Research Brief 184: Linking Site Specific Contaminant Mixtures to Biological Responses

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Superfund Research Program
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Background

Understanding environmental exposures and accurately predicting their impact on human and aquatic ecosystem health requires innovative, interdisciplinary approaches. Quantifying exposure is complicated. For example, measures of "total" ambient contaminant concentrations may represent only a rough estimate of potential exposures – in part because such analyses measure only specifically defined contaminants of interest. In addition, concentration measurements may not accurately reflect the bioavailable fraction of contaminants, or take into account the synergistic or agonistic interactions of compounds in a contaminant mixture.

Dr. Kim Anderson at the Oregon State University SRP is working to refine and combine two technologies to assess the toxicity of bioavailable contaminant mixtures present in the environment. Building upon lab work and field trials conducted at a Superfund Megasite in the lower Willamette River (Portland, OR), her research team created a bio-analytical tool that can assess multiple biological responses to environmentally relevant mixtures in a whole organism vertebrate model.

Graduate fellow (Sarah Allan) from Dr. Anderson's group preparing LFT for deployment in the field.

Advances

Dr. Anderson's biological response indicator devices for gauging environmental stressors (BRIDGES) uses passive sampling devices plus an embryonic zebrafish developmental model.

Passive sampling devices (PSDs): Basically, PSDs are low density polyethylene tubing used as *in situ* samplers. They mimic key mechanisms of bioconcentration and interact only with the dissolved fraction of the contaminant, allowing researchers to focus on bioavailability and activity, rather than on the mere presence of chemicals. PSDs also have size-discrimination capabilities similar to cell membranes so contaminants too large to penetrate gills or other epithelium cannot pass through the PSD membrane. While passive sampling devices generally contain a small volume of lipid, such as triolein, Dr. Anderson's team demonstrated that lipid-free tubing (LFT) are both reliable and cost-effective. They developed extraction methods for LFTs that reduce labor, eliminate chlorinated solvents, and reduce overall solvent use while improving recovery of target analytes. LFT extracts have been used extensively for chemical analysis and more recently in bioassays that assess toxicity.

Research associate (Kevin Hobbie) and graduate fellow (Sarah Allan) from Dr. Anderson's group prepare LFT cages for deployment in the Portland Harbor Superfund Megasite in the lower Willamette River.

Embryonic zebrafish model: Dr. Anderson's group collaborated with Dr. Tanguay's Aquatic Biomedical Models Facility Core to expose embryonic zebrafish to LFT extract in order to assess the toxicity of environmentally relevant contaminant mixtures. Embryonic zebrafish are an ideal model for full organism bioassays and are widely used to investigate developmental toxicity. Zebrafish have many advantages over other vertebrate bioassay models with respect to their size, husbandry and early morphology. Furthermore, the embryos are nearly transparent, allowing for clear non-invasive visualization of internal organs.

Research associate (Kevin Hobbie) and graduate fellow (Sarah Allan) from Dr. Anderson's group work on the bow of a boat in the Portland Harbor Superfund Megasite in the lower Willamette River, placing LFT on deployment devices.

Application of BRIDGES to Portland Harbor Superfund Megasite: To evaluate whether the BRIDGES tool can effectively link site-specific bioavailable contaminant mixtures to multiple biological responses, the researchers deployed

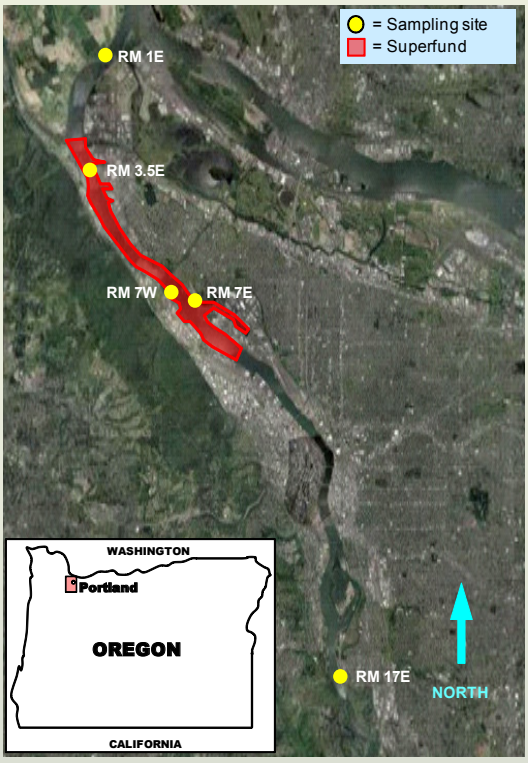
LFT PSDs for 21 days at five locations within and outside of the Portland Harbor Superfund Megasite. They exposed zebrafish embryos to LFT extracts at approximately 6 hours post fertilization (hpf) and scored the developmental impacts at 30 and 126 hpf.

Dr. Anderson's research team modified an embryonic zebrafish metric (EZM) developed to assess nanomaterial toxicity. They determined a score (or metric) for each embryo by evaluating 18 endpoints including mortality and the presence or absence of morphologic malformations including deformations of the heart, yolk sac, tail, and notochord. The EZM integrates multiple biological responses into a single, non-specific overview of general toxicity that facilitates general comparisons between treatment groups. The EZM scores were highest for embryos exposed to extracts from sampling sites within the Superfund Megasite and an exposure concentration–response was observed for LFT extracts from those sites.

Graduate researcher (Lane Tidwell) from Dr. Anderson's group retrieving LFT from a site on the Columbia River, downstream from the Portland Harbor Superfund Megasite.

Dr. Anderson's team found that additional analysis of individual endpoints provides different insights into site specific toxicity than EZM alone. The researchers found that both the type and frequency of toxic endpoints observed were significantly different between sites. For example:

- Mortality was so high for embryos exposed to extracts from sampling site RM 3.5 E (see map) within the Superfund Megasite that data on sublethal developmental effects could not be collected.
- Notochord waviness was observed only in embryos exposed to extracts from the sampling site RM 7W (within the Superfund Megasite, see map) whereas significantly higher incidence of underdeveloped bodies was only observed for RM 7E on the opposite bank of the river. These significant differences in toxicity show an association with differences in the concentrations of PAHs, PCBs, organochlorine pesticides and other chemicals of concern detected at these two sites.



LFT passive samplers were deployed in the water column at the sites indicated by the yellow circles. The Portland Harbor Superfund Megasite is outlined in red. The McCormick and Baxter Superfund site is located on the east bank at river mile 7 (RM 7E).

Significance

Many biological exposure studies are not conducted at environmentally relevant concentrations and/or are not performed with realistic mixtures typical of contaminated sites. This limits their applicability to address important human and environmental health questions related to real-world exposure scenarios and biological responses. Dr. Anderson's work demonstrates the effectiveness the BRIDGES bio-analytical tool to link bioavailable contaminant concentrations to biological responses, providing an interface between environmental exposure and aquatic/human health risk.

Dr. Anderson believes the BRIDGES bio-analytical tool could be used as a complementary tool for environmental and risk assessment in conjunction with chemical characterization of sites. BRIDGES could inform management actions by providing site-specific mixture toxicity data that could be used to validate management actions or suggest further investigate or reassessment.

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To learn more about this research, please refer to the following sources:

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