General Concepts of Exposure Assessment of Chemical Contaminants in Food & Water
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
INTRODUCTION AND BACKGROUND CONCEPTS

مقدمة ومفاهيم أساسية
The Risk Analysis Paradigm and the Role of Exposure Assessment

Information

RESEARCH
- Epidemiology
- Clinical studies
- Animal studies
- In vitro & in silico studies
- Modeling

RISK ASSESSMENT
- Hazard Identification
- Dose-Response Assessment
- Exposure Assessment
- Risk Characterization

RISK MANAGEMENT
- Social
- Economic
- Legal
- Ban
- More research
- Standards: air, water, food
- Priorities: research, regulation

Research Needs
Assessment Needs
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

– Attributed to Paracelsus, 16th c. Swiss physician & chemist
The Utility of Risk Assessment in Environmental Decision Making

RISK ASSESSMENT
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RISK MANAGEMENT
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Standards:
- air, water, food

Priorities:
- research, regulation
Source-to-Effect Continuum
التواصل بين المصدر إلى التأثير

Exposure = f (concentration, behavior, time)

Stressor Domain
- Source/stressor formation
- Fate and transport
- Environmental concentration

Receptor Domain
- Effect/outcome
- Biological event
- Target tissue dose

Source/stressor formation → Fate and transport → Environmental concentration → Exposure = f (concentration, behavior, time) → Effect/outcome
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 = \( f(\text{Concentration, Time, Behavior}) \)

EPA Guidelines for Exposure Assessment (1992)
• **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

Potential Dose = \( \frac{C \times IR \times CF \times ED \times EF}{AT \times BW} \)

Absorbed Dose = Potential Dose \times 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: Mass contaminant / Averaging time \times Body weight
Dose Illustrated

Oral Route

Exposure

Potential dose

Chemical

Mouth

Intake

Applied dose

G.I. Tract

Uptake

Biologically effective dose

Organ

Effect

Respiratory Route

Exposure

Potential dose

Chemical

Mouth

Intake

Applied dose

Lung

Uptake

Biologically effective dose

Organ

Effect

Dermal Route

Exposure

Potential dose

Chemical

Skin

Uptake

Applied dose

Biologically effective dose

Organ

Effect
CLASS ACTIVITY

EXPOSURE ASSESSMENT:
EXAMPLES OF EXPOSURE
• 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
المثل الأول: البنزين في مياه الشرب

- 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

المثل الأول: البنزين في مياه الشرب

**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?
- What is the Average Daily Dose (ADD)
- Please estimate average daily dose based on assumptions
Exposure Example 1: Average Daily Dose

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

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

الجرعة اليومية المتوسطة

جرعة اليومية المتوسطة
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

المثال رقم 2 للتعرض: تعرض الجلد للمعادن في التربة

- Jim’s vegetable garden
- Raised beds for tomatoes and other vegetables
- Garden soil contaminated with nickel and lead
- Jim doesn’t use gloves
- Concentration of nickel in soil is 1mg/kg soil

Please calculate: the applied dose, the absorbed dose and the biologically effective dose
Dermal Route

Exposure

Potential dose

Applied dose

Internal/absorbed dose

Biologically effective dose

Organ

Effect

Uptake

Skin

Metabolism

Chemical

Amount of lead/nickel that actually contacts skin

Amount of lead/nickel in soil contacting skin

Amount of lead/nickel that crosses skin barrier

Potential exposure: Skin Exposure to Soil Metals

المثال رقم 2 للتعرض: تعرض الجلد للمعادن في التربة
Exposure Example 3: Kitchen Smoke Inhalation
المثال رقم 3 للتعرض: استنشاق الدخان في المطبخ

• Jim likes to cook burgers on his kitchen range

• Hamburgers + Hot Pan + Too Much Time = Smoke!

• Smoke inhalation from the fire

• *Please calculate the inhalation exposure of Jim?*
Exposure Example 3: Kitchen Smoke Inhalation
المثال رقم 3 للتعرض: استنشاق الدخان في المطبخ

- 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
المثال رقم 4 للتعرض: ابتلاع بقايا المبيدات

• Jim grows tomatoes and peppers in the garden

• He eats produce in the garden or in the home without washing

• Exposure during application
  ▪ Dermal
  ▪ Inhalation
Exposure Example 4: Ingestion of Pesticide Residues
المثال رقم 4 للتعرض: ابتلاع بقايا المبيدات

Oral Route

Chemical

Exposure

Potential dose

Mouth

Intake

Applied dose

G.I. Tract

Uptake

Metabolism

Internal dose

Organ

Biologically effective dose

Effect

Amount of malathion in stomach

Amount of malathion that actually reaches the nervous system

Amount of malathion that crosses stomach barrier

Oral Route

Chemical

Exposure

Potential dose

Mouth

Intake

Applied dose

G.I. Tract

Uptake

Metabolism

Internal dose

Organ

Biologically effective dose

Effect

Amount of malathion in stomach

Amount of malathion that actually reaches the nervous system

Amount of malathion that crosses stomach barrier

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
EXPOSURE CONSIDERATIONS
• 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
عناصر التعرض

• **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

<table>
<thead>
<tr>
<th>Pollutant Source</th>
<th>Exposure Pathway</th>
<th>Receptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaking storage tank</td>
<td>Ingestion of water</td>
<td>Human drinking</td>
</tr>
</tbody>
</table>
• **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
- 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