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CAN WE APPLY A SITE-SPECIFIC ECOLOGICAL RISK ASSESSMENT FRAMEWORK FOR MICROPLASTICS?

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The Big Picture

Are we at a point where we could conduct an ecological risk assessment (following a specific regulatory framework?)

Spoiler alert…..no.

But! Let's discuss what data is available and what we still need….

Objective

- ✓ Microplastic state of the science is quickly evolving
- ✓ California is the only state with microplastic regulations currently, additional states may follow
- ✓ Microplastics could end up being regulated as a toxic substance that will need to be addressed under programs such as:
  - Resource Conservation and Recovery Act (RCRA)
  - Comprehensive Environmental Response, Compensation, and Liability Act (CERLCA) [aka Superfund]
- ✓ If regulated, will need to conduct ecological risk assessment (ERA) on a site-specific basis
- ✓ Bridge discussions between academia, government, and industry for data needs

Using the EPA CERCLA paradigm, can an ERA framework for microplastics be applied to individual sites?

Methods

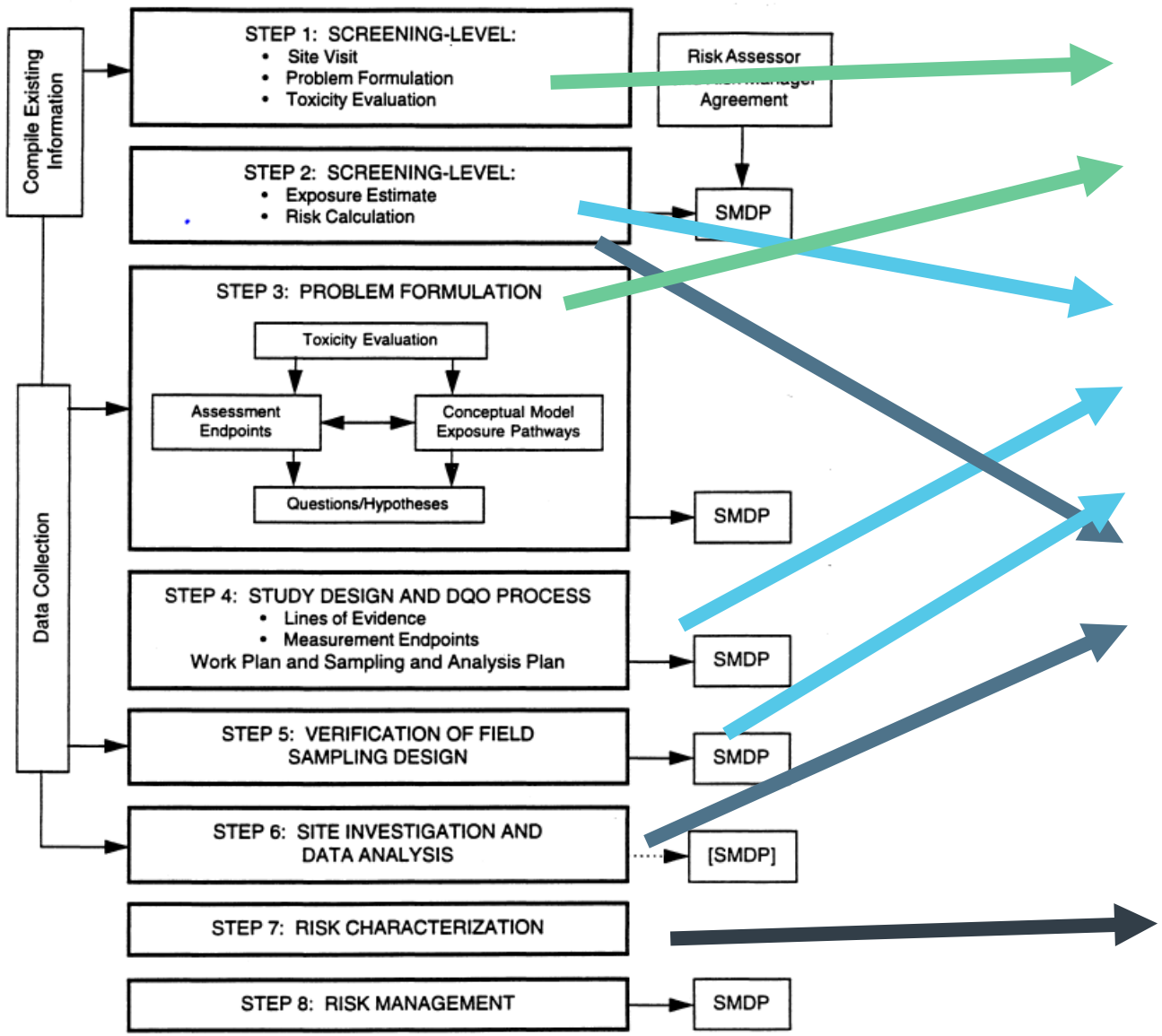
Reviewed each step of the CERCLA framework and assessed current state of microplastics (MP) science

Sources:

- *Ecological Risk Assessment Guidance for Superfund* (USEPA, 1997)
- *Navy Guidance for Conducting Ecological Risk Assessment* (Department of the Navy, update TBD)
- *Guidance for Assessing the Ecological Risks of PFAS to Threatened and Endangered Species at Aqueous Film Forming Foam Impacted Sites* (Conder et al., 2020)

- Focus on commonly used framework for CERCLA
- This is a high-level approach
- The state of the science is rapidly changing!

EPA CERCLA Framework



Problem Formulation

Exposure Assessment

Effects Assessment

Risk Characterization

ERA Components

Problem Formulation

- Build conceptual site model (CSM)
- Environmental setting
- Source
- Fate and transport
- Potential ecological receptors
- Complete exposure pathways

Exposure Assessment

- Select representative species
- Select assessment endpoints
- Select screening values, benchmarks, toxicity reference values
- Identify and collect site-specific data needs
- Develop exposure point concentrations (EPCs) for each media

Effects Assessment

- Estimate concentrations of chemicals in diet and diet items of selected species

Risk Characterization

- Info from exposure assessment and effects assessment combined for quantitative risk estimates
- Calculation of hazard quotients (HQs)

Microplastics-Specific

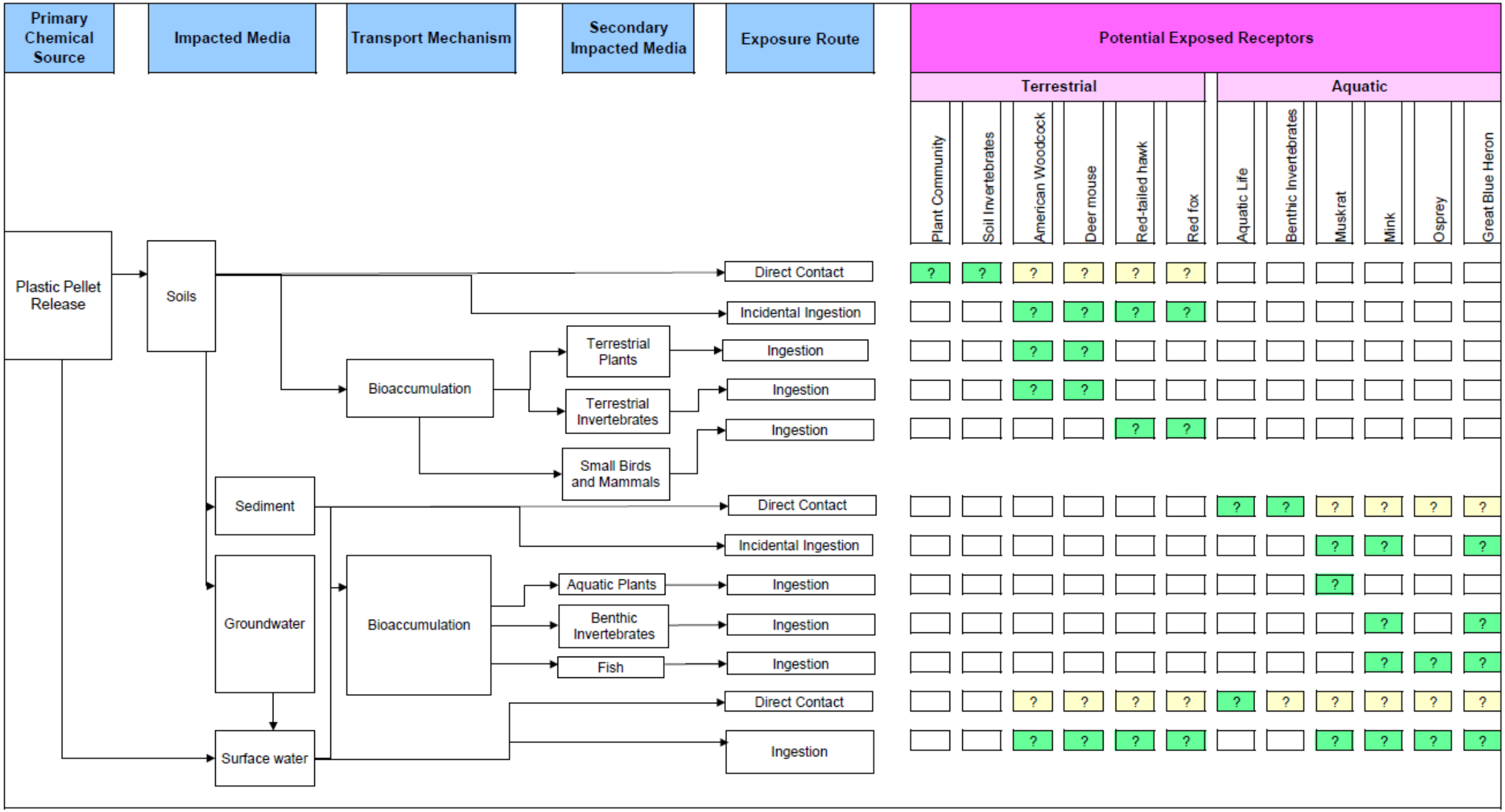
Problem Formulation | Exposure Assessment | Effects Assessment | Risk Characterization

- Site-specific environmental setting and sources
  - Differ depending on each facility/location
  - Use general microplastics CSM to identify site specific considerations
  - Site history – knowing MP characteristics important
- Fate and Transport
  - Aquatic habitats -> more information
  - Terrestrial habitat, groundwater, biota -> less information
- Receptors of concern
  - Plants, invertebrates, mammals, birds
- Complete exposure pathways
  - Use fate and transport information and receptors of concern to evaluate complete or potentially complete exposure pathways

Example:
A production facility spilled plastic pellets on ground during transport; the site is adjacent to a stream

On-site terrestrial habitats (soil) and off-site aquatic habitat (surface water, sediment) are target habitat.

A CSM was developed to identify complete exposure pathways



Notes:

Complete exposure pathway that will be quantitatively evaluated.

Potentially complete, but insignificant pathway.

Incomplete exposure pathway; no evaluation or management action is necessary.

Microplastics-Specific

Problem Formulation | **Exposure Assessment** | Effects Assessment | Risk Characterization

- Representative species
  - Habitats, trophic level, sensitive to MPs
- Exposure parameters for species
  - Frequency/duration of exposure
  - Body weight, food ingestion rates, bioavailability
- Identify screening levels/toxicity reference values (TRVs)
- Sampling & Analysis
  - Standardization, potential for cross contamination, quality control
  - Analytical methods – FTIR, Raman, microscopy
  - Data reporting (particle count vs mass)

Plastic-Pellet Release Site Example:

- Representative receptors were chosen based on habitats and trophic levels as shown in the CSM.
- Compile exposure parameters
- At the facility will need to collect soil, sediment, and surface water samples for microplastic analysis.
  - No standardized sampling methods, use literature (ITRC 2023 guidance)
  - Raman or FTIR for analysis, data in particle count or mass

Microplastics Specific

Problem Formulation | Exposure Assessment | **Effects Assessment** | Risk Characterization

- Screening level assessment
  - Compare concentrations from abiotic media against screening levels
  - Screening levels don't exist for MPs!
  - Use effect levels from literature (use caution)

Screening levels:
- Medium-specific, generic, conservative
- Used to identify contaminants of potential concern
- Often based on no-effect values
- Not used as clean up values

$$Hazard\ quotient = \frac{exposure\ point\ concentration}{screening\ level}$$

Microplastics Specific

Problem Formulation | Exposure Assessment | **Effects Assessment** | Risk Characterization

- Exposure estimates for lower trophic receptors (invertebrates/plants)
  - Compare concentrations from abiotic media against benchmarks

Benchmarks:

- Aquatic life – concentrations in water (or sediment) known to have an absence or effect (or association with an adverse effect)
- From peer-reviewed literature (tox studies with plants, earthworms, inverts, etc)
- Different from generic screening levels

Microplastics Specific

Problem Formulation | Exposure Assessment | **Effects Assessment** | Risk Characterization

Exposure estimates for upper trophic receptors (birds/mammals)

- Food web modeling to estimate average daily dose (ADD)

Toxicity Reference Values (TRVs):

- Daily ingested dose estimates (mg/kg body weight*day) known to have an absence or effect (or association with an adverse effect)
- Acute or chronic tests
- Best studies note dietary dose given to the animals and a clear communication of the level of effects observed (with stats analysis)
- NOAEL (No Observed Adverse Effect Level) TRVs
- LOAEL (Lowest Observed Adverse Effect Level) TRVs
- Endpoint should be based on growth, reproduction, survival

Microplastics-Specific

Problem Formulation | Exposure Assessment | **Effects Assessment** | Risk Characterization

$$ADDi_{COPEC} = (EPCi_{COPEC} \times FIR \times Pi) + (EPC_{SW} \times DWI) \times AUF \times (1/BW)$$

where:

$ADDi$	$ADDi_x$ = Average Daily Dose for Dietary Item "*i*" for COPEC (mg/kg bw-day)
$EPCi_{copc}$	Exposure Point Concentration (mg/kg dry weight) in soil, sediment or dietary items
EPC_{SW}	Exposure Point Concentration (mg/L) in surface water
P_i	Proportion of Diet Item "*i*"
FIR	Daily Food Ingestion (kg dry weight/day)
DWI	Daily Drinking Water Ingestion Rate (L/day)
AUF	Area Use Factor - based on receptor Home Range
BW	Body Weight

Note units needed for data – mg/kg dry weight for soil/sediment. How does this get resolved if MP data is in a particle count?

Microplastics-Specific

Problem Formulation | Exposure Assessment | **Effects Assessment** | Risk Characterization

Plastic-Pellet Release Site Example: Can we calculate ADD for a mink?

Needed information and data

- Exposure Factors for mink
  - Diet – invertebrates, fish, incidental sediment ingestion
- Microplastics concentrations
  - Sediment
  - Surface water (drinking water)
- Predicted (or actual) invertebrate tissue concentration and fish tissue concentration
  - Are there uptake models or biota-sediment accumulation factors available?
  - Or collect actual tissue data and plug this into the model
- TRVs
  - Unable to identify

Parameter Definition	Units	Mink
Body Weight	kg	1.0
Daily Food Ingestion Rate (dry matter)	kg, dw/day	0.049
Proportion of Diet - Aquatic Vegetation	kg diet item, dw/kg diet, dw	0
Proportion of Diet - Invertebrates	kg diet item, dw/kg diet, dw	0.3
Proportion of Diet - Fish	kg diet item, dw/kg diet, dw	0.7
Proportion of Diet - Sediment	kg diet item, dw/kg diet, dw	0.03
Daily Water Ingestion	L/day	0.1
Home Range	acres	34
Total Site Area	acres	16
Area Use Factor	proportion	0.5

- ✓ Exposure factors
- ✓ Media concentration
- ✗ Uptake models
- ✗ TRVs

Microplastics-Specific

Risk characterization for lower trophic receptors

$$Hazard\ quotient = \frac{exposure\ point\ concentration}{benchmark}$$

Exposure estimates for upper trophic receptors (birds/mammals)

$$Hazard\ Quotient = \frac{Average\ Daily\ Dose}{TRV}$$

× Unable to calculate HQs due to lack of benchmarks and TRVs

Plastic-Pellet Release Site Example:

- No screening levels and benchmarks, but may be able to identify effects data for aqueous media
- Not able to calculate average daily dose

Additional Data Considerations and Thoughts

- Toxicity testing needs
  - Many tests use polystyrene spheres (virgin material)
  - Expand testing to better understand different microplastics characteristics (size, shape, polymer, environmental toxins) and how each one affects toxicity
  - Physical vs chemical impact
  - High quality data
- Toxicity of Microplastics Explorer (ToMEx) available
  - Effects data for aquatic organisms
  - Ability to derive species sensitivity distributions
  - Quality reviews completed on all data
- Background data
  - Due to widespread nature, will need to consider how to assess ambient conditions
  - For facilities, will need to know what polymers types are generated/released to compare against background
- What will screening levels, benchmarks, and TRVs look like?
  - Multiple to account for the diversity of MP characteristics? (Size, polymer, shape)
  - Or will there be one ultra conservative number that represents all MPs?

Summary of Key Data Needs

Problem Formulation	• Fate and transport for terrestrial, groundwater, biota
Exposure Assessment	• Standardized sampling and analysis • Data reporting (particle count vs mass)
Effects Assessment	• Lack of screening values and toxicity reference data • Need for expanded toxicity testing • No uptake models available
Risk Characterization	• Need appropriate screening levels/TRVs to calculate HQs • Background data

Are we there yet?

Although a lot of progress has been made in certain areas of microplastics research, there are still many data gaps that exist to be able to complete an ERA following a CERCLA framework

If microplastics could be regulated under programs such as RCRA or CERCLA, it will be important to have open dialogue between academia, government, and industry to discuss and identify research needs so that ecological risk assessments can be conducted in the future

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Thank you!

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