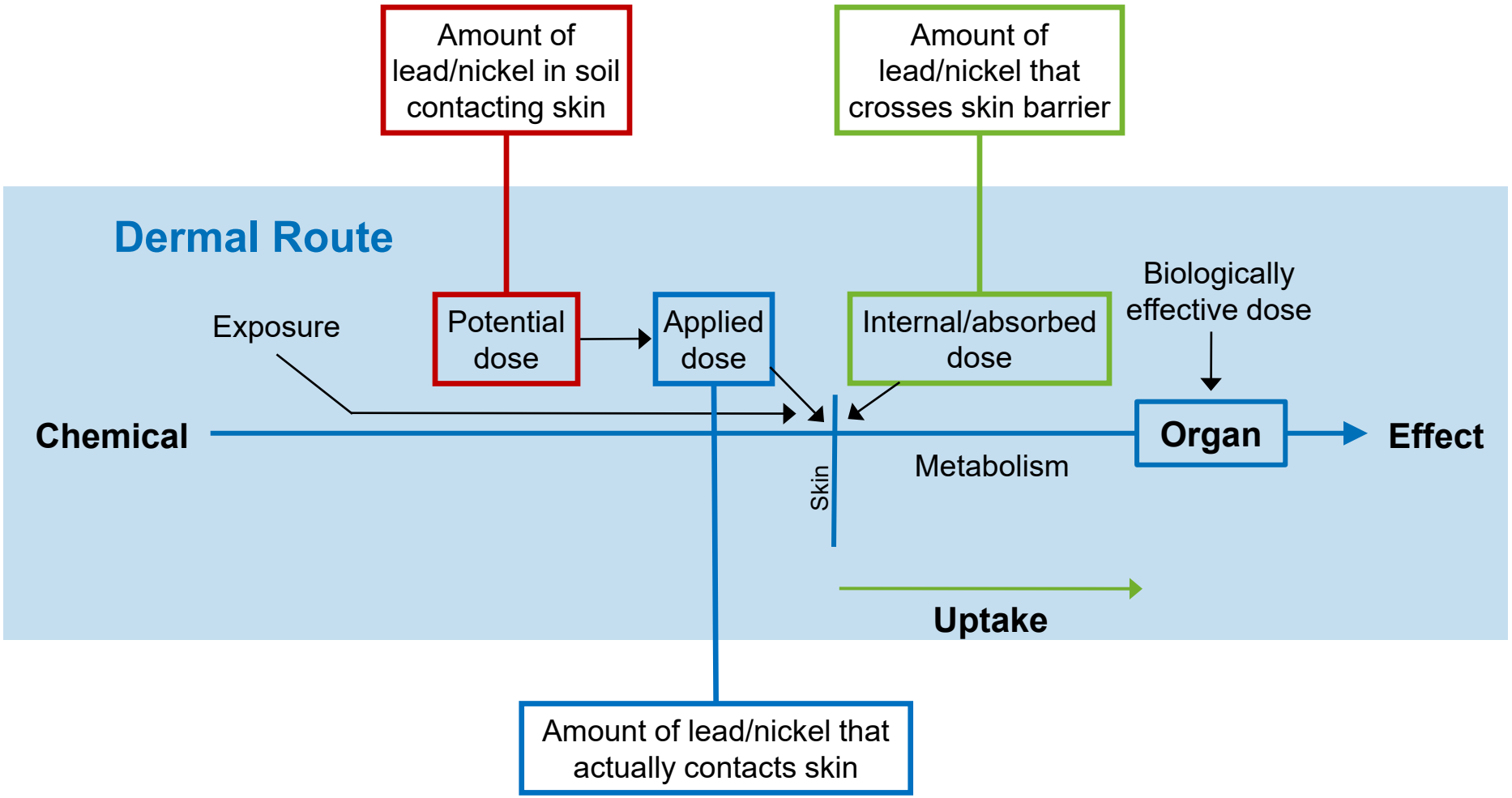
$$LADD = \frac{[C \times IR \times ED \times EF]}{[BW \times LT]}$$

- LADD is a projection based on current data
- Key element of risk assessment

Exposure Example 2: Skin Exposure to Soil Metals

- Jim's vegetable garden
- Raised beds for tomatoes and other vegetables
- Garden soil contaminated with nickel and lead
- Jim doesn't use gloves

Exposure Example 2: Skin Exposure to Soil Metals



Exposure Example 3: Kitchen Smoke Inhalation

- Jim likes to cook burgers on his kitchen range
- Hamburgers + Hot Pan + Too Much Time = Smoke!
- Smoke inhalation from the fire

Exposure Example 3: Kitchen Smoke Inhalation

- Jim's smoke exposure was brief, but he still didn't feel well

Acute Exposure: Short-term exposure that lasts no longer than a day

Contaminants in smoke are varied and complex

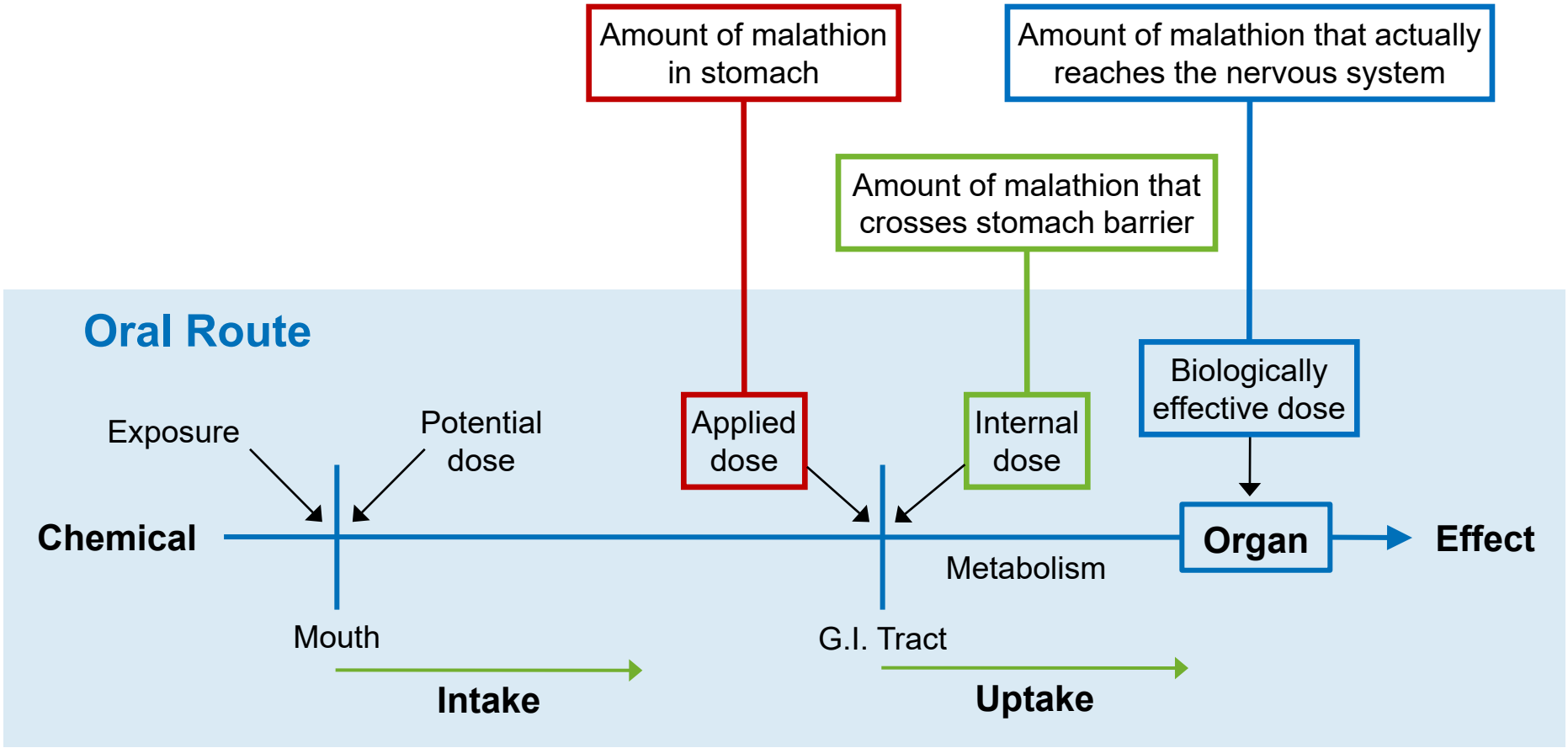
- Difficult exposure to characterize, compared to others

Exposure Example 4: Ingestion of Pesticide Residues

- Jim grows tomatoes and peppers in the garden
- He uses malathion to control insect problems

- He eats produce in the garden or in the home without washing
- Exposure during application
  - Dermal
  - Inhalation

Exposure Example 4: Ingestion of Pesticide Residues



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Exposure Examples: Concepts Introduced

Benzene in Drinking Water
- Intake versus Uptake
- Chronic Exposure
- Average Daily Dose

Skin Exposure to Soil Metals
- Dose (Potential and Internal)
- Absorbed Dose
- Uptake versus Intake

Kitchen Smoke Inhalation
- Acute Exposure
- Complex Mixtures
- Exposure Characterization

Pesticide Residues on Produce
- Applied Dose
- Internal Dose
- Biologically Effective Dose

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EXPOSURE CONSIDERATIONS

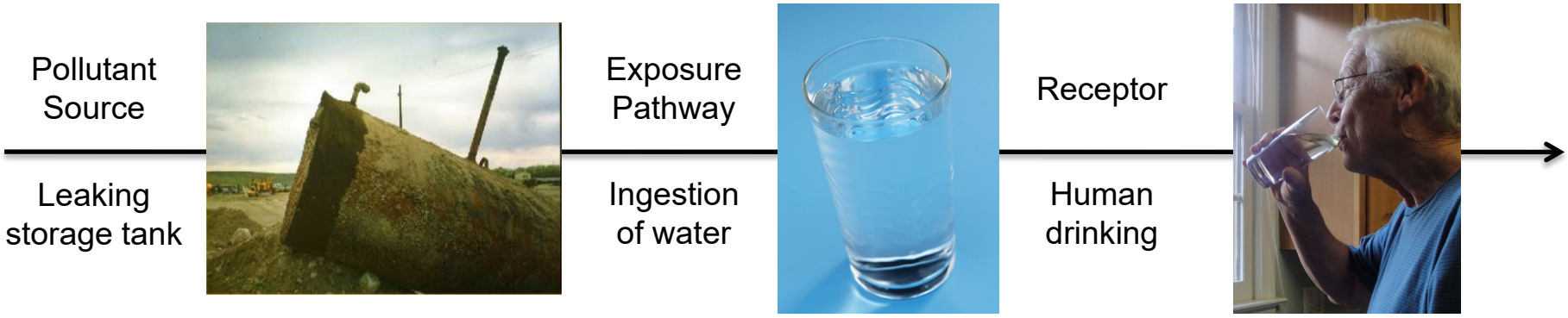
Individual- versus Population-Level Assessments

- Exposure assessment usually conducted for populations or groups
- **Exposure factors**, or characteristics of the population, important to estimate exposure and risk:
  - Food and water intake
  - Population behaviors
  - Inhalation rates
  - Other factors relevant to scenario

- **Variability** and **uncertainty** in exposure factors

Elements of Exposure

- **Pollutant source:** Where are the pollutants coming from, at what rate, and where are they going?
- **Exposure pathways:** Connection between pollutant source and exposure including exposure media and route of exposure. Useful in identifying exposures of concern
- **Contaminants of concern:** Specific contaminants that are of concern for human health for the exposure pathway
- **Receptor:** The individual or population that is exposed



Exposure Factors

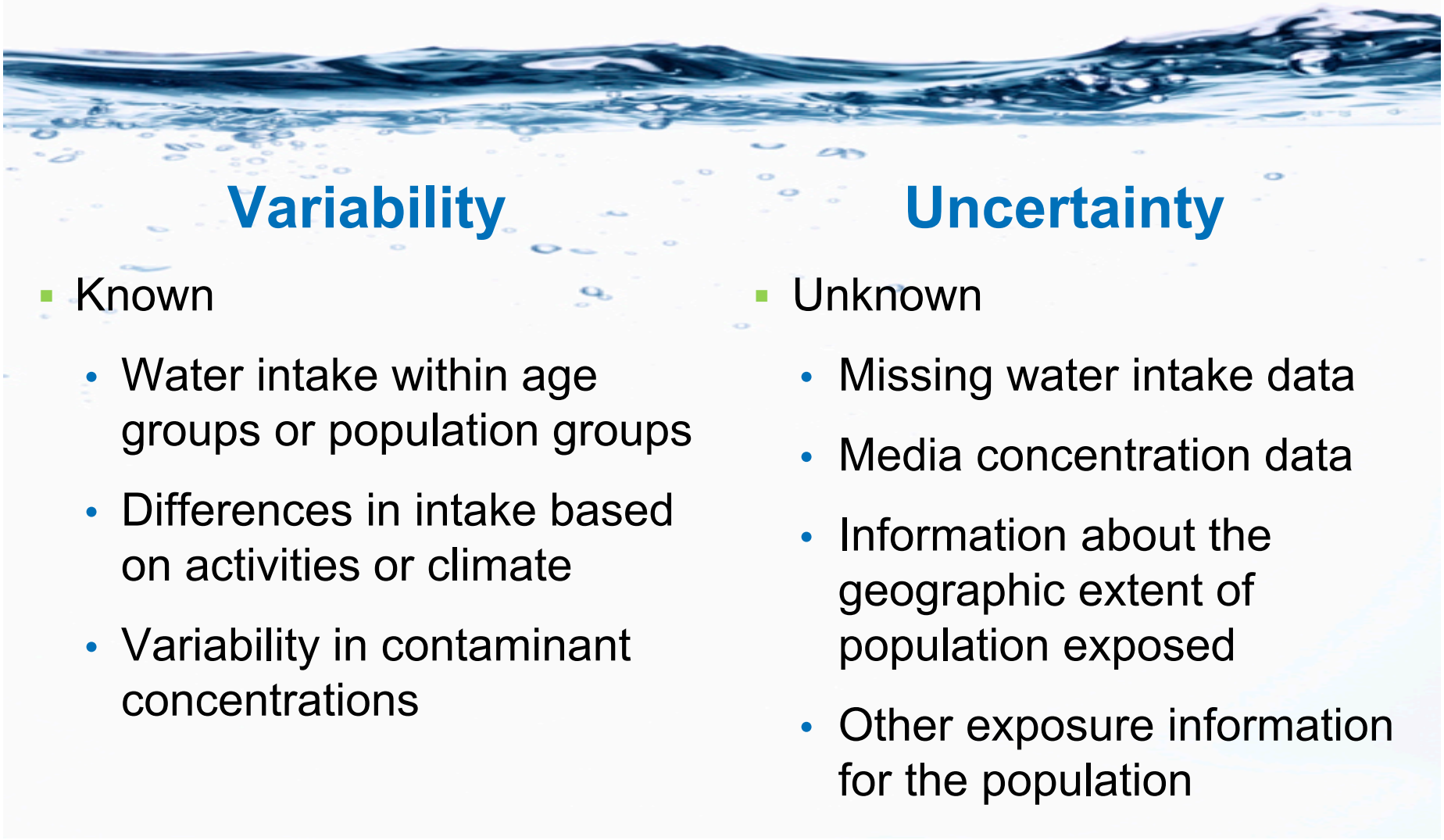
- **Exposure Factors**: Account for variability in populations, and allow for assessment of the risks to those populations
- Include:
  - Ingestion and inhalation rates
  - Skin exposure factors
  - Body weight
  - Life expectancy
  - Others

Uncertainty and Variability

- **Uncertainty** refers to a lack of knowledge arising from:
  - Incomplete data
  - Incomplete understanding of processes
- Reduce by collecting more data or better data
- Compensate for by approximations and assumptions

- **Variability** refers to heterogeneity or diversity
  - Inherent property of a population
- Characterize with more data
- Cannot reduce or eliminate, only describe

Variability versus Uncertainty in Water Intake



Variability

- Known
  - Water intake within age groups or population groups
  - Differences in intake based on activities or climate
  - Variability in contaminant concentrations

Uncertainty

- Unknown
  - Missing water intake data
  - Media concentration data
  - Information about the geographic extent of population exposed
  - Other exposure information for the population

EPA's Guidelines for Exposure Assessment

- Published in 1992
  - Revised version currently under development
  - Topics and chapters

    Introduction

    Chapter 1: General Concepts in Exposure Assessment

    Chapter 2: Planning an Exposure Assessment

    Chapter 3: Gathering and Developing Data for Exposure Assessments

    Chapter 4: Using Data to Determine or Estimate Exposure and Dose

    Chapter 5: Assessing Uncertainty

    Chapter 6: Presenting the Results of the Exposure Assessment

Other Key EPA Resources

- Exposure Factors Handbook and Child-Specific Exposure Factors Handbook
- Example Exposure Scenarios
- Risk Assessment Guidance for Superfund (RAGS)
- Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants
- Dermal Exposure Assessment: Principles and Applications
- Additional resources available

EXA Course Series

402 – Approaches for Quantifying Exposure

403 – Developing Exposure Scenarios and Calculating Dose

404 – Fate and Transport

405 – Monitoring and Modeling Strategies

406 – Obtaining and Using Exposure Factor Data

407 – Assessing Uncertainty and Variability

408 – Interpreting Biomonitoring Data

409 – Lead Case Study

410 – Dioxin Case Study

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For more information:

Abdel-Razak Kadry, DVM, PhD, DABT
U.S. EPA/ORD/CCTE
1200 Pennsylvania Ave. NW
Mailcode 8601-RR
Washington, DC 20460
Telephone: 1-202-564-0180
kadry.abdel@epa.gov

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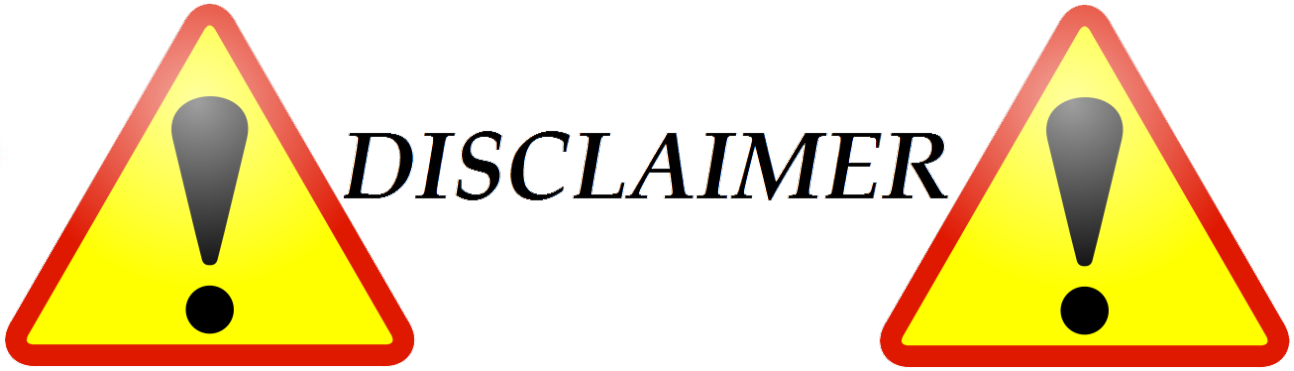

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