



Office of Research and Development

SAFE AND SUSTAINABLE WATER RESOURCES RESEARCH PROGRAM



Research Area 3 Overview: Human Health and Aquatic Life Criteria

*Presented to the Board of Scientific Counselors
October 29, 2020*



Human Health and Aquatic Life Criteria

- The goal of this work is to provide OW with essential information and tools needed for establishing and updating Agency criteria, including:
 - The Five-Year Review of the Recreational Water Quality Criteria
 - Future updates of human health criteria
 - Future revisions to aquatic life criteria
- Our research also supports Regions and States in the implementation of these criteria

Output 3.1: Data and innovative tools to advance public health protection from microbial contaminants in surface water

Output 3.2: Data and innovative tools to advance public health from consumption of chemical contaminants in surface waters and aquatic organisms

Output 3.3: Science to advance the methodology for deriving water quality criteria to protect aquatic life from toxic chemicals





Data and Innovative Tools to Advance Public Health from Consumption of Chemical Contaminants in Surface Waters and Aquatic Organisms

Product 1

Occurrence and toxicity data needed for the prioritization of environmental chemicals in surface water for human health and aquatic life criteria development

Product 2

Development, application, and evaluation of effects-based measures for the detection and characterization of similarly acting groups of chemicals in aquatic systems





Occurrence and toxicity data needed for the prioritization of environmental chemicals in surface water for HH and aquatic life criteria development

Problem: The number of chemicals in commerce requiring risk evaluations exceeds available resources. Prioritization efforts limited by a lack of chemical occurrence, co-occurrence, and toxicity data.

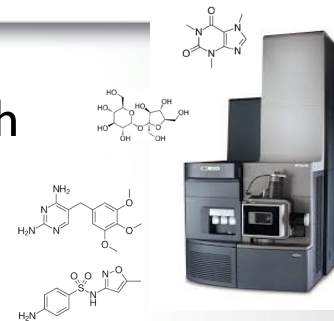
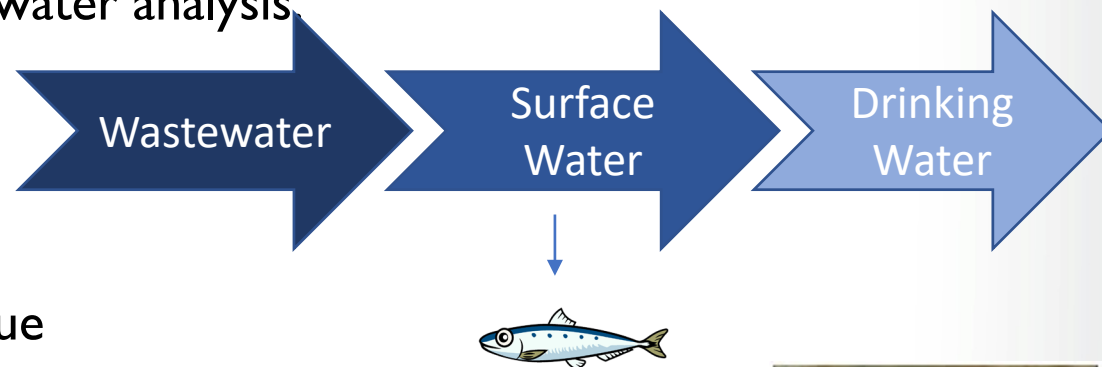
Action: Collect chemical occurrence data in surface water and fish tissue (or surrogate tissue). Develop predictive models for chemical co-occurrence.

Expected Outcome: Additional data and measures to aid in the prioritization of chemicals for criteria development.



Product 1a: Chemical Occurrence and Bioaccumulation

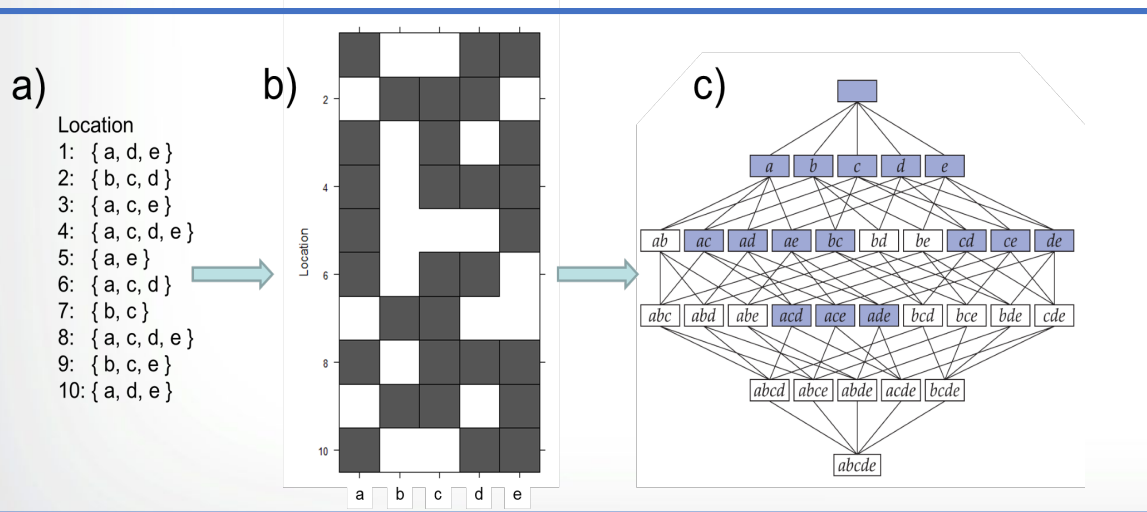
- Nontargeted analysis, suspect screening, and targeted chemistry will be used to investigate which chemicals have the potential to be present in surface water and/or bioaccumulate in fish tissue.
- Nontargeted analysis methods are already being developed and applied in an environmental watershed as a pilot study for surface water and drinking water analysis.
- Nontargeted methods will then be applied to:
 - Grab sampled surface waters
 - POCIS integrative samplers as a surrogate for fish tissue
 - Fish tissue samples and extracts
 - Predictive models and tools may also be incorporated
- Targeted methods can be developed for highest priority chemicals.
- Drinking water will also be surveyed (SSWR 7.2.3, CCL6).



POCIS Device

Product 1b: Patterns of Co-Occurrence

- This product investigates the utility of frequent itemset mining (FIM) to determine those combinations of chemicals that occur together most frequently in water.
- Presently, using FIM to determine the most frequently occurring combinations among 50 chemicals measured at 540 locations (Batt et al., 2017).



Items (any detect)	Items (MDL)	Items (QL)
4,4'-DDE; PBDE-47	4,4'-DDE; PBDE-47	4,4'-DDE; PBDE-47
4,4'-DDE; trans-Nonachlor	4,4'-DDE; PCB-153	4,4'-DDE; PCB-153
4,4'-DDE; PCB-153	4,4'-DDE; PCB-180	PBDE-47; PCB-153
4,4'-DDE; PCB-180	4,4'-DDE; trans-Nonachlor	4,4'-DDE; PBDE-47,PCB-153
4,4'-DDE; PCB-118	PBDE-47; PCB-153	PCB-153; PCB-180
PBDE-47; trans-Nonachlor	PCB-153; PCB-180	4,4'-DDE; PCB-118
PBDE-47; PCB-153	4,4'-DDE; PBDE-47,PCB-153	4,4'-DDE; PCB-180
4,4'-DDE; PBDE-47; trans-Nonachlor	PBDE-47; PCB-180	PCB-118; PCB-153
PBDE-47; PCB-180	4,4'-DDE; PCB-118	4,4'-DDE; PCB-153,PCB-180
4,4'-DDE; PBDE-47; PCB-153	4,4'-DDE; PCB-153,PCB-180	PBDE-47; PCB-180

In FY21 and FY22, we will:

- Apply FIM to occurrence data to determine the most frequently occurring chemical combinations for OW, Regions, States
- Compare FIM to other co-occurrence methodologies
- Investigate various threshold detection strategies



Development, application, and evaluation of effects-based measures for the detection and characterization of similarly acting groups of chemicals in aquatic systems

Problem:

- Concentration \neq Exposure.
- Lacking biological context for interpretation
- Mixture interactions and non-chemical influences
- Lamplight effect

Action:

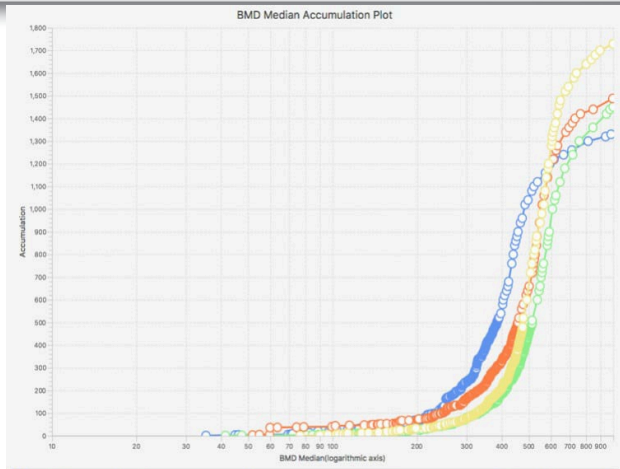
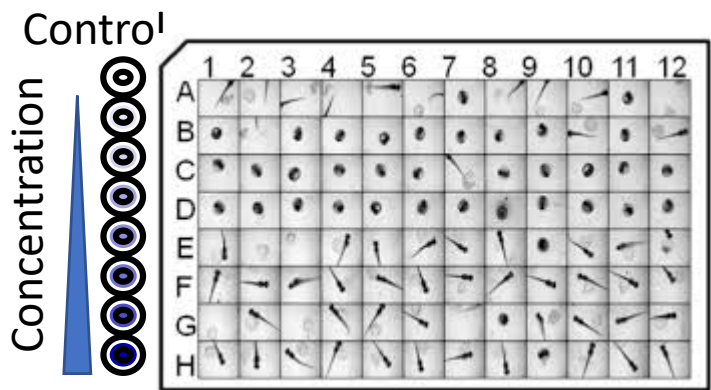
- Develop new methods that address current limitations

Expected Outcome:

- Ability to address longstanding issues of mixture toxicity and risk
- Provide biological context
 - Relate concentration to response
 - Potential to regulate chemicals as groups
 - Account for environmental variables
 - Non-targeted, biologically-based risk
- Generate more holistic estimates of risk based on fewer assumptions



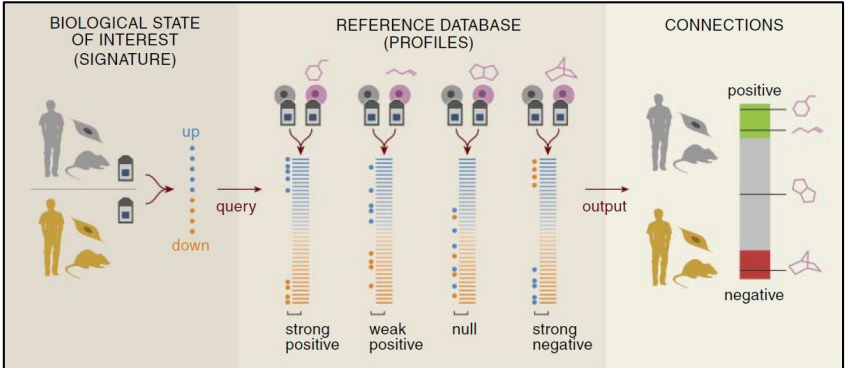
Product 2a: In vivo transcriptomic signature



Points of Departure



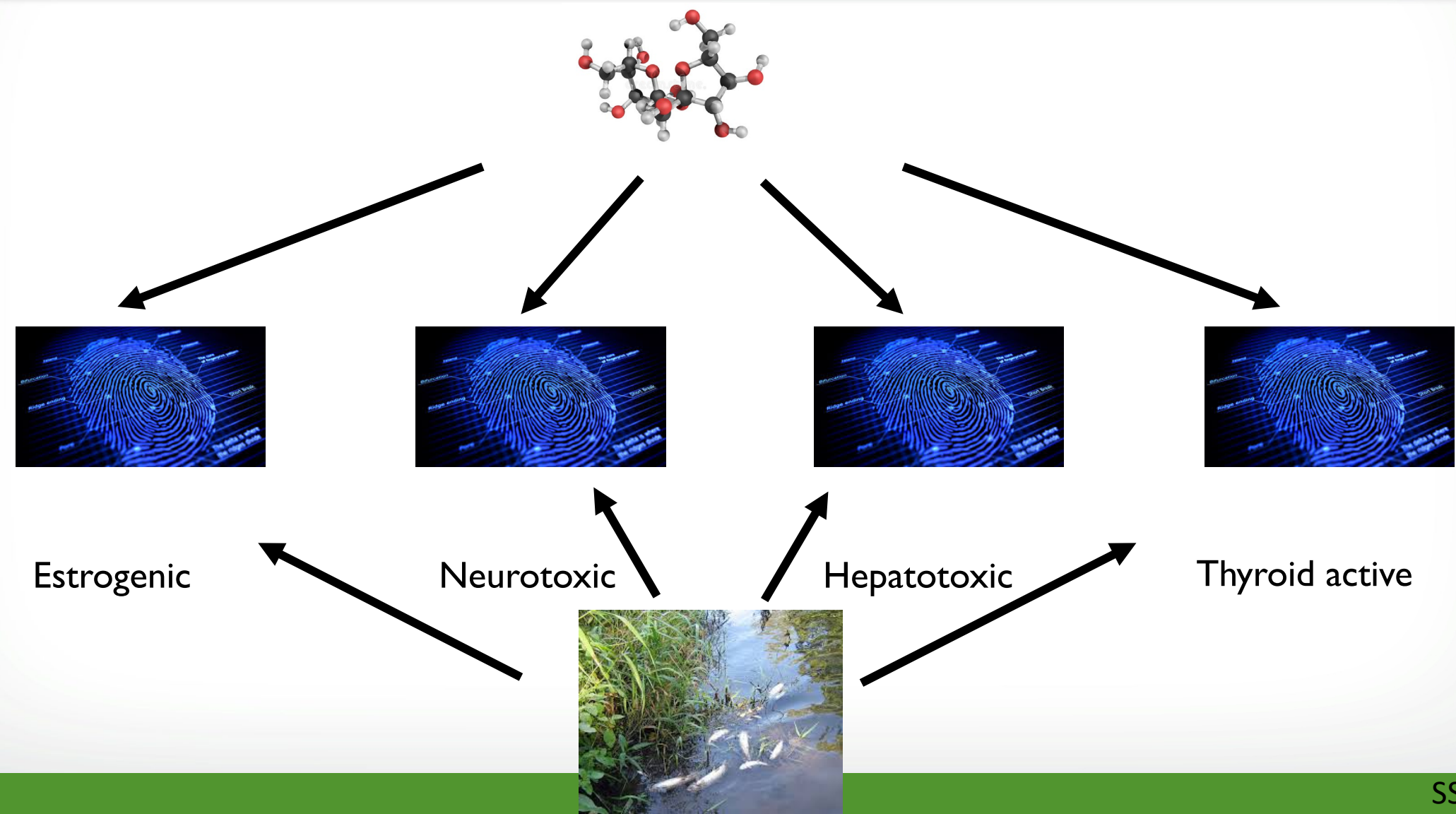
Biomarker Development



Connectivity Mapping (CMAP)



Product 2a: Identification of MOA – chemical grouping & extrapolation



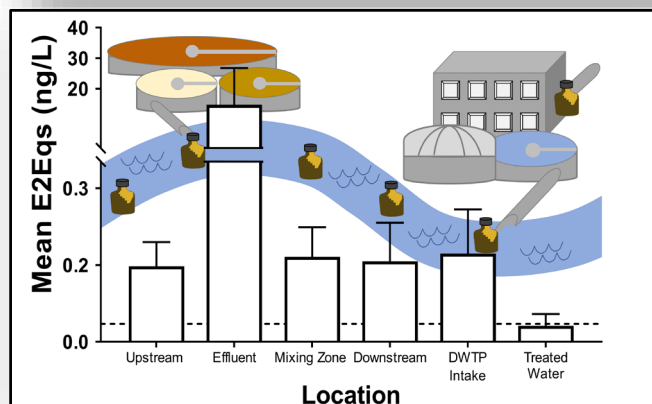
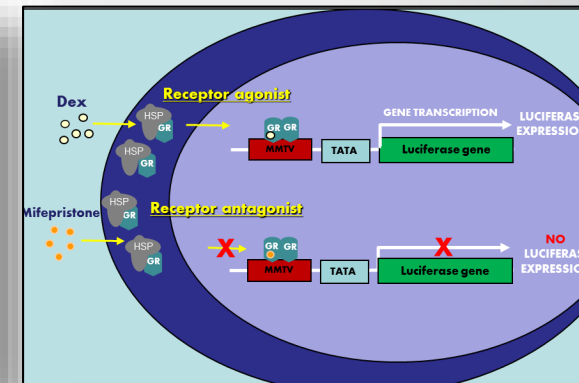
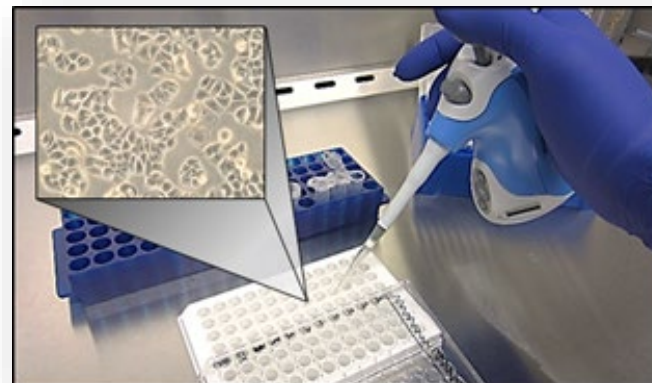
Developed in-house, validated, medium-throughput

Cumulative measurements of biological activity

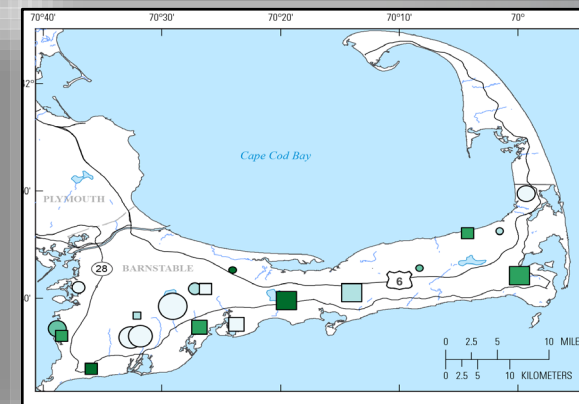
- Estrogen Receptor
- Androgen Receptor
- Glucocorticoid Receptor

Bioassay Workgroup with California Waterboards

- Monitoring Trigger Level = follow up/rescreen



Medlock Kakaley *et al.* 2019 Sci Total Environ



Bradley *et al.* (internal review) Sci Total Environ



Science to Advance the Methodology for Deriving Water Quality Criteria to Protect Aquatic Life from Toxic Chemicals

- ORD and OW have collaboratively identified various tools and approaches for improving characterization of risk in aquatic life criteria (ALC) and for developing ALC for chemicals lacking robust toxicological data.
- The SSWR, CSS, and SHC research programs are further developing selected tools/approaches, focusing on per- and poly-fluorinated alkyl substances (PFASs) to support OW goals for PFAS regulation and the Agency's PFAS Action Plan.
- Effects of chemical mixtures will be included in these efforts, both for the new research with PFASs and ongoing work with major geochemical ions (Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Cl^- , SO_4^{2-} , HCO_3^-).

Product 1

Methods to support development of aquatic life criteria for mixtures of major geochemical ions in freshwater aquatic communities

Product 2

Methods and information to support development of aquatic life criteria for per- and poly-fluorinated alkyl substances

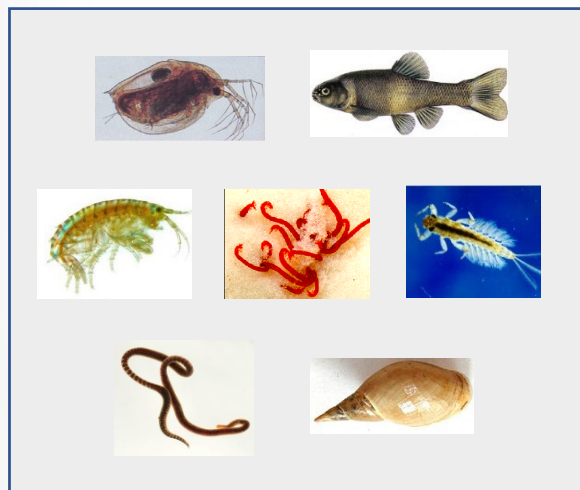




Methods to support development of aquatic life criteria for mixtures of major geochemical ions in freshwater communities

Research Across Different Levels of Biological Organization

Single Species Toxicity Tests (CCTE/GLTED)



Experimental Streams (CEMM/WECD)



Natural Communities (CEMM/WECD, Regions)



(Ongoing research from previous StRAPs, to be finished in FY21)



Methods to support development of aquatic life criteria for mixtures of major geochemical ions in freshwater communities

Toxicity of major ion mixtures in single-species toxicity tests

- Issue: Limited scope for ion compositions in available toxicity data
- Approach: Test multiple aquatic species over a broad range of ion composition

Acute lethality for 6 species; chronic/subchronic toxicity for 4; 11 salts

Single salt toxicity in a wide range of toxicity test dilution waters

Binary salt mixture tests to evaluate ion interactions

Development of exposure metrics and models to assess any ion mixture

Validation of models with synthetic complex mixtures emulating field exposures

Status/Ongoing Activities:

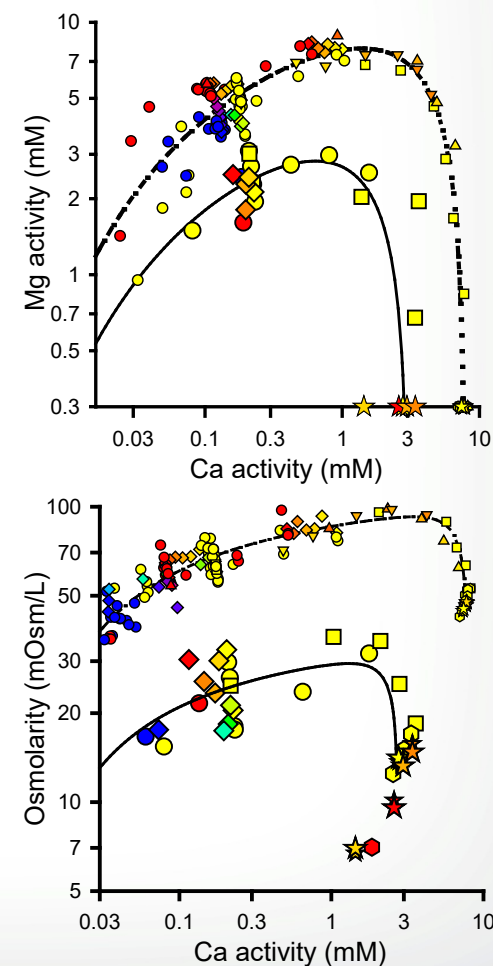
Testing completed

Results published for *Ceriodaphnia dubia*

Papers in preparation for other species

Ongoing consultations with OW regarding criteria development

Ion activities at acute LC50s and chronic EC20s for *Ceriodaphnia dubia*





Methods to support development of aquatic life criteria for mixtures of major geochemical ions in freshwater communities

Response of experimental ecosystems to major ion elevations

💧 **Issue:** Improving ion risk assessment based on experimental stream response

💧 **Approach:** Test major ion toxicity in EPA's Experimental Stream Facility (ESF)

Structural and functional responses monitored for multiple taxa and trophic levels not testable in single-species tests

Mesocosm tests help validate and evaluate proposed exposure limits for criteria development

Five experiments with single salts and with mixtures simulating deep well brines (DWB) and coal mining leachates (MTM)

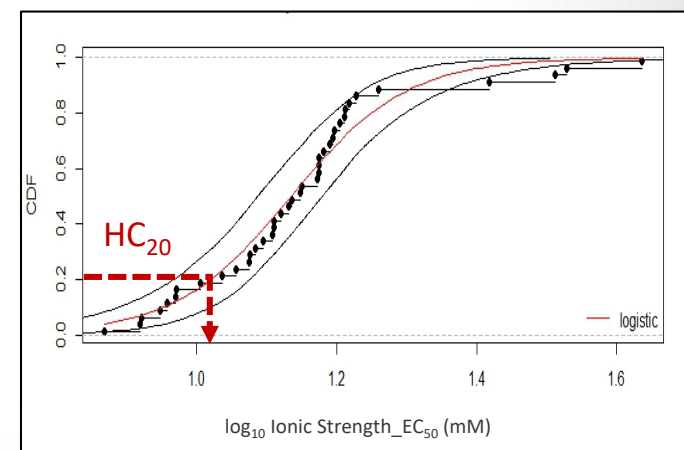
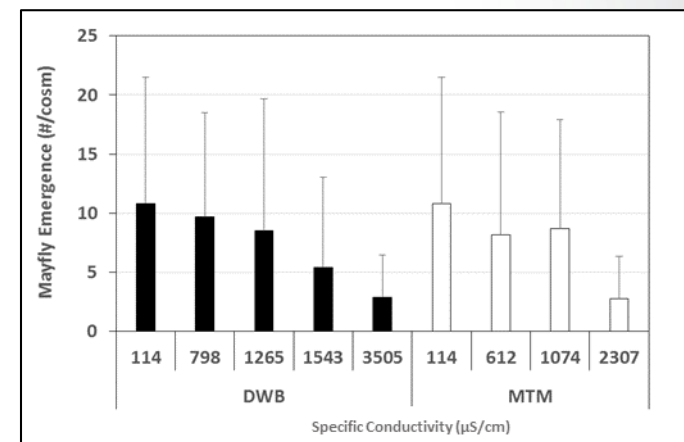
Effect concentrations (ECs) for each response calculated and summarized as response distribution

Simultaneous toxicity tests using selected single-species

💧 **Status/Ongoing Activities:**

Testing Completed

Papers in preparation

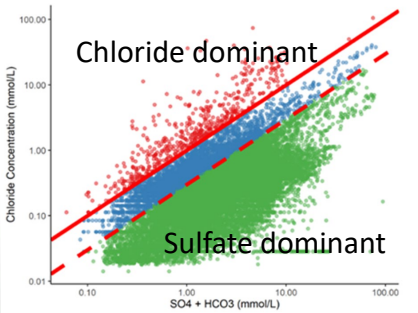
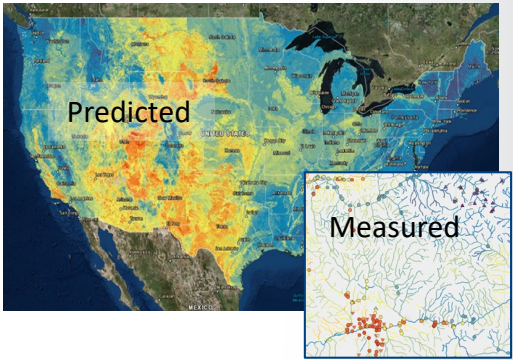
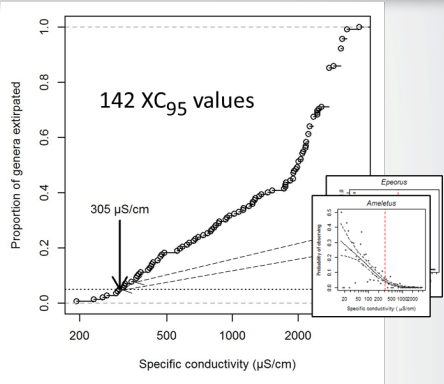




Methods to support development of aquatic life criteria for mixtures of major geochemical ions in freshwater communities

Assessing effects of major ions based on field observations

- Background: Field observations used to estimate extirpation of 5% of genera as a function of conductivity, based on paired chemistry and species occurrence data
- Issue 1: Need for estimates of background ion concentrations and conductivity
- Status/Ongoing Activities:
 - Development of predictive model for background conductivity
 - Software for predicted background and curated measurements (Freshwater Explorer)
- Issue 2: Impacts of confounding factors and data limitations on assessments
- Status/Ongoing Activities:
 - Testing of and clarifying implementation regarding data adequacy, ion ratios
 - Development of datasets with different ion compositions for New England and Appalachia to evaluate effects on biological responses





Methods and information to support development of aquatic life criteria for per- and poly-fluorinated alkyl substances

Whole-organism evaluations of chronic PFAS toxicity to freshwater aquatic organisms

💧 **Issue:** Uncertainties and variability regarding chronic toxicity of PFASs to aquatic organisms

💧 **Approach:**

Focus on chronic toxicity to sensitive invertebrates

Apply/develop short-term sublethal assays for selected invertebrates

Compare short-term assays to full chronic studies for selected PFASs

Apply short-term assays to a broad set of PFASs

Assess mixture toxicity for selected PFAS combinations

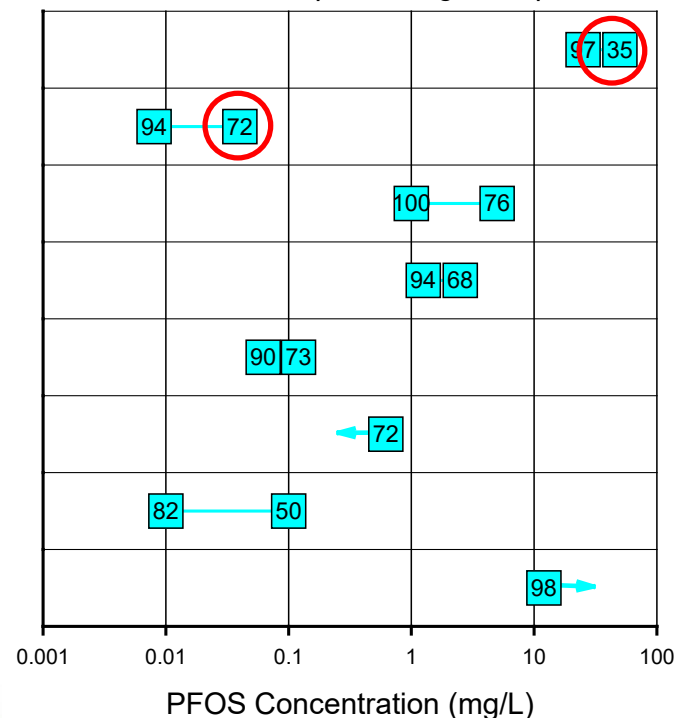
💧 **Status/Near-Term Activities:**

New effort

Develop short-term assays for *Chironomus dilutus* and *Hyalella azteca*

Conduct initial tests on *C. dubia*, *C. dilutus*, and *H. azteca* with 4 PFASs

NOECs/LOECs for *Daphnia magna* Reproduction



Grouped chemical approaches to toxicity extrapolation

- 💧 **Approach:** Toxicity-normalized hazard quotient (HC5n)

Normalize toxicity data to a single sensitive aquatic species tested for each chemical

Chemical-specific HC5 = HC5n × Chemical-specific effect concentration for sensitive species

- Validate approach using existing, curated, non-PFAS data

Evaluate other approaches:

Web-ICE; thresholds of toxicological concern





Methods and information to support development of aquatic life criteria for per- and poly-fluorinated alkyl substances

Occurrence and bioaccumulation of PFASs in marine systems

💧 **Issue:** Uncertainty regarding risk assessment needs for PFASs in marine systems.

💧 **Approach:**

Review occurrence/bioaccumulation of PFASs in marine systems

Bioaccumulation serves to confirm bioavailability of PFASs to marine organisms

Include marine organisms ranging from lower trophic levels to commercially-important fish and wildlife

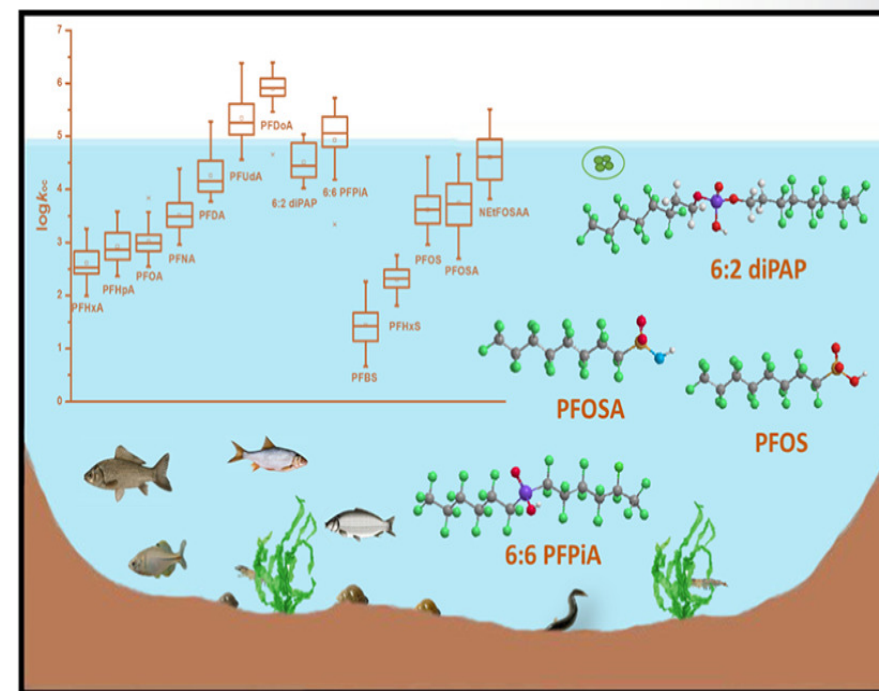
Literature search to include all defined PFAS structures

💧 **Activities:**

Literature search underway, with consideration of feasible scope

Consultation with OW regarding marine PFAS regulatory needs

Final report in FY22



(From Chen et al. (2018))