Ecological Risk Assessment of Multimedia Hazardous Air Pollutants: Estimating Exposure and Effects

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Complexity in Ecological Risk Assessments

Multiple

- chemical contaminants
- pathways of exposure
- ecosystems or habitats
- sources
- sites
- susceptible receptors and endpoints

A Regulatory Context

Assessment question: What is the remaining (residual) ecological risk from Hazardous Air Pollutants (HAPs) emitted from a particular industrial source category after MACT (maximum achievable control technology) standards have been promulgated and implemented?

Regulatory goal: To determine whether residual risk standards are necessary to prevent an "adverse environmental effect." *Note that cost, energy, safety and other factors must be taken into account before a decision is made to prevent an adverse environmental effect.*

Scope of the Problem

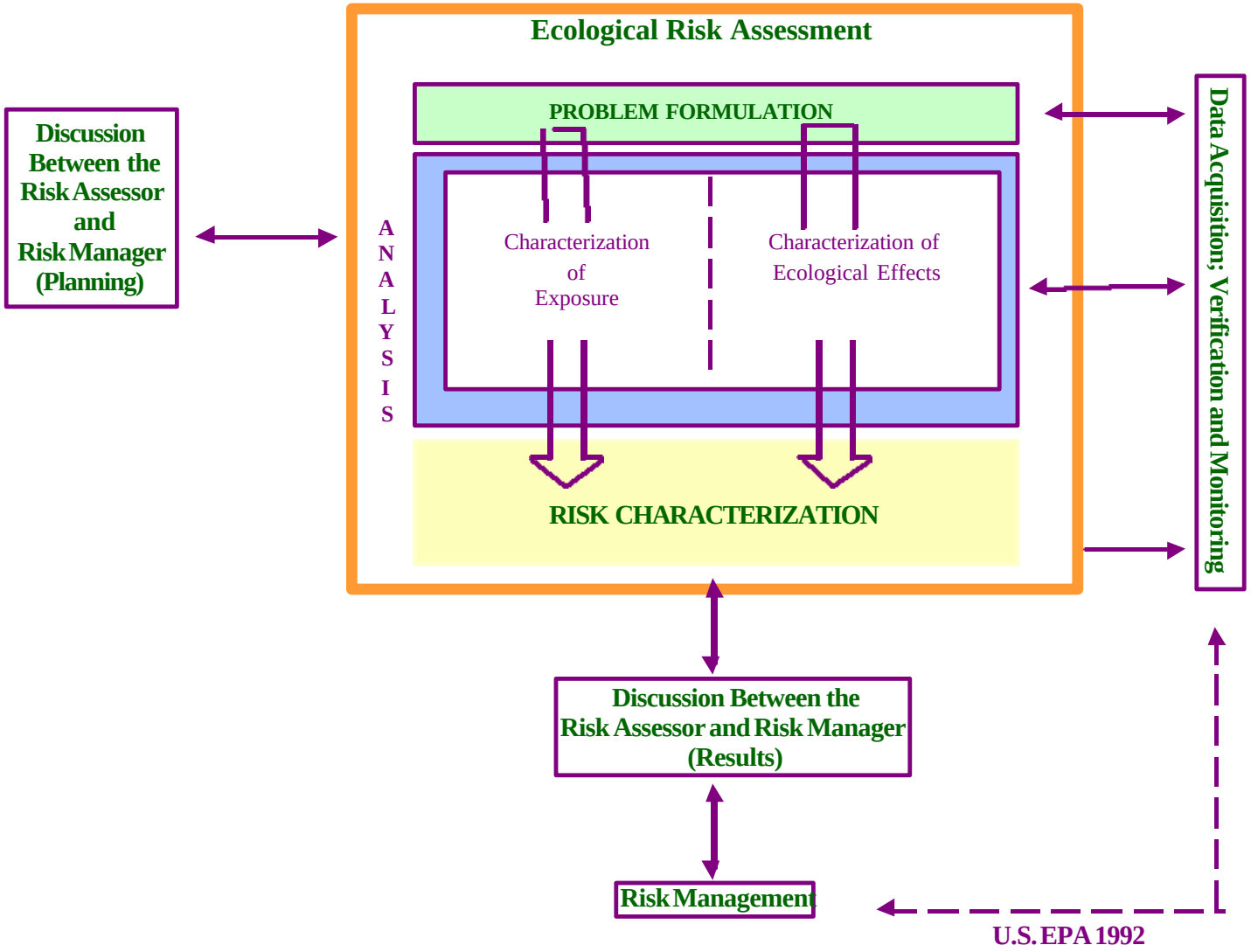
- <10 to 100s of facilities
- <5 to >100 HAPs per source category
  - about 14 mercury-cell chloralkali plants, 1 HAP
  - about 16 secondary lead smelters, 16 HAPs
  - about 370 synthetic organic chemical manufacturers, 111 HAPs
- Potentially numerous
  - ecological receptors
  - terrestrial and aquatic ecosystems
  - wind, precipitation patterns per source category

Ecological Risk Assessment Methodology for Multimedia Hazardous Air Pollutants

Hurdles:

- development of a transport, fate and exposure model that is applicable to a wide range of pollutants at regional and local spatial scales
- description of generic ecosystems for screening purposes
- selection of exposure-response models that can accommodate multiple exposure routes for ecological receptors

EPA Framework for Ecological Risk Assessment



Simplified Residual Risk Assessment Process

Review HAPs emitted from source category for potential for multimedia distribution

No

Evaluate air concentrations predicted from application of regulatory air dispersion model against air/inhalation toxicity values for terrestrial wildlife, plants

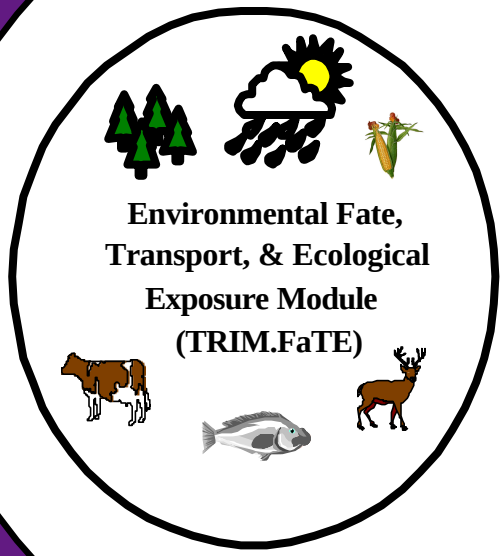
Yes

Utilize multimedia model such as TRIM.FaTE and toxicity values for relevant pathways

Exposure Analysis

	Superfund	Residual Risk
Assessment endpoint entities	Site-specific populations and communities	Populations and communities near individual or similar, multiple facilities
Pollution source	Past spill, burial, air emissions	Current air emissions
Contact media	Soil, water, sediment, diet, rarely air	Air, soil, water, sediment, diet
Chemical concentrations	Constant or slowly decreasing in soil; variable in water, sediment	Changing in all relevant media with time
Exposure assessment boundaries	Definable by spill locations, facility boundaries; gradients of contamination in streams	Not easily defined; gradients of contamination in all relevant media
Role of measurement vs modeling	Measurement data emphasized; limited modeling	Limited measurement data; modeling emphasized

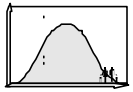
TRIM



Environmental Fate, Transport, & Ecological Exposure Module (TRIM.FaTE)

Exposure Event Module (TRIM.Expo)

Risk Characterization Module (TRIM.Risk)



Social, Economics, & Political Factors

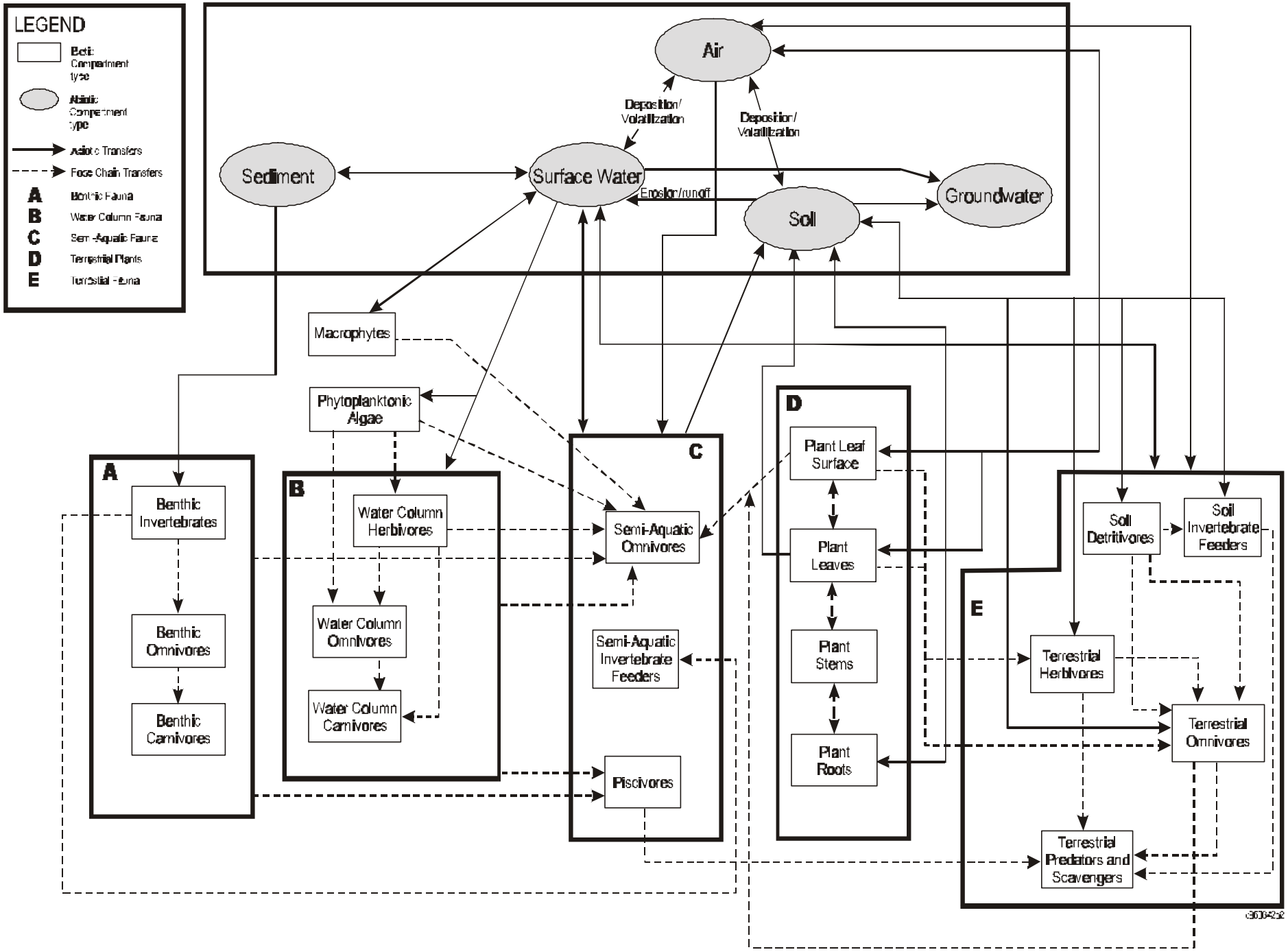
Risk Management Decision

Regulatory Action

TRIM.FaTE

- Mass is conserved.
- Transfers of HAPs occur among multiple media.
- Ecological receptors are exposed via multiple pathways.
- Chemical transformations are represented.
- Spatial scale is flexible.
- Temporal scale and time steps are flexible.
- Capability to perform uncertainty and variability analysis is embedded.

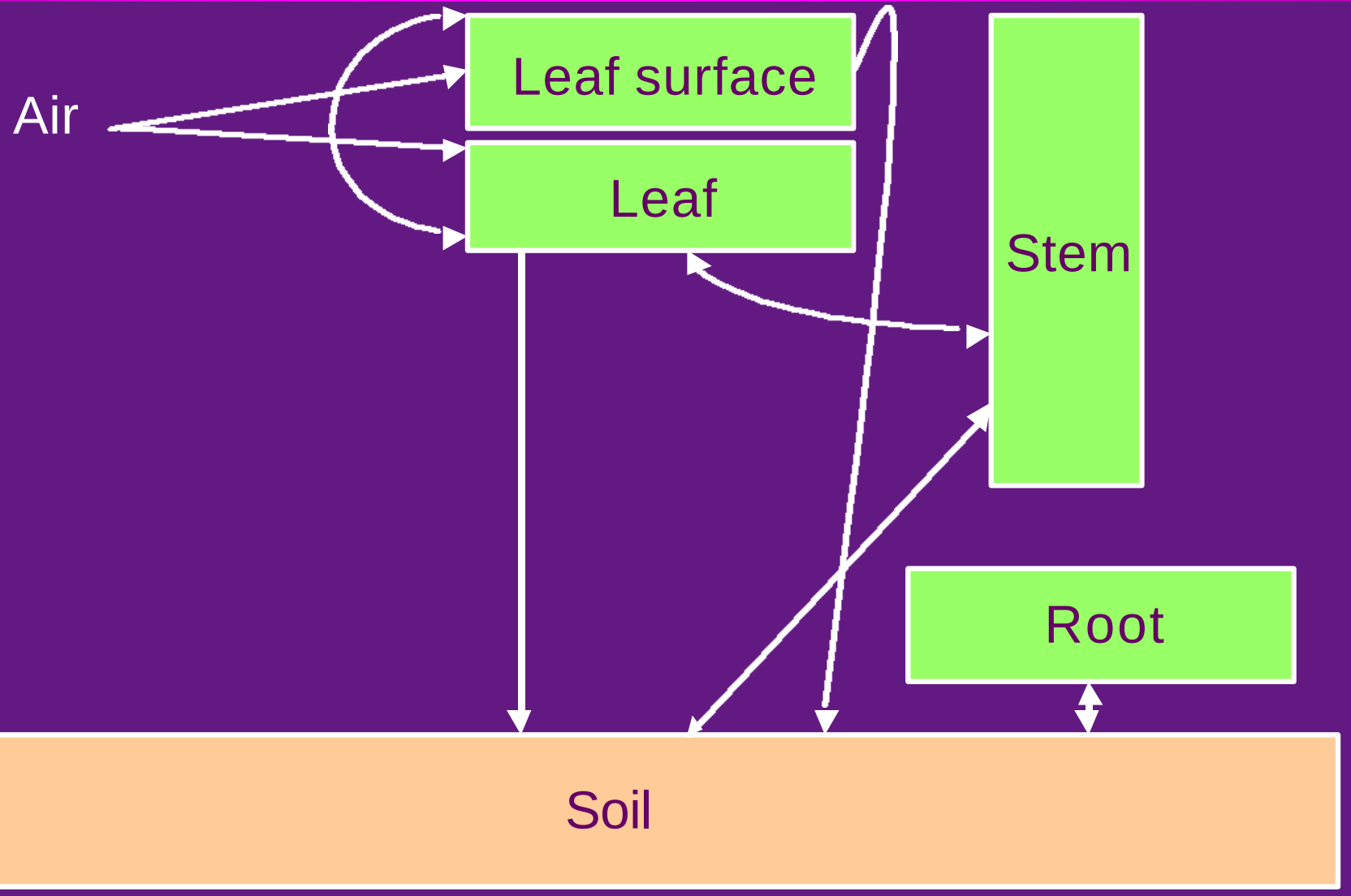
- Limited testing of implementation of model for mercury and nonionic organic chemicals has occurred.


LEGEND
Biotic Compartment type
Abiotic Compartment type
Abiotic Transfers
Food Chain Transfers
A Benthic Fauna
B Water Column Fauna
C Semi-Aquatic Fauna
D Terrestrial Plants
E Terrestrial Fauna
Air
Deposition/ Volatilization
Deposition/ Volatilization
Sediment
Surface Water
Erosion/runoff
Soil
Groundwater
Macrophytes
Phytoplanktonic Algae
A
Benthic Invertebrates
Benthic Omnivores
Benthic Carnivores
B
Water Column Herbivores
Water Column Omnivores
Water Column Carnivores
C
Semi-Aquatic Omnivores
Semi-Aquatic Invertebrate Feeders
Piscivores
D
Plant Leaf Surface
Plant Leaves
Plant Stems
Plant Roots
E
Soil Detritivores
Soil Invertebrate Feeders
Terrestrial Herbivores
Terrestrial Omnivores
Terrestrial Predators and Scavengers

Representative Species -- Examples

Compartment Type	Representative Subgroup
Macrophyte	*Elodea densa*
Water column carnivore	Largemouth bass
Benthic invertebrate	Mayfly
Terrestrial insectivore	Black-capped chickadee
Piscivore	Common loon, mink, belted kingfisher
Terrestrial predator/scavenger	Red-tailed hawk, long-tailed weasel

TRIM.FaTE model plant

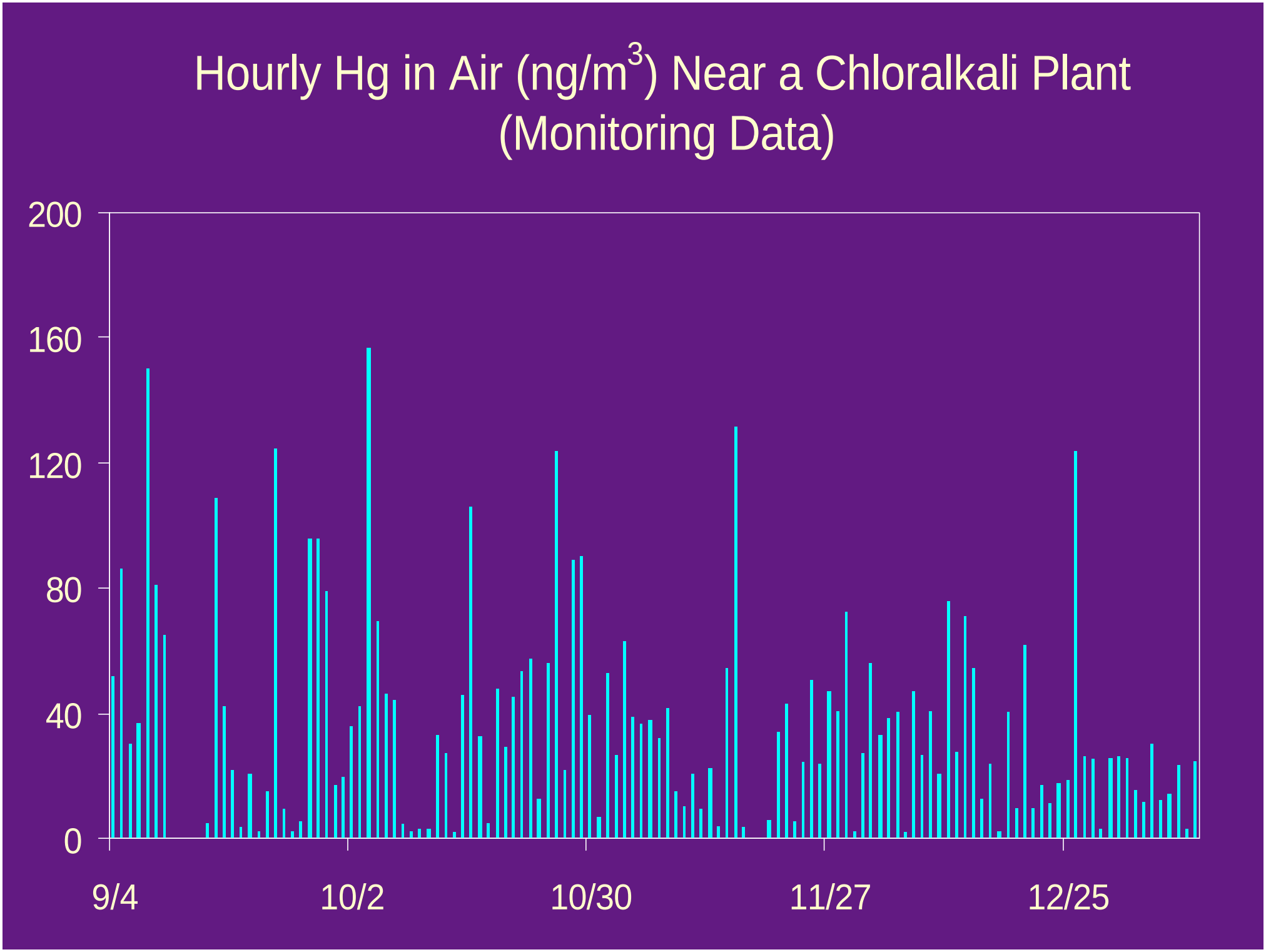


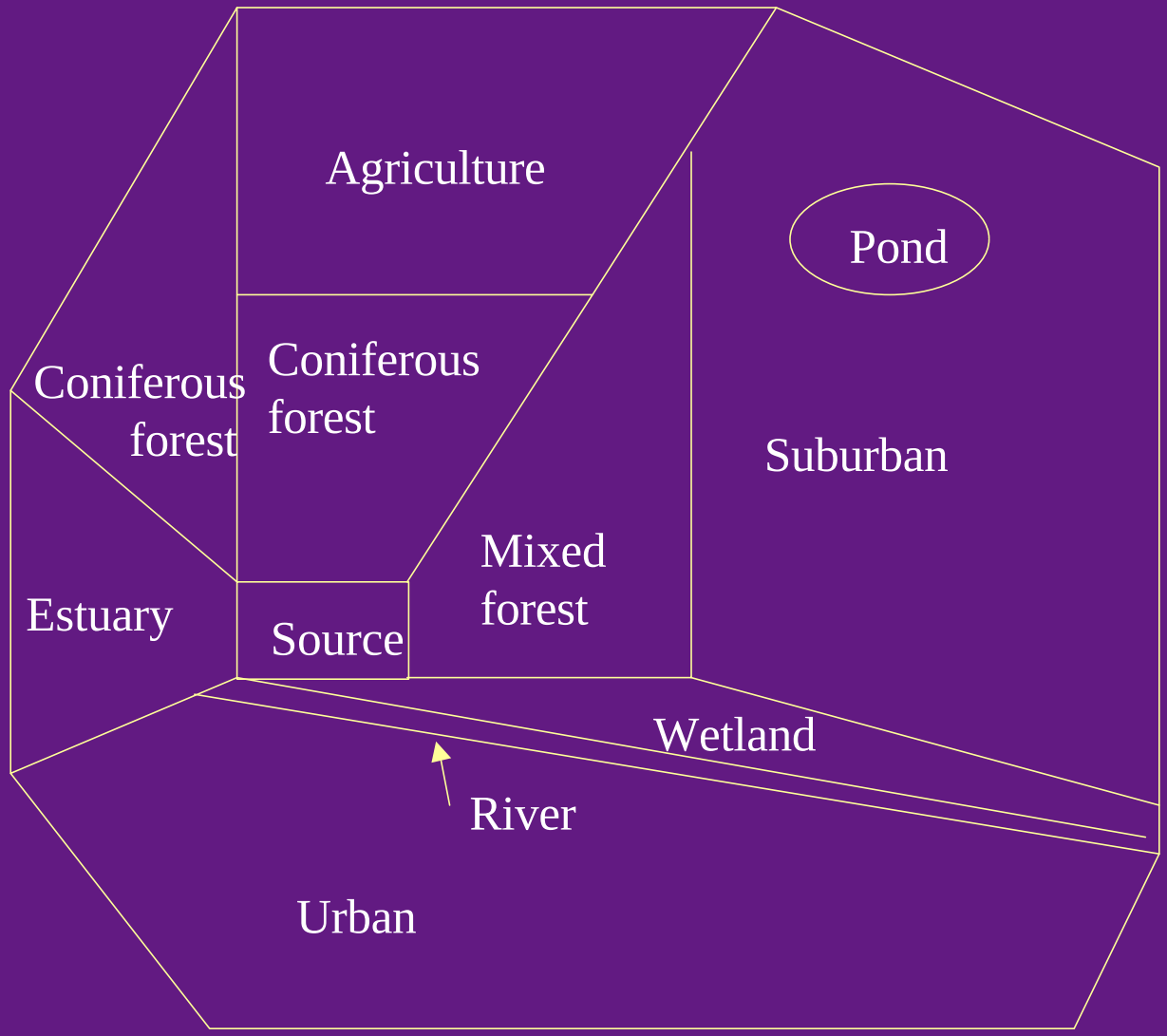
Algorithm Library

- Ability to use alternative equations to represent transfer processes
  - dynamic and equilibrium representations of dietary uptake by fish
  - conductance of vapor phase chemical through plant stomata
  - uptake of chemical from soil or soil water by earthworms
  - uptake of chemical from soil by plant roots, expressed with respect to octanol-water partition coefficients or other empirical measurements

Seasonal Processes in TRIM.FaTE

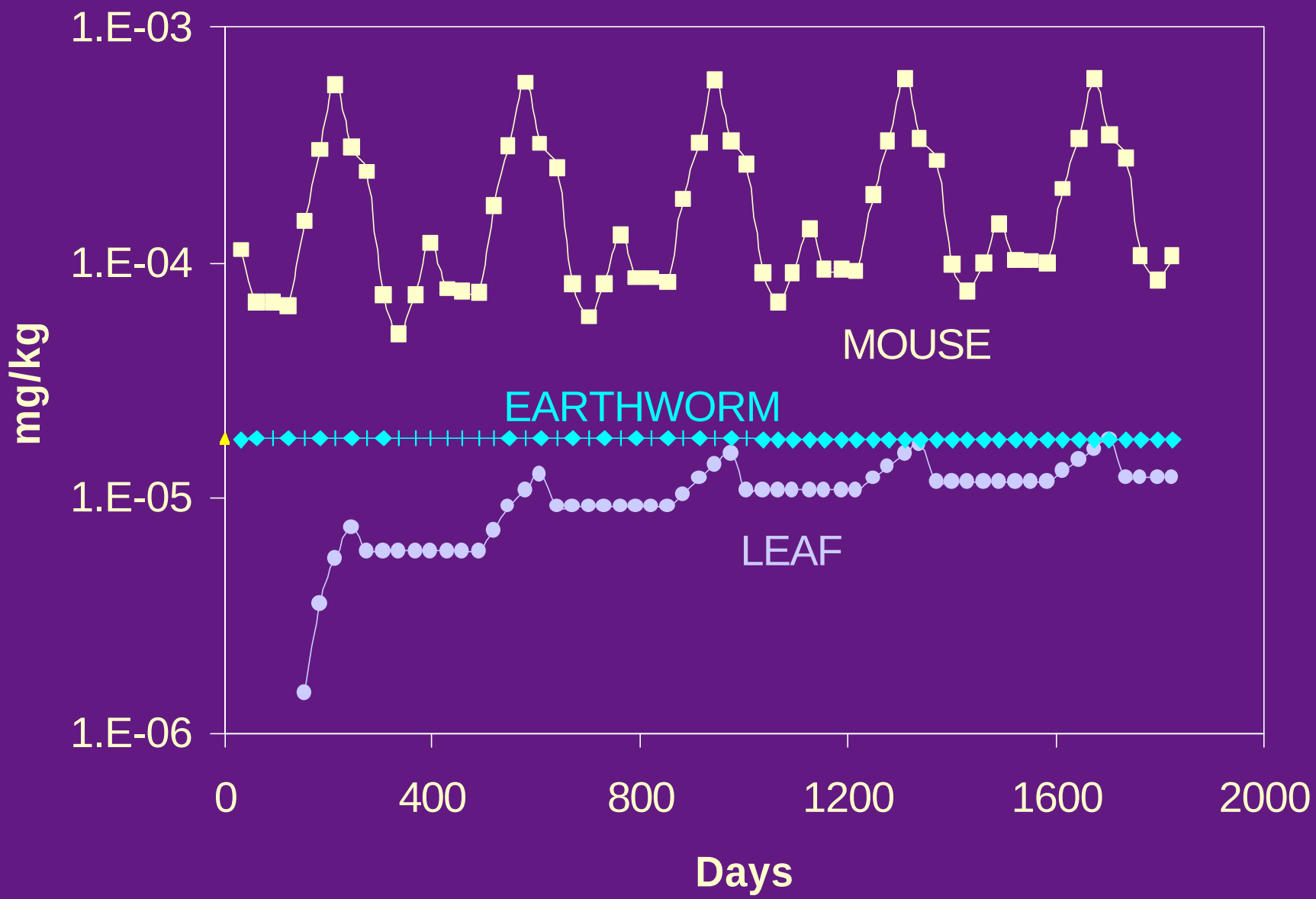
	Spring	Summer	Fall	Winter
Litterfall (decid tree, herb, grass)	Does not occur	Does not occur	Chemical moves from leaf and its surface to soil	Does not occur
Litterfall (conifer)	Chemical moves from leaf and leaf surface to soil	Chemical moves from leaf and leaf surface to soil	Chemical moves from leaf and leaf surface to soil	Chemical moves from leaf and leaf surface to soil
Interception of deposition by decid tree	Occurs	Occurs	Occurs part of the time	Does not occur
Uptake of chemical by plant	Occurs	Occurs	Occurs part of the time	Does not occur
Excretion to eggs, milk[1]	Occurs	May occur	Does not occur	Does not occur
Dietary uptake[1]	Seasonal diet	Seasonal diet	Seasonal diet	Seasonal diet
Snowfall[1]	Does not occur	Does not occur	Does not occur	May delay movement of chemical to soil


Hourly Hg in Air (ng/m3) Near a Chloralkali Plant
(Monitoring Data)
200
160
120
80
40
0
9/4
10/2
10/30
11/27
12/25



Hypothetical land parcels for a TRIM.FaTE run

Concentrations of Divalent Hg in Ecological Receptors



TRIM.FaTE Exposure Outputs

- Concentrations in abiotic environmental media
- Concentrations in biotic tissues
- Doses to biota

- Issues:
  - Available exposure-response models or thresholds
  - Duration of exposure that leads to effect
  - Sensitive life stage windows

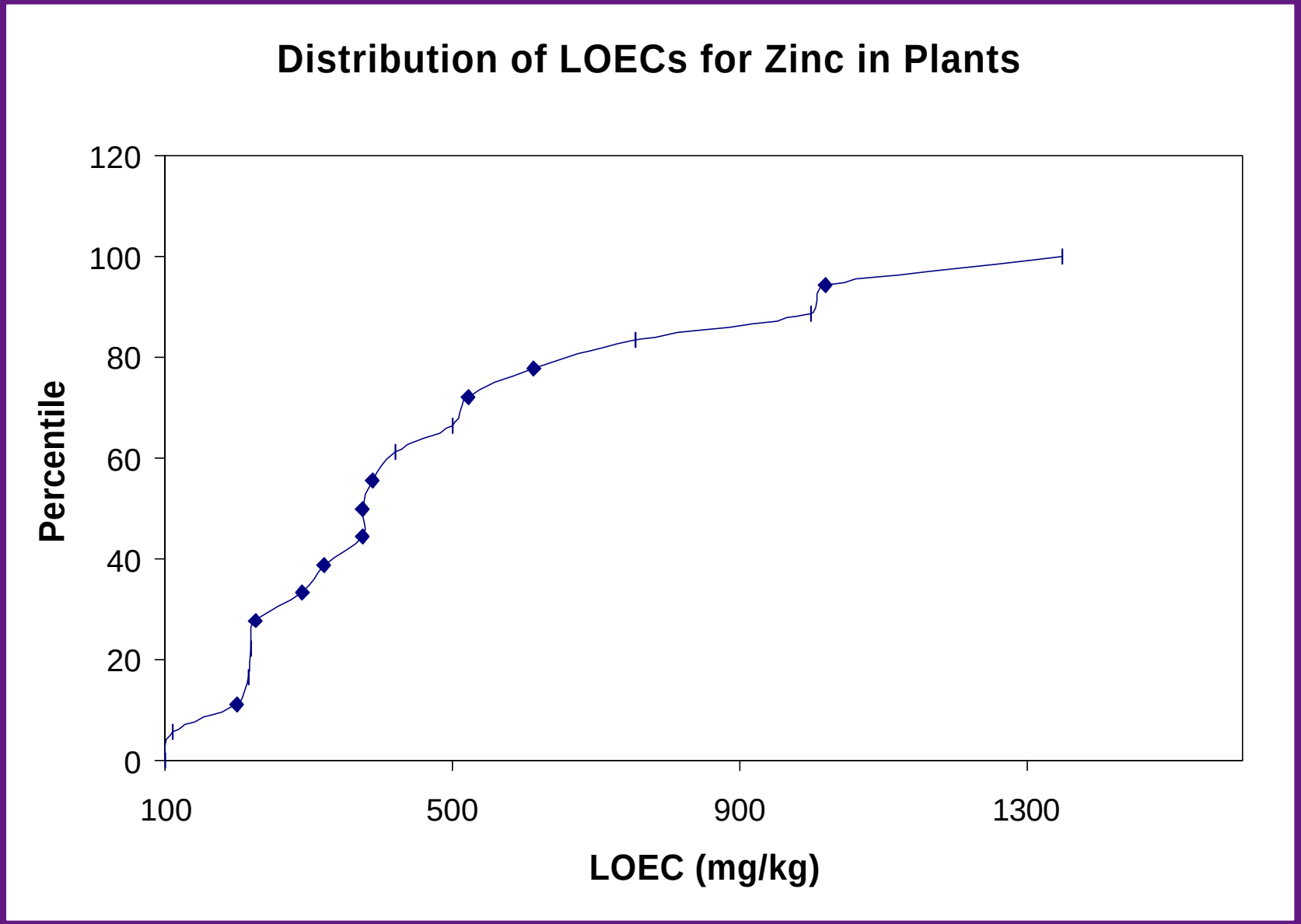
Evaluation of TRIM.FaTE

- Conceptual model evaluation
- Mechanistic evaluation
- Data quality evaluation
- Structural evaluation
- Performance evaluation

Toxicity Benchmarks for Use in Analysis of Effects

Endpoint Entity	Route of Exposure	Appropriate Benchmark
Plant community	Air to leaf and soil to root	Plant tissue concentration
	Air to leaf	Air or plant tissue concentration
	Soil to root	Soil or plant tissue concentration
Soil invertebrate community	Soil to organism	Soil concentration
Mammal or bird population	Diet, air, soil, or water to organism	Total dose or body burden
	Inhalation	Air concentration or dose
Fish community	Diet or water to organism (nonbioaccumulative chemicals)	Water concentration or body burden
	Diet to organism (bioaccumulative chemicals)	Body burden

Analysis of Effects



Screening Analyses

- Designed to identify situations or HAPs for which risks are unlikely to be of concern and those for which additional analysis is required
- Inexpensive
- Quick
- Use existing data
- Use conservative input parameters in models

TRIM.FaTE Set-Up
Options for screening analyses

- Use small number of volume elements
- Use small number of compartment types
- Use small number of facilities
- Use default data rather than high-resolution field measures or GIS estimates
- Use typical regional background concentrations
- Minimize number of weather scenarios
- Use small number of representative chemicals
- Maximize model time step

Refined Risk Characterization

- high level of reliance on site-specific exposure parameters
- weight of evidence approach (e.g., consideration of measurements of Hg in fish)
- consideration of spatial and/or temporal distribution of risk
- uncertainty analysis

Uncertainties

- Analysis of Exposure
  - source term
  - pollutant transfer rates among some media and biota
  - chemical transformation rate constants in all media
  - exposure concentrations that occur at small scales
- Analysis of Effects
  - Ecotoxicity of many of the 188 HAPs to many species
  - Interactions of chemical toxicants

Summary

EPA needs a consistent ecological risk assessment methodology for the multimedia HAPs in the Residual Risk Program

Problem Formulation: Primary challenges include defining "adverse environmental impact," selecting corresponding assessment endpoints, and achieving a good balance between site-specific and generic data and model scenarios.

Exposure Analysis: EPA is well on its way to providing estimates of exposure, using the TRIM.FaTE model.

Effects Analysis: Some ecotoxicity benchmarks exist, and others (e.g. fish and plant tissue concentrations) are in need of development.

Risk Characterization: The challenges are to develop screening and refined assessment and uncertainty analysis methodologies for HAPs.

Some Relevant Documents

- USEPA. 1999. Residual Risk Report to Congress. Office of Air Quality Planning and Standards. Research Triangle Park, NC. EPA-453/R-99-001.

- USEPA. 1998. Guidelines for Ecological Risk Assessment. Risk Assessment Forum. Washington, D. C. EPA/630/R-95/002F.

- Beaulieu, S. M., and A. B. Babbit. 1997. Evaluation of Decision Framework for the Assessment of Residual Ecological Risks Associated with the Release of Hazardous Air Pollutants. Research Triangle Institute. Research Triangle Park, NC.

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- http://www.epa.gov/ttn/uatw/urban/trim/trimpg.html