



# Hazard Identification and Risk Assessment in Food Products Based on Heavy Metal Contamination

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# References

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- U.S. EPA risk assessment documents including:
  - Risk Assessment Guidance for Superfund
  - Presenter's Manual for "Superfund Risk Assessment and How You Can Help"

# Goals and Objectives



- Review **risk** assessment **process**
- Discuss **components of risk** assessment
- Review **types of data** used in **risk** assessment

# Types Of Risk Assessment

- Human Health Risk Assessment

The **characterization** of the **probability** of potentially adverse health effects from human exposures to environmental hazards.

- Ecological Risk Assessment

A process that estimates the **likelihood** of undesirable ecological effects occurring as a result of **human activities**.

# What is Risk Assessment?

“ Risk Assessment is the process of determining, either **quantitatively** or **qualitatively**, the **probability** and **magnitude** of an undesired event.”

(Oklahoma Corporation Commission Risk Assessment Guidance Document, 1994)

# EPA Definition of Health Risk Assessment

## ■ Risk assessment:

Qualitative and quantitative evaluation of the **risk** posed to human health and/or the environment by the **actual or potential** presence and/or use of **specific pollutants**

*From EPA's "Terms of Environment" Glossary*

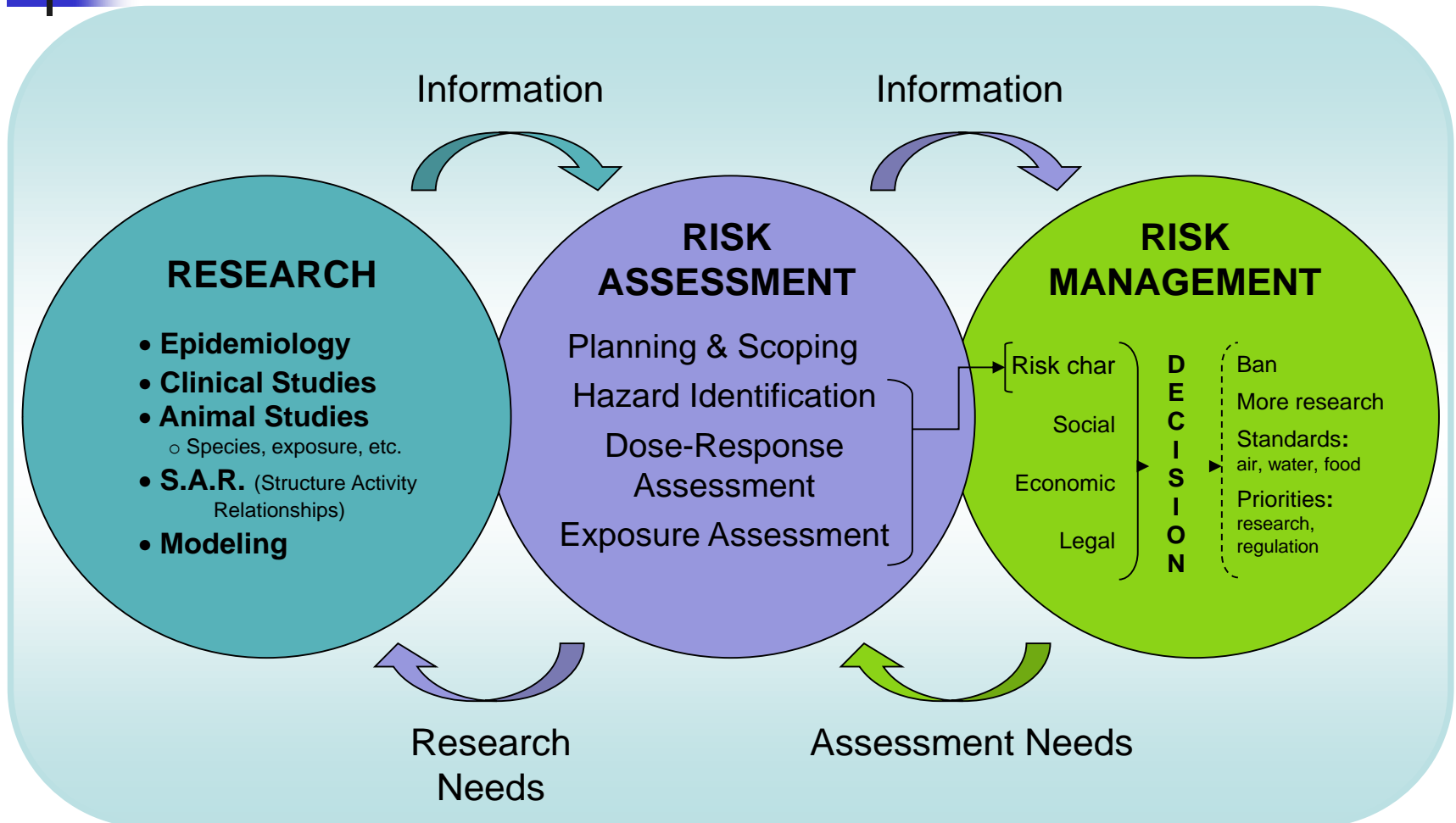


# Risk assessment:

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- An important concept to understand is that “risk” typically refers to the **probability, or likelihood**, that something might happen in the **future**.
- From the Terms of the Environment glossary, **risk** is “a **measure** of the **probability** that **damage** to **life, health, property**, and/or the **environment** will occur as a result of a **given hazard**.”
  - Hazard – is the potential to cause harm, by injury or ill health.
  - Risk – is the likelihood of a hazard doing harm.

# Overview of Human Health Risk Assessment





# Planning and Scoping

## Identify the Problem

- What causal agents should be considered? *(chemical, bacteria...)*
- Who is affected? *(age, race, sensitive/susceptible, gender... )*
- Where does the **problem/ gaps** exist? *(sample size, sampling, missing data..)*
- What are risk management needs? *(uncertainties, legal, methods, technology, Financial, impact, employee, ...)*
- What are stakeholder needs?



# Four Steps to A Risk Assessment Document

1. Hazard Identification
2. Dose-Response Assessment
3. Exposure Assessment
4. Risk Characterization



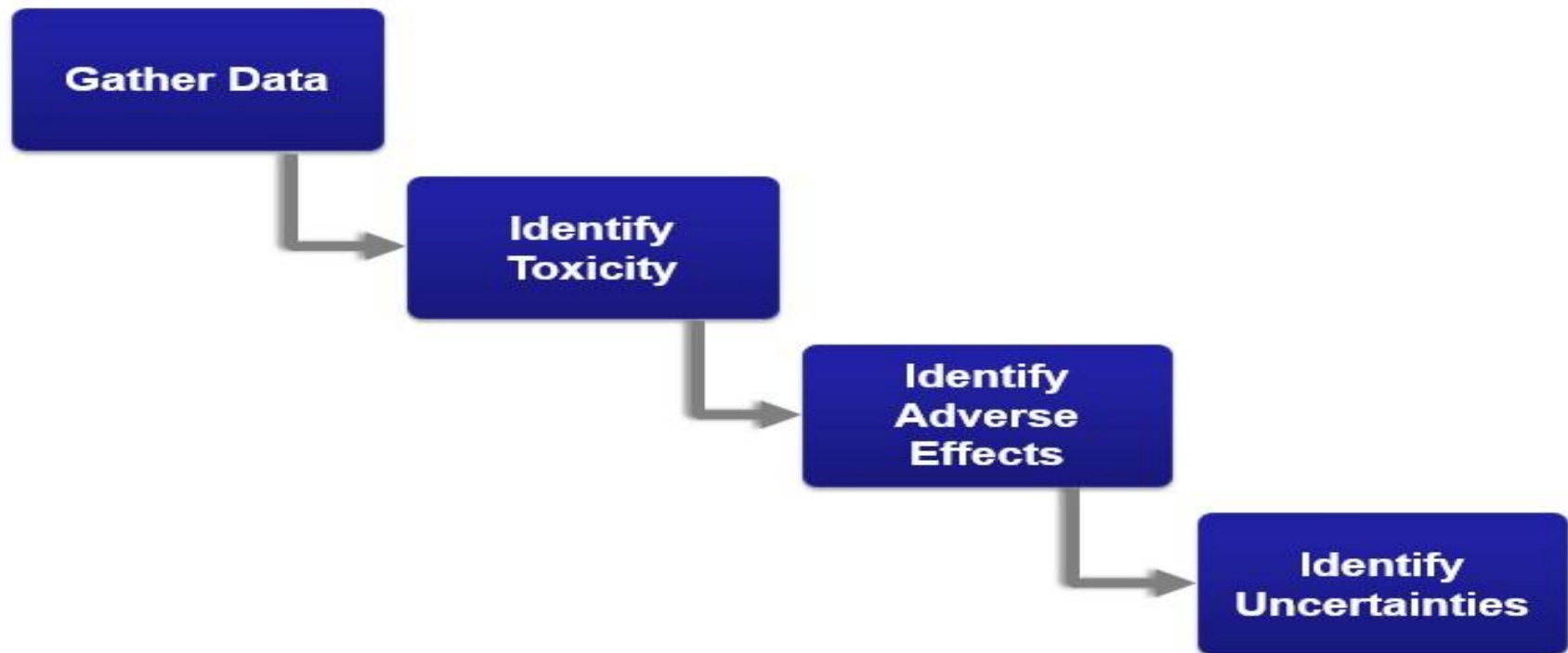


# 1. Hazard Identification

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Hazard identification involves **gathering data** and **evaluating toxicity** data on the types of **health adverse effect** (injury or disease) that may be produced by a chemical and the conditions of exposure under which injury or disease is produced.

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# Hazard Identification – Data

## Gather Data

- What are the chemicals? *(Chemical and physical properties)*
- Which human populations might be affected?
- What toxicity data are available? *(Cancer, Non-Cancer....)*
  - ✓ Human Data (H.R.A.)
    - Epidemiology studies
    - Controlled human exposure studies
  - ✓ Animal Bioassay Data (E.R.A.)
  - ✓ Other Data
    - In Vitro Data
    - Structure-activity relationships
    - Metabolic data
    - Genomics



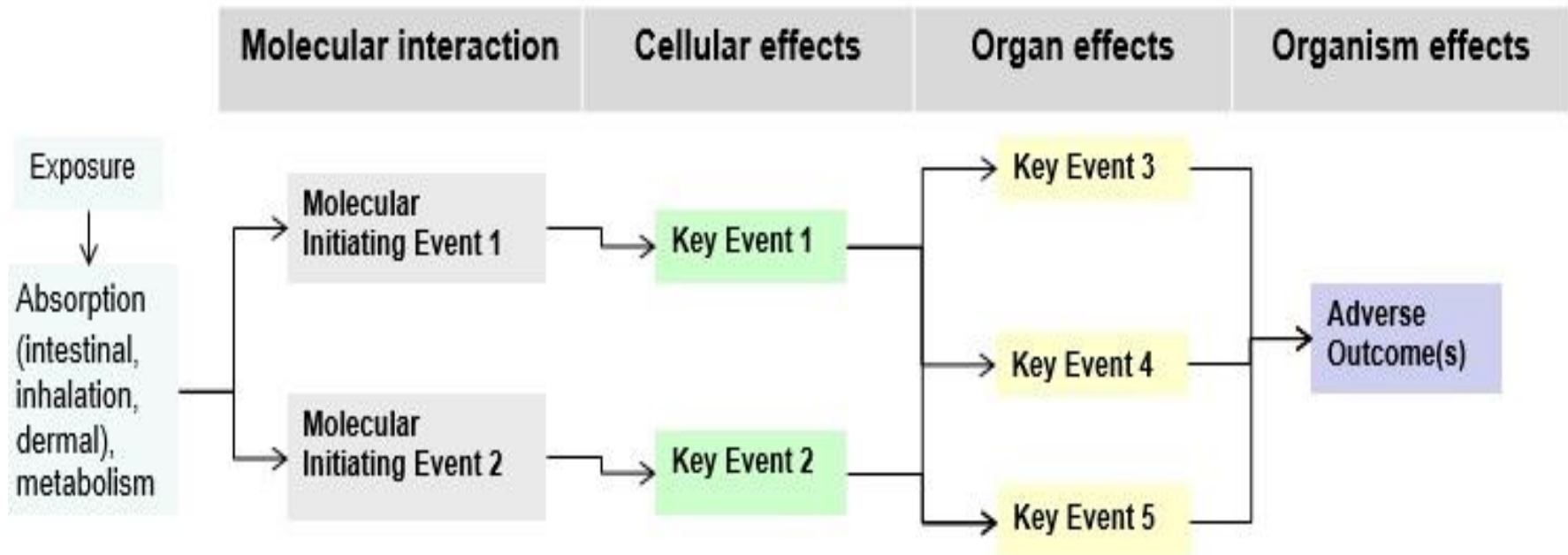
# Hazard Identification – toxic

## How toxic is the chemical?

- **Effects** – What **effects** are observed from the data collected?
- **Toxicokinetics** – What does the **body do** to the chemical? **(ADME)**
- **Toxicodynamics** – What does the **chemical do** to the body?
- **Mode of action** – How does the chemical act to produce an effect?
- **Causality Framework** – A way to organize and evaluate toxicity information to assess causality given those data.
- **Weight of evidence** – How likely is this chemical to cause non-cancer effects or cancer and under what conditions?

# Frameworks used for evidence integration

- Adverse Outcome Pathways (AOPs) [OECD].
- Mode of Action Analysis [IPCS WHO].



*Adapted from OECD 2013; Vinken et al 2013; Meek et al., 2013*



# Hazard Identification – Adverse Effect

## What are the adverse effects?

**Adverse effect:** A biochemical change, functional impairment, or pathologic lesion that **affects** the performance of the **whole organism**, or **reduces an organism's ability** to respond to an additional environmental challenge (*U.S. EPA IRIS Glossary*).

- What are the **affected organs or tissue** systems?
- What is the **severity** of effects?
- *Who is more **sensitive** or **susceptible**?*
- *What factors affect susceptibility?*



# Toxicity sources

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- For more information:
  - ToxCast:  
<http://epa.gov/ncct/toxcast/>
  - ACToR:  
<http://actor.epa.gov/actor>
  - ToxCast Data:  
<http://epa.gov/ncct/toxcast/data.html>
  - CSS Dashboards:  
<http://actor.epa.gov/actor/faces/>  
  
[CSSDashboardLaunch.jsp](#)
- ECotox  
<https://cfpub.epa.gov/ecotox/>





# Exposure Contexts

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➤ **Emergency Response**

*Example: EPA's Provisional Advisory Levels*



➤ **Occupational**

*Example: CDC-NIOSH Recommended Exposure Limits*



➤ **Ambient or General Public**

*Example: CDC-ATSDR Minimal Risk Levels & EPA-IRIS Reference Dose/Concentrations*



<https://www.epa.gov/iris>

<https://cfpub.epa.gov/ncea/iris/search/index.cfm>





# Hazard Identification: Uncertainties

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Uncertainty occurs because of **a lack of knowledge**. It is not the same as variability.

- Uncertainty can often be reduced by collecting **more and better data**.
- Variability is an **inherent property** of the **population** being evaluated. (*Adapted from U.S. EPA IRIS Glossary*)

## Examples:

- Using animal data
- Variability within the human population
- Extrapolating the study duration (*sub-chronic/chronic..*)
- Strength of database/ Quality of data (*method, measurement, bias, sample size....*)





## 2. Dose-Response Assessment

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- The dose-response assessment involves describing the **quantitative** relationship between the **amount of exposure** to a chemical and the **extent of toxic injury or disease**.
  - The description is different for non-carcinogenic versus carcinogenic effects.



# Terminology based *U.S. EPA IRIS*

## *Glossary*

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- **Reference Value:** An estimate of an exposure for a given duration to the human population (including susceptible subgroups) that is likely to be **without an appreciable risk of adverse health effects over a lifetime.**
- **Dose (mg/kg-day):** Milligram substance per kilogram body weight per day.
- **Concentration (mg/L, mg/kg, or mg/m<sup>3</sup>):**  
Milligram substance per liter **water,**  
kilogram **soil** or **food,**  
or cubic meter **air.**



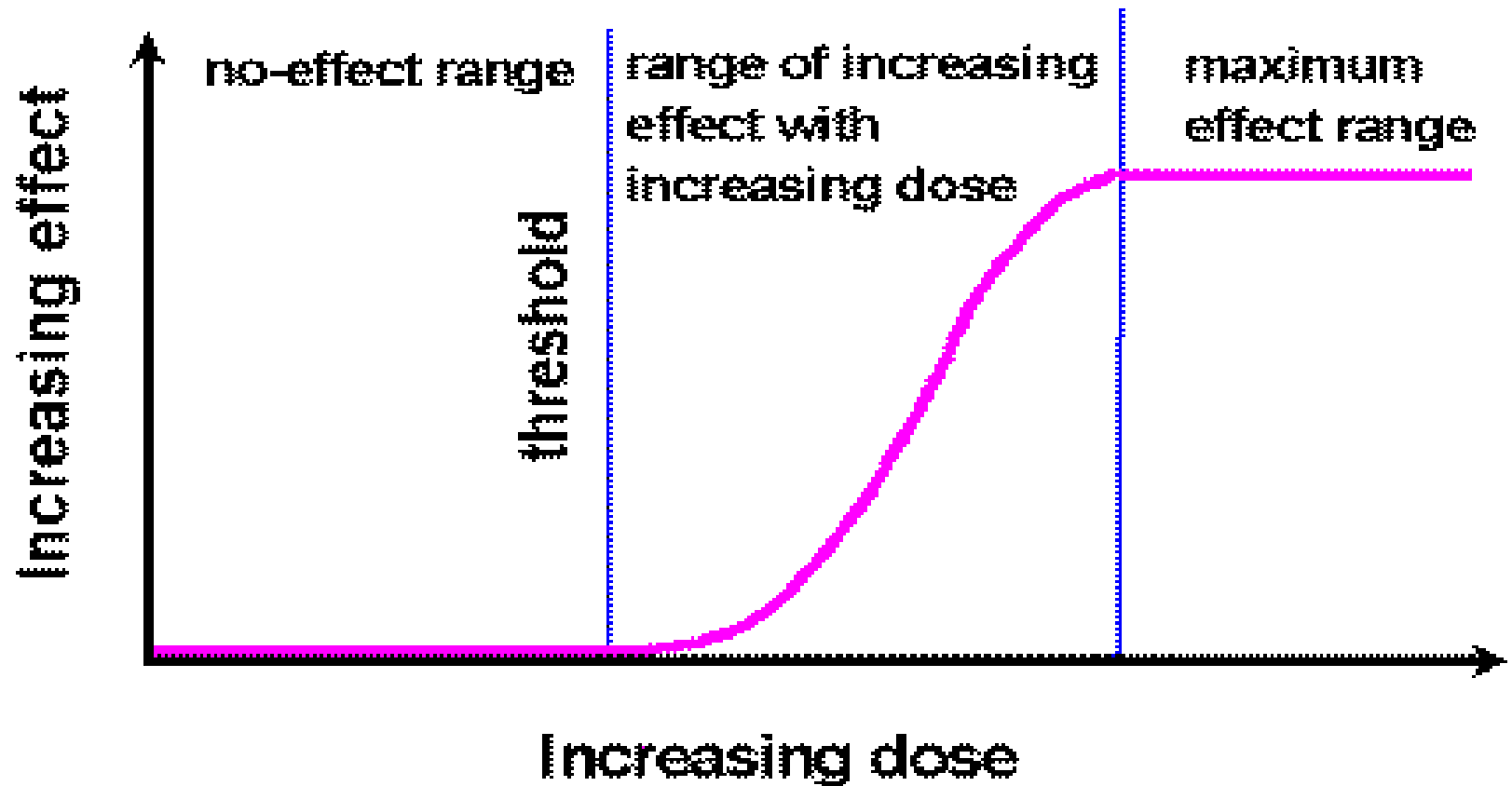
# Reference values

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Reference values are **chemical doses or exposure concentrations at or below** which adverse health effects in a population are **not expected to occur**. When these reference values are not purely health-based, in that other factors are also considered in the development of the value, effects might occur, but the frequency and severity of these effects is deemed **"tolerable."** This concept is often referred to as **"acceptable risk."**

- A chemical concentration in a specified environmental medium is commonly expressed as quantity of a substance per quantity of medium.
- Though these are two of the most common metrics for expressing reference values, some reference values are expressed as proportion of the population estimated to be affected at a specified concentration.

# Dose-Response





# Dose-Response Terminology

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## **LOAEL**

Lowest-Observed-Adverse-Effect Level.  
Lowest dose at which significant adverse effects are observed.

## **NOAEL**

No-Observed-Adverse-Effect Level.  
Highest dose at which no significant adverse effects are observed.

## **BMD**

Benchmark Dose. An exposure to a low dose of a substance that is linked with a low (1-10%) risk of adverse health effects, or the dose associated with a specific biological effect.

## **BMDL**

A lower, one-sided confidence limit on the BMD.

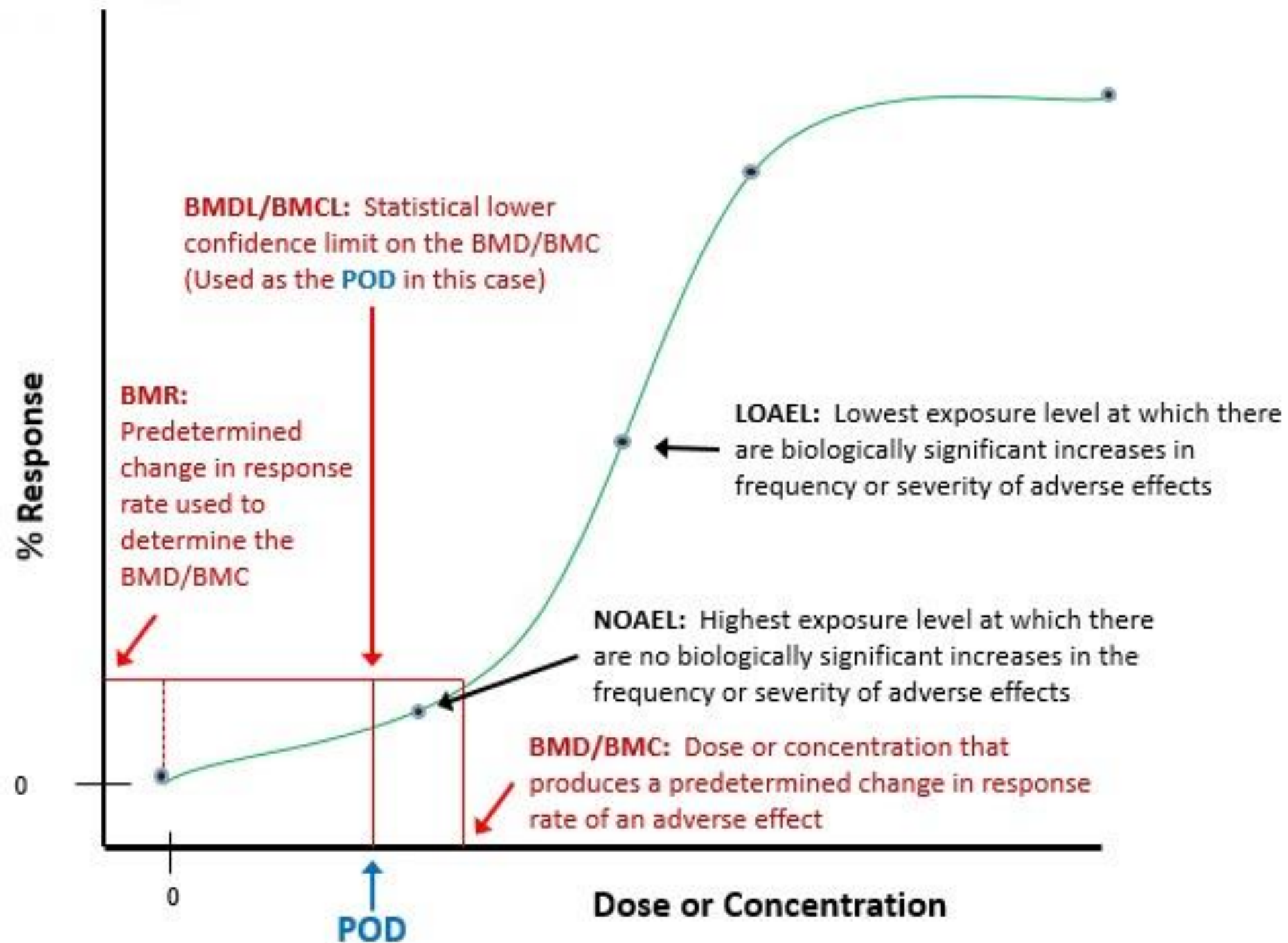
## **Critical effect**

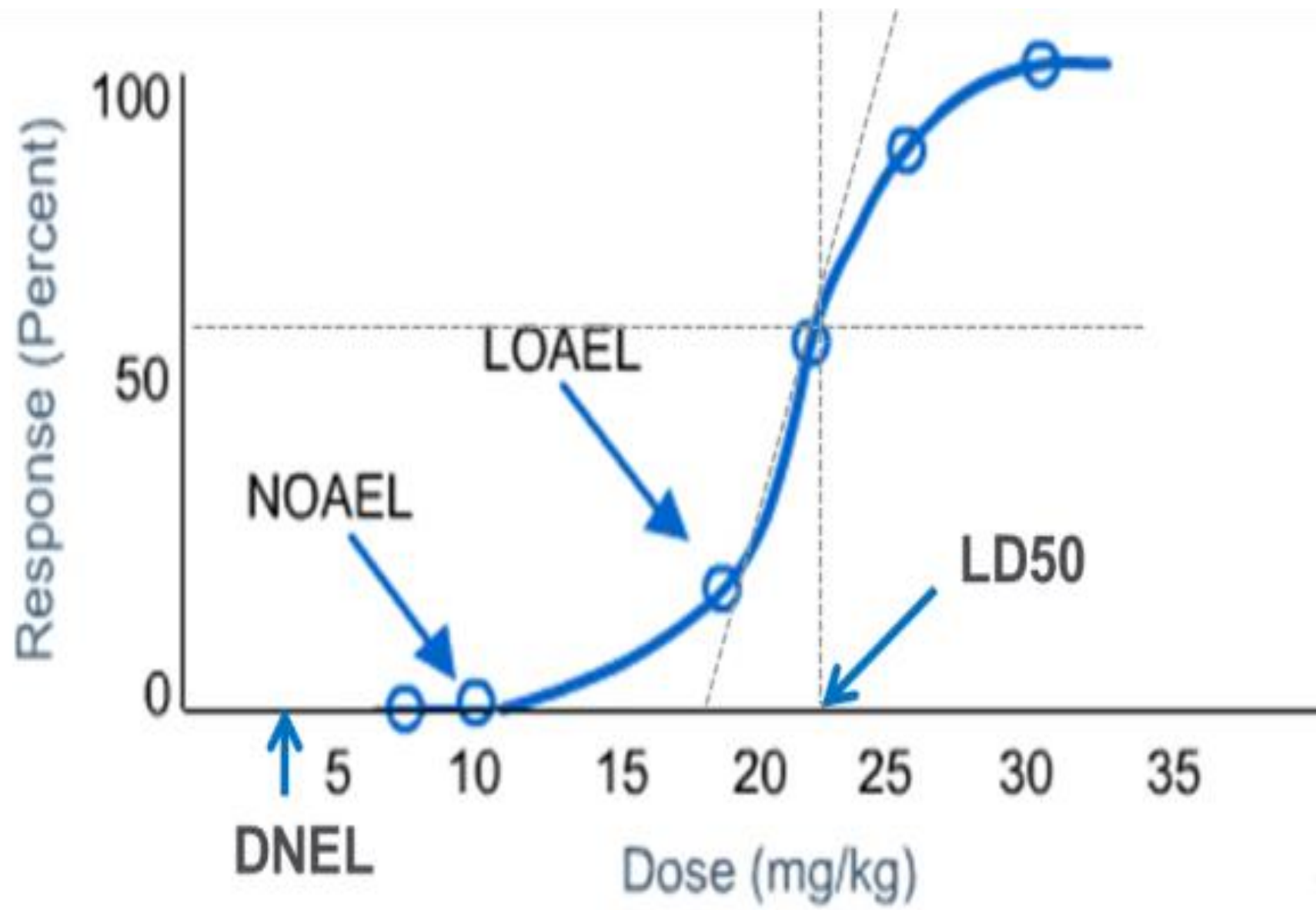
The first adverse effect or its known precursor that occurs to the most sensitive species as the dose rate of an agent increases.

## **Point of Departure**

The dose-response point that marks the beginning of a low dose extrapolation.









# Non-Carcinogenic Effects

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- Allowable Daily Intake - The US Food and Drug Administration, the World Health Organization, and the Consumer Product Safety Commission use the **Allowable Daily Intake (ADI)** to calculate permissible chronic exposure levels.
  - The ADI is determined by applying safety factors to the highest dose in chronic human or animal studies that has been demonstrated not to cause toxicity.



# Non-Carcinogenic Effects - Continued

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- Reference Dose - The US Environmental Protection Agency has slightly modified the ADI. For the EPA, the acceptable safety level is known as the **Reference Dose (RfD)**
  - an estimate of a daily exposure level for human populations, including **sensitive subpopulations**, that is likely to be without an **appreciable risk** of deleterious health effects during a lifetime



# Non-Carcinogenic Effects - Continued

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- Minimum Risk Levels (MRLs), used by ATSDR, are similar to the EPA's Reference Dose (RfD) and Reference Concentration (RfC).
  - An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.



# Carcinogenic Effects

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- Mathematical models are used to extrapolate from the high doses used in animal experiments to the low doses to which humans are normally exposed in a chronic setting.

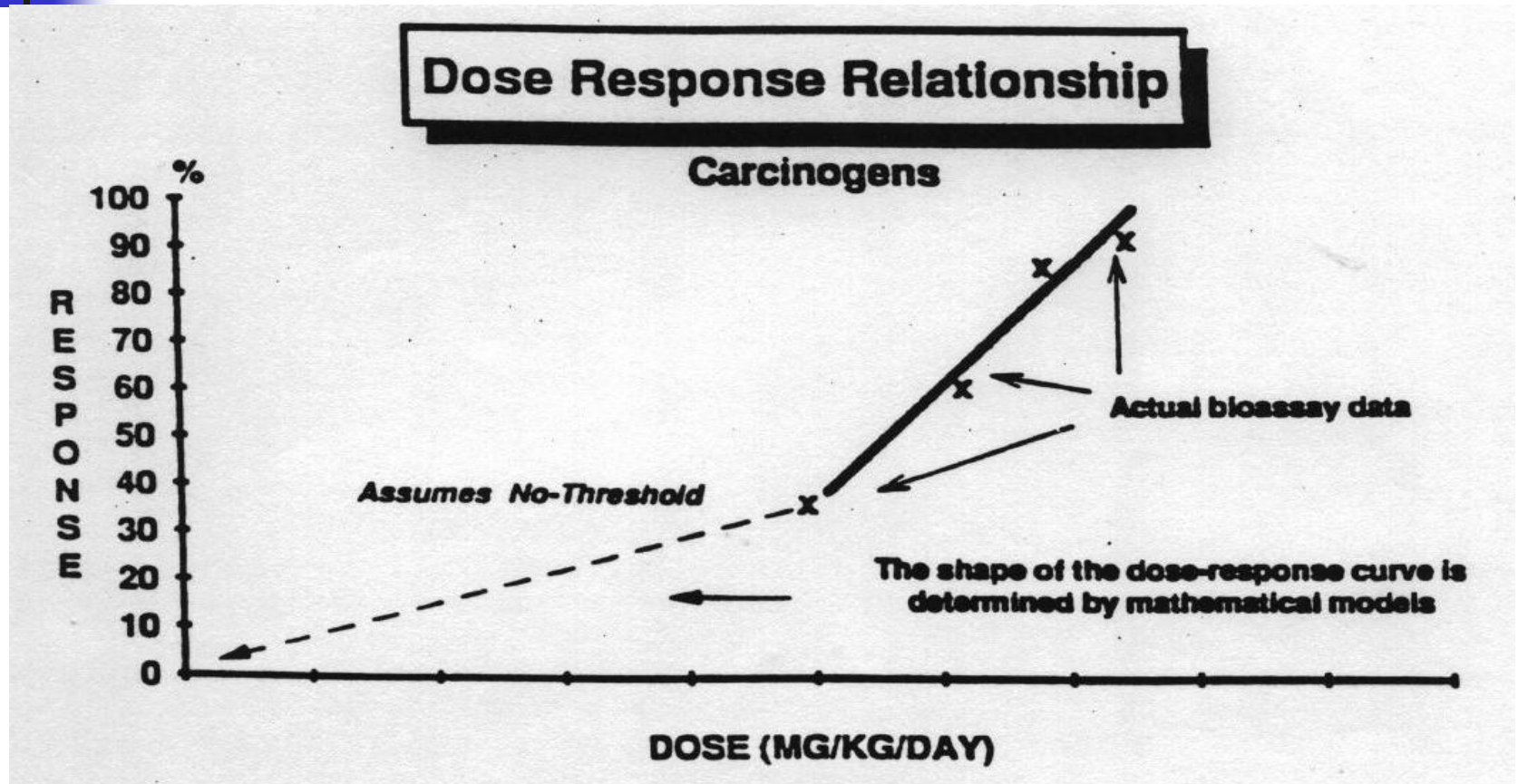


# Carcinogenic Effects - Continued

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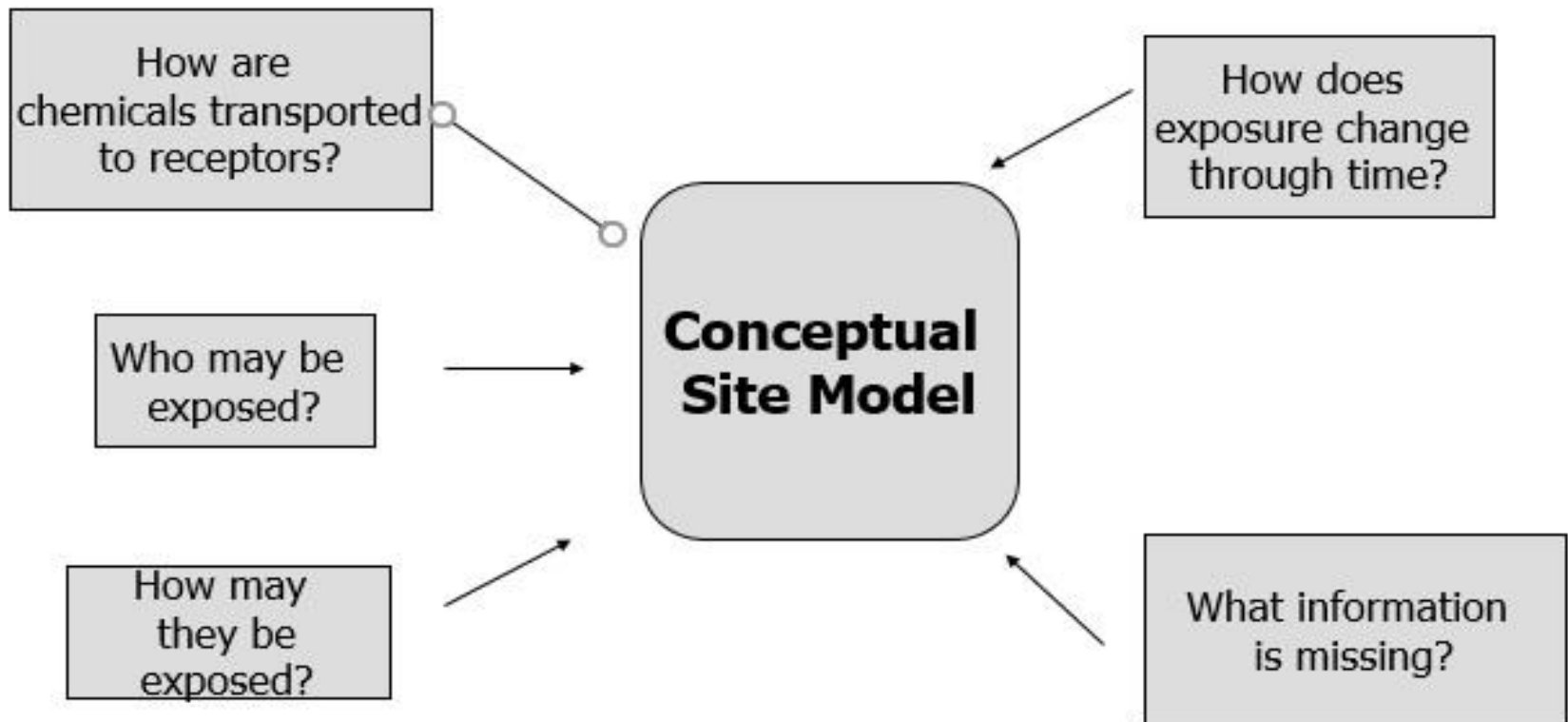
- The key risk assessment parameter derived from the carcinogen risk assessment process is the “**slope factor**”. The slope factor is a toxicity value that **quantitatively** defines the **relationship** between **dose** and **response**.

# Carcinogenic Effects - Continued

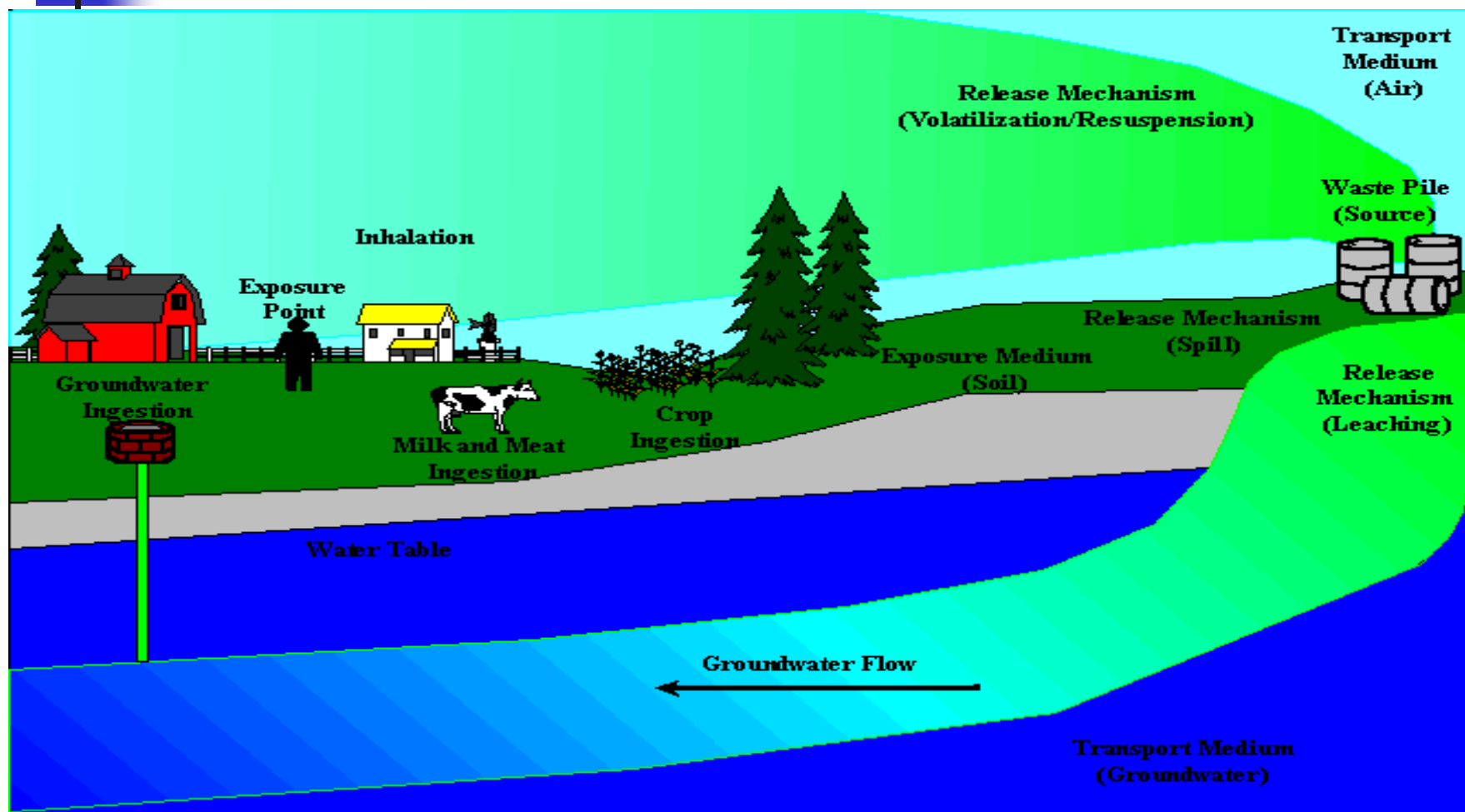




# Input for Conceptual Site Model



# Conceptual Site Model (Oak Ridge National Lab, 2002)





# Carcinogenic Effects - Continued

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- Slope Factor = a plausible upper-bound estimate of the probability of a response per unit intake of chemical over a lifetime
  - Risk per unit dose
  - Units of Risk  $(\text{mg/kg-day})^{-1}$
  - Symbol for Slope Factor =  $q_1^*$



# Cancer Assessment Categories

**TABLE 21.3. EPA Cancer Assessment Categories**

<b>Group A — human carcinogen</b>	<b>Sufficient human evidence for causal association between exposure and cancer</b>
<b>Group B1 — probably human carcinogen</b>	<b>Limited evidence in humans</b>
<b>Group B2 — probably human carcinogen</b>	<b>Inadequate evidence in humans, sufficient evidence in animals</b>
<b>Group C — possible human carcinogen</b>	<b>Limited evidence in animals</b>
<b>Group D — not classifiable as to human carcinogenicity</b>	<b>Inadequate evidence in animals</b>
<b>Group E — no evidence of carcinogenicity in humans</b>	<b>At least two adequate animal tests or both epidemiology and animal studies which are negative</b>

## RESEARCH

- **Epidemiology**
- **Clinical Studies**
- **Animal Studies**
  - Species, exposure, etc.
- **S.A.R.** (Structure Activity Relationships)
- **Modeling**

Information

## RISK ASSESSMENT

Planning & Scoping  
Hazard Identification  
Dose-Response Assessment  
Exposure Assessment

Information

## RISK MANAGEMENT

[Risk char  
Social  
Economic  
Legal]

**D  
E  
C  
I  
S  
I  
O  
N**

Ban  
More research  
Standards:  
air, water, food  
Priorities:  
research,  
regulation

Research  
Needs

Assessment Needs



## 3. Exposure Assessment

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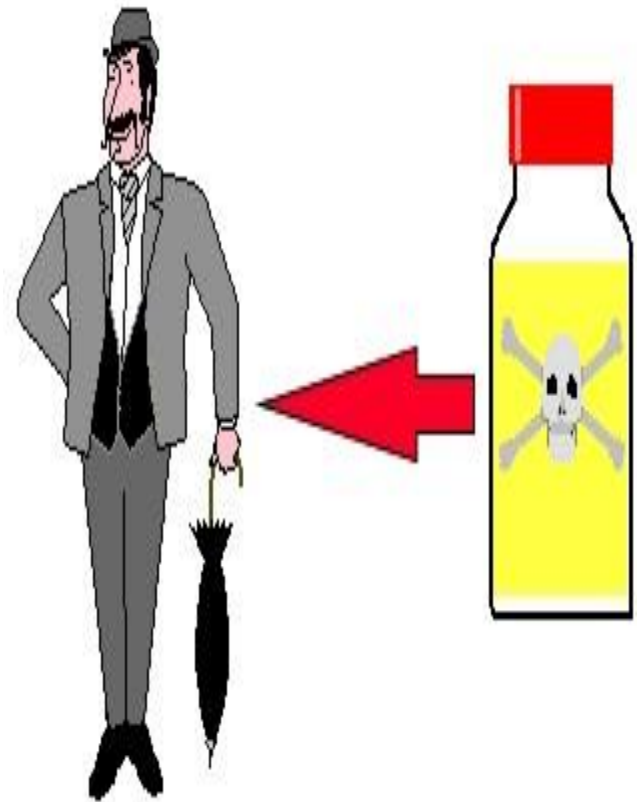
**Exposure** is contact made between an **agent** and **a target**

- **Exposure Assessment** The process of estimating or measuring the **magnitude, frequency, and duration** of exposure to an agent, along with the **number** and **characteristics of the population** exposed.

*(U.S. EPA Exposure Factors Handbook)*

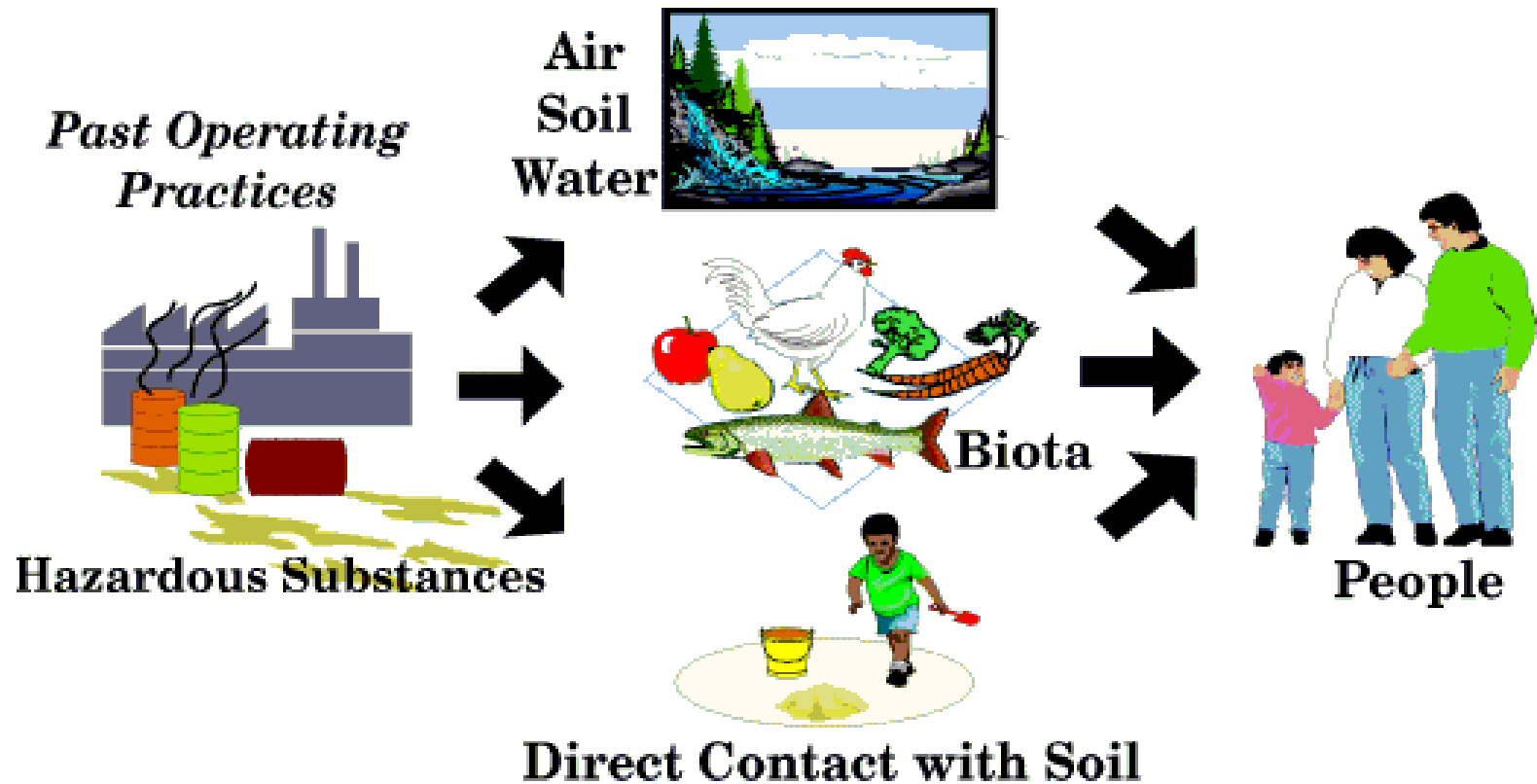
# Exposure Assessment

- **Who is Exposed?**
  - Adult, Child, Special Populations
- **How Are They Exposed?**
  - Ingestion, Inhalation, Skin Contact
- **What is the Concentration of Chemical to Which They are Exposed?**
  - ppm in Water or Soil, food
- **How Often Are They Exposed?**
  - Days per year, Number of years



# Exposure Pathway Diagram

## Exposure Pathways







# Identification of Exposure Pathways

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- Contaminated groundwater – ingestion (drinking water), dermal contact (bathing), and inhalation of volatile organic compounds (showering)
- Surface water and sediments – incidental ingestion and dermal absorption of contaminants (people in bodies of water)
- Contaminated food – ingestion of contaminated fish tissue, vegetables and fruit grown in contaminated soil or covered with contaminated dust, meat, and dairy products

# Quantify Exposure

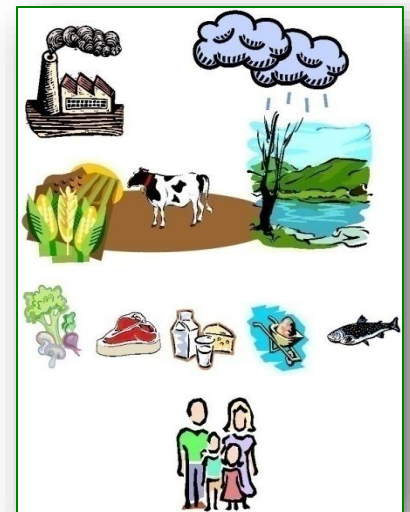
## Point of Contact Measurement



## Reconstruction of Dose



## Scenario Evaluation



# Quantify Exposure

## Point of Contact Measurement (Field Measurements)



- Measure chemical concentrations over time
- At or near **point of contact** **for** exposure in question
- Various sampling methods

Examples of point of contact measurements: *Personal air sampler, Radiation dosimeter that an individual wears*

# Quantify Exposure

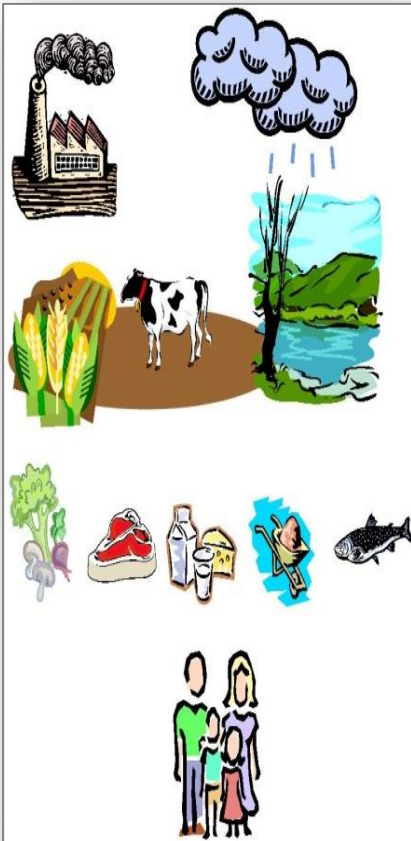
## Reconstruction of Dose (Clinical Measurements)



*E.g. Cotinine is a metabolite of nicotine that can be used as a biomarker of exposure to tobacco products or environmental tobacco smoke.*

- Attempt to quantify **internal dose** based on physiological data
- Using measurements from the **body, tissues**
- **Biomarkers** of **exposure**, metabolites — involves extrapolation. Predictive estimate.

# Quantify Exposure



## Scenario Evaluation

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

## References that can be consulted for exposure factors:

- EPA's Exposure Factors Handbook.
- EPA's Superfund Risk Assessment Guidance.
- <https://www.epa.gov/expobox>



# Exposure Assessment Equation: Average Daily Dose (ADD) for non-cancer effects

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

C = Concentration of the contaminant within the media of interest (mg/kg; mg/L; mg/cm<sup>2</sup>; mg/m<sup>3</sup>)

CR = Contact rate of the media of interest (g/d; L/d; cm<sup>2</sup>/d; m<sup>3</sup>/d)

EF = Exposure frequency (365 day/year)

ED = Exposure duration (30 year)

BW = Body weight (70 kg)

AT = Averaging time (10950 day)

**References that can be consulted for exposure factors:** [EPA's Child-Specific Exposure Scenarios Examples](#)

- EPA's Exposure Factors Handbook.
- EPA's Superfund Risk Assessment Guidance.
- <https://www.epa.gov/expobox>



## Exposure Assessment Equation: life Average Daily Dose (LADD) for Cancer effects

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

C = Concentration of the contaminant within the media of interest (**mg/kg**; **mg/L**; mg/cm<sup>2</sup>; mg/m<sup>3</sup>)

CR = Contact rate of the media of interest (**Kg/d**; **L/d**; cm<sup>2</sup>/d; m<sup>3</sup>/d)

EF = Exposure frequency (365 day/year)

ED = Exposure duration (**70 years**)

BW = Body weight (70 kg)

AT = Averaging time (**25550 days**)



## 4. Risk Characterization

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**Risk characterization** is the integration of information on hazard, exposure, and dose-response to provide an estimate of the likelihood that any of the identified adverse effects will occur in exposed people.

(IRIS Glossary Definition)

- Compares toxicity information to the exposure profiles developed for people we think might be exposed.
- Estimates likelihood that adverse effects will occur in people who are exposed.
- Includes assumptions and uncertainties associated with all steps in the risk assessment process.





# Risk Characterization: Outcome

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**Noncancer Hazard Quotient (HQ):** Ratio of estimated exposure to reference level at which no adverse health effects are expected.

**Noncancer Hazard Index (HI):** The sum of hazard quotients (HQs) for substances that affect the same target organ or organ system.

**Cancer Risk:** Incremental probability of developing cancer for an individual exposed to a given chemical over a lifetime.



# Risk Characterization: Non-cancer Hazard Quotient

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$$\text{Hazard Quotient (HQ)} = \frac{\text{ADD} \left( \frac{\text{mg}}{\text{kg-day}} \right)}{\text{RfD} \left( \frac{\text{mg}}{\text{kg-day}} \right)}$$

**RfD:** reference dose

**ADD:** average daily dose

**If ADD is < RfD, then no problem- except when dealing with multiple chemicals**

# Risk Characterization: **Hazard** **Index**



- Rather than same mode-of-action (MOA), similarity is determined at the level of target organ
- For the HI approach, risks to humans are estimated under the implicit assumption that components are toxic in the same target (organ or system)

$$***HI = HQ1 + HQ2 + HQ3***$$

HI < 1 is assumed, to denote safety over a lifetime  
HI > 1 is assumed risk management decision necessary



# Risk Characterization: cancer Hazard Quotient

$$\text{Cancer Risk (Oral)} = \text{LADD} \left( \frac{\text{mg}}{\text{kg} - \text{day}} \right) \times \frac{\text{Oral}}{\text{Slope Factor}} \left( \frac{\text{mg}}{\text{kg} - \text{day}} \right)^{-1}$$

- **CR**  $\leq 1 \times 10^{-6}$  ( Acceptable or safe food)
- $1 \times 10^{-6} \leq \text{CR} \leq 1 \times 10^{-4}$  \*(Borderline)
- **CR**  $\geq 10^{-4}$  \*(High risk)

\* risk management decision necessary

# Further information:

Parameters	Values	Units
<b>Exposure frequency (EF)</b>	365	days/year
<b>Exposure duration (ED)<sup>b,c</sup></b>	30 (non-carcinogenic); 70 (carcinogenic)	years
<b>Body weight (BW)<sup>a</sup></b>	Adult: 70 Male: ? Female: ? Child: 16	kg
<b>Average exposure time (AT)<sup>c</sup></b>	10950 (non-carcinogenic); 25550 (carcinogenic)	days
<b>Reference dose (RfD)</b>	0.004 for Cu, 0.3 for Zn, 0.3 for Ba, 0.14 for Mn, 0.0005 for Cd, 0.2 for B, 1.5 for Cr, 0.02 for Ni, 0.005 for Mo, 0.005 for Se, 0.0003 for Hg, 0.035 for atrazine, 0.02 for acetochlor, 0.0003 for hexachlorobenzene, 0.02 formalathion, 0.001 for chlorpyrifos	mg/kg/day
<b>Slope factor (SF)</b>	1.5 for As, 0.38 for Cd, 0.23 for atrazine, 1.6 for hexachlorobenzene, 0.34 for p,p-DDE, 0.24 for p,p-DDD	(kg·d)/mg

U.S. EPA, Risk Assessment Guidance for Superfund (RAGS), volume I: Human Health Evaluation Manual (HHEM) supplemental guidance.

WashingtonDC: Office of emergency and remedial response; 1991 [EPA/540/R-92/003].

c. U.S. EPA. Exposure Factors Handbook: 2011 Edition. Washington, DC: Office of Research and Development; 2011 [EPA/600/R-090/052F].

[https://iris.epa.gov/AtoZ/?list\\_type=alpha](https://iris.epa.gov/AtoZ/?list_type=alpha)

Pollutants		Carcinogenic effects			Non-carcinogenic effects	
	U.S. EPA. IRIS	WHO.IARC	SF (kg·d/mg)	Source of the data	RfD (mg/kg-day)	Source of the data
Copper (Cu)	D (not classifiable as to human carcinogenicity)	Not listed	NA	NA	4.00E-03	Wang et al.,2014
Zinc (Zn)	NA	Not listed	NA	NA	3.00 E-01	IRIS
Cadmium (Cd)	B1 probable human carcinogen)	1(Carcinogenic to humans)	0.38	Wen et a.,2012	5.00E-04	IRIS
Chromium (Cr)	Not listed	3(Not classifiable as to its carcinogenicity to humans)	NA	NA	1.50E+00	IRIS
Nickel (Ni)	The U.S. EPA has not evaluated soluble salts of nickel.	2B(Possibly carcinogenic to humans)	NA	NA	2.00E-02	IRIS
Arsenic (As)	A (human carcinogen)	1(Carcinogenic to humans)	1.50	RAIS	3.00E-04	IRIS
Mercury (Hg)	D (not classifiable as to human carcinogenicity)	3(Not classifiable as to its carcinogenicity to humans)	NA	NA	3.00E-04	IRIS
Atrazine	NA	3(Not classifiable as to its carcinogenicity to humans)	0.23	RAIS	3.50E-02	IRIS
Acetochlor	NA	Not listed	NA	NA	2.00E-02	IRIS
Hexachloro-benzene	B2 (probable humancarcinogen)	2B(Possibly carcinogenic to humans)	1.60	IRIS	3.00E-04	IRIS
p,p'-DDE	B2 (probable humancarcinogen)	Not listed	0.34	RAIS	Not listed	IRIS
p,p'-DDD	B2 (probable humancarcinogen)	Not listed	0.24	RAIS	Not listed	IRIS

# Example:

1. اگر میزان متوسط آرسنیک در آرد گندم توزیع شده در سطح شهر مشهد برابر با  $0.2 \text{ mg/kg}$  باشد و میزان متوسط مصرف روزانه افراد از محصولات غذایی ترکیب شده با آرد برابر با  $0.6 \text{ kg/d}$  نسبت خطر بهداشتی و سرطان زایی را محاسبه کنید.

1. ADD OR LADD

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

2.

$$\text{Hazard Quotient (HQ)} = \frac{\text{ADD} \left( \frac{\text{mg}}{\text{kg-day}} \right)}{\text{RfD} \left( \frac{\text{mg}}{\text{kg-day}} \right)}$$

3.

$$\text{Cancer Risk (Oral)} = \text{LADD} \left( \frac{\text{mg}}{\text{kg-day}} \right) \times \text{Oral Slope Factor} \left( \frac{\text{mg}}{\text{kg-day}} \right)^{-1}$$

Variables	ADD (mg/kg.day)	LADD (mg/kg.day)
C	0.2 mg/kg	0.2 mg/kg
CR	0.6 kg/day	0.6kg/day
EF	365 days	365 days
ED	30 years	70 years
BW	70 kg	70 kg
AT	10950	25550
RFD (As)		0.0003 mg/kg/d
OSF (As)		1.5 mg/kg/d



$$1. \text{ ADD} = 0.2 * 0.6 * 365 * 30 / 10950 * 70 = 0.00171$$

$$1. \text{ LADD} = 0.2 * 0.6 * 365 * 70 / 25550 * 70 = 0.00171$$

$$2. \text{ HQ} = \text{ADD} / \text{RFD} = 0.00171 / 0.0003 = 5.71$$

$$3. \text{ CR} = \text{ADD} * \text{RFD} = 0.00171 * 1.5 = 0.00255 = 2 \times 10^{-3}$$

Variables	ADD (mg/kg.day)	LADD (mg/kg.day)
C	0.2 mg/kg	0.2 mg/kg
CR	0.6 kg/day	0.6kg/day
EF	365 days	365 days
ED	30 years	70 years
BW	70 kg	70 kg
AT	10950	25550
RFD (As)		0.0003 mg/kg/d
OSF (As)		1.5 mg/kg/d



$$\text{HQ} = 5.71 > \text{RFD} > 1 \text{ (High)}$$

$$\text{CR} = 2 \times 10^{-3} > 1 \times 10^{-4} \text{ (High)}$$



Risk management decision necessary

# Dermal pathway (water and soil)

## Dermal Absorbed Dose – Water Contact

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT} \quad (3.1)$$

where:

<u>Parameter</u>		<u>Definition (units)</u>	<u>Default Value</u>
DAD	=	Dermally Absorbed Dose (mg/kg-day)	–
DA <sub>event</sub>	=	Absorbed dose per event (mg/cm <sup>2</sup> -event)	Chemical-specific, see Eq. 3.2, 3.3 and 3.4
SA	=	Skin surface area available for contact (cm <sup>2</sup> )	See Exhibit 3-2
EV	=	Event frequency (events/day)	See Exhibit 3-2
EF	=	Exposure frequency (days/year)	See Exhibit 3-2
ED	=	Exposure duration (years)	See Exhibit 3-2
BW	=	Body weight (kg)	70 kg (adult) 15 kg (child)
AT	=	Averaging time (days)	noncarcinogenic effects AT = ED x 365 d/yr carcinogenic effects AT = 70 yr x 365 d/yr



# Absorb dose per event

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## Dermal Absorbed Dose Per Event for Inorganic Compounds – Water Contact

$DA_{event}$  (mg/cm<sup>2</sup>-event) is calculated for inorganics or highly ionized organic chemicals as follows:

$$DA_{event} = K_p \times C_w \times t_{event} \quad (3.4)$$

where:

<u>Parameter</u>	<u>Definition (units)</u>	<u>Default Value</u>
$DA_{event}$ =	Absorbed dose per event (mg/cm <sup>2</sup> -event)	—
$K_p$ =	Dermal permeability coefficient of compound in water (cm/hr)	Chemical-specific, see Exhibit A-6 and Appendix B
$C_w$ =	Chemical concentration in water (mg/cm <sup>3</sup> )	Site-specific, non-ionized fraction, see Appendix A for more discussion
$t_{event}$ =	Event duration (hr/event)	See Exhibit 3-2



# Kp

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## EXHIBIT 3-1

### PERMEABILITY COEFFICIENTS FOR INORGANICS

Compound	Permeability Coefficient $K_p$ (cm/hr)
Cadmium	$1 \times 10^{-3}$
Chromium (+6)	$2 \times 10^{-3}$
Chromium (+3)	$1 \times 10^{-3}$
Cobalt	$4 \times 10^{-4}$
Lead	$1 \times 10^{-4}$
Mercury (+2)	$1 \times 10^{-3}$
Methyl mercury	$1 \times 10^{-3}$
Mercury vapor	0.24
Nickel	$2 \times 10^{-4}$
Potassium	$2 \times 10^{-3}$
Silver	$6 \times 10^{-4}$
Zinc	$6 \times 10^{-4}$
All other inorganics	$1 \times 10^{-3}$

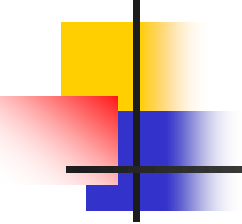
## EXHIBIT 3-2

### RECOMMENDED DERMAL EXPOSURE VALUES FOR CENTRAL TENDENCY AND RME RESIDENTIAL SCENARIOS – WATER CONTACT

Exposure Parameters	Central Tendency Scenario				RME Scenario			
	Showering/ Bathing		Swimming		Showering/ Bathing		Swimming	
Concentration- $C_w$ (mg/cm <sup>3</sup> )	Site-specific		Site-specific		Site-specific		Site-specific	
Event frequency- EV (events/day)	1		Site-specific		1		Site-specific	
Exposure frequency- EF (days/yr)	350		Site-specific		350		Site-specific	
Event duration- $t_{\text{event}}$ (hr/event)	Adult <sup>1</sup>	Child <sup>2</sup>	Adult	Child	Adult <sup>1</sup>	Child <sup>2</sup>	Adult	Child
	0.25	0.33	Site-specific		0.58	1.0	Site-specific	
Exposure duration- ED (yr)	9	6	9	6	30	6	30	6
Skin surface area- SA (cm <sup>2</sup> )	18,000	6,600	18,000	6,600	18,000	6,600	18,000	6,600
Dermal permeability coefficient- $K_p$ (cm/hr)	Chemical-specific values Exhibits B-3 and B-4							

<sup>1</sup> Adult showering scenario used as the basis for the chemical screening for the dermal pathway, as shown in Appendix B, Exhibits B-3 and B-4. Event duration for adult exposure is based on showering data from the EFH (U.S. EPA, 1997a).

<sup>2</sup> Event duration for child exposure is based on bathing data from the EFH (U.S. EPA, 1997a).

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- reasonable maximum exposure (RME). The Risk Assessment Guidance. for Superfund: Human Health Evaluation Manual (Part A) (U.S. EPA. 1989) also known as RAGS, defines the RME as the highest exposure. that is reasonably expected to occur at a site and in practice is.
  - The central tendency exposure represents a median or average





# Additional Resources

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- EPA Benchmark Dose Software  
<http://www.epa.gov/ncea/bmds/>
- EPA-Expo-Box (A Toolbox for Exposure Assessors)  
<https://www.epa.gov/expobox>
- EPA Risk Assessment Guidelines:  
<http://www.epa.gov/riskassessment/guidance.htm>
- Human Health Risk Assessment Program  
<https://www.epa.gov/aboutepa/about-human-health-risk-assessment-program>





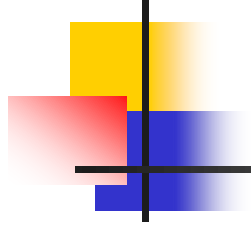


# Crystal Ball Programs

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