Correlating OPAH concentrations with zebrafish toxicity of Gulf of Mexico samples around the Deepwater Horizon oil spill: a bottom-up approach

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Abstract

The 2010 Deepwater Horizon oil spill introduced a wide range of bioavailable contaminants in the Gulf of Mexico, including PAHs and OPAHs. Previous research suggests that PAHs are not the primary driver of toxicity in some contaminated sites.[1] We observed unique OPAH signatures at each of four sites in the Gulf of Mexico during and after shoreline oiling, with concentrations of OPAHs in passive sampling device extracts varying 100-fold across sites and sampling locations. Laboratory-made standard mixtures have been created that simulate exposures of OPAH concentrations detected during shoreline oiling in near-shore water in each LA, MS, AL, and FL. We are investigating the toxicity contribution of selected OPAHs relative to the toxicity of the whole sample by utilizing an *in vivo* developmental model with embryonic zebrafish (*Danio rerio*).

Objective

In order to assess the toxicity that can be attributed to detected OPAHs alone,

1. Create standard mixtures that mimic the concentrations and ratios of OPAHs detected in passive sampling device extracts.
2. Utilize the *in vivo* developmental model with embryonic zebrafish (*Danio rerio*) at Sinnhuber Aquatic Research Laboratory.
3. Compare the bioactivity of these standard mixtures that of the whole passive sampling device extract.

This bottom-up approach will provide potential insight into specific drivers of toxicity and will be useful in developing a model to predict toxicity in resident organisms with passive sampling devices.

BACKGROUND

OPAHs in the Gulf of Mexico

- Polycyclic aromatic hydrocarbons (PAHs) and derivatives such as oxygenated PAHs (OPAHs) are detected in the environment arising from both natural and anthropogenic sources (Figure 1).[2,3]
- OPAHs are recognized as environmental toxicants potentially more toxic than the parent PAHs.[2,4]
- PSD extracts have been used in conjunction with bioassays to assess the toxicity of freely dissolved, environmentally-relevant contaminants (Figure 3). [5,6,7]
- If toxicity is not driven by PAHs, could OPAHs be the primary driver?

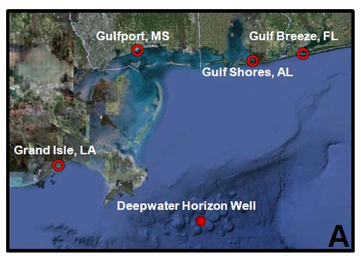


Figure 2. PSD deployment locations and site of Deepwater Horizon oil rig, Gulf of Mexico (Allan et al. 2012a).

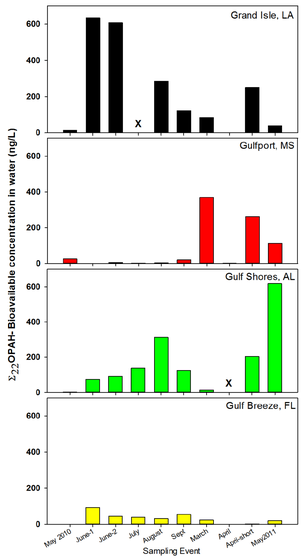


Figure 1. Freely dissolved Σ_{22}OPAH concentrations in water, Gulf of Mexico May 2010 - May 2011.

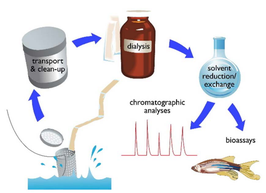


Figure 3. BRIDGES PSD function and attributes.

Hypothesis$_A$: Bioactivity of site-specific standard OPAH mixtures will match that of LFT extracts.

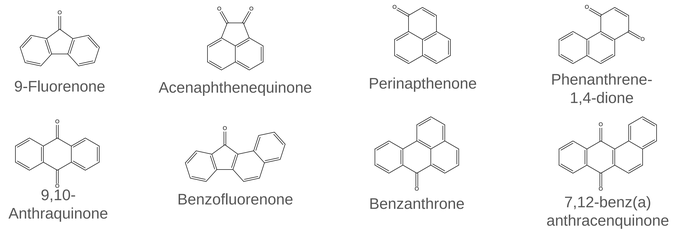
METHODS

1. Create Standard OPAH Mixtures

that mimic detected OPAH concentrations during shoreline oiling

Table 1. OPAH concentrations (ppb) detected in LFT extract, deployed June 11 - July 7 2010, Gulf of Mexico. In this deployment, only 8 OPAHs were detected of the 22 in the GC/MS method.

OPAH concentration (ppb)	LA	MS	AL	FL
9-Fluorenone	-	-	-	18
Acenaphthenequinone	-	-	44	-
Perinapthenone	-	330	140	-
Phenanthrene-1,4-dione	2200	-	-	160
9,10-Anthraquinone	4700	-	72	150
Benzofluorenone	2200	140	120	100
Benzanthrone	-	-	49	-
7,12-benz(a)anthracenquinone	590	77	59	68



2. Embryonic Zebrafish Bioassay

High-throughput (n=40) analysis of 22 endpoints at two time points (24 hours and 5 days post-fertilization) in a model vertebrate species (Figures 4 and 5).

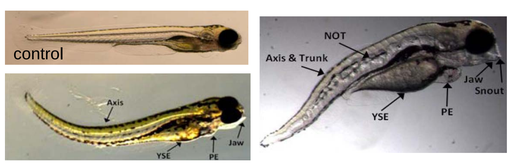


Figure 4. Examples of morphological endpoints in developmental zebrafish bioassay. YSE = yolk sac edema, PE = pericardial edema, NOT = notochord (Allan et al. 2012b).

EXPECTED RESULTS

3. Assess Bioactivity

If OPAHs are driving toxicity, then we expect results of zebrafish assay to be similar between the site-specific standard mixtures and the respective complete LFT extract.

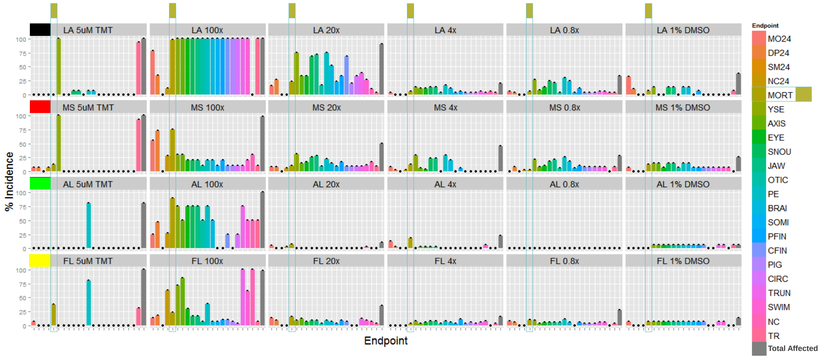


Figure 5. Developmental zebrafish assay results for LFT extract exposure at four dilutions for each of four Gulf of Mexico sites, field-deployed from June 11 – July 7 2010. 5uM TMT is positive control, and 1% DMSO is negative control. 5 day post-fertilization mortality is highlighted in each treatment.

NEXT STEPS

- Compare the bioactivity of these standard mixtures to that of the whole PSD extract.
- Utilize other bioassay, *e.g.* Salmonella mutagenicity assay
- Examine other classes of organic contaminants with BRIDGES tool
- Develop BRIDGES model with silicone-PSD
  - H_A: Si-PSD blank extract will not elicit a toxic response in zebrafish assay.
  - H_A: Si-PSD will sequester more semi-polar compounds, by weight, than lipid-free tubing.
  - H_A: Combining silicone-PSD & LFT deployments at a site will increase the number of contaminants sequestered.

References: **1.** Allan, S. E., B. W. Smith, R. L. Tanguay, and K. A. Anderson (2012). "Bridging Environmental Mixtures and Toxic Effects." Environmental Toxicology and Chemistry **31**(12): 2877–2887. **2.** Bandowe, B. A. M. and W. Wilcke (2010). "Analysis of Polycyclic Aromatic Hydrocarbons and Their Oxygen-Containing Derivatives and Metabolites in Soils." Journal of Environment Quality **39**(4): 1349. **3.** Lundstedt, S., P. A. White, C. L. Lemieux, K. D. Lynes, I. B. Lambert, L. Oberg, P. Haglund, and M. Tysklind (2007). "Sources, Fate, and Toxic Hazards of Oxygenated Polycyclic Aromatic Hydrocarbons (PAHs) at PAH- contaminated Sites." AMBIO: A Journal of the Human Environment **36**(6): 475-485. **4.** Knecht, A. L., B. C. Goodale, L. Truong, M. T. Simonich, A. J. Swanson, M. M. Matzke, K. A. Anderson, K. M. Waters, and R. L. Tanguay (2013). "Comparative developmental toxicity of environmentally relevant oxygenated PAHs." Toxicology and Applied Pharmacology. In Press. **5.** Anderson, K. A., D. Sethajintanin, G. Sower, and L. Quarles (2008). "Field trial and modeling of uptake rates of in situ lipid-free polyethylene membrane passive sampler." Environ Sci Technol **42**(12): 4486-4493. **6.** Hillwalker, W. E., S. E. Allan, R. L. Tanguay, and K. A. Anderson (2010). "Exploiting lipid-free tubing passive samplers and embryonic zebrafish to link site specific contaminant mixtures to biological responses." Chemosphere **79**(1): 1-7. **7.** Allan, S. E., B. W. Smith, and K. A. Anderson (2012). "Impact of the Deepwater Horizon oil spill on bioavailable polycyclic aromatic hydrocarbons in Gulf of Mexico coastal waters." Environmental Science and Technology **46**(4): 2033-2039.

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