# Environmental Sampling Strategies for Disasters: Lessons Learned from Hurricane Harvey Response

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## Abstract

Introduction: Hurricane Harvey left Houston, Texas severely flooded and residents concerned about chemicals released from Superfund and Brownfield sites. Consequently, public health and other agency response plans for post-disaster sampling were questioned by residents, researchers, and the media. Since emergency response is considered dynamic, continuous refinements are needed to improve preexisting frameworks. An example of this is development of a sampling plan for post-disaster exposure assessment to characterize hazards and risks in affected areas to facilitate risk communication. Despite advances in emergency preparedness since 2001, gaps remain for both emergency communications and harmonization of post-disaster intervention methods.

Results: In 2016, baseline exposure data was collected from Houston environmental justice neighborhoods as part of community engaged research. In 2017, post-Harvey, our team collected additional samples using two strategies. First, we sampled sites with pre-Harvey reference data. Second, we sampled around known hazardous sites in close proximity to populated areas. While this sampling strategy was community- or hazardous-site focused, it may be subject to bias. Furthermore, due to the unpredictability of disasters, baseline data is often unavailable. Therefore, we created a post-disaster exposure map and calculated preliminary risk characterization hazard quotients for detected PAHs using the U.S. EPA Regional Screening Level (RSL) Calculator. Each of the compounds analyzed for, all were at low detection levels. Based on coordinates of the samples collected in Houston, Universal Kriging (UK) will be applied to develop a systematic sampling strategy to evaluate environmental exposures post-Harvey and contribute to a framework to apply towards other future emergency responses.

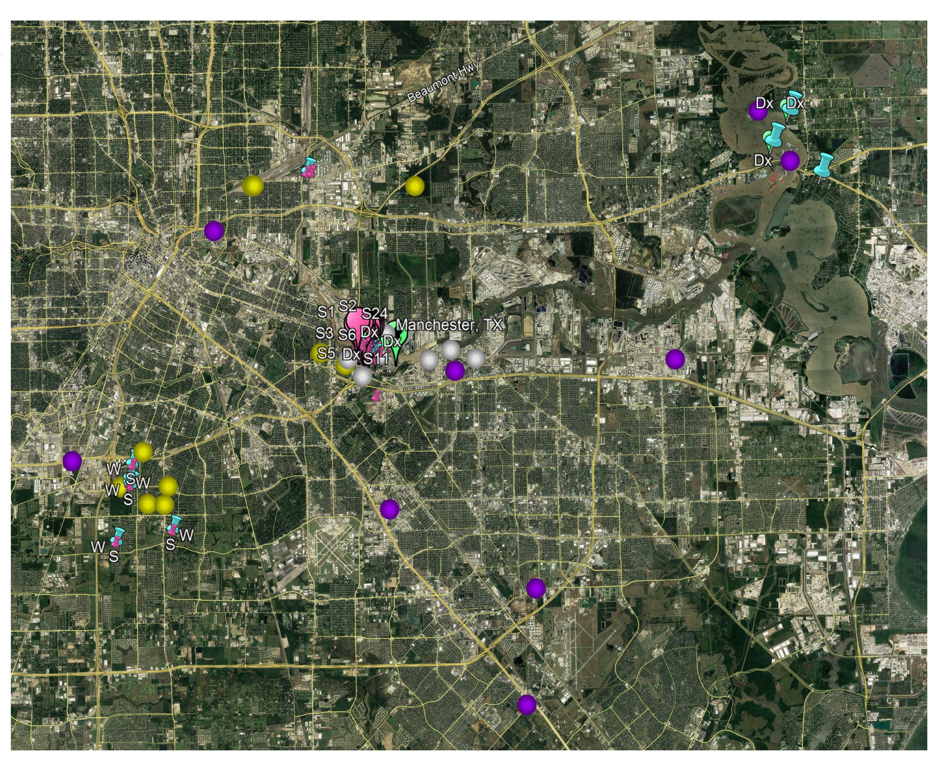
## Background

- Houston, TX has 66 Superfund sites listed as either ongoing projects or have been taken off the National Priorities List (NPL)[4].
- Screening list for analytical chemistry referenced historical chemical uses in the Houston Superfund sties
- Compounds analyzed for are listed in Figure 2B

## Methods: Sampling & Analysis

- On 1 Sept 2017 mobilization occurred as soon as Harvey cleared Houston, TX
- Figure 1 summarizes all samples collected in Houston
- Goal: obtain as many representative samples and develop a screening process in which to analyze for environmentally relevant contaminants
- Due to prior sampling in Fall 2016, the initial 24 Manchester soil/sediment and all 8 water samples were chosen to serve as a relative comparison of pre- and post data.
- Based on relative geographical location, a group of 12 samples were analyzed for dioxins
- The U.S. EPA's Regional Screening Level (RSL) Calculator was used to calculate the chronic and subchronic Hazard Quotients (HQ) for the EPA's 16 Priority PAHs (Figure 4 A-E) using detected concentrations.

A



B

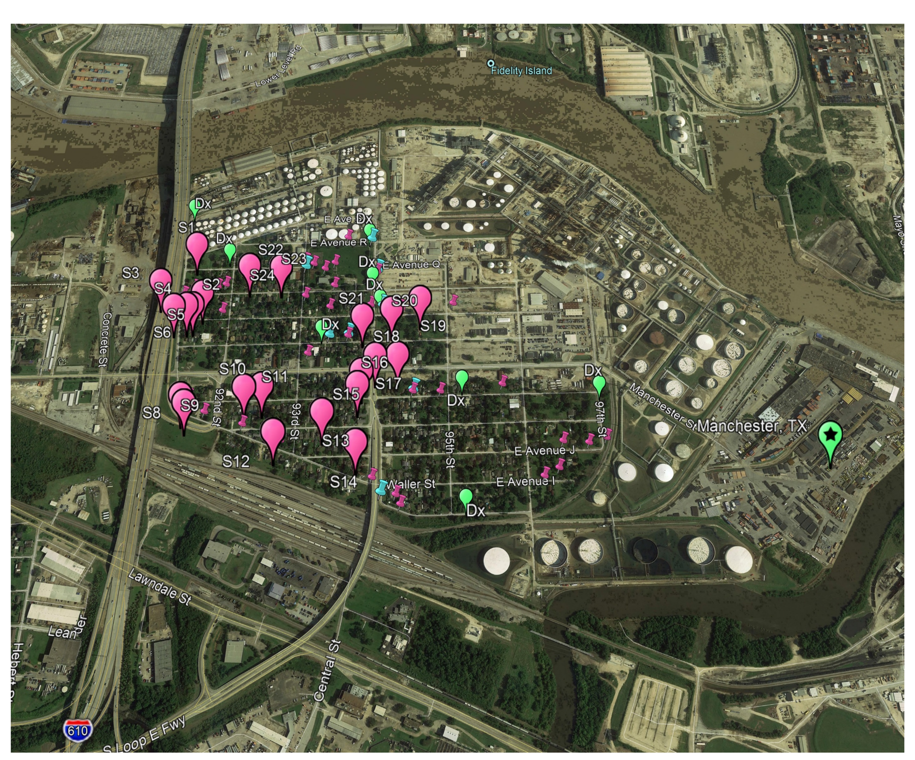


**Figure 1:**
**Map of all samples collected in Houston, TX the first two weeks of September**

| Legend | Figure 1A | Figure 1B |
|---|---|---|
| | Superfund sites (purple sphere) | 24 Samples Analyzed (pink mark |
| | Brownfield sites (yellow sphere) | Samples Analyzed for Dioxins (green mark) |
| | Industries (silver sphere) | |
| | Water samples (blue pin) | |
| | Sediment samples (pink pin) | |

## Results

- **Figure 2** provides a visual summary of all samples collected in Houston during the first two weeks of September 2017
- A summary of total samples collected either in Manchester or at nearby Brownfield and Superfund sites are listed in **Figure 2A**
- An outline of which samples were analyzed for specific compounds is outlined **in Figure 2B**
- **Figure 3** highlights PAH results for calculated Hazard Quotients (HQ) utilizing the U.S. EPA Regional Screening Level (RSL) Calculator
- **Figures 3 B-E** provide graphics of initial risk characterization HQs for both Child and Adult Sub-chronic and Chronic scenarios

**Figure 2**

A

| Soil Samples | Water Samples | Location |
|---|---|---|
| 68 | 8 | Manchester |
| 17 | 15 | Near Brownfield & Superfund Sites |

B

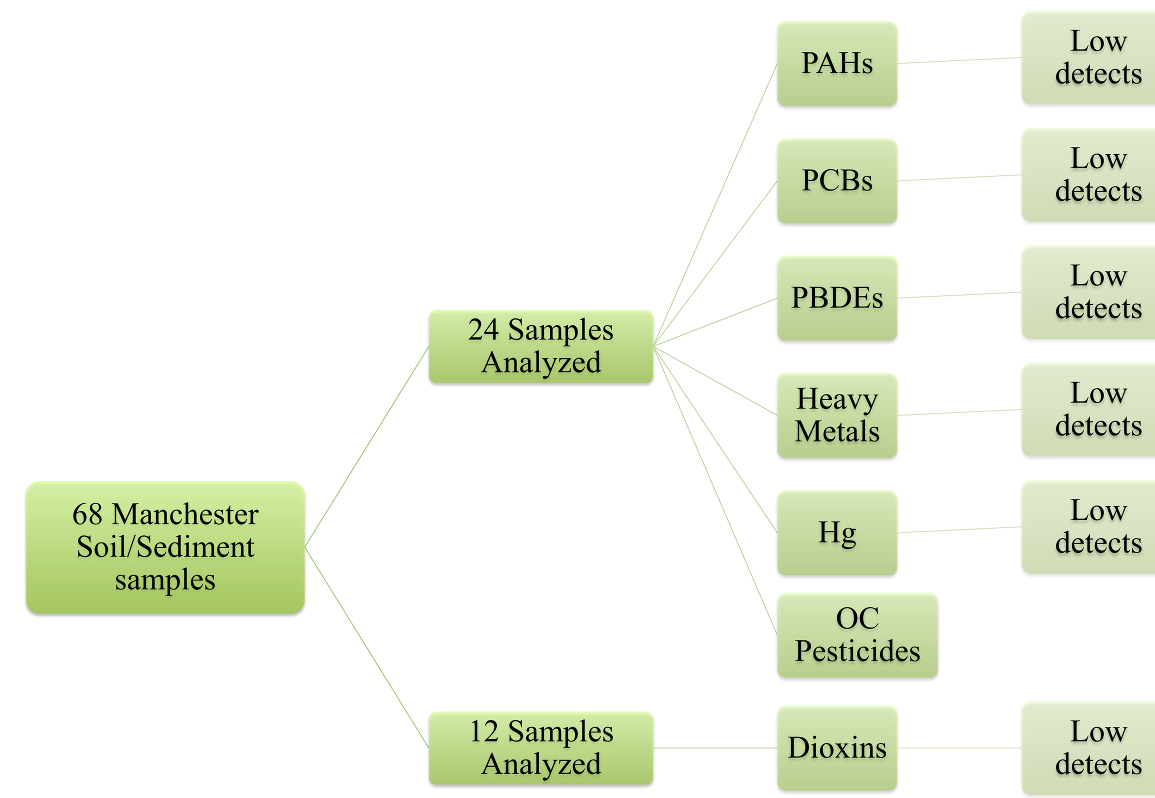
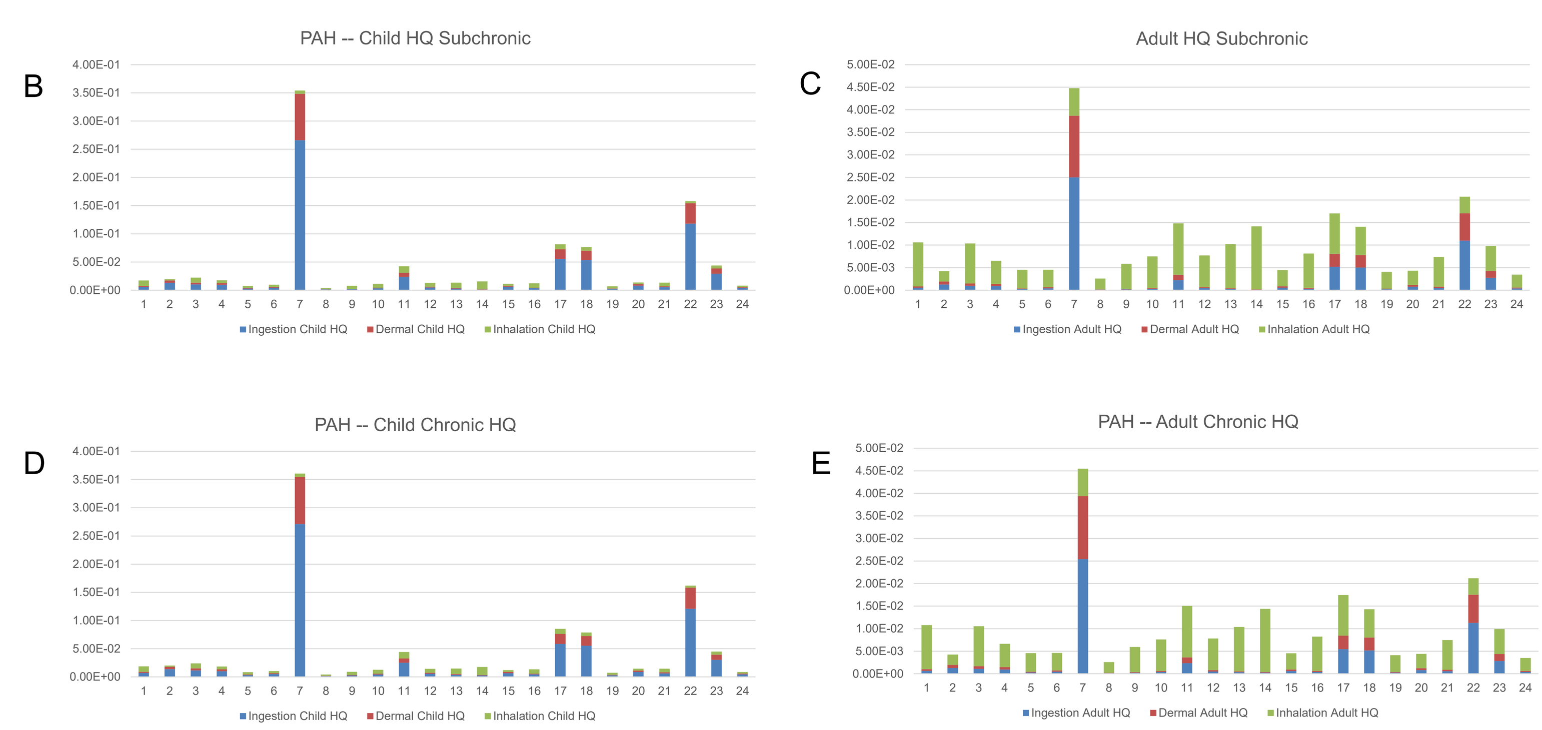



**Figure 3**

A

| EPA's 16 Priority PAHs |
|---|
| Acenaphthene |
| Acenaphthylene |
| Anthracene |
| Benzo(a)anthracene |
| Benzo(a)pyrene |
| Benzo(b)fluoranthene |
| Benzo(g,h,i)perylene |
| Benzo(k)fluoranthene |
| Chrysene |
| Dibenzo(a,h)anthracene |
| Fluoranthene |
| Fluorene |
| Indeno(1,2,3-c,d)pyrene |
| Naphthalene |
| Phenanthrene |
| Pyrene |




## Discussion

- Universal Kriging (UK) will be applied to current and future Houston samples to:
  1. Develop a spatial model of contaminant concentrations
  2. Aid in the determination of future sampling locations
- Universal Kriging requires a variogram model and utilizes an unknown mean structure over the spatial domain; the mean is often dependent on latitude and longitude information amongst other relevant covariate information.
- Steps in applying UK: first determine the necessary mean structure varying over space followed by flexible spatial covariance models to account for spatial dependence of the concentration distribution
- Under current sampling conditions, the investigation focused on a cluster of 24 samples which does not aid in proper mean structure estimations
- Future analysis of more samples outside of Manchester, TX is required to develop the spatial model and sampling map
- UK will therefore aid in the development of a sampling strategy that will aim to be systematic and unbiased for future emergency responses

## Research Translation

Implementation of a post-disaster sampling framework could aid residents, public health agencies, and the media by:

(1) speeding rapid needs assessments via the generation of appropriate sampling locations required for assessment, and

(2) providing a tracking method for future post-disaster investigations to develop interventions.

## Lessons Learned

- Communication and data sharing between disciplines is valuable to contextualizing and conveying science to both the public, policy makers, and the media
- Stream-lining both sampling and analytical capabilities is key to timely reporting
- Creating an analytical suite to analyze samples aids in developing a future screening method of post-disaster samples
- While low level detects of compounds found, they will provide an initial baseline for future reference
- More distributed samples are required for Universal Kriging of contaminant concentrations

## Future Applications

- Apply Universal Kriging to all contaminant concentrations analyzed
- Develop a standardized screening process for environmental contaminants in Houston, TX and consider the role of complex mixtures in the screening process
- Establish a method to convey and contextualize the meaning of the low level detects to the communities and public

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