Quantitative Methods for Allocating Multiple Contaminants in Sediments

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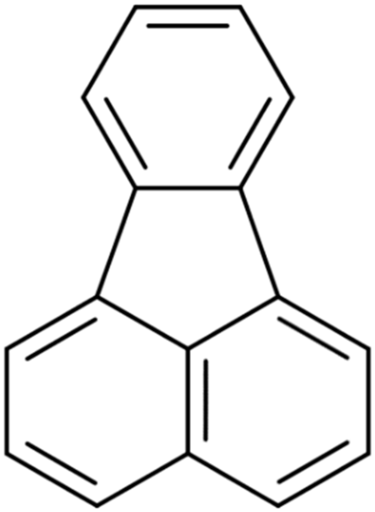
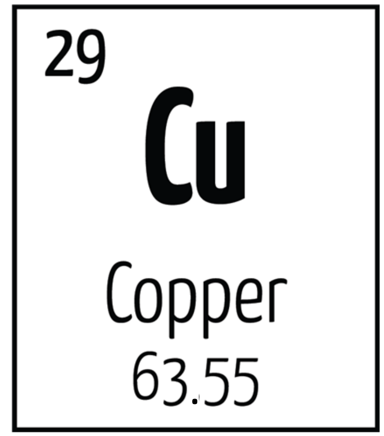
Many Urban Sediment Sites Have Multiple Contaminants

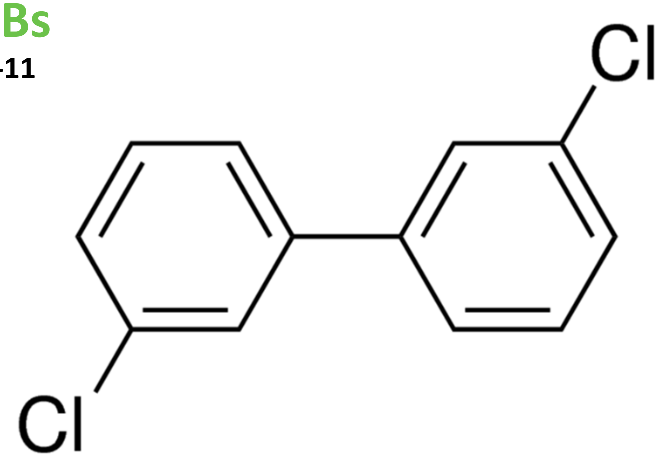
PAHs
Fluoranthene



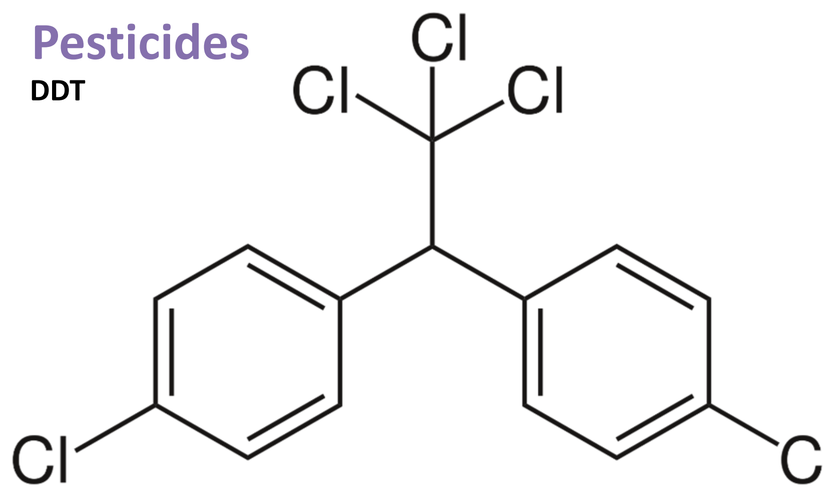
Metals
Copper



PCBs
PCB-11



Pesticides
DDT



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Complex Sediment Sites Are Often Addressed through CERCLA

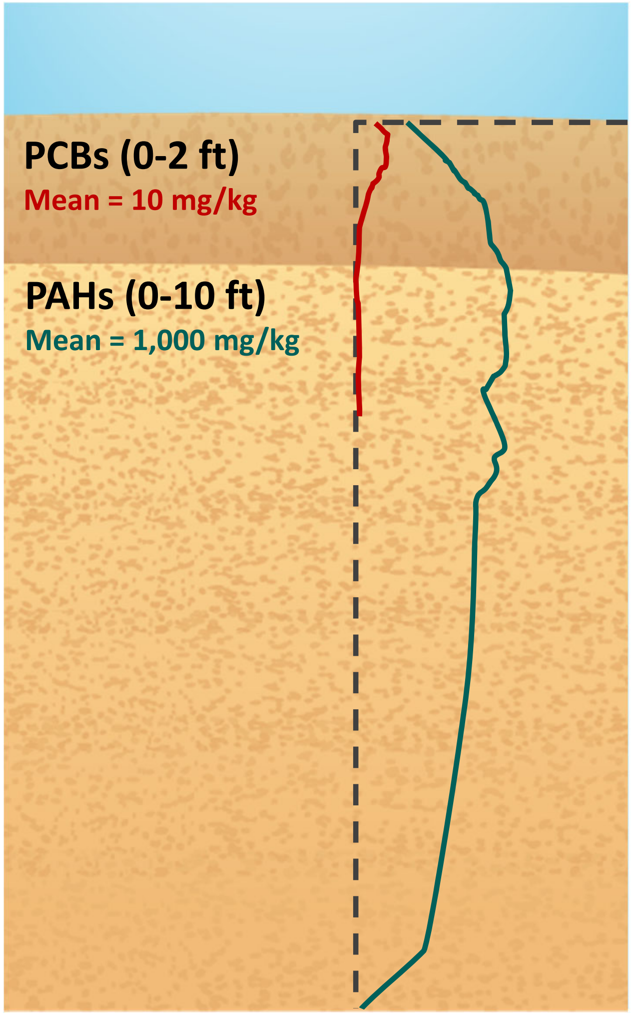
- Cost recovery mechanisms (private parties and US EPA) for potentially responsible parties (PRPs)
- Joint and several liability provision of CERCLA brings many PRPs to the table
- Often involves costly litigation or dispute resolution proceedings
- Recurring issues:
  - Forensically isolating PRP contributions
  - Evaluating relative contribution of different contaminants

Quantitative Approaches

- Stand-alone cost analysis
- Incremental cost analysis
- Relative contribution analysis

Example Site

- PCBs limited to surface sediments (0-2 ft)
  - Mean concentration = 10 mg/kg
  - PRG = 1 mg/kg
- PAHs present in surface (0-2 ft) and deep sediments (2-10 ft)
  - Mean concentration = 1,000 mg/kg
  - PRG = 10 mg/kg
- $100M Remedy – dredge all PCB and PAH impacts and restore
  - $1M for PCB sampling and TSCA compliance
  - $1M for mobilization/demobilization



Stand-Alone Cost (SAC) Analysis

- Calculate the cost to address each contaminant in the absence of the other contaminants (each contaminant "stands alone")
- Normalize based on actual costs

Option 1:
Constrained to Selected Dredging Remedy

		PCBs	PAHs	Total
SAC ($M)	Remedy	5.0	98.0	103.0
	Mob.	0.5	1.0	1.5
	Total	5.5	99.0	104.5
%		5.3	94.7	100.0

Option 2:
Not Constrained to Selected Dredging Remedy

		PCBs (Cap)	PAHs (Dredge)	Total
SAC ($M)	Remedy	2.5	98.0	100.5
	Mob.	0.2	1.0	1.2
	Total	2.7	99.0	101.7
%		2.7	97.3	100.0

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Incremental Cost (IC) Analysis

- Identify costs associated with risk/remedy driver (*e.g.*, "Principal Threat Waste") then identify incremental costs associated with other individual contaminants
- Can be sensitive to order because common costs (*e.g.*, mob/demob) are assigned to the driver

		PAH IC (PAH 1st)	PCB IC (PCB 2nd)
IC ($M)	Remedy	98 – full remedy; no TSCA compliance, no PCB sampling	1 - TSCA compliance, PCB sampling
	Mob.	1	0
	Total	99	1
%		99	1

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Incremental Cost (IC) Analysis: Shapley Value

- When the risk/remedy driver is unclear or subject to debate, the Shapley Value can be used
- Shapley Value – concept used in Game Theory
  - Consider all possible orders for calculating incremental costs (possible outcomes), assign occurrence probabilities to each possible outcome, then calculate expected value for each outcome

	Possible Outcome - Cost ($M)	Occurrence Probability (%)	Expected Value ($M)
PAHs 1st, PCBs 2nd	1	80	0.8
PCBs 1st, PAHs 2nd	5.5 (includes mob. cost; same as SAC Option 1)	20	1.1
Total Expected Value (PCBs)			1.9

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Relative Contribution Analysis

- For co-mingled contaminants, relative contribution analysis is often used
- Surrogates used for relative contribution to cost, *e.g.,* risk, volume, mass
  - Surrogates should be grounded in cost causation principles
- Consider different ways to treat the data geographically:
  - Average over whole remedy area
  - Sub-divide into segments/depth
  - Thiessen polygons
  - Individual samples or stations

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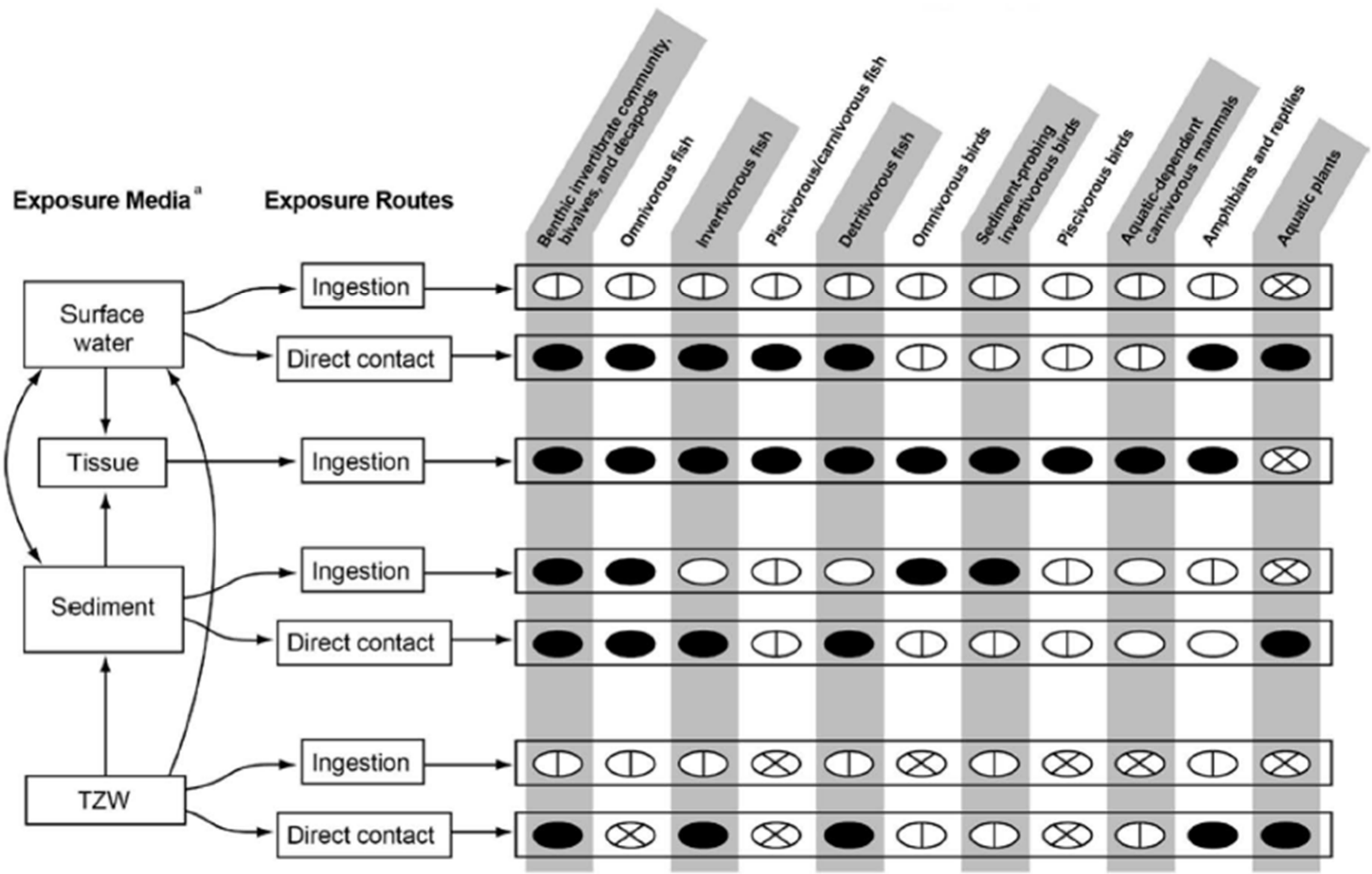
Untangling Relative Risk Contribution for each Ecological Receptor Can Be a Challenge



[a] Includes exposure media with at least one complete exposure pathway evaluated in the BERA.

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How Should Receptors/Pathways be Weighed Against Each Other?

Relative Contribution Analysis: PRG Approach

- Site-specific risk-based cleanup goals, *e.g.*, Preliminary Remediation Goals (PRGs), can be used to assign relative contribution
- PRGs are established for specific contaminants and are tied to cost causation
- In the absence of site-specific PRGs, PRGs established at other sites can be used (central tendency or more sophisticated probabilistic approach) – where comparable

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Relative Contribution Analysis: PRG Approach Example

1. Calulate PRG ratios:

$X_{PRG} = [X]/PRG_{X'}$

Sample	PRG Ratios	
	$tPAH_{PRG}$	$tPCB_{PRG}$
1	1.6	1.8
2	3.4	0.4
3	2.9	-
4	0.5	-

2. Calculate Exceedance Frequency ($X_{\%EX}$) and Relative Exceedance Frequency ($rX_{\%EX}$):

$X_{\%EX} = 100*(\text{number of } X_{PRG} > 1)/(\text{number of } X_{PRG} > 0)$

	$tPAH_{PRG}$	$tPCB_{PRG}$	Total
Exceedance Frequency, $X_{\%EX}$	75%	50%	125%
Relative Exceedance Frequency, $rX_{\%EX}$	60%	40%	-

3. Calculate Exceedance Intensity (X_{ExIn}) and Relative Exceedance Intensity (rX_{ExIn}):

$X_{ExIn} = \text{Average of } X_{PRG} > 1$

	$tPAH_{PRG}$	$tPCB_{PRG}$	Total
Exceedance Intensity, X_{ExIn}	2.6	1.8	4.4
Relative Exceedance Intensity, rX_{ExIn}	59%	41%	-

4. Calculate the Exceedance-Intensity Factor:

$X_{EF} = (rX_{\%EX}) * (rX_{ExIn})$

	$tPAH_{PRG}$	$tPCB_{PRG}$	Total
Exceedance-Intensity Factor, X_{EF}	0.36	0.16	0.52
Normalized Exceedance-Intensity Factor, nX_{EF}	69%	31%	-

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Conclusions

- Every site is unique but most have multiple contaminants and multiple PRPs
- Evaluate your options – different approaches can yield different results

Questions?

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