Passive Air Samplers for Community Monitoring of Air Toxics Following Hurricane Ida in Terrebonne Parish

Sarah Besson

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Passive Air Samplers for Community Monitoring of Air Toxics Following Hurricane Ida in Terrebonne Parish

by

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Undergraduate honors thesis under the direction of

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Baton Rouge, Louisiana
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I. Introduction

For the last century, South Louisiana has played an important role in the oil, gas, and chemical industries for the United States. Due to the widespread production of these products, air quality has become an increasing concern for nearby residents. One of the United States’ major cities, New Orleans, Louisiana, is surrounded by these industries along the Mississippi River. Even though these companies operate under the United States Environmental Protection Agency’s (EPA) regulations, harmful fumes are still being emitted into the air that are causing local concerns regarding carcinogens and particulate matter that may be in the air. Prolonged exposure to particulate matter is a known cause of numerous illnesses: cardiovascular disease, lung cancer, and neurodegenerative disorders (Pirhadi et al., 2020). The New Orleans area has received national attention for “Cancer Alley,” an area that has had an exceedingly high rate of cancer since the late-1900s (Figure 1.0) (Younes et al., 2021). Following the Clean Air Act of 1970 and the Pollution Prevention Act of 1990, air quality has begun to improve from the tightened restrictions; however, South Louisiana still faces many threats to air quality, including natural disasters.

Figure 1.0: Map of Cancer Alley, Louisiana (Hawthorne, 2019)
The lack of knowledge and increasing complaints of homeowners near industrial and chemical companies called for the development of an accessible device capable of surveying the air quality near residents’ homes. Many of these complaints come from residents in the 9th Ward District and Irish Channel areas in New Orleans, Louisiana, since they believe they are being exposed to carcinogenic chemicals every time they leave their homes or go outside (McAllister, 2021). Residents feel that their voices are not being heard, despite there being over 850 odor complaints by this community since 2018 (McAllister, 2021). A passive air sampling device was chosen due the lack of samplers currently measuring semi-volatile organic compounds (SVOCs) in the air; it is relatively inexpensive to build; and it requires low maintenance. SVOCs are present in several different groups: polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and polychlorinated dibenzodioxins (PCDDs). SVOCs are emitted into the air by a variety of sources such as brownfields, legacy production facilities, industrial sources, and combustion sources. Conventional SVOC monitoring techniques are expensive to determine accurate concentrations in ambient air, so they cannot be used often or at a high enough resolution in a low-income community (Ravikrishna, 2010). Low-cost, passive SVOC monitoring devices are a possible solution to routinely measuring air quality in communities surrounded by industrial sites that currently do not have a voice. The opinions and concerns of residents will be taken into consideration during the duration of this design. It is critical to empower the people, especially those facing environmental injustice, to collect information on illegal releases from nearby chemical and industrial plants to ensure the air quality does not pose unnecessary health risks. It is equally important to monitor air quality following a natural disaster since
existing monitoring stations are often destroyed, and people are in extremely vulnerable states. People in desperate situations should not have worry that they may be breathing contaminated air, especially contaminants that could impact their health in the future.

Residents of the Irish Channel, which is located near New Orleans’ Garden District, have voiced that they are experiencing negative health symptoms such as nausea, headaches, dizziness, burning sensation in eyes, and shortness of breath associated with the recent expansion of BWC Harvey’s petrochemical storage and transfer facility (JOIN for Clean Air, 2021). BWC Harvey has been linked as a possible source to hundreds of odor complaints from over 150 households by the Louisiana Department of Environmental Quality (LDEQ) (McAllister, 2021). This does produce serious concern regarding the state of air quality in the area since over 7,000 people live within one mile of the BWC Harvey facility (Figure 2.0) (Palmer & Banks, 2021)

Figure 2.0: Homes in proximity to BWC Harvey and close-up (Base map: Google Earth)

Residents of the Lower 9th Ward District in New Orleans are also experiencing increasing concerns about their environmental quality. Several incidences are impacting their environment: car explosions, vehicular oil spills, debris from standpipes, debris from gravel lots, and fires from surrounding industrial plants (Keeling, 2021).
Unfortunately, the residents who are experiencing these issues are low-income, low-
education families who do not notice anything that is happening outside of their homes
that cannot be seen with the naked eye. Racial injustice is not uncommon to South
Louisiana, an area where communities of underrepresented people are often targeted for
new chemical and waste development sites (Younes et al., 2021). Since minimal air
quality data is collected within this area, it is well worth analyzing samples in this area to
provide these people with the truth on what they are breathing.

Air quality can be altered by other sources, even natural phenomena. Because of the
proximity to the Gulf of Mexico, every year South Louisiana faces a major threat from
June 1\textsuperscript{st} to November 30\textsuperscript{th}: hurricanes. In the Atlantic, the 2020 hurricane season named
thirty storms, the most of any Atlantic hurricane season since 1851 (Wells, 2020). Out of
thirty storms, five of those storms made landfall in Louisiana, the most to hit Louisiana in
one season.

On August 29, 2021, Hurricane Ida tore through Louisiana leaving thousands of
homes and businesses devastated. The most southern part of the state, bayou country,
received the worst of Ida. For almost twenty-four hours, Houma, LA, in Terrebonne
Parish endured 150 miles per hour (mph) winds as Hurricane Ida’s eyewall brought
tremendous damage to the city. Figure 3.0 shows the devastation to one business, Houma
Paint and Industrial Supply, but hundreds of other structures had the same fate.
As soon as Hurricane Ida passed, linemen began to survey the damage left behind. Damaged structures that needed replacement or repair throughout Terrebonne Parish’s power grid included approximately 30,000 poles, 6,000 transformers, and over 36,000 spans of wire (Copp, 2021). Nearly 80% of these structures were located within the hardest-hit areas in Terrebonne Parish. By September 29, 2021, one month after the hurricane made landfall, 10% of Terrebonne Parish residents remained without power. Since weeks went by with no electricity, many residents relied on portable or natural gas generators as their main source of power. While generators may provide immediate relief, most may have a long-term effect on air quality.

Hurricane Maria made landfall in Puerto Rico on September 20, 2017, leaving the island devastated and approximately 90% of the island without power (Subramanian et al., 2018). Three months following Hurricane Maria, nearly 50% of the island still remained without power. Because of the lack of electricity for an extended period of time, many residents had to rely on backup generators as a main source of energy, similar to Terrebonne Parish. There was little data on air quality collected by the Puerto Rico
Environmental Quality Board immediately following Hurricane Maria since the storm destroyed the majority of air monitoring stations around the island.

To begin monitoring air quality in Puerto Rico, four low-cost, real-time affordable multi-pollutant (RAMP) samplers were deployed near the San Juan Metro Area (SJMA) from mid to late November of 2017 (Subramanian et al., 2018). All four of the samplers were capable of measuring carbon monoxide (CO), nitrogen dioxide (NO₂), and ozone (O₃). Additionally, two of the RAMPs could measure nitric oxide (NO) while the two remaining samplers could measure sulfur dioxide (SO₂). This type of sampler is ideal in low-income countries, or countries devastated by natural disasters, since they can be deployed rapidly and operate off of low-power solar panels. Also, a black carbon (BC) monitor was deployed in the same area and timeframe.

The study found significant impact on air quality from backup generator usage (Subramanian et al., 2018). High concentrations of SO₂ at over 200 parts per billion (ppb) were identified in SJMA on multiple days, as well as CO concentrations between 3 to 4 parts per million (ppm). To put these concentrations into perspective, current EPA regulations on SO₂ and CO are 75 ppb based on 1-year average of 1-hour daily maximum concentrations and 9 ppm in an 8-hour timeframe, respectively (EPA, 2021). When compared to the EPA’s AP-42 source profiles, the ambient data shows a potential source of the air emissions as “gasoline and diesel stationary combustions units,” which correlated with the use of backup generators (Subramanian et al., 2018). If exposure to SO₂ is only in the short-term, health effects may include damage to respiratory systems and difficulty breathing (EPA, 2022). Long-term effects can cause severe lung damage when combined with large concentrations of particulate matter (PM).
Another study on air quality was conducted in New Orleans, LA, following Hurricane Katrina in the Fall of 2005. South Louisiana is flooded with industrial complexes, which may have had a significant effect on air quality if damaged during the storm. Hurricane Katrina made landfall on August 29, 2005, bringing catastrophic flooding to the city and left thousands dead or in desperate need of help. Following the hurricane, the EPA deployed passive air monitoring devices from October of 2005 to February of 2006 (Chung et al., 2009). A total of eighteen samplers were deployed at multiple outdoor sites throughout the area, which are specified in Chung et al. Indoor air quality was not sampled by the EPA in this study. The samplers could detect twenty-nine volatile organic compounds (VOCs) including benzene, toluene, ethylbenzene, and xylenes. Passive air samplers were chosen for this study since they are user-friendly and require little to no energy to operate, which is imperative in a city where electricity disappeared for weeks. The type of samplers utilized in this study were 3M 3500 Organic Vapor Monitor (OVM) badges.

Following the study, it was concluded that the presence of VOCs affecting outdoor air quality in New Orleans, LA was minimal (Chung et al., 2009). Not including benzene, toluene, and carbon tetrachloride, the majority of the VOCs did not have concentrations greater than their detection limits, and the EPA guidelines for VOCs in outdoor air were never exceeded by any VOC. However, this study demonstrated the usefulness of a low-cost, no-electricity passive air sampler in times of need to ensure people are not living with polluted air. If this study had been conducted inside of flooded homes, the results would probably have been much worse. Currently, there is minimal published research on VOC levels inside of home following Hurricane Katrina.
Besides structural damage, Hurricane Ida left residents without food, water, gas, or other resources for weeks. Before aid could come, many homeowners had to watch as the inside of their water-damaged homes began to mold. Mold can cause serious health effects in humans such as infections, respiratory illnesses, skin irritation, and chronic headaches (4 Health Effects of Mold from Water Damage).

Hurricane Ida damaged many gas stations and energy production facilities. Over three months have passed since Ida passed through Louisiana, but air quality is still being affected since industrial plants were forced to flare off much of their waste due to no access to electricity shortly after the hurricane (Ramirez & Ellis, 2021).

II. Design Task

A passive air sampler was chosen for this project due to its low-cost, low maintenance nature. Passive air samplers of different forms were researched, and a sampler using XAD-2 resin was chosen and built. These samplers were used to analyze the air quality in three different areas in South Louisiana: Baton Rouge, New Orleans, and Houma. The presence and corresponding concentration of SVOCs in the air were determined, if applicable. Members of the communities were included during the project since the main goal is to give the public the truth about what they may be breathing so that air quality and community health can be improved where needed. A deployment plan was created that involved working with a group of New Orleans and Houma residents to determine any needs and concerns they may have with this project and to communicate any relevant results found with these community members. While results of the sampling in New Orleans and Baton Rouge will be mentioned in this paper, the main focus will be the results found in Houma, LA following Hurricane Ida.
III. Design Considerations and Alternatives

A passive air sampler measures a variety of chemicals, mainly VOCs and SVOCs, in the air through the adsorption of gaseous chemicals by a sorbent inside of the device which is then processed inside of a lab (Wania & Shunthirasingham, 2020). Besides the ease of use, longevity of sample duration, and low cost, passive samplers can be more reliable than active samplers since they do not rely on additional mechanical equipment, such as pumps, to operate. SVOCs are defined as molecules that appear at a significant extent in both the gas and liquid phases, which have a vapor pressure range of approximately $10^{-1}$ and $10^{-6}$ pascals (Pa).” (Wania & Shunthirasingham, 2020) SVOCs are a danger to human health since most are carcinogenic to humans, so it is important to understand the extent of their concentrations in air (Wania & Shunthirasingham, 2020). SVOCs were chosen to be analyzed in this design due to their origins, mainly industrially produced contaminants.

There are numerous types of PAS’s that target different chemicals, as well as many modifications to further improve performance. First, a main consideration when designing a PAS is a kinetic versus equilibrium distinction. A kinetic air sampler is typically chosen for less volatile compounds while an equilibrium sampler is chosen for more volatile compounds, due to the variability in magnitude of these compounds (Wania & Shunthirasingham, 2020). A thermodynamic parameter is used for equilibrium-based passive sampling: “the equilibrium sorption coefficient between gas-phase and sorbent.” (Wania & Shunthirasingham, 2020) Uptake capacity is another important factor to consider when designing an equilibrium-based passive air sampler, but it is greatly affected by the ambient air temperature. Because of this, weather patterns are another
important consideration in an equilibrium-based air sampler design. For kinetic-based passive air samplers, an important consideration during design is the sampling rate, which is determined by a time-averaged air concentration. To optimize the design of a kinetic-based passive air sampler, a large sorptive thickness would need to be chosen (Wania & Shunthirasingham, 2020). Since equilibrium is almost impossible to establish due to ever-changing weather conditions and difficulty associated with estimating a suitable sorptive thickness for kinetic samplers, a combination of both is often used.

Another main consideration in the design of a passive air sampler is the use of a porous diffusive barrier or a nonporous membrane to control the sampling rate (EPA, 2014). When a porous diffusive barrier is used, air can flow more freely in the sampler, and allows for a large range in uptake rakes to allow flexibility in meeting design requirements (EPA, 2014). However, a nonporous membrane is hydrophobic making it ideal to use in a high-humidity area, such as South Louisiana.

Two types of samplers were considered for this design: polyurethane foam passive air samplers (PUF-PAS) and polymeric adsorbent passive air samplers (XAD) Polyurethane foam (PUF) is used as a sorbent in air samplers, and a PUF-PAS sampler has extensive data available for research due to its widespread use (Wania & Shunthirasingham, 2020). PUF is also inexpensive, easy to use, easy to store, and tends to have a high capacity. However, PUF-PASs have been observed to have a large range of sampling rates from numerous calibration studies in indoor environments, which tend to be stable when compared to outdoor environment. This variability in sampling rates can be contributed to wind speed, making it non-ideal in high-velocity wind areas like South Louisiana.
XAD is extensively used as a sorbent in air sampling (Wania et al., 2003). A form of XAD, XAD-2, has a higher uptake capacity compared to PUF and a higher stability of sorbed compounds during storage. XAD-2 is a type of resin, so the sampler would need a casing that houses the resin while still allowing contact with air to trap SVOCs. Thus, an XAD passive sampler (XAD-PAS) is a reliable choice for outdoor environments due to its high uptake capacity and ability to endure long testing periods without maintenance.

In order to accurately determine the concentration of a VOC or SVOC, the sorbent is placed in a protected casing with uniform openings to allow for molecular diffusion and a controlled flow on air (Wania & Shunthirasingham, 2020). The size of the openings must be small enough to prevent convective transport that results in an overestimation of the concentration (Wania & Shunthirasingham, 2020). Transport in passive air samplers must consist only of molecular diffusion to allow the sampling rate to be “directly proportional to its cross-sectional area and inversely proportional to its length.” (WMO, 1998)

The proposed design will explain a clear rationale for the development of passive samplers after extensive research on SVOCs in urban air environments and standard methods for traditional measurements. Critical parameters like wind speed and temperature are determined by the synoptic weather patterns of the area of concern, and the benefits and detriments of kinetic and equilibrium-based samplers will be explored. The proposal will detail a deployment plan that involves working alongside a community group and being receptive to their needs, communicating the process and conditions with these community members, using field data to optimize the design parameters, and estimating costs for the full-scale deployment of the designed system.

IV. Sampler Design
The chosen design for the sampler used in this project consisted of two versions: preliminary and final. The preliminary version was used to sample the air in Baton Rouge, New Orleans, and Houma due to a quick assembly time and inexpensive cost to allow samples to be collected as soon as possible. This preliminary design consisted of an unused, empty paint can used as a shelter and one pantyhose stocking used as a casing for the XAD-2 (Figures 4.0 and 5.0).

![Preliminary Sampler Design Sketch](image)

**Figure 4.0: Preliminary Sampler Design Sketch**

![Inside of Preliminary Sampler in Houma, LA](image)

**Figure 5.0: Inside of Preliminary Sampler in Houma, LA**

The components of the final design of the sampler are presented in Figure 6.0, which were developed using Solidworks. The design consists of three layers, an inner tube, an outer tube, and a casing for the XAD-2 Resin. The outer tube is used as a protection
barrier of the XAD-2 against wind, rain, and wildlife. It is closed at the top, but open at
the bottom to allow airflow to the resin. A 7-inch aluminum tube was used as the outer
casing. To cover the outer tube at the top, a 0.0620-inch-thick aluminum sheet was rolled
and cut to create a disk and was welded onto the tube. For the inner tube, a 4-inch
aluminum tube that is 0.035-inches thick was used. To connect the inner and outer tubes,
and 8-inch by 8-inch aluminum plate was placed in a water jet to cut zig-zag standoffs.
These zig-zags were attached to the tubes using blind rivets with a diameter of 5/32-
inches. The fabrication of the final design was completed by Roger Green of the
Advanced Manufacturing and Machining Facility at Louisiana State University. To house
the XAD-2 resin, a 20-cm long tube made of a fine mesh was formed and enclosed using
removable 1-inch round end caps (Figure 6.0). This mesh tube was connected to the inner
aluminum tube with a S-hook.

Figure 6.0: Side, Top, and Bottom View of Final Sampler Design and Resin Casing

V. Experimental Plan

There are two key unknowns that were tested during the duration of this design:
hazardous SVOCs in the air and possible relations between found constituents and
noxious fumes experienced by a community. To analyze the samples, a Dionex ASE
(accelerated solvent extractant) 350, RapidVap by Labconco, and a 5973 Network Mass
Selective Detector by Agilent Technologies (gas chromatograph-mass spectrometer) were used.

To use the Dionex ASE 350:

1. Weigh the sample using a digital scale.
2. Once weighed, mix the sample with one scoop of diatomaceous earth.
3. Insert the mixture into the extraction cell and place cellulose disks at the bottom and top of the mixture. Use a hammer to slightly compact the mixture.
4. Place extraction cells into autosampler tray on an ASE Accelerated Solvent Extractor and run the cycle (machine must be set at 100°C and 1500 psi).
   a. R1 / R2 must contain empty bottles
   b. Align the cell with empty bottle
   c. Open the nitrogen tank before turning machine on
   d. Press “system status” then “rinse” to prepare machine
   e. Once it is done prepping, it will say “idle”
   f. Press “start” to run cycle
   g. Check machine every 5-10 minutes ensure cycle is running smoothly
   h. Ensure nitrogen tank and machine are turned off after cycle is done.

To run the RapidVap by Labconco:
1. After the samples are ran in the ASE machine, place each sample in a glass cylinder and run the sample through a rapid evaporator until there is approximately 10 milliliters of sample remaining.

To prepare the samples for the 5973Network Mass Selective Detector by Agilent Technologies:

1. Prepare a blank sample
   a. Use a syringe to transfer one milliliter (mL) of the internal standard into the sample vial

2. Transfer samples to vials
   a. Use a syringe to transfer one milliliter (mL) of the sample from the RapidVap and five microliters (µL) of the internal standard into a sample vial
   b. Rinse syringes with hexane acetone (C₉H₂₀O) three times between samples

To run the 5973Network Mass Selective Detector by Agilent Technologies:

1. Collect 1 mL of sample in a vial and run sample in gas chromatograph-mass spectrometer
   a. Align blank sample in slot 1
   b. Insert sample vial into slot 2
   c. Open “Instrument #2” program file from desktop
   d. Select “Run” and create file destination
   e. Start scan and allow to run for 24 hours

2. Extract results from instrument program
a. Open “Instrument #2” program file from desktop

b. Select “File” > “Load data file” > “File Name” to open gas chromatograph

c. Select “Spectrum” > “Library search report” > “Screen” to export scan summary

d. Reduce scan summary data to include only those with quality of 60% or higher.

VI. Results

A sampling program was conducted using the preliminary sampling design at five locations in Houma, LA (Figure 7.0), one location in Baton Rouge (30.42697, -91.16982), and six locations in New Orleans (Figure 8.0) during a six-month period. The objective of this sampling program was to examine the effectiveness of the XAD resin to capture target and non-target SVOCs in communities of interest. The target contaminants were a list of pyrogenic (combustion originating) and petrogenic (crude oil origin) PAHs.

Figure 7.0: Houma Sampling Locations (Base Map: Google Earth)
Before air concentrations were computed, the passive sampling rate (PSR) (Equation 1.0) was calculated using local meteorological parameters for each sample: T, temperature (K); P, pressure (hPa); and v, wind speed (m/s) (Gong, 2017).

$$PSR = \left(0.16 \frac{T^{1.75}}{P} - 2.07\right) e^{0.92v - 2.12}$$  

Equation 1.0

Meteorological parameters varied between cities and between samples. All meteorological parameters were gathered from Weather Atlas (Weather Atlas, 2022). In Houma, for Samples 1 and 2, data used for temperature, pressure, and wind speed were 318.15 K, 1014 hPa, and 3.82 m/s, and for Samples 3-6, 323.15 K, 1014 hPa, and 4.25 m/s, respectively. For Sample 1 from Baton Rouge, data used for temperature, pressure, and wind speed were 327.15 K, 1014 hPa, and 2.52 m/s, and Sample 2 used 317.15 K, 1014 hPa, and 2.81 m/s, respectively. For Samples 1 and 2 from New Orleans, data used for temperature, pressure, and wind speed were 318.82 K, 1014 hPa, and 4.29 m/s, respectively. Sampling rates can be found in Table 1.0.

Table 1.0: Passive Sampling Rates (m$^3$/day)

| Location/Sample # | Houma 1-2 | Houma 3-6 | Baton Rouge 1 | Baton Rouge 2 | New Orleans 1-2 | New Orleans 3-5 |
Equation 2.0 was then used to calculate the concentrations of target-specific chemicals in the air (Table 2.0) (Gong, 2017).

\[ PSR = \frac{APAS}{C_{air}t} \quad \text{Equation } 2.0 \]

Where \( APAS \) is the amount of persistent organic pollutants (POP) found in the XAD (pg/sample), \( t \) is the sampling duration in days, and \( C_{air} \) (pg/m\(^3\)) is the gas phase concentration of the POP sorbed by the XAD during the sampling period. Gas-phase concentrations for target chemicals are summarized in Table 2.0.

Table 2.0: Gas-phase Concentrations of Target Chemicals [mg/m\(^3\)]

<table>
<thead>
<tr>
<th>Location/ Sample #</th>
<th>Naphthalene</th>
<th>C3-dibenzothiophenes</th>
<th>C4-phenanthrenes</th>
<th>C1-chrysenes</th>
<th>C2-chrysenes</th>
<th>C3-chrysenes</th>
<th>Benzo(a)pyrene</th>
<th>Hopanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houma 1</td>
<td>NA</td>
<td>2.38E-05</td>
<td>1.01E-04</td>
<td>7.89E-04</td>
<td>6.59E-05</td>
<td>3.60E-05</td>
<td>2.23E-03</td>
<td>NA</td>
</tr>
<tr>
<td>Houma 2</td>
<td>1.26E-01</td>
<td>8.60E-05</td>
<td>2.81E-05</td>
<td>1.00E-04</td>
<td>6.29E-05</td>
<td>3.11E-05</td>
<td>4.41E-03</td>
<td>NA</td>
</tr>
<tr>
<td>Houma 5</td>
<td>8.22E-01</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Baton Rouge 1</td>
<td>6.08E-03</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Baton Rouge 2</td>
<td>NA</td>
<td>NA</td>
<td>3.12E-04</td>
<td>2.43E-02</td>
<td>1.01E-03</td>
<td>9.36E-04</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>New Orleans 1</td>
<td>2.52E-02</td>
<td>1.68E-04</td>
<td>2.43E-06</td>
<td>6.48E-06</td>
<td>9.12E-06</td>
<td>1.32E-05</td>
<td>NA</td>
<td>6.04E-04</td>
</tr>
<tr>
<td>New Orleans 2</td>
<td>NA</td>
<td>1.66E-04</td>
<td>1.13E-05</td>
<td>1.30E-05</td>
<td>7.29E-06</td>
<td>1.13E-05</td>
<td>NA</td>
<td>1.86E-04</td>
</tr>
<tr>
<td>New Orleans 3</td>
<td>NA</td>
<td>6.15E-04</td>
<td>4.49E-06</td>
<td>2.45E-04</td>
<td>1.89E-05</td>
<td>7.62E-06</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>New Orleans 4</td>
<td>NA</td>
<td>1.27E-05</td>
<td>1.98E-06</td>
<td>6.23E-05</td>
<td>1.37E-05</td>
<td>6.85E-06</td>
<td>NA</td>
<td>5.39E-04</td>
</tr>
</tbody>
</table>

Samples 3, 4, and 6 from Houma did not produce target-specific results, as well as Sample 5 from New Orleans. In Houma, Sample 1 was collected on the outside of a home December 10, 2021 through January 16, 2022; Samples 2 and 6 were collected inside of a severely damaged home from December 10, 2021 through January 16, 2022; and...
Samples 3-5 were collected from February 24, 2022 through March 3, 2022 outside of three businesses within highly-populated areas. In Baton Rouge, Samples 1 and 2 were collected from underneath the I-10 overpass on Dalrymple Dr. from October 29, 2021 to November 1, 2021 and December 13, 2021 to December 17, 2021, respectively. Sample 1 was collected to ensure XAD-2 resin was capable of detecting SVOCs in the air. Naphthalene was detected in this sample and is classified as a SVOC and PAH, which proves the capability of XAD-2 in detecting the target chemicals. Sample 2 was collected to verify Sample 1’s results. In New Orleans, Samples 1 and 2 were deployed in New Orleans from December 14, 2021 through February 25, 2022, and Samples 3-6 were deployed from March 9, 2022 to March 25, 2022. On March 22, 2022, the Lower 9th Ward District experienced severe thunderstorms, which produced a tornado. Following this extreme weather event, only three samplers were found. The use of internal standards on the gas chromatograph allowed for quantitative reports that included concentration values for the specific compounds listed in Table 2.0, and an additional library search report included a list of chemical matches with a quality ranging from 1-100%. Significant (2 or more locations sharing a chemical) non-target chemicals with a 95% match or over are summarized in Table 3.0.

Table 3.0: Significant Non-Target Chemicals with 95% or over match

<table>
<thead>
<tr>
<th>Location/Sample #</th>
<th>Houma 1 &amp; 3</th>
<th>Houma 2</th>
<th>Houma 4</th>
<th>Baton Rouge 1</th>
<th>Baton Rouge 2</th>
<th>New Orleans 1-2</th>
<th>New Orleans 3-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
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</tbody>
</table>

VII. Discussion

In all samples collected from Houma, Baton Rouge, and New Orleans, a particular category of SVOCs, PAHs, which are byproducts of the combustion of oil and similar
sources, were overwhelmingly present (CDC, 2009). The results of New Orleans and Baton Rouge will not be analyzed further since that is not the focus of this paper; these results were used to represent data from two major cities in South Louisiana. All compounds with detected concentrations that were found in Houma were PAHs. PAHs represent the largest percentage of pathogenic ultrafine particles, and the most notable sources of PAHs found in urban areas are gasoline aromatics (Mishra et al., 2016). PAHs are known to be extremely dangerous to humans since they are known human carcinogens and can easily mutate (Patel et al., 2020). The EPA’s list of sixteen most highly concentrated PAHs include Naphthalene \( \text{C}_{10}\text{H}_{8} \), Acenaphthene \( \text{C}_{12}\text{H}_{10} \), Acenaphthylene \( \text{C}_{12}\text{H}_{8} \), Anthracene \( \text{C}_{14}\text{H}_{10} \), Phenanthrene \( \text{C}_{14}\text{H}_{10} \), Fluorene \( \text{C}_{13}\text{H}_{10} \), Fluoranthene \( \text{C}_{16}\text{H}_{10} \), Benzo(a)anthracene \( \text{C}_{20}\text{H}_{12} \), Chrysene \( \text{C}_{18}\text{H}_{12} \), Pyrene \( \text{C}_{16}\text{H}_{10} \), Benzo(a)pyrene \( \text{C}_{20}\text{H}_{12} \), Benzo(b)fluoranthene \( \text{C}_{20}\text{H}_{12} \), Benzo(k)fluoranthene \( \text{C}_{20}\text{H}_{12} \), Dibenz(a,h)anthracene \( \text{C}_{22}\text{H}_{14} \), Benzo(g,h,i)perylene \( \text{C}_{22}\text{H}_{12} \), and Indeno[1,2,3-cd]pyrene \( \text{C}_{22}\text{H}_{12} \) (Patel et al., 2020). Of the 16 priority PAHs listed by the EPA, four of those compounds were found in Houma: Naphthalene, Benzo(a)pyrene, Chrysenes, and Phenanthrenes.

Naphthalene was found at the highest concentration of any SVOC in Houma in two samples: Sample 2 and Sample 5. Naphthalene is classified as a Group C carcinogenic risk, meaning it is a possible human carcinogen (Buckpitt et al., 2010). Humans can be exposed to naphthalene by all three exposure routes: inhalation, ingestion, and dermal contact. There are a variety of symptoms associated with short-term exposure to naphthalene: headache, confusion, general feeling of unease, nausea, abdominal pain, irritation in bladder, jaundice, hematuria, dermatitis, and corneal damage (NIOSH,
The main target organs of naphthalene exposure are the eyes, skin, blood, liver, kidneys, and central nervous system (NIOSH, 2019b). Naphthalene is present in urban air at an average concentration of 0.18 ppb. From the National Institute for Occupational Safety and Health (NIOSH), the immediately dangerous to life or health (IDLH) value is 250 ppm. All samples produced air concentrations below the IDLH value, but all reported naphthalene concentrations exceed 0.18 ppb. In Sample 5 from Houma, the concentration of naphthalene in air was 160 ppb, and Sample 2 had a concentration of 24 ppb. Sample 1 from New Orleans had a naphthalene concentration of 5 ppb. Although Houma is an industrial area, Naphthalene could be present in these high concentrations near residential due to the historical uses of the compound in household products such as mothballs.

All other SVOCs and PAHs found in Houma, excluding dibenzothiophene, are known as coal tar pitch volatiles (CTPVs). CTPVs become present in the air once coal tar pitch, a dark-colored residue with no defined shape, reaches its melting point (OSHA, n.d.). CTPVs can be exposed to humans through inhalation or dermal contact (NIOSH, 2019a). CTPVs target the respiratory system, skin, bladder and kidneys, and produce symptoms such as dermatitis and bronchitis. CTPVs are a known human carcinogen with lungs, kidneys, and the skin as possible cancer sites. According to NIOSH, the Occupational Safety and Health Administration’s (OSHA) permissible exposure limit (PEL) of CTPVs, which is based on a time weighted average (TWA) of 8 hours during a 40-hour work week is 0.2 mg/m³ (NIOSH, 2019a). The NIOSH regulatory exposure limit (REL), which is based on a TWA of 10 hours during a 40-hour work week is 0.1 mg/m³ (NIOSH, 2019a). The IDLH value for CTPVs is 80 mg/m³ (NIOSH, 2019a). Although several CTPVs were found in each sample, no concentrations exceeded any regulations.
Using the EPA’s Enforcement and Compliance History Online (ECHO) database, possible source identifications can be found. Within Houma’s zip code of 70360, there are 42 active facilities with ICIS-Air IDs for stationary sources of air pollution. These companies are monitored by the EPA to ensure they remain in compliance, and the data is reported for public use. Of the 42 facilities with ICIS-Air IDs, there is one major industrial facility: the Houma Generating Station. This facility emits a variety of chemicals such as VOCs and naphthalene. The second largest industrial area in Houma has a zip code of 70363. This area has 298 facilities with 68 of those having ICIS-Air ICIDs. There are five major industrial facilities in this area: Eugene Island, Gulf Island Fabrication Inc, LaShip LLC, North American Fabricators LLC, and the Terrebonne Parish Consolidated Government. Contaminants emitted by these facilities include Naphthalene, PAHs, and VOCs. Based on the results found in the sampler, possible source identifications could be made.

Since South Louisiana is an industrial area, it is difficult to pinpoint a specific source of these compounds. However, one theory is the use of portable generators as a primary source of electricity during a lengthened period of time following Hurricane Ida, similar to Puerto Rico following Hurricane Maria. Portable generators are essentially internal combustion engines that generate power temporarily, especially in the aftermath of a natural disaster (Subramanian et al., 2018). PAHs are emitted into the environment through multiple natural sources, such as volcanic eruptions, but they produce PAHs in smaller concentration with little effect on air quality (Patel et al., 2020). Several anthropogenic sources are the main cause of PAH pollution: industrial, mobile, domestic, and agricultural emissions. One of these stands out as a major factor in damaging air
quality following a hurricane: mobile sources. While mobile emissions refer to the
exhaust of automobiles and other forms of transportation, it is important to note the type
of engine an automobile has: an internal combustion engine (Baimatova et al., 2017).
Since automobiles and generators are made up of the same type of engine, it can be
assumed they have a similar impact on air quality, only at different scales. The samples
taken from Cenac Marine Services and Houma Paint and Industrial Supply did not detect
notable concentration of PAHs. However, immediately following Hurricane Ida, these
businesses, as well as most around them, did not operate while the city was being cleaned
up and power had yet to be restored. These facilities were not exposed to the emissions of
portable generators like many residential buildings were since they were not commonly
used in this area. Automobile exhaust fumes were also lower at this time due to the
majority of residents being unable to work and the shortage of gas. Since several months
have gone by since Hurricane Ida made landfall, the use of portable generators as a
primary source of power is almost nonexistent since the energy grid has been repaired. If
another round of sampling was completed PAH emissions had decreased, it could be
concluded that generators did alter the air quality from extended use.

Another possible source for the contaminants found in Houma are contaminants
that have been contained in enclosed spaces throughout buildings, becoming exposed
from damage caused by Hurricane Ida. These contaminants would have also been
exposed to high temperatures due to the lack of electricity and air conditions inside of
buildings immediately following the storm, increasing their emissions into the ambient
air.
Hundreds of non-target compounds were detected in the qualitative report in terms of quality. These compounds can be used to identify contaminants of concern, but their concentration is not available without the use of an internal standard corresponding to a specific compound. However, the knowledge of constituents in the air is still very valuable and can be connected to possible sources of pollution. The most common and concerning chemical found on the qualitative reports was Benzene, found in every sample except Sample 4 from Houma. Benzene is a known human carcinogen which can be exposed through inhalation, dermal contact, and ingestion and can be found in products made from coal and petroleum (Benzene). Octadecene was found in Sample 4 from Houma, Sample 2 from Baton Rouge, and Samples 1 and 2 from New Orleans. Octadecene hazards or uses have not been fully investigated according to the Fischer Scientific Safety Data Sheet (Material Safety Data Sheet, 2004). Phenol was found in Sample 2 from Houma and Samples 1 and 2 from New Orleans. Phenol is not a carcinogen, but presents a hazard when any amount is ingested, contacted with the skin at 5 ppm, or inhaled with an IDLH of 250 ppm (Phenol). Phenol is widely used in industries – it is used for medicine as a slimicide, antiseptic, and disinfectant, and used to manufacture products, there are many possible sources (Phenol).

Gas chromatographs were drawn and auto-integrated to show the abundance of contaminant at specified residence times. The particles in the mass spectrometer were broken down into chemical shapes to determine what non-target compounds were present. Figures 10.0-14.0 show chromatographs for a blank sample and Sample 2 from Houma.
Figure 10.0: Chromatograph for Blank Sample

Figure 11.0: Auto-Integrated Chromatograph for Blank Sample
Figure 12.0: Chromatograph for Sample 2 From Houma
The major concern that remains in Houma is at what extent were residents exposed to these dangerous concentrations of PAHs, especially around their homes. The majority of PAHs are carcinogenic, so they do present a major threat to the health of Houma’s residents. It will be important to spread awareness of these findings to inform residents of what they were exposed to.
Since the final design of the sampler has not been able to be deployed for a significant period of time, a few issues may arise. As the sampler is constructed of aluminum some corrosion might occur with long term exposure to the elements. To mitigate these challenges a protective coating could be applied to the exterior of the sampler before deployment. Additionally, when possible, the sampler’s exterior should be wiped dry after rain events.

VIII. Full Scale Design

A growing movement to increase knowledge of air quality in urban environments is the idea of placing low-cost air monitors in specific locations to determine a pattern of contaminants in the ambient air. Since South Louisiana is an industrial area, a sampler design was needed that matched the environment and climate. Since South Louisiana experiences high-temperatures year-round, is susceptible to high-velocity winds due to proximity to the Gulf Coast, and a high volume of cold fronts in the winter, the sampler was designed to have a shelter capable of withstanding the Southern climate and prevent the XAD-2 from being expelled into the air. A full-scale use for the designed sampler would be to place a network of low-cost samplers within a specific geographical area. The network could consist of ten samplers or more, depending on the size of the area of concern. An example of the full-scale design could be used in New Orleans. In the outdoor air sampling that occurred in Puerto Rico following Hurricane Maria, 5 passive air samplers were deployed in the SJMA and sulfur dioxide, carbon dioxide, and black carbon were identified in significant concentrations (Subramanian et al., 2018). The SJMA has an area of approximately 5.94 km$^2$. The Lower 9$^{th}$ Ward District and Irish Channel District have a combined area of approximately 8.97 km$^2$. Since the area of
concern in New Orleans is roughly twice the size of the SJMA, ten samplers would be ideal to get sufficient results and remain at the lowest possible cost of approximately $926.50, excluding labor. To use this design within an entire community, samplers would need to be deployed at similar times in strategic locations to represent a scatter plot. Prior to deployment, residents would be interviewed for health and odor surveys. If residents are overwhelmingly concerned over a specific industrial facility, target-chemicals can be specified prior to sampling based on contaminants emitted or stored by that facility. After surveys are complete, locations for the sampling network can be determined based on the residents’ willingness to host a sampler. Potential sources can also be identified from the EPA National Emissions Inventory based off survey feedback and industrial facilities’ proximity to neighborhood. Once all preliminary surveys and research are conducted, the samplers would be deployed to identify initial target and non-target contaminants. After analyzing the results from those samplers, the direction of possible sources of contaminants could be determined.

An implementation of the full-scale design is modeled in Figure 15.0. The white circles represent samplers within a 10-unit community that contained low concentrations of a compound emitted by a neighboring facility, which is represented by the blue rectangle. The blue circles represent samplers that contained high concentrations of chemicals found at the same facility. From this information, it would be straightforward to determine that the probable source of pollution in the area is the facility. A remediation plan can then be developed between the point source facility, community, and relevant government agencies to ensure appropriate permits were obtained and regulations are being upheld.
IX. Cost of the Final Design of Sampler

Table 4.0 lists each component of the sampler’s final design, and their associated costs.

Table 4.0 Breakdown of Raw Materials

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Size/ Weight</th>
<th>Units per sampler</th>
<th>Cost per unit</th>
<th>Product Page</th>
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<tbody>
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</tr>
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</table>

Raw cost per sampler $92.65

X. Community Relations Acceptance Plan

When this design is implemented within an entire neighborhood, community involvement will be continued as it was during preliminary sampling, except on a wider scale. To have a successful project, following sampling and analyzation of results, the public should be made aware of the extent of contaminants present in their community. During the New Orleans sampling, Beth Butler, exposed our group to her Louisiana-based non-profit, A Community Voice, which gave us insight on the work the group has
done to increase social and economic justice. In Houma, we were able to talk to several residents eager to have their air sampled in response to a catastrophic natural disaster. Full-scale deployment of these samplers would involve mapping out a network to place numerous samplers in affected neighborhoods, and working alongside residents to reach their peers through word of mouth, Facebook, Twitter, and other social media platforms.

Prior to deployment, residents will be able to make suggestions to their local representatives if they feel their community is being neglected and should be added to the list of affected or vulnerable communities. Additionally, they will have access to lab results and be encouraged to voice complaints and concerns that may give us context as to where these contaminants are sourced from. Decision making will be handled by government legislators in conjunction with the recommendations of appropriate Louisiana State University faculty. By enlisting the community members to lend their unique home-field perspective to the research, their willingness to accept this proposal is more probable. Based on success rates in non-emergent situations, this design could be expanded to sample a community devasted by a natural disaster to ensure air quality has not been compromised.

XI. Conclusion

This design was inspired by residents in the New Orleans area submitting complaints of strange odors coming from industrial sites nearby their homes. In order to help track these odors, passive air samplers were constructed to detect SVOCs. The samplers that were deployed in the New Orleans and Baton Rouge area that detected a large number of SVOCs and PAHs in the air. After Hurricane Ida passed in Houma, the design was expanded to determine the effect of a natural disaster on air quality in indoor and outdoor
settings. Due to the large presence of PAHs in South Louisiana, remediation efforts should be considered to protect the health of these people. The United States Federal Government currently has regulations and controls in place for PAHs in air, water, and soil in the workplace (Abdel-Shafy & Mansour, 2016). Outside of the workplace, especially following naturally disaster, it is equally important to monitor PAH exposure to residents. Several efforts could be made to protect people year-round such as reducing PAH emissions from the oil and chemical industries, spreading public awareness about PAH exposure and resulting consequences, and adding further treatment and filtration methods to industrial processes (Abdel-Shafy & Mansour, 2016). For portable generators, particle traps and further restrictions can be placed on emissions starting in production that target PAHs, not just carbon monoxide.

XII. Sources

4 Health Effects of Mold from Water Damage. Retrieved December 3 from https://www.rmraz.com/4-health-effects-mold-water-damage/


