

**REPORT**  
**Faculty Mini-Grants for Educational Research**

**Project Title:** Class redesign for chemistry 375 – Principles of Environmental Monitoring

**Principle Investigator:** Yinfa Ma, Department of Chemistry  
Missouri University of Science and Technology  
Schenk Hall 320  
Phone: 573-341-6220  
E-mail: [Yinfa@mst.edu](mailto:Yinfa@mst.edu)

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## **Summary**

In this proposed study, we have integrated three field trips and three experiments into chemistry 375 course: (1) Field trip for water sampling, water sample collection, and analysis; (2) field trip for tree core analysis, tree core sampling and analysis to learn how to use tree as an environmental monitoring tool and how to use the results from tree core to predict the soil contamination level; (3) Field trip for air sampling, air sample collection, and organic component analyses. After samples were collected, the students, two students as a team, analyzed the samples using state-of-art instruments and they presented their data in the class about their finding. In addition, each student submitted a formal report in a journal format for grading. Through these activities, students claimed to learn a lot through these hand-on experiences and real-world sample collection and analysis. Comparing the pre-survey and post-class survey, the data clearly demonstrated that addition of these activities, including field trips, real sample collection and analyses, significantly enhanced student learning about how to conduct environmental monitoring. The data will be presented in this report.

## **Purpose of the Project**

*Background:* In the past, the chemistry 375 class was designed in the way that only lectures were delivered in the classroom and there were no field trips and experiments designed for the class. The lectures talked about governmental regulations on environmental issues, resources on environmental contaminations, and environmental monitoring on environmental contaminants to assure our citizens having a clean air, water, and soil. The class spent a lot of times on sampling (air, water, soil, plants, etc.), sample preparation, sample analysis with different types of analytical techniques, data analysis, quality control (QC) and quality assurance (QA), and reporting.

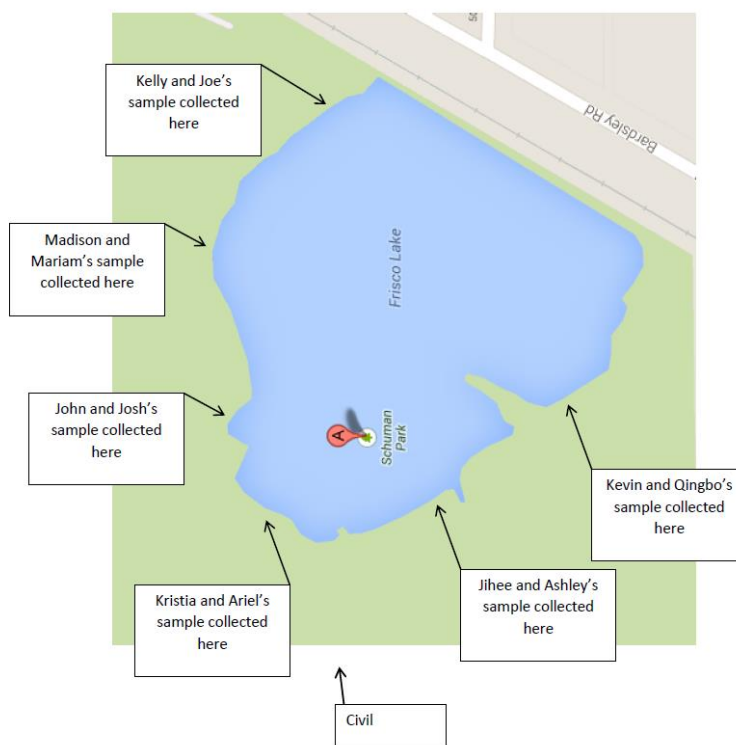
*The gap:* Most of the students in this class want to have careers that related to environmental monitoring or research. However, students are lack of knowledge on how to collect different types of samples to conduct environmental monitoring, what are the correct ways to prepare samples for environmental analysis. Most importantly, students do not know how to collect representative samples to make the data be representative to the real environmental situations. For example, when students walk to a lake to collect water samples, where the water samples shall be taken? How much samples shall be taken? How to preserve the samples? To provide students with real environmental sampling experiences, field trips should be designed to bring students to the real field to collect water samples and allow them to come back to the lab to analyze the interested environmental contaminants (for example, heavy metals, including mercury, lead, chromium, copper, nickel, etc. and organic compounds, such as pesticides and herbicides).

*Purpose of the project:* The purpose of this educational research project was to design three field trips, real world sample collections, and sample analysis (air, water, and tree core) to allow chemistry 375 students to conduct real environmental monitoring to prepare them to be ready for environmental monitoring for their future job force. The designed field trips, sample collection and analysis will be integrated into chemistry 375 class in the future.

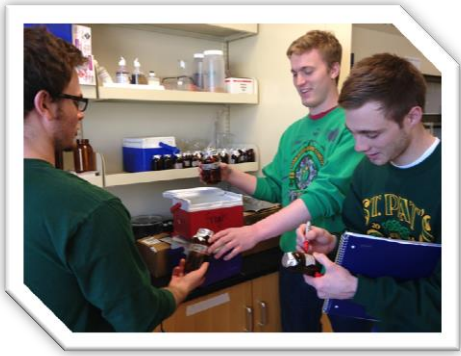
## Methodology

### **A. Field trip for water sampling, sample collection, and analysis.**

1. Site selection. Based on the water contamination level, Schuman Lake in Rolla was a great sampling site for water sampling and monitoring.
2. Sampling collection procedures and pre-sample collection preparation (detailed handout is attached at the end of the report as appendix 1). (1) Students must read the procedures carefully and design their experiments in details so that they understand where the water samples and how many samples will be collected, including field blanks and duplicates. (2) Students must prepare containers, glassware, and tools to get ready for sample collection before schedule field trip. (3) Students must conduct literature search to understand clearly what they will measure for the water samples and the characteristics of each chemicals they will measure to assure that the data they measure are valid.
3. Field trip and sample collection. The class is scheduled for all students to walk to Schumann Lake at the same time, and a brief lecture was given on how to collect representation water samples, field blanks, and duplicates. Different groups were asked to collect water samples at different locations, as shown in **Figure 1**. Some representative photos are shown in **Figure 2**. When students came back to Missouri S&T campus, they were also asked to collect water samples from campus water for result comparisons.



**Figure 1.** Schuman lake park water sampling sites and measured data in each group.



**Figure 2.** Representative photos of students collecting water samples at Schumann Lake.

4. Water sample analysis. Students conducted the experimental measurements for the water samples they collected by using state-of-art instruments (as shown in **Figure 3**):
  - Temperature
  - pH
  - Turbidity
  - Conductivity
  - Free chlorine (FC)
  - Total chlorine (TC)
  - Non-purgeable organic carbon (NPOC)
  - Total nitrogen (TN)



**Figure 3.** Instruments used for measuring NPOC, TN, and turbidity.

5. *Data analysis and report.* After data were collected from different instruments, students used appropriate software, such as Excel, to analyze the data and to find standard deviations of the data and compare with the data from other groups in the class. By the due time, all students were required to turn in their formal report for the water analysis. To enhance the communication skill, students are required to present their data in the front of their peers in the class. Examples of a formal report and a PPT presentation slides are attached in the appendix.

**B. Tree core sample analysis to monitor soil/water contamination.**

1. *Site selection.* Based on the possible soil/water contamination history and contamination level, the trees planted by Professor Joel Burken's research group were used for this study.





**Figure 4.** Field trip to the tree field and soil/water contamination well to explain how to use tree as a sensor to monitor the levels of local soil/water contamination.

2. Sampling collection procedures and pre-sample collection preparation (detailed handout is attached at the end of the report as appendix 2). (1) Students must read the procedures carefully and design their experiments in details so that they understand where the tree samples and how many samples will be collected, including field blanks and duplicates. (2) Students must prepare containers, glassware, and tools to get ready for tree core sample collection before schedule field trip. (3) Students must conduct literature search to understand clearly what they will measure for the tree core samples and the characteristics of volatile organic compounds (VOCs) they will measure to assure that the data they measure are valid. Some pictures of laboratory preparation for tree core sample collection are shown in **Figure 5**.



**Figure 5.** Laboratory preparation for tree core sample collection.

3. Field trip and sample collection. The class is scheduled for all students to walk to tree field that close to the Schumann Lake at the same time, and a brief lecture was given on how to collect tree core samples, field blanks, and duplicates. Different groups were asked to collect tree core samples from different types of trees, as shown in **Figure 6**.



**Figure 6.** Selected pictures of tree core sampling.

4. Tree core sample analysis. Students conducted the experimental measurements for the following VOCs for the tree core samples they collected by using state-of-art instruments (as shown in **Figure 7**):  
 cis-dichloroethene, (cDCE)  
 trichloroethene (TCE)  
 tetrachloroethene (PCE)



**Figure 7.** The Solid phase micro extraction – gas chromatography – mass spectrometer (SPME-GC-MS) instrument used for VOC analysis for the tree core samples.

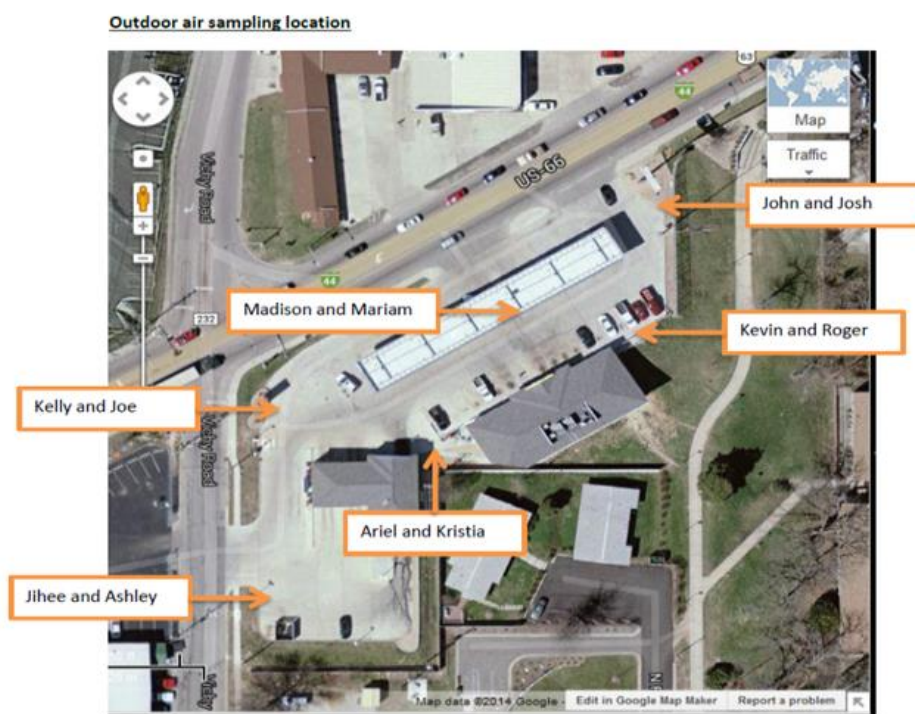
5. Data analysis and report. After data were collected from the sample analysis, students used appropriate software, such as Excel, to analyze the data and to find



standard deviations of the data and compare with the data from other groups in the class. By the due time, all students were required to turn in their formal report for the tree core analysis. To enhance the communication skill, students are required to present their data in the front of their peers in the class. Examples of a formal report and a PPT presentation slides are attached in the appendix.

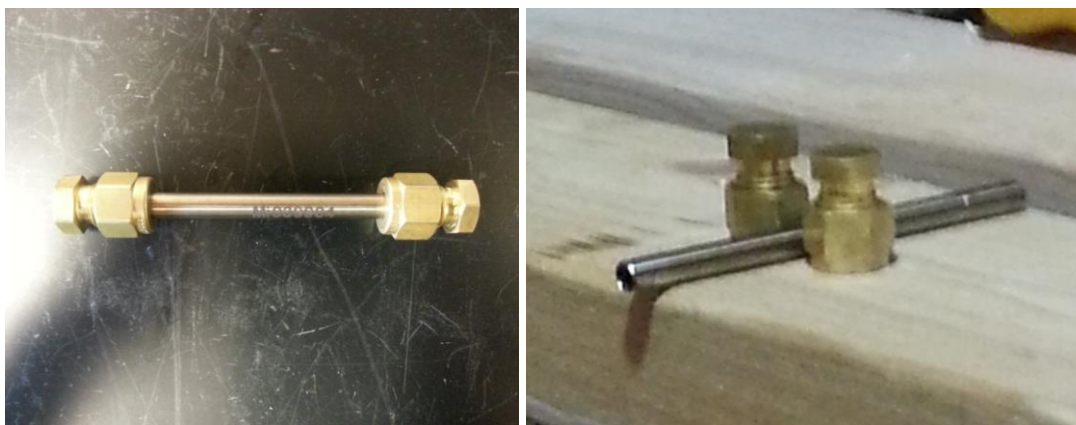
### C. Environmental Air Monitoring.

1. Site selection. Based on the nature of air pollution, two sapling sites were chosen: student's dormitory and one site close to a gas station. The site assignment for each group is shown in **Figure 8**.



**Figure 8.** Air sapling site for each student group (two students for each group).

2. Sampling collection procedures and pre-sample collection preparation (detailed handout is attached at the end of the report as appendix 3. (1) Students must read the procedures carefully and design their experiments in details so that they understand where the air samples and how many samples will be collected, including field blanks and duplicates. (2) Students must prepare their air sampling device for air sample collection before schedule field trip. (3) Students must conduct literature search to understand clearly what they will measure for the air samples and the characteristics of volatile organic compounds (VOCs) they may detect to assure that the data they measure are valid. The sampling device (the adsorption/thermo-desorption tube) for air is shown in **Figure 9**.



**Figure 9.** Adsorption/thermo-desorption air sampling device.

3. Field trip and sample collection. The class is scheduled for all students to walk to the sampling sites (as shown in Figure 8) in a gas station in Rolla at the same time. After a brief lecture was given to all students at one sampling site on how to collect air samples, field blanks, and duplicates, students walked to their specific sampling sites for air sampling.
5. Organic compound analysis. Students conducted the thermo-desorption- gas mass spectrometry (TD-GC-MS) to analyze the possible organic compounds in the air samples they have collected (as shown in **Figure 10**):



**Figure 10.** The TD-GC-MS used for organic compound analysis in the air samples.

5. Data analysis and report. After data were collected from the air sample analysis, students used appropriate software, such as Excel, to analyze the data and to find standard deviations of the data and compare with the data from other groups in the class. By the due time, all students were required to turn in their formal report for the air sample analysis. To enhance the communication skill, students are required to present their data in the front of their peers in the class. Examples of a formal report and a PPT presentation slides are attached in the appendix.

## **Results**

After these three designed field trips, sample collection, sample analysis, formal report, and classroom presentation of their experimental data, students claimed that they have learned tremendous information and knowledge on environmental monitoring. These hand-on experiences helped them greatly on understanding the class lectures. The pre-class survey and post-class survey results are attached in the appendix for review. Here are the brief data obtained for each experiment.

### **1. Water sample collected from Schumann Lake (as shown in Table 1 and 2).**

**Table 1.** Data comparison for the tap water samples from different groups.

<b>Tap Water</b>					
<b>Group</b>	<b>Sample ID</b>	<b>Temperature (°C)</b>	<b>pH</b>	<b>Turbidity (NTU)</b>	<b>Conductivity (μS)</b>
<b>Jihee and Ashley</b>	Tap	21.0	7.30	0.26	440
	Tap Dup	20.9	7.26	0.14	430
	% Difference	0.48%	0.55%	60.0%	2.30%
	Tap FB	22.9	7.51	0.01	6.11
<b>John And Josh</b>	Tap	19.9	7.40	0.08	437
	Tap Dup	20.9	7.48	0.16	438
	% Difference	4.90%	1.08%	66.7%	0.23%
	Tap FB	21.3	8.36	0.05	1.83
<b>Kristia and Ariel</b>	Tap	7.5	7.30	0.03	487
	Tap Dup	7.6	7.31	0.05	475
	% Difference	1.32%	0.14%	50.0%	2.49%
	Tap FB	7.20	8.28	0.11	1.49
<b>Kelly and Joe</b>	Tap	25.0	7.44	0.06	435
	Tap Dup	25.0	7.45	0.01	432
	% Difference	0.00%	0.13%	143%	0.69%
	Tap FB	25.0	6.53	0.01	1.36
<b>Kevin and Qingbo</b>	Tap	14.6	7.32	0.01	461
	Tap Dup	13.1	7.36	0.01	463
	% Difference	10.8%	0.54%	0.00%	0.43%
	Tap FB	23.6	6.10	0.03	1.22
<b>Madison and Mariam</b>	Tap	15.8	7.41	0.65	460
	Tap Dup	15.8	7.32	0.47	458
	% Difference	0.00%	1.22%	32.1%	0.44%
	Tap FB	22.7	6.68	0.16	2.98

**Table 2.** Data comparison for the Schumann water samples from different groups.

<b>Schuman Lake</b>								
<b>Group</b>	<b>Sample ID</b>	<b>Temperature (°C)</b>	<b>pH</b>	<b>Turbidity (NTU)</b>	<b>Conductivity (µS)</b>			
<b>Jihee and Ashley</b>	SL	16.3	7.01	3.79	448			
	SL Dup	15.3	7.05	4.11	457			
	% Difference	6.33%	0.57%	8.10%	1.99%			
	SL FB	19.9	7.35	0.02	8.83			
<b>John And Josh</b>	SL	16.0	7.06	1.42	604			
	SL Dup	18.5	7.01	1.56	598			
	% Difference	14.5%	0.71%	9.40%	1.00%			
	SL FB	20.2	7.71	0.15	1.56			
<b>Kristia and Ariel</b>	SL	7.4	7.17	3.64	530			
	SL Dup	7.8	7.22	3.59	528			
	% Difference	5.26%	0.69%	1.38%	0.38%			
	SL FB	6.80	6.88	0.14	6.63			
<b>Kelly and Joe</b>	SL	25.0	7.50	2.16	477			
	SL Dup	25.0	7.57	2.11	479			
	% Difference	0.00%	0.93%	2.34%	0.42%			
	SL FB	25.0	5.90	0.01	1.41			
<b>Kevin and Qingbo</b>	SL	17.2	7.70	2.27	464			
	SL Dup	16.0	7.67	2.44	468			
	% Difference	7.23%	0.39%	7.22%	0.86%			
	SL FB	24.3	6.30	0.18	1.25			
<b>Madison and Mariam</b>	SL	15.5	7.67	3.36	515			
	SL Dup	15.2	7.69	3.68	517			
	% Difference	1.95%	0.26%	9.09%	0.39%			
	SL FB	22.6	6.78	0.01	16.72			
Sample	Temperature (°C)	pH	Turbidity	Conductivity	FC	TC	NPOC	TN
Jihee & Ashley	15.8	7.03	3.95	452.5	0.035	0.045	2.759	0.2068
John & Josh	17.25	7.035	1.49	601	0.035	0.385	2.02215	0.130155
Kristia & Ariel	7.6	7.195	3.615	529	0.03	0.03	2.585	0.16905
Kelly & Joe	25	7.535	2.135	478	0.03	0.02	2.439	0.153
Madison & Mariam	15.35	7.68	3.52	516	0.025	0.01	2.462	0.18215

From these data, we can see clearly that the data from all groups are quite close which means that all of them have done a great work for their sample analysis.



2. Tree core sample analysis data (as shown in Table 3).

**Table 3.** Data comparison for the tree core sample analysis data from different groups.

Tree Core					
Sample ID		Tree Type	cDCE (ppb)	TCE (ppb)	PCE (ppb)
Tree Core 1	Ashley Ash	Ash	ND	0.0016	0.0001
	John Ash	Ash	ND	ND	0.0001
	KLC Ash	Ash	ND	0.0138	0.0265
	MA 1	Ash	ND	0.0029	0.0128
	Ariel Ash	Ash	7.24	0.0425	0.0104
	Kristia 1	Black Walnut	ND	ND	0.0353
	KW Oak	Oak	ND	ND	0.0003
Tree Core 2	Ashley Oak	Oak	ND	ND	0.0004
	John Oak	Oak	ND	ND	0.0003
	KLC Oak	Oak	ND	ND	0.0005
	Kristia 2	Oak	ND	ND	0.0004
	Ariel Oak	Oak	ND	0.0142	0.0004
	MA 2	Oak	2.51	ND	0.0143
	JB	Oak	ND	ND	0.0075
Blank			ND	ND	ND

3. Air sample analysis data (for indoor and outdoor) (as shown in Table 4 and Table 5).

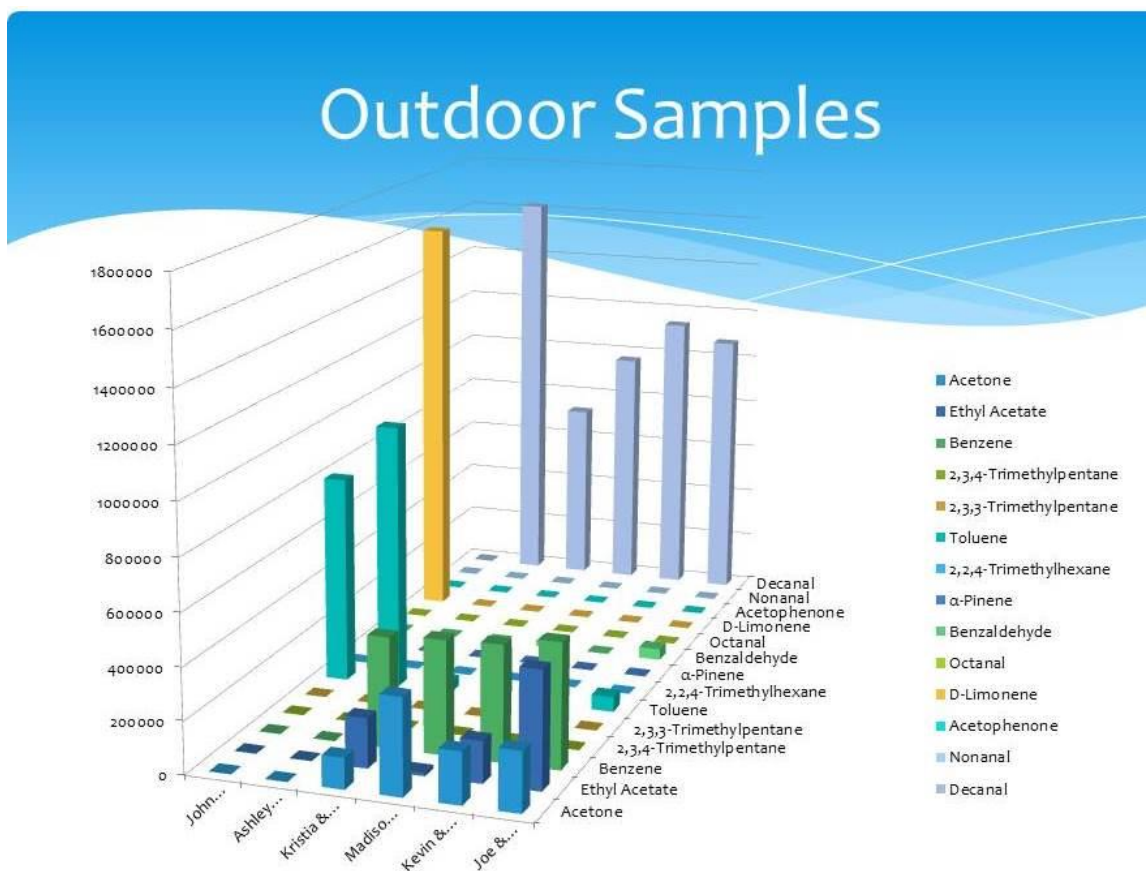
**Table 4.** Data comparison for the indoor air sample analysis data from different groups.

Analyst	Indoor Location	Acetone	Ethyl Acetate	Benzene	2,3,4-Trimethylpentane	2,2,3-Trimethylpentane	2,2,4-Trimethylhexane	Toluene	$\alpha$ -Pinene	Octanane	D-Limonene	Acetophenone	Ethyl Acetate	Nonanal	Decanal
John	Basement						X			X					
Ashley	Bedroom				X		X								X
Kristia	Laundry Room	X	X	X	X		X			X		X			X
Madison	Car	X	X	X			X					X			X
Mariam	Living Room	X	X	X			X					X			X
Ariel	Bedroom	X	X				X			X		X			X
Belinda	Closet						X			X					
Kevin	Car	X	X	X			X								X
Josh	Laundry Room	X	X	X			X		X	X		X			X
Roger	Mass-Spec Exhaust	X	X		X		X	X					X	X	X
Joseph	Bedroom	X	X	X			X		X			X			X
Kelly	Lounge	X	X	X			X								X

**Table 5.** Data comparison for the outdoor air sample analysis data from different groups.

Location	Acetone	Ethyl Acetate	Benzene	Toluene	Benzaldehyde	D-Limonene	Decanal
1	ND	ND	ND	1028957	ND	ND	1619896
2	118484	189604	422635	42938	ND	ND	723347
3	228364	447186	478863	58952	44166	ND	1075406
4	368112	12522	436762	177095	20480	ND	968316
5	198356	159143	443830	48110	ND	ND	1139587
6	ND	ND	ND	805403	ND	1600406	ND

For clarity, the outdoor air analysis results are also shown in **Figure 11**.



**Figure 11.** Data comparison for the outdoor air sample analysis data from different groups

## **Conclusions**

Through these three designed field trips, real-world sample collection and analysis, formal report and classroom presentations, the students in the class truly understand how to conduct environmental monitoring for contaminated water, air, and soil samples (using tree core). These experiments also enhanced significantly on their communication skills through classroom presentations and formal reports.

## **Future Implications**

These experimental designs will definitely be integrated into chemistry 375 class teaching if I am the instructor. If any other chemistry professors teach this class, the information, including field trip, sample collection, sample analysis, data analysis, formal report and presentations, will be transferred to the professor who will teach this class. I will be willing to help the professor to integrate these active learning activities into his/her lectures (and give him/her all of the notes I have for the class).

## **Plans for Further Dissemination**

Based on the data we have collected, we are in the processing to write two manuscripts to be submitted to *Journal of Chemical Education* or similar journals for publication. In addition, we will present our data at local or national conferences next year, such as *Pittsburgh Conference* or *American Chemical Society annual meetings*.

# Appendix

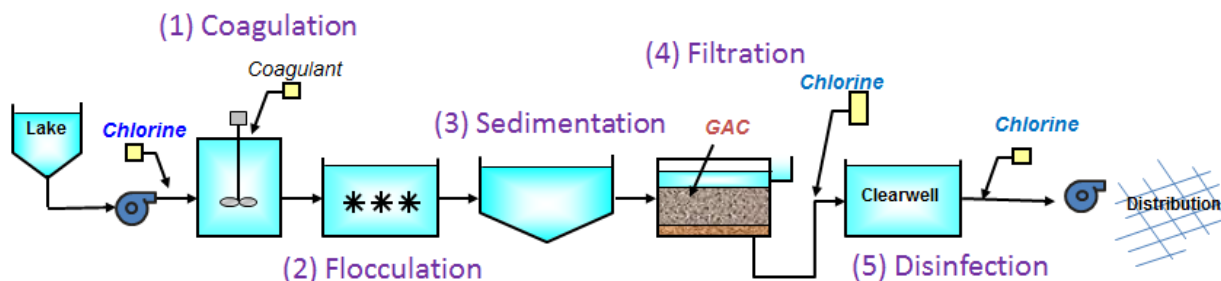
1. Handout for Experiment 1 - Drinking Water Monitoring
2. Handout for Experiment 2 – Tree core sample analysis to monitor soil/water contamination
3. Handout for Experiment 3 - Environmental Air Monitoring
4. Formal report for water sample analysis
5. Formal report for tree core sample analysis
6. Formal report for air sample analysis
7. A representative class room presentation slides for water and tree core analysis
8. A representative class room presentation slides for air sample analysis
9. Pre-course survey results
10. Post-course survey results



## Experiment 1 - Drinking Water Monitoring

### Introduction:

Drinking water monitoring is crucial to ensure the safety of public health; however, it is just as important to balance protection from microbial contaminants and disinfection by-products (DBPs). For this reason, the United States Environmental Protection Agency (USEPA) regulates the nation's public drinking water supply by the Safe Drinking Water Act (SDWA) to protect the public's health. A schematic of a drinking water treatment process is given below. The source water of each treatment plant is just as important as the treatment process. If the source water is pristine, and there is no contamination of the water throughout the treatment plant, the treatment process will produce drinking water within compliance set by the EPA. However, water sources are not pristine; they may contain chemicals from runoff, industrial and municipal discharge, leaching, etc. which may produce DBPs that are harmful to human health. The common water treatment procedures are as following:



**Coagulation** – destabilizes colloidal and fine suspended solids; initial aggregation of particles

**Flocculation** – gentle agitation to aggregate destabilized particles; form larger and rapid settling flocs

**Sedimentation** – settle out flocs and some dispersed particles

**Filtration** – retain particles through sedimentation, straining, flocculation, and interception mechanisms of sand filter

**Disinfection** – to control microbial contaminants in drinking water

### Pre-collection:

Preparation of collection materials is mandatory when collecting water, even more so when on-site testing is being performed. When the samples return to lab, it is also important to

have an idea of where the concentration of the monitored parameters and contaminants are to enhance, simplify, quicken, and reduce cost of the analyses. For this reason, you are to electronically submit the answers for the questions stated below by the deadline assigned.

There are many different parameters of water that can be characterized, for example: pH, UV-Vis, conductivity, turbidity, free chlorine (FC), total chlorine (TC), free ammonia, monochloramine (MCA), nonpurgable organic compounds (NPOC), total nitrogen (TN), trace metal elements, major anions, and regulated and unregulated contaminants. For each water sample collected you will be responsible for monitoring pH, UV-Vis, conductivity, turbidity, FC, and TC.

1. Why must the sample be filtered for monitoring parameters such as FC and TC?
2. How do you calibrate a pH meter to prepare for sample analysis if you anticipate the pH to measure around pH 7.9? (I.e. how many (and which) standards do you use to calibrate the probe?)
3. FC and TC are measured by utilizing a HACH kit pillow, and the spectrophotometric monitoring technique has a detection range of 0.02 to 2.00 mg/L Cl<sub>2</sub>. To minimize your measurement time and consumption of reagent pillows, research the approximate FC residue you plan to see in both water samples and discuss why ( you will collect water samples from Schuman Lake and tap water from Missouri S&T campus).

### **Collection:**

The water monitored in this collection consists of two different sources to provide you a foundation of understanding of the water you are drinking here on campus. For one of the collections we will travel out into the field to collect Schuman Lake water to demonstrate untreated water. The other water source can be any drinking fountain on campus that you wish to monitor. I suggest one person to monitor the filtered and another to monitor the unfiltered drinking fountains in Schrenk to see if there can be any observed differences between the two.

Monitoring in the field requires a field blank sample, consisting of ultrapure lab water, which is brought into the field and exposed to the collection area to provide a background and ensure no contamination by the field site. Duplicates of samples are required to ensure the sample is representative of the water source as well as the reproducibility of the detection method. Spiked samples are utilized to check recovery of the method, depending on the analyte monitored, an individual sample may need to be collected for this purpose. Different matrices result in different spike recovery. For example, surface water generally may result in lower spike recovery than ground water.

For a water collection, these are the steps that are followed. Bottles are cleaned according to the analyte specific method and baked in the oven to dry. The bottles are then capped to

prevent contamination. Some analytes require a quenching agent to prevent further reactions within the matrix to occur (ex. Nitrosamine require sodium thiosulfate, a dechlorinating agent, to be added to eliminate residual chlorine). The collection bottles are placed into coolers and transported to collection site. The field blank should be opened and placed on a safe surface while the samples are collected. If the sample is being taken from a spigot, it must be opened and allowed to equilibrate for three to five minutes, ensuring the sample taken is representative of the water being sampled. If the collection bottle does not contain a quenching agent, the bottle should be rinsed out once with the water sample being collected. Fill the bottle according to the analyte method. For example, if perchlorate is being analyzed within the water sample, the water sample must be collected in a separate bottle and then filtered with sterile syringe and surfactant free cellulose acetate filter into a sterile HDPE bottle, only filling the HDPE bottle two-thirds full as perchlorate is susceptible to microbiological degradation by anaerobic bacteria. Once your sample is collected, cap the sample and the field blank. If the sample contains a quenching agent, make sure to agitate the sample for 15 seconds. Pack the bottles securely back into the cooler and fill with ice (or frozen ice packs) and transport back to lab. Once the samples are back to lab, they must be immediately characterized and analyzed and placed in the refrigerator.

For this collection you will need the following bottles labeled as:

- Schuman lake
- Schuman lake duplicate
- field blank
- Tap water
- tap water duplicate
- field blank

Make sure to label your bottles with the sample name (above), date you will sample on, and your initials.

Day one of collection we will go out into the field and collect you water samples. Make note of where you collected your sample. Day two of collection you will characterize your water samples. The following characteristics must be analyzed on each sample, including the blank.

- pH, UV-Vis, conductivity, turbidity, FC, and TC

You will be responsible for placing your results neatly into an excel table and sending your results to Danielle. Danielle will collect and send out the results of all groups' data. In your report, make sure to discuss your results with the results of others. Be creative, such as mapping the results which were significant and different.

#### Post-collection:

Write up a report of your findings and compare the water sources. Did the results match what you expected to monitor? Detail what each characteristic measurement can tell you about the water you are monitoring. From the water characterizations performed, are there any

interferences or details that could cause error in your measurements – list two for each. What are the primary and secondary standards of drinking water, and what is regulated under each? Are any of the measurements you monitored for the water samples regulated under these standards? What are stage 1 and stage 2 of disinfectant by-product rules, and what is the major difference between them? Identify a drinking water DBP (regulated or unregulated, it can also be a group of DBPs) and the EPA method developed and approved to monitor. Provide an outline of sample preparation for DBPs analysis and provide the instrumentation utilized.

Note:

A report style will be posted on blackboard along with manuals from each instrument that will be utilized in characterization. Please read the materials to be familiar with each measurement that needs to be used.



## **Experiment 2 – Tree core sample analysis to monitor soil contamination**

### **Introduction**

The standard ground water monitoring currently is performed by large drilling equipment to create sampling wells. This is a costly investment and invasive. Dr. Burken's group has developed a less invasive and cost effective sampling technique utilizing passive samplers, solid phase samplers (SPSs). These SPSs are used when monitoring is desired to be continuous, over long periods of time when continual removal of tree cores is not practical. The SPSs allow for monthly monitoring of the same tree.

Schuman Park Lake is known to have contaminated ground water due to improper disposal of chlorinated solvents from a nearby dry cleaner over 40 years ago. These chlorinated solvents are very persistent, moderately hydrophobic, yet, hydrophilic enough to be transported by a tree. Wells have been drilled to try to locate the edge of the plume along with monitoring the concentrations of these solvents in the ground water. Dr. Burken's group has monitored trees around the plume to measure the concentration of these contaminants which are able to be removed by the trees. You will be responsible for monitoring one of these sample points of an on-going investigation (SPSs), along with a tree core of your own.

### **Pre-collection**

1. The sample vials must be cleaned and ready for tree core samples. You must calculate carefully how many vials you need for the whole experiment, including quality control and quality assurance vials.
2. Conduct literature search to find out the experimental conditions for VOC analysis and instruments used for the VOC analysis.
3. Understand the chemical characterization of some common VOCs in solid/water so the VOCs you are interested will not degrade under the experimental conditions.

### **Sampling:**

#### **Experiment 1:**

To be able to utilize tree core samples as a concentration related to that of the ground water being monitored, the partitioning coefficient must be determined. To determine the partitioning coefficient a dosing chamber is utilized. The dosing chamber for this class will not be utilized to determine the partition coefficient of different tree types, but to determine an unknown

concentration. Tree twig samples will be taken from Schuman Lake and placed into the dosing chamber until equilibrium has been reached. Along with the sample placed into the dosing chamber, a blank will also be obtained and analyzed to determine the concentration of VOCs within the original tree sample before dosing. The samples will be analyzed by solid phase micro extraction – gas chromatography – mass spectrometry (SPME – GC – MS).

### **Experiment 2:**

SPSs are being monitored each month by Matt Limmer. Last month we placed SPSs into the trees at Schuman Lake. These SPSs will be removed from the sampling trees and replaced with new SPSs. The removed SPSs will be placed into sampling vials and allowed to equilibrate, then analyzed by the SPME – GC – MS. Tree cores will also be taken from other trees around Schuman Lake. These tree cores will be placed into sampling vials to be equilibrated and also be analyzed.

### **Post-Collection:**

Write up a report of your findings. Compare the cost of one sample when using a ground well and tree core. When using the ground well technique, also include the estimated cost of drilling the well. Try to find the actual costs to approximate these comparisons, and include your references.

Did the undosed tree sample contain any VOCs? Compare your calculated concentration of the dosing chamber to the other groups. How well did the VOCs partition into your tree sample, and at what concentration? How close is your concentration to the known spiked concentration of VOCs in the PDMS of the dosing chamber?

In the tree core samples, what VOCs were observed? If no VOCs were observed, does this mean there are no contaminants within the tree? If there are VOCs observed, how well do you anticipate the concentration to represent the ground water contamination (also reference partitioning in dosing chamber)? Compare your results to the other groups and try to map out the contamination concentrations.

What are your thoughts on these methods utilized to monitor VOCs in ground water? Do you think these are better implemented than the traditional sampling wells? Are they as representative of the true ground water concentrations? If not, is it worth the tradeoff (cost vs ease)?

## **Experiment 3 - Environmental Air Monitoring**

### **Background**

When you think of environmental monitoring, you may envision trees, water, and the food you eat. Many may not consider the air we breathe unless it is a region of high smog density. Yet, there are many other concerns faced in the realm of air pollution. Consider this: where are you most of your day – inside or outside? Most of you will answer inside – school, work, home, gym, ect. As a culture we spend a lot of time indoors, however, the air in the building came from outdoors; unless preventative measures have taken place, the air from outside enters the building unchanged. However, indoor air adds another dimension to consider.

Take a look around you, how many items can you identify that smell – either a sweet fragrance or some annoying odor. Well, that weird odor that you walk into when you enter a room may be due to the partitioning of VOCs and SVOCs into the room's air. Let's take paint for example. The paint on the wall, you can smell it while application takes place. Even after the paint is applied and dried, you can still smell a "new paint coating" for a while if not properly ventilated. Think about it, all those organic compounds have to go somewhere – fabrics such as carpeting, couches, and clothing or other surfaces.

There are many different techniques that can be utilized to analyze air; two major categories are passive and active sampling. You will utilize passive air sampling with thermal desorption tubes. For this experiment we are going to take a survey of two locations – one indoor and one outdoor. The indoor sample can be taken from any approved place you choose. However, since you are responsible for absorption tubes, please select your location thoughtfully. Meaning, choose a place where the tube will be safe and not prone to disturbance or removal (from others). I advise you choose a location where you spend a majority of your time to observe the VOCs present and the relative abundance. This could mean your house, dorm, office, ect. Another sample will be taken at Mobile on the Run, a gas station near the library, as your outdoor sample.

### **Analysis**

A stainless steel tube will have been filled with an absorbent (Tenax TA, Markes), conditioned, and be ready for sample collection. After collection of the sample, the tubes will be analyzed by a thermal desorption – gas chromatograph – mass spectrometer. The samples will be loaded one by one and analyzed, as the instrument does not have an autosampler. The analytes absorbed onto your tube will be thermally desorbed into the GC – MS where they will be separated and identified by



retention time. The method contains common VOCs, and you will be responsible for identifying those analytes.

### Indoor Sample

For your indoor air analysis, each student will receive a thermal desorption tube. After further instructions given during the lab period, you will take your tube home and start your experiment. Make sure that you make note of which tube number is yours. When you open your tube and start your sampling, make sure to write down the start date, time, location, and tube number in your lab book. After allowing the air sample to diffuse for two days, cap the tube, and write down the end date, time, location, and tube number in your lab book. As the tube will be given out on Friday, the tube should be brought back on Monday for analysis.

### Outdoor Sample

The outdoor analysis will take place during a class period. Each group will have one tube per group. Each group will have a different region of the gas station to monitor, as indicated by the filled out map that will be distributed by email. Please make note of the time you start your sample and end (uncap and cap).

### Analytes Monitored

The method set up for the thermal desorption – GC – MS has already been developed to identify and monitor the following compounds:

- |                          |                          |
|--------------------------|--------------------------|
| • Benzaldehyde           | • 2,2,4-trimethylhexane  |
| • Nonanal                | • Toluene                |
| • Octanal                | • 2,3,4-trimethylpentane |
| • 2,3,3-trimethylpentane | • Decanal                |
| • Ethylacetate           | • $\alpha$ -pinene       |
| • Benzene                | • D-limonene             |
| • Acetone                | • Acetophenone           |

Upon completion of the analysis, you will receive the chromatogram along with a list of retention times and peak areas of each sample. You will need to identify the compounds listed above within your samples based on the retention times. This is only a qualitative experiment.



### Pre-Monitoring Questions

- 1) What is the difference between passive and active air sampling?
- 2) Based on the monitored VOCs, what is the order in which you expect them to elute? What did you base it off of?
- 3) We are utilizing thermal desorption tubes. What is another sampling device that could have been used? Name an advantage and disadvantage of each.
- 4) Create a table and identify one indoor and outdoor source of each compound. Make sure to cite your sources, with a link.

Example:

Compound	Indoor Source	Outdoor Source
Benzaldehyde		
Nonanal		

### Post-Monitoring

Provide structures for each analyzed compound.

Identify the VOCs present at the indoor and outdoor locations. Hypothesize, based on location of placement for your indoor air sample, where the identified compounds may have come from. Make comparisons between the indoor and outdoor length of sampling time, relative intensities, and exposure risks. Where there any VOCs that you didn't expect, but did observe?

Are any of these compounds regulated in the air by the EPA? If so, which ones and what is the limit? For each compound found in your indoor air sample, give two adverse health effects. Make sure to cite your sources, including a link.

Sexton et al., 2004 reports VOC levels in monitored indoors (primary residence) and outdoor air samples. Table 2 provides a list of observed VOCs in both indoor and outdoor air. Compare the compounds they observe versus yours. Are your results similar? Give your reasons for observing, or not observing, the compounds compared to Sexton et al. As peak area is proportional to the mass collected on the tube, you can ratio the indoor to outdoor air concentrations (I:O) to compare your results to Table 2.

Map out the concentrations of each compound observed at the gas station. Is your outdoor air sample representative? If not, what changes could be made to collect a more representative sample?

**\*\*During all of your reporting, if you list a table of compounds, please list them by order of their retention time.**

## **Measuring Frisco Lake Contamination Levels and Analyzing the Missouri S&T Campus Drinking Water for Free Chlorine, Total Chlorine, Non-Purgeable Organic Carbon, and Total Nitrogen.**

**Kevin Clark<sup>1</sup>, Qinbo Yang<sup>1</sup>**

**<sup>1</sup>Department of Chemistry, Missouri University of Science and Technology**

### **I. Experimental Objectives**

- Collect samples from different areas around Frisco Lake and measure the pH, turbidity, free chlorine, total chlorine, and total organic carbon.
- Collect samples from different areas around campus to determine if there is a difference in the water around campus and then compare this to Frisco Lake.
- Inject a known concentration of TN and NPOC and determine percent recovery.
- Understand the process of water sampling.
- Understand how to effectively and accurately analyze water samples.
- Practice and understand current methods of analyzing water samples.

### **II. Introduction**

Water samples are a great way to directly measure and monitor contaminants within a body of water. Ground water sampling arose from monitoring programs for drinking water, specifically those that monitored drinking water ground wells. This was regulated by the EPA and still is under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) <sup>1</sup>. A problem that was soon discovered was that current monitoring techniques, if applied to larger bodies of water, would not yield representative samples of the body of water. This resulted in a change in the way water samples are collected and analyzed in order to yield data that is more representative of the entire body of water in which it is collected from.

When monitoring drinking water different things need to be considered. The first is free chlorine and total chlorine levels. Chlorine is used to treat water to kill bacteria and make it drinkable for humans. However, chlorine is also toxic to humans in high concentrations and as such the EPA sets regulations on the amount of free and total chlorine that should be within drinking water. Chlorine is introduced into water as Chloramine, Chlorine, and chlorine dioxide each used for a slightly different environment to treat different things. For example Chlorine dioxide, unlike the other two compounds, is used to control taste and odor of water. One problem that can occur during the treatment of water with chlorine is the formation of disinfectant by products (DBPs). DBPs are toxic to humans and thus the EPA also regulates the amount of DBPs within a drinking water sample. The current methods used to monitor large bodies of water for contamination are the same that are used to monitor drinking water.<sup>2</sup>

Before a sample is collected and even before leaving for a monitoring site a number of things must be completed. The first is the cleaning of the vessels used to collect the water samples. This is crucial so that contamination does not occur and thus the sample collected is truly representative of the body of water. Amber bottles should be used to limit the amount of light exposure the sample receives to ensure that degradation of organic compounds does not occur. The final thing is to ensure that a

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proper field blank is prepared. An amber bottle of Milli-Q water should be obtained in the lab before leaving. Once at the sample site the bottle should be exposed to the environment that the samples are collected from. Once all samples are collected the field blank should be capped and analyzed like all other samples. To further decrease light degradation and changes in temperature of the water, the samples should be placed in a cooler once collected and immediately brought back to lab for analysis. To ensure accurate data a duplicate sample should be collected at each location. If all of this is done, the samples will be the most representative that they can be for the body of water they were collected from.<sup>3</sup>

An advantage to the new way of monitoring is that the samples obtained are truly representative of the entire body of water, assuming they are collected and handle properly. Direct water sampling provides a way to determine exactly what is in the water as compared to other ways of monitoring contamination like tree samples. These specific water samples that were collected from Frisco Lake can be compared to contamination levels detected by the surrounding trees by Dr. Burken's group. Contamination levels within Frisco Lake are being monitored as the nearby dry cleaning plant used to dump chlorinated solvents in that area. The tree samples previously obtained are used to monitor ground water in the area while these water samples will be used to measure contamination of Frisco Lake directly as well as examine drinking water around campus.

The specific things being monitored within the Frisco lake samples as well as the samples around campus are pH, conductivity, turbidity, free chlorine (FC), total chlorine (TC), non-purgeable organic carbon (NPOC), and total nitrogen (TN). Each of these samples will need to be filtered by a 0.45 micron filter before FC, TC, NPOC, and TN can be analyzed. The pH is measure by an AB 15/15+ pH meter. Conductivity is measured by an Accumet AP75 portable waterproof conductivity meter. Turbidity is measured using an Orbeco Hellige TB200 turbidimeter. Free chlorine and total chlorine are measured using USEPA Power Pillows. The non-purgeable organic carbon and total nitrogen are measured using a shimadzu corporation total organic carbon analyzer TOC-L<sub>CPH/CPN</sub>. All of these were used to analyze water samples at Frisco Lake as well as the filtered and unfiltered water on the 1<sup>st</sup> floor of Schrenk, the water fountain on the 3<sup>rd</sup> floor of Civil, the water fountain on the 1<sup>st</sup> floor of the Physics building, and the basement tap water and second floor fountain water in the library.

### III. Experimental procedures and chemical reagents

#### Sample Collection:

1. Obtain all supplies needed in order to collect samples including:
  - I. Sample Vials (cleaned).
    - i. One for a sample, one for a duplicate, and one for a field blank.
  - II. Sample Vial Caps.
  - III. Cooler for storage.
  - IV. Field Blank Vial filled with Milli-Q Water.
  - V. Journal for notes.
2. Scout out the area to determine the number of samples needed to be collected in order to provide a representative sample of Frisco Lake.
3. Determine the locations on campus that will be analyzed.

4. Determine the best time to collect both sets of samples and analyze the samples immediately.

**NOTE:** *This will take approximately 3 hours total so plan accordingly. Once the samples are collected analysis needs to be completed for everything.*

5. Take everything you will need to your first sampling location.
6. Place the cooler down on the ground next to the lake and take out the field blank vial.
7. Open the vial to the atmosphere while you are collecting other samples.
8. Open your first sample vial.
9. Rinse the vial out 3 times with water from Frisco Lake.

**NOTE:** *Try to avoid the algae and other large particulate matter within the lake.*



**Figure 1: Water Vial Rinsing:** *Qingbo Yang rinsing out the first sample vial before the sample was collected and returned to the cooler.*

10. Fill the sample vial to the top of the container.

**NOTE:** *Be sure the vial is completely full. If it is not some of the VOC may react with the oxygen and will not be detected.*

11. Close the sample vial
12. Open the duplicate sample vial.



**Figure 2: Water Collection:** Kevin Clark collecting the duplicate water sample ensuring no particular matter is in the sample.

13. Repeat steps 9 through 11.
14. Seal the field blank vial.
15. Return all the sample vials to the cooler and take it back to lab.
16. Obtain the next set of sample vials to collect the water sample on campus.
17. Proceed to the sample location (ours was the 1<sup>st</sup> floor of Schrenk, specifically the filtered water).
18. Open the field blank sample and set it to the side so it can be exposed to the same environment as the sample being collected.
19. Allow the filtered water to run for 5 minutes.
20. Open the first sample vial and collect a sample.
21. Fill the sample vial to the top of the container.

**NOTE:** Be sure the vial is completely full. If it is not any VOCs that may be in the sample will react with the atmosphere in the container and will not be detected.

22. Close the sample vial.
23. Open the duplicate sample.
24. Repeat steps 19 through 22.
25. Seal the field blank vial.
26. Return the sample vials to the cooler and take it back to lab.
27. Begin analysis for all 6 samples.

pH Sample Analysis

1. Ensure the AB 15/15+ pH meter is calibrated appropriately before conducting analysis.  
**NOTE:** For instructions on how to do this see K.L Cheng and Da-Ming Zhu's article "On Calibration of pH Meters" published in 2005 in *Sensors*.
2. Take an aliquot of one of the samples into a clean sample vial
3. Rinse the pH probe with Milli-Q water
4. Place the probe into the holding apparatus and lower it into the sample being monitored
5. Allow the pH meter to equilibrate in the sample and record the pH value
6. Remove the probe.
7. Rinse the sample vial and pH probe with Milli-Q water.
8. Repeat steps 2 through 7 for the remaining samples.

Conductivity Sample Analysis

1. Ensure the Accumet AP75 portable waterproof conductivity meter is calibrated correctly before conducting analysis.
2. Take an aliquot of one of the samples into a clean sample vial.
3. Rinse the conductivity meter with Milli-Q water.
4. Place the probe into the sample vial.
5. Allow the meter to equilibrate.
6. Record the conductivity and temperature.
7. Remove the probe.
8. Rinse the sample vial and conductivity meter with Milli-Q water
9. Repeat steps 2 through 8 for the remaining samples.

Turbidity Sample Analysis

1. Ensure the orbeco Hellige TB200 turbidimeter is calibrated correctly before conducting analysis.
2. Take an aliquot of one of the samples into a clean sample vial.
3. Place the sample vial into the turbidimeter.
4. Hold down the read button while rotating the sample vial within the turbidimeter.
5. Continue rotating the sample vial until the smallest measurement is found.
6. Record the turbidity value of the sample.
7. Remove the sample vial and rinse with Milli-Q water.
8. Repeat steps 2 through 7 for the remaining samples.

Filtering Samples

1. Obtain 6 clean syringes.
2. Obtain a 0.45 micron filter for each of the 6 syringes.

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3. Prepare the filtering apparatus.
4. Place a clean smaller sample vial beneath each hole in the apparatus.
5. Fill each syringe with a different aliquot of each sample.
6. Place a 0.45 micron filter on the end of each syringe.
7. Place the correct syringe above the sample vial in the apparatus.
8. Place the board on top of the syringes.
9. Place the lead bricks on top of the board.
10. Watch the apparatus carefully

**CAUTION:** *The lead bricks are extremely heavy and if not placed and monitored closely they may fall off and cause harm.*

11. When all syringes are empty fill each syringe again and repeat steps 7 through 10. If necessary replace each of the 0.45 micron filter.
12. If needed each can be filtered without the use of the apparatus.

**NOTE:** *If choosing to filter by hand this will take immensely more amount of time and energy.*

13. Seal each of the sample vials and the original sample vials.

14. Place the original sample vials into the coolers.

**NOTE:** *Do not throw these samples away! If you run out of filtered samples you will need to filter more of the original sample.*

### FC Sample Analysis

1. Obtain an aliquot of filtered sample water.
2. Place in a clean sample vial.
3. Zero out the apparatus.
4. Open the FC powder pillow and empty the contents into the clean sample vial filled with sample.
5. Swirl the sample cell for approximately 30 seconds. If chlorine is present the sample will turn pink.
6. Place the sample into the apparatus and push the READ button.
7. Record the FC value.
8. Remove the sample vial and clean with Milli-Q Water.
9. Repeat steps 1 through 8 for the remaining samples.

### TC Sample Analysis

1. Obtain an aliquot of filtered sample water.
2. Place in a clean sample vial.
3. Zero out the apparatus.
4. Open the TC powder pillow and empty the contents into the clean sample vial filled with sample.
5. Swirl the sample cell for approximately 3 minutes. If chlorine is present the sample will turn pink.



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6. Place the sample into the apparatus and push the READ button.
7. Record the TC value.
8. Remove the sample vial and clean with Milli-Q Water.
9. Repeat steps 1 through 8 for the remaining samples.

### NPOC/TN Sample Analysis

1. Prepare a spiked sample with a target concentration of 5 mg/dL of TN and NPOC.
2. Run each sample through a Shimadzu Corporation total organic carbon analyzer TOC-L<sub>CPH/CPN</sub>.
3. Record the measured TN and NPOC concentrations.
4. Determine percent recovery for each.

### Data Analysis

1. Compile all of the measured results into a nice table in an Excel document.
2. Determine the percent relative difference for each of the measured values for each sample
3. Determine the concentration QC percent recovery for the each spiked NPOC and TN samples.
4. Compare the results between other Frisco lake samples to determine if your sample is a representative sample.
5. Compare the data collected from around campus to each other to determine the quality of water on campus.
6. Compare the drinking water to the water collected from Frisco lake and examine any similarities and/or differences.
7. Compile all data into excel and format to look professional.

For this experiment the water samples were analyzed using a number of different instruments. The pH was measured using an AB 15/15+ pH meter. The AB 15/15+ pH meter has an LCD of screen size 3" by 4.25". It has a range of -1.99 to 19.999 with a resolution of 0.1/0.01/0.001. The Conductivity was measured using an Accumet AP75 portable waterproof conductivity meter. The Accumet AP75 portable waterproof conductivity meter has an accuracy of  $\pm 1\%$  of the full scale with a range of 0.00 to 19.99  $\mu\text{S}$  for conductivity. For temperature it has a range of 0.0 to 100.0  $^{\circ}\text{C}$  with an accuracy of  $\pm 0.5^{\circ}\text{C}$ . The Turbidity was measured using an orbeco Hellige TB200 turbidimeter. The orbeco Hellige TB200 turbidimeter has an accuracy of  $\pm 2\%$  of the reading or 0.01 NTU. The response time is less than 14 seconds and the resolution is 0.01 NTU when the value is below 100.0 NTU, 0.1 NTU for 100.0 to 999.0 NTU, and 1.0 NTU for 1000 to 1100 NTU. The Free chlorine and total chlorine was measured using USEPA Power Pillows and Method 8021 and Method 8167 approved by the EPA, respectively. Both methods have a precision of a 95% confidence interval and a sensitivity of 0.02 mg/L  $\text{Cl}_2$ . The non-purgeable organic carbon and total nitrogen were measured using a Shimadzu Corporation total organic carbon analyzer TOC-L<sub>CPH/CPN</sub>. The Shimadzu Corporation total organic carbon analyzer TOC-L<sub>CPH/CPN</sub> has a

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detection limit of 4 µg/L for the TOC-L<sub>CPH</sub> and 50 µg/L for the TOC-L<sub>CPN</sub> with a reproducibility of 1.5% for the TOC-L<sub>CPH</sub> and 3.0% for the TOC-L<sub>CPN</sub>.

### IV. Results and Discussion

**Table 1: Kevin and Qingbo's Frisco Lake and Campus Water Data:** This data was obtained and analyzed from Frisco Lake as well as the filtered water on the 1<sup>st</sup> floor of Schrenk.

Kevin and Qingbo	Sample	Temp (°C)	pH	Turbidity	Conductivity	FC (ppm)	TC (ppm)	NPOC	TN
	Tap FB	23.6	6.1	0.03	1.22	<IDL	0.01	0.4611	0
	Tap	14.6	7.32	0.01	461	0.03	0.03	0.4455	0
	Tap Dup	13.1	7.36	0.01	463	0.02	<IDL	0.4857	0
	Average	13.85	7.34	0.01	462	0.025	---	15.8	0
	% RPD Tap	10.83%	0.54%	0.00%	0.43%	40.00%	---	8.63%	0.00%
	SL FB	24.3	6.3	0.18	1.25	0.01	0.01	0.4938	0
	SL	17.2	7.7	2.27	464	0.02	<IDL	2.59	0.2002
	SL Dup	16	7.67	2.44	468	<IDL	<IDL	2.589	0.1722
	Average	16.6	7.685	2.355	466	---	---	2.5895	0.1862
	% Recovery	---	---	---	---	---	---	51.78%	3.44%
	% RPD SL	7.23%	0.39%	7.22%	0.86%	---	---	0.04%	15.04%

**Table 2: Jihee and Ashley's Frisco Lake and Campus Water Data:** This data was obtained and analyzed from Frisco Lake as well the 1<sup>st</sup> floor of the physics building.

Jihee and Ashley	Sample	Temp (°C)	pH	Turbidity	Conductivity	FC	TC	NPOC	TN
	Tap FB	22.9	7.51	0.01	6.11	0.03	0.01	0.8409	0.1802
	Tap	21	7.3	0.26	440	0.22	0.23	0.8184	0
	Tap Dup	20.9	7.26	0.14	430	0.18	0.26	1.02	0
	Average	20.95	7.28	0.2	435	0.2	0.245	0.9192	0
	% RPD Tap	0.48%	0.55%	60.00%	2.30%	20.00%	12.24%	21.93%	0.00%
	SL FB	19.9	7.35	0.02	8.83	0.01	0.02	0.6373	0
	SL	16.3	7.01	3.79	448	0.03	0.05	2.733	0.2116
	SL Dup	15.3	7.05	4.11	457	0.04	0.04	2.785	0.202
	Average	15.8	7.03	3.95	452.5	0.035	0.045	2.759	0.2068
	% Recovery	---	---	---	---	---	---	55.70%	4.04%
	% RPD SL	6.33%	0.57%	8.10%	1.99%	28.57%	22.22%	1.88%	4.64%

**Table 3: John and Josh's Frisco Lake and Campus Water Data:** This data was obtained and analyzed from Frisco Lake as well the basement of the library.

John and Josh	Sample	Temp (°C)	pH	Turbidity	Conductivity	FC	TC	NPOC	TN
	Tap FB	21.3	8.36	0.05	1.83	0.01	0.03	0.7012	0
	Tap	19.9	7.4	0.08	437	0.18	0.4	0.7634	0.05281
	Tap Dup	20.9	7.48	0.16	438	0.28	0.25	0.9009	0
	Average	20.4	7.44	0.12	437.5	0.23	0.325	0.83215	0.026405
	% RPD Tap	4.90%	1.08%	66.67%	0.23%	43.48%	46.15%	16.52%	200.00%
	SL FB	20.2	7.71	0.15	1.56	0.01	0.02	0.7526	0.06099
	SL	16	7.06	1.42	604	0.02	0.48	0.6363	0.01271
	SL Dup	18.5	7.01	1.56	598	0.05	0.29	3.408	0.2476
	Average	17.25	7.035	1.49	601	0.035	0.385	2.02215	0.130155
	% Recovery	---	---	---	---	---	---	68.16%	4.95%
	% RPD SL	14.49%	0.71%	9.40%	1.00%	85.71%	49.35%	137.07%	180.47%

**Table 4: Kristia and Ariel's Frisco Lake and Campus Water Data:** This data was obtained and analyzed from Frisco Lake as well as the 3<sup>rd</sup> floor of the civil building.

Kristia and Ariel	Sample	Temp (°C)	pH	Turbidity	Conductivity	FC	TC	NPOC	TN
	Tap FB	7.2	8.28	0.11	1.49	0.01	0.02	0.5526	0.0731
	Tap	7.5	7.3	0.03	487	0.52	0.58	0.7921	0.1054
	Tap Dup	7.6	7.31	0.05	475	0.24	0.28	0.7014	0
	Average	7.55	7.305	0.04	481	0.38	0.43	0.74675	0.0527
	% RPD Tap	1.32%	0.14%	50.00%	2.49%	73.68%	69.77%	12.15%	200.00 %
	SL FB	6.8	6.88	0.14	6.63	<IDL	0.01	0.6143	0
	SL	7.4	7.17	3.64	530	0.02	0.02	2.499	0.1811
	SL Dup	7.8	7.22	3.59	528	0.04	0.04	2.671	0.157
	Average	7.6	7.195	3.615	529	0.03	0.03	2.585	0.16905
	% Recovery	---	---	---	---	---	---	53.42%	3.14%
	% RPD SL	5.26%	0.69%	1.38%	0.38%	66.67%	66.67%	6.65%	14.26%

**Table 5: Kelly and Joe's Frisco Lake and Campus Water Data:** This data was obtained and analyzed from Frisco Lake as well as the 2<sup>nd</sup> floor of the library.

Kelly and Joe	Sample	Temp (°C)	pH	Turbidity	Conductivity	FC	TC	NPOC	TN
	Tap FB	25	6.53	0.01	1.36	<IDL	<IDL	0.4771	0
	Tap	25	7.44	0.06	435	0.17	0.22	0.6575	0.07438
	Tap Dup	25	7.45	0.01	432	0.17	0.24	0.7071	0.03856
	Average	25	7.445	0.035	433.5	0.17	0.23	0.6823	0.05647
	% RPD Tap	0.00%	0.13%	142.86%	0.69%	0.00%	8.70%	7.27%	63.43%
	SL FB	25	5.9	0.01	1.41	<IDL	<IDL	0.4346	0
	SL	25	7.5	2.16	477	0.03	0.02	2.393	0.1589
	SL Dup	25	7.57	2.11	479	0.03	0.02	2.485	0.1471
	Average	25	7.535	2.135	478	0.03	0.02	2.439	0.153
	% Recovery	---	---	---	---	---	---	49.70%	2.94%
	% RPD SL	0.00%	0.93%	2.34%	0.42%	0.00%	0.00%	3.77%	7.71%

**Table 6: Madison and Mariam's Frisco Lake and Campus Water Data:** This data was obtained and analyzed from Frisco Lake as well as the unfiltered water on the 1<sup>st</sup> floor of Schrenk.

Madison and Mariam	Sample	Temp (°C)	pH	Turbidity	Conductivity	FC	TC	NPOC	TN
	Tap FB	25	6.53	0.01	1.36	<IDL	<IDL	0.4771	0
	Tap	25	7.44	0.06	435	0.17	0.22	0.6575	0.07438
	Tap Dup	25	7.45	0.01	432	0.17	0.24	0.7071	0.03856
	Average	25	7.445	0.035	433.5	0.17	0.23	0.6823	0.05647
	% RPD Tap	0.00%	0.13%	142.86%	0.69%	0.00%	8.70%	7.27%	63.43%
	SL FB	25	5.9	0.01	1.41	<IDL	<IDL	0.4346	0
	SL	25	7.5	2.16	477	0.03	0.02	2.393	0.1589
	SL Dup	25	7.57	2.11	479	0.03	0.02	2.485	0.1471
	Average	25	7.535	2.135	478	0.03	0.02	2.439	0.153
	% Recovery	---	---	---	---	---	---	49.70%	2.94%
	% RPD SL	0.00%	0.93%	2.34%	0.42%	0.00%	0.00%	3.77%	7.71%

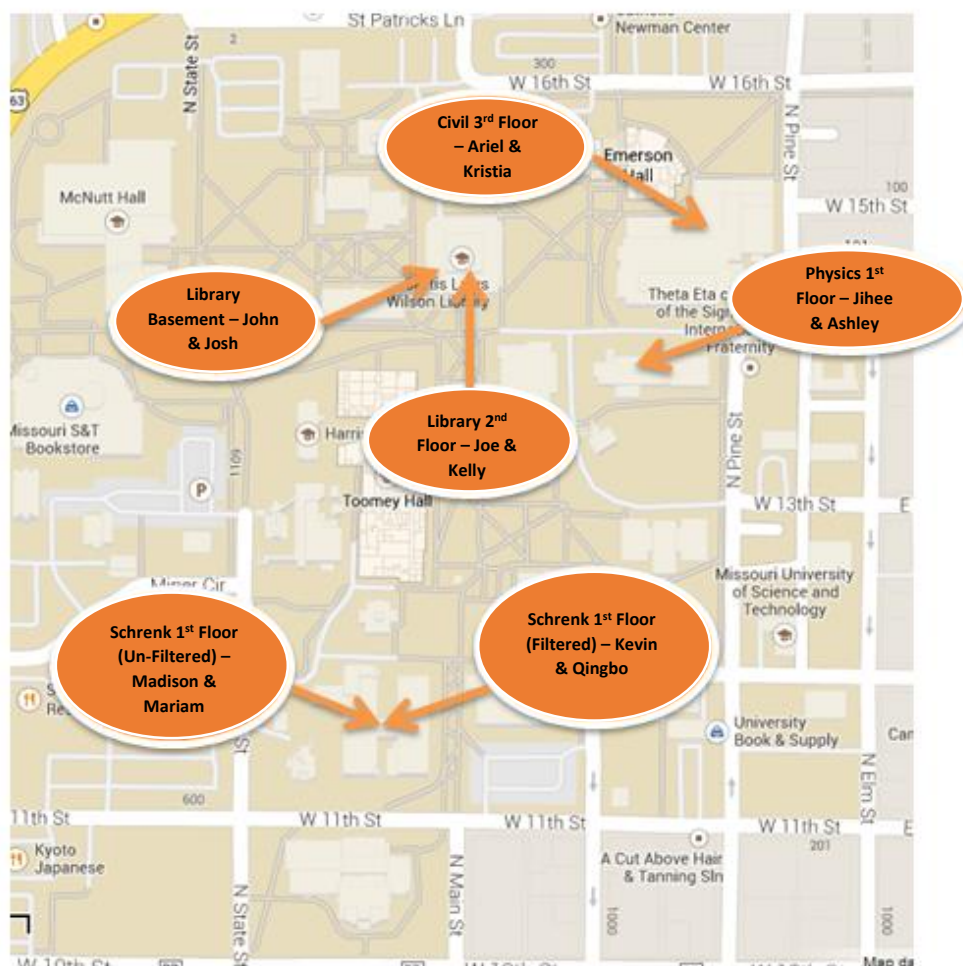
**Table 7: Spiked Data:** This data was obtained from the spiked samples. A percent recovery was obtained for each sample as a target concentration of 5mg/dL was desired. The highlighted cells correspond to our data.

Sample Name	TN Concentration	%TN Recovery	NPOC Concentration	%NPOC Recovery
Grobe Tap	6.256	125.12%	5.669	113.38%
Grobe SL	6.163	123.26%	5.958	119.16%
Ashley Tap	18.17	363.40%	17.43	348.60%
Ashley SL	18.88	377.60%	19.17	383.40%
KA Tap	6.115	122.30%	5.93	118.60%
KA SL	6.341	126.82%	8.221	164.42%
Mad Tap	17.39	347.80%	19.44	388.80%
Mad SL	19.38	387.60%	17.79	355.80%
KLC Tap	5.878	117.56%	5.664	113.28%
KLC SL	6.515	130.30%	7.947	158.94%
JK Tap	6.116	122.32%	5.814	116.28%
JK SL	6.341	126.82%	7.84	156.80%
	Target TN Concentration	5.00 mg/dL	Target NPOC Concentration	5.00 mg/dL



**Figure 3: Frisco Lake Sampling Locations:** Locations for all of the samples collected around Frisco Lake and the group that collected the sample.

## Water Sampling Report



**Figure 4: Missouri S&T Sampling Locations:** Locations for all samples collected around campus and the group that collected each sample.

Every piece of data collected provides us with information about the way it was treated, if treatment was done, or the overall quality of the water. The pH should have a value closer to 7 if it has been treated and is safe for human consumption. Water that is not treated or intended for human consumption will be closer to 8 due to the organic matter within the water. Conductivity should be approximately the same for all samples and the conductive ability of water will not be greatly affected by the amount of particulate matter we will be measuring. The turbidity should be higher (above 1) for samples that are not treated due to the large amount of particulate matter. Samples that have been treated and are intended for human consumption should have a low turbidity value. The amount of free chlorine and total chlorine should be higher for samples that have been treated as they are treated with chlorine. As for samples from untreated water these should be lower as chlorine should not have been introduced into the water. The non-purgeable organic carbon and total nitrogen should be low for treated samples and higher for untreated samples due to the higher amount of particular and decomposing matter.



## Water Sampling Report

Since this experiment utilizes a number of different apparatus to obtain all of the data there can be a potential number of errors. The first error for any of the pieces of data could be improper calibration of the apparatus as the calibration was not conducted by us. As for the pH if the pH meter is not allowed to equilibrate in the sample before the measurement is recorded then the value may not be correct. With conductivity, if the probe is not properly cleaned then a correct measurement may not occur. When utilizing the turbidimeter the sample must be continually rotated until the lowest value is seen. If this is not done then the correct value will not be obtained. When measuring free chlorine and total chlorine if the sample is not filtered properly or the powder not allowed to dissolve completely before analysis then an error in data reporting will occur. For the NPOC and TN measurements the same could be said as samples had to be filtered before analysis could occur. Although we did not directly run these samples a mishandling of the samples could also cause an error to occur. Despite all of the potential errors if great care is taken then the likelihood that any of these would occur is minimal.

For the samples that our group collected from Frisco, the results were mostly as expected (see Table 1). The pH was a little above 7 which is not surprising due to the organic compounds within the lake which also explains the higher turbidity levels. The conductivity was to be expected and was very similar to the conductivity of the samples collected on campus. Free chlorine and total chlorine was detected but in very low quantities which is to be expected as chlorine should not have been added to the lake. NPOC and TN was detected within the lake although it was a little lower than expected considering the known amount of carbon containing compounds within the lake. In comparison to the rest of the collected data from the other groups our pH, conductivity, FC, TC, NPOC, and TN was roughly the same (see Tables 2 through 6). This should be expected since the samples were collected from the same body of water and thus each sample is representative to the body of water collected. Although turbidity was different between groups this could be to an uneven distribution of particulate matter throughout the lake and the fact that certain areas around the lake may have more particulate matter.

For the Spiked Data samples every single group detected a higher amount of sample than should have been introduced in the sample vials. Some of the groups even measured almost four times as much of a concentration (see Table 7). This could be explained by improper handling of samples which could have led to contamination or an improper amount of sample was introduced and thus a concentration four times what should have been introduced could have been detected. Further analysis into the way the samples were handled, prepared, and analyzed to determine exactly what the cause was.

As for the samples collected across campus (see Figure 4) our pH, turbidity, conductivity, NPOC, and TN was to be expected for a sample that had been filtered and made suitable for drinking (see Table 1). However, the amount of free chlorine and total chlorine found in our sample indicates that it may not be being treated properly as levels are very low. The other thing is that our filtered sample in comparison to the unfiltered sample collected (see Table 6) was almost identical in every value. This could indicate that the 'filtered' water on the first floor of Schrenk is not really filtered or that one of the groups collected the wrong sample. This test will need to be repeated at this location in order to determine if a mistake was made. As for the remaining samples on campus each measured value was to be expected and those samples appear to have been treated and are most likely safe for human consumption.

The EPA regulates a number of things in water that we can drink. National primary drinking regulations (NPDWRs) are standards that the EPA can legally enforce that apply to public water systems.

## Water Sampling Report

There are a number of different things that are considered primary drinking regulations from microorganisms and organic chemicals to disinfectants and disinfectant byproducts. As for what we measured turbidity and chlorine levels are primary drinking regulations. Along with national primary drinking regulations the EPA also has national secondary drinking water regulations (NSDWRs). NSDWRs are standards that the EPA cannot legally enforce. These compounds cause cosmetic and aesthetic effects to water samples but pose no real harm to humans. The pH that we measured is an example of a NSDWRs. A few others are corrosivity, color, odor, and total dissolved solids.<sup>4,5</sup>

During the treatment of water DBPs or disinfectant byproducts can form due to the interaction of the chlorine with the volatile organic compounds within the water. Although a number of the DBPs are harmful to humans in low quantities, some in low quantities pose no known harm to humans. One of these is Bromide. The EPA regulates that bromides may not occur in quantities greater than 1.0 ppm. The EPA monitors the amount of Bromide in water using Method 300.0. In this method a small amount of sample is introduced into an ion chromatograph. The anions being examine (in this case bromine) is separated and measured. The amount is then quantified and is compared to the maximal limit. If the amount is below this max amount then the sample and are that it was collected from is in compliance.<sup>6</sup>

With DBPs there are two distinct stages. Stage 1 disinfectants and disinfection byproducts rules are intended to reduce the amount of exposure that humans are exposed to with community water systems, specifically for any disinfectant that introduced at any point in the treatment process. Stage 2 disinfectants and byproducts rule address those disinfection byproducts formed due to the introduction of disinfectants that are intended to improve the overall quality of the drinking water.<sup>7</sup>

If Frisco Lake is considered to be source water and after analysis the alkalinity average is found to 73 mg/L as  $\text{CaCO}_3$  then approximately 40% of TOC must be removed. The maximum amount of TOC allowed for the finished water of the facility is 2.0 mg/L. TOC is the total organic compound and is used as a surrogate measure for the amount of DBPs within a water sample.<sup>8</sup>

## V. Conclusion

Overall the samples collected around Frisco Lake were overall to be expected. Although the total amount of non-purgeable organic carbon and total nitrogen was a little low the other measured values including, pH, turbidity, conductivity, temperature, free chlorine, and total chlorine was to be expected. It appears that the dumping of chlorinated solvents by the Laundromat nearby did not enter Frisco Lake or the contamination was not high enough to be detected. However, the samples collected appear to be representative for the entirety of Frisco Lake. For the samples collected around campus there was no observed difference between the filtered and unfiltered water on the 1<sup>st</sup> floor of Schrenk and it appears that it has not been properly treated. As such it is recommended that this water is avoided. As for the rest of the drinking water on campus it appears to be treated and safe for human consumption. This method for analyzing samples is extremely time consuming, although, it appears to be fairly accurate. The method provides a great depth of information about the samples and thus is effective at determining contamination levels within Frisco Lake and across the Missouri S&T Campus.

## VI. Monitoring Experience

Overall this monitoring experiment was very enlightening to the amount of work and time it takes to analyze water samples. I learned a lot more about what exactly water sampling is and what it can be used to monitor and determine. I also learned more about the techniques/spectrometers used to analyze the samples. I think it would be beneficial if we were able to monitor more areas on campus so we could better compare them, specifically in terms of areas that have filtered and unfiltered like on the first floor of Schrenk. Another thing would be beneficial would be knowing the amount of time it takes to analyze all the samples beforehand. I was under the impression it wouldn't take that long and as such did not have a lot of time carved out in my day to actually complete the analysis. The most helpful thing was having Danielle available to ask any questions about the lab and during the analysis of the samples. A final improvement would be to actually have the field blanks samples filled with Milli-Q water before proceeding out to collect samples.

## VII. Acknowledgements

I would like to thank the Environmental research center for providing the instruments and equipment for the experiment. I would also like to thank Danielle West for all the extra time she put into the lab in order to help us gather and analyze our data as well as for the help in understanding exactly what we were seeing. I would also like to thank Matt Limmer for the word he did to collect tree samples so we can compare ground water contamination to contamination in the lake itself. I would also like to thank Dr. Ma for allowing us to put what we are learning in the classroom into practice and the opportunity to present our data and findings to improve our public speaking skills. Finally I would like to thank Qingbo Yang for his help in sample collection, data analysis, and enthusiasm in conducting this experiment.

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## **Monitoring Ground Water VOC Contamination Utilizing Tree Cores, Solid Phase Samplers, and Dosing Chamber by Solid Phase Micro-Extraction – Gas Chromatography – Mass Spectrometry**

**Kevin Clark<sup>1</sup>, Qinbo Yang<sup>1</sup>**

**<sup>1</sup>Department of Chemistry, Missouri University of Science and Technology**

### **I. Experimental Objectives**

- Monitor the VOC concentrations in tree samples at Schuman Lake
- Use a dosing chamber to introduce a known concentration of chlorinated solvents into a tree sample and then determine the percent recovery of the chlorinated solvents
- Understand the process of tree sampling
- Understand how to effectively and accurately analyze tree samples
- Practice and understand current methods of analyzing tree samples

### **II. Introduction**

Tree cores can provide a way to measure the amount of contamination that is within the ground in a specific area. A tree's root system is vast and differs based on the type of tree. Some trees have a taproot that goes straight into the ground, sometimes over 15 feet while other trees have shallow root systems that can allow it to absorb nutrients that are close to the surface. A tree will absorb material that is within the area that their roots are contained in. When the root hairs (tiny hairs located on roots to increase surface area and absorb nutrients) absorb nutrients they are transported through the root system and up the tree through the xylem. The xylem is a network of cells that essentially form a pipeline that allows the tree to transport nutrients from the root system to the rest of the tree. When a tree core is obtained you extract a portion of the tree including the xylem, thus when you analyze this sample you are measuring what was absorbed by the root system. This in turn means that you obtain a snapshot into the concentration of chemicals within the area.

The current method of utilizing tree core samples to map/monitor volatile organic compounds (VOCs) in an area was first utilized in the early 1960s by Castelfranco and others. He examined plants and utilized them as a mechanism to remediate subsurface VOCs. Castelfranco's idea was based upon the American astronomer, A.E. Douglass, who related the width of tree-cores to the wet and dry periods in the area. The first mapping of VOCs utilizing tree core samples was conducted by Broblesky at the Savannah River Site in South Carolina. Broblesky wanted to track a plume of chlorinated solvent that was beneath a flooded cypress swamp. He successfully mapped the concentrations of cis-dichloroethene and trichloroethene in the area simply by utilizing tree cores.

This tree core sampling provides a number of different advantages. The first is that it is very applicable to a number of different VOCs and the amount of VOCs measured within the tree core sample is a very good indicator for the amount of VOC subsurface contamination. As such, Dr. Burken's group utilizes the sample core method in order to monitor chlorinated solvents in the area surrounding Schuman pond. These chlorinated solvents were utilized by the Laundromat that is directly up the hill

## Tree Sampling Report

from Schuman pond. These solvents were not properly disposed of and as such entered into the area. Dr. Burken's group initially dug wells in the area in order to locate the edge of contamination and to better determine how widespread this contamination was. After this was determined they planted Sycamore trees in the area and have been continuing monitoring the concentration levels of the VOCs in the area. Dr. Burken's group also placed solid phase samplers (SPSs) into some of the other trees in the area surrounding Schuman pond. This allows them to take multiple samples from the same tree without having to core the tree continuously and thus risk killing it. The SPSs are removed once a month, replaced with new ones, and then placed into sample vials. The samples are then allowed to equilibrate and are then analyzed utilizing a solid phase micro extraction – gas chromatography – mass spectrometry (SPME – GC – MS).

Three specific chemicals that are currently being monitored in the area are cis-dichloroethene, (cDCE), trichloroethene (TCE), and tetrachloroethene (PCE). A calibration curve is obtained based upon known concentrations and measured peak area that was obtained from the SPME – GC – MS. This information was then utilized to calculate the concentration of samples that were obtained from trees in the area. The specific trees that samples were taken from were Ash, Black Walnut, Oak, Maple, Bald Cypress, Willow, and Northern Red Oak. Our specific trees were an Ash, Oak, and Bald Cypress Tree.

### III. Experimental procedures and chemical reagents

#### Sample Collection:

1. Obtain all supplies needed in order to collect samples including:
  - I. Sample Vial (cleaned).
  - II. Cutters (cleaned) for cutting branches.
  - III. Sample Vial Caps.
  - IV. Journal for notes.
  - V. Forceps (for SPS collection).
  - VI. Tree Coring Device.
2. Scout out area to determine the number of samples that will be collected to understand the number of sample vials needed.
3. Collect a twig sample from a tree near Schuman lake.

**CAUTION:** *Cutters are sharp and pose a potential hazard.*

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**Figure 1: Tree Branch Sampling:** *A photograph of the tree that was sampled for analysis in the dosing chamber.*



**Figure 2: Tree Branch Sample:** *A photograph of the tree branch sample that was then placed into the sample vial and introduced in the dosing chamber back at the lab.*

4. Immediately place the sample into the vial and seal it with the cap.
5. Record the location, time of day, temperature, and type of tree in your journal.
  - I. Location: Next to Schuman Park (see Figure 12)
  - II. Time of Day: 10:50 AM
  - III. Temperature: 9 °C
  - IV. Type of Tree: Bald Cypress
6. Move on to a tree that is away from the lake.



## Tree Sampling Report

7. Obtain a core from the tree using the Tree Coring Device.

**CAUTION:** *Tree Coring Device is very sharp and poses a potential hazard.*



**Figure 3: Tree Coring Device in Action:** *The Tree Coring Device that was utilized in action. This device was used to obtain all tree cores.*

8. Immediately place the sample into the vial and seal it with the cap.
9. Record the location, time of day, temperature, and type of tree in your journal.
  - I. Location: Near 16<sup>th</sup> Street (see figure 11)
  - II. Time of Day: 10:13 AM
  - III. Temperature: 7°C
  - IV. Type of Tree: Ash
10. Move on to a tree that is a large distance from the lake.
11. Obtain a core from the tree using the Tree Coring Device.
12. Immediately place the sample into the vial and seal it with the cap.



**Figure 4: Final Tree Core Obtained:** A photograph of the final tree core that was obtained contained in the sample vial next to the hole that it was extracted from.

13. Record the location, time of day, temperature, and type of tree in your journal.
  - I. Location: Near Campus Town Apartments (see figure 11)
  - II. Time of Day: 10:23 AM
  - III. Temperature: 10°C
  - IV. Type of Tree: Oak Tree
14. Move on to a tree near the lake that has an SPS.
15. Carefully remove the cap over the SPS.
16. Use the Forceps to remove the SPS from the tree and place it into a sample vial.
17. Replace the removed SPS with a new SPS.
18. Replace the cap over the hole with the SPC.
19. Place the sample into the vial and seal it with the cap.
20. Record the location, time of day, temperature, and type of tree in your journal.
  - I. Location: Near Schuman Pond (see figure 11)
  - II. Time of Day: 10:34 AM
  - III. Temperature: 9°C
  - IV. Type of Tree: Ash Tree

## Tree Sampling Report

### Sample Analysis

1. Bring all sample vials back to the lab.
  2. Place the twig obtained from the first tree into a dosing chamber of 60 mL of PDMS oil.
    - a. Our chamber was specifically 700 mg/m<sup>3</sup> cDCE, 1 mg/m<sup>3</sup> PCE, and 25 mg/m<sup>3</sup> TCE.
    - b. Ensure that you remember the vial you placed your sample into.
- Note:** If the sample will not fit into the vial cut it in half.
3. Leave the sample in the dosing chamber for about a week to ensure that it has absorbed the concentrations within the dosing chamber.
  4. Remove the sample from the dosing chamber.
  5. Place the sample into the solid phase micro extraction – gas chromatography – mass spectrometry (SPME-GC-MS).
  6. Analyze all tree core samples in the SPME-GC-MS.
  7. Read the peak area from the chart given.
  8. Compile all data into excel.
  9. Run a three different samples of known concentration for five different concentrations through the SPME-GC-MS.
  10. Read the peak from the chart given.
  11. Compile data into excel with corresponding concentrations.

### Data Analysis

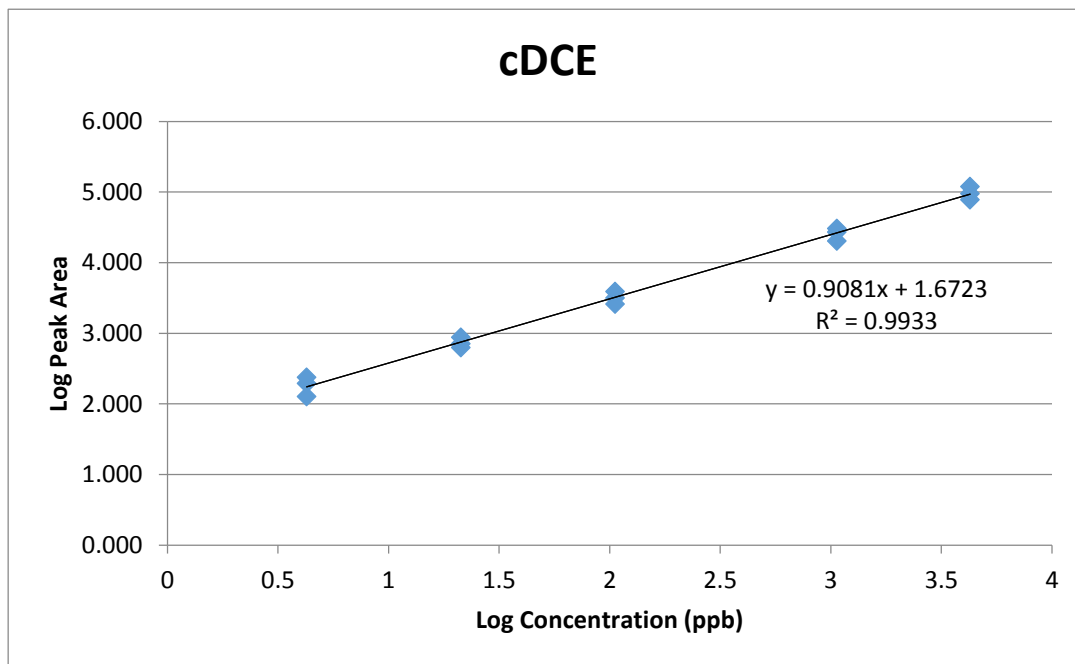
1. Create a calibration curve from the peak area of the five different concentrations for each of the three compounds being analyzed.
2. Plot the log of the peak area vs the log of the concentration.
3. Obtain a linear line of best fit and record the equation of the line.
4. Utilize the equation for each of the three compounds to determine the concentration in each sample taken.
5. Compile all data into excel and format to look professional.

For this experiment the tree core samples were analyzed using an Agilent GC Model 7890 with a uECD SPME-GC-MS. The auto sampler that was used in conjunction with the SPME-GC-MS was a CTC Analytics COMBI PAL. The SPME-GC-MS utilizes Capillary Flow Technology and Retention Time Locking to provide better separation and maintain retention times, respectively. It also has an Agilent Inert Flow Path and Multimode Inlet to achieve better sensitivity and provide a programmable temperature vaporizing injector, respectively. The retention time repeatability is <0.008% and has an area repeatability of < 1% RSD. The SPME-GC-MS has two inlets, four detector signals, and three detectors with a column that has dimensions of 28 x 31 x 16 cm. The maximum achievable temperature ramp rate is 120°C/min with a maximum run time of 16.7 hours. The SPME-GC-MS utilizes MassHunter Software with Integrated Intelligence to provide precise peak analysis.

## IV. Results and Discussion

**Table 1: cDCE Calibration Curve Data:** Standard Data obtained for cDCE for 5 different known concentrations used to create the cDCE calibration curve.

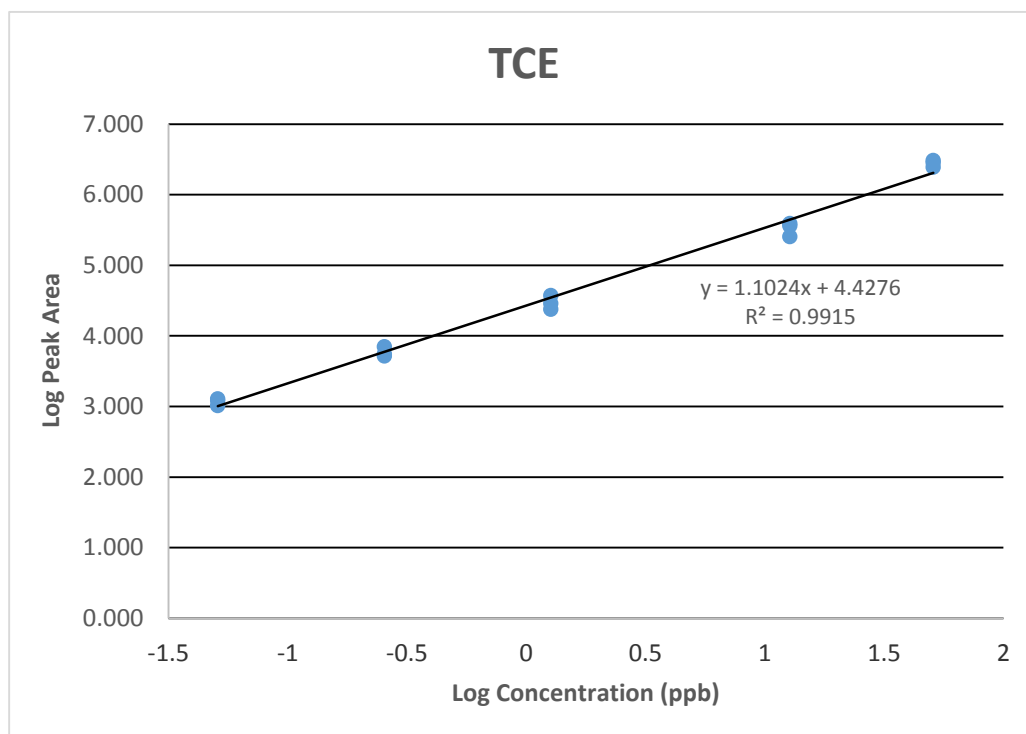
cDCE				
Standard	Concentration (ppb)	log Concentration (ppb)	Peak Area	log Peak Area
1	4259.348199	3.629343145	78363.4	4.894
			95180.9	4.979
			120430.8	5.081
2	1064.83705	3.027283153	20414.7	4.310
			27217	4.435
			30460.9	4.484
3	106.1042413	2.025732744	2611.2	3.417
			3160.6	3.500
			3908	3.592
4	21.28151905	1.328002624	631.5	2.800
			716.9	2.855
			884.6	2.947
5	4.258738973	0.629281022	128.3	2.108
			196.2	2.293
			238.1	2.377



**Figure 5: cDCE Calibration Curve:** Calibration Curve obtained from graphing the log of the peak area vs the log of the concentrations from the data in Table 1. The equation for the line of best fit provides a means to determine unknown concentrations of samples with similar peak areas.

**Table 2: TCE Calibration Curve Data:** Standard Data obtained for TCE for 5 different known concentrations used to create the TCE calibration curve.

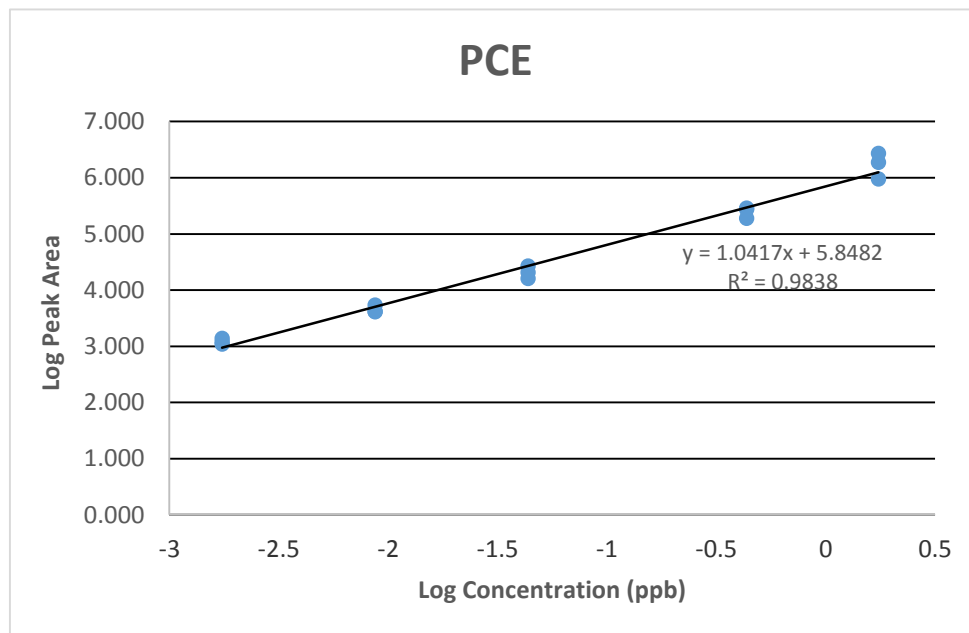
TCE				
Standard	Concentration (ppb)	log Concentration (ppb)	Peak Area	log Peak Area
1	50.9384	1.707045627	2464093	6.392
			2847570.8	6.454
			3050339	6.484
2	12.7346	1.104985636	256061.9	5.408
			364377.7	5.562
			392159.3	5.593
3	1.2710	0.10413571	23854.8	4.378
			28736.6	4.458
			37469	4.574
4	0.2546	-0.594154487	5198	3.716
			5546.3	3.744
			7036.2	3.847
5	0.0509	-1.292988402	1034.2	3.015
			1215.4	3.085
			1278.7	3.107



**Figure 6: TCE Calibration Curve:** Calibration Curve obtained from graphing the log of the peak area vs the log of the concentrations from the data in Table 2. The equation for the line of best fit provides a means to determine unknown concentrations of samples with similar peak areas.

**Table 3: PCE Calibration Curve Data:** Standard Data obtained for PCE for 5 different known concentrations used to create the PCE calibration curve.

PCE				
Standard	Concentration (ppb)	log Concentration (ppb)	Peak Area	log Peak Area
1	1.7429	0.241262944	948090.6	5.977
			1874313.5	6.273
			2722676.5	6.435
2	0.4357	-0.360797047	189804.6	5.278
			272791.7	5.436
			288731.5	5.460
3	0.0436	-1.360970543	16134.4	4.208
			20662.2	4.315
			26697.8	4.426
4	0.0087	-2.059801756	4130.2	3.616
			4157.6	3.619
			5400.8	3.732
5	0.0017	-2.758743997	1385.4	3.142
			1202.6	3.080
			1098	3.041



**Figure 7: TCE Calibration Curve:** Calibration Curve obtained from graphing the log of the peak area vs the log of the concentrations from the data in Table 3. The equation for the line of best fit provides a means to determine unknown concentrations of samples with similar peak areas.

# Tree Sampling Report

**Table 4: Complete Standard Calibration Curve Data:** *Standard Data obtained for cDCE, TCE, and PCE for 5 different known concentrations used to create the cDCE, TCE, and PCE calibration curves.*

Sample	Vial	Sample Name	cDCE Peak Area	TCE Peak Area	PCE Peak Area
Standards	Vial 31	STD5	128.3	1034.2	1385.4
	Vial 32	STD4	631.5	5198	4130.2
	Vial 33	STD3	2611.2	23854.8	16134.4
	Vial 34	STD2	20414.7	256061.9	189804.6
	Vial 35	STD1	78363.4	2464093	948090.6
	Vial 36	DI WATER	---	---	---
	Vial 37	STD5	196.2	1215.4	1202.6
	Vial 38	STD4	716.9	5546.3	4157.6
	Vial 39	STD3	3160.6	28736.6	20662.2
	Vial 40	STD2	27217	364377.7	272791.7
	Vial 41	STD1	95180.9	2847571	1874313.5
	Vial 42	DI WATER	---	---	---
	Vial 43	STD5	238.1	1278.7	1098
	Vial 44	STD4	884.6	7036.2	5400.8
	Vial 45	ST3	3908	37469	26697.8
	Vial 46	STD2	30460.9	392159.3	288731.5
	Vial 47	SDT1	120430.8	3050339	2722676.5

**Table 5: Tree Core Sample Data:** *Peak Areas for the 3 different compounds (cDCE, TCE, and PCE) from the obtained Tree Cores around Schuman Pond. These values are used to determine the unknown concentrations for each of the 3 compounds*

Sample	Vial	Sample Name	cDCE Peak Area	TCE Peak Area	PCE Peak Area
Tree Core	Vial 17	Krista 2	---	---	218.9
	Vial 18	ASHLEY OAK	---	---	204.3
	Vial 19	Krista 1	---	---	21657.9
	Vial 20	KW OAK	---	---	143.6
	Vial 21	JOHN ASH	---	---	55.9
	Vial 22	ASHLEY ASH	---	22.1	54.4
	Vial 23	KLC OAK	---	---	239
	Vial 24	BLANK	---	---	---
	Vial 25	MA	---	43	7521
	Vial 26	KLC ASH	---	238.5	16082.1
	Vial 27	JOHN OAK	---	---	163.7
	Vial 28	JB	---	---	4290.5
	Vial 29	MA	108.4	---	8439.5
	Vial 48	Ariel Ash	283.9	822.3	6078.1
	Vial 49	Ariel Oak	---	245.7	218.2



## Tree Sampling Report

**Table 6: SPS Sample Data:** Peak Areas for the 3 different compounds (cDCE, TCE, and PCE) from the obtained SPS Samples around Schuman Pond. These values are used to unknown concentrations for each of the 3 compounds in the SPS samples.

Sample	Vial	Sample Name	cDCE Peak Area	TCE Peak Area	PCE Peak Area
SPS	Vial 3	SPS 1	170.1	946.7	6991.4
	Vial 4	SPS 2	165.2	1938.8	41068.3
	Vial 5	SPS 3	924.7	38030.1	3431892.3
	Vial 6	SPS 4	328.1	3710.5	62791.5
	Vial 7	SPS 5	---	---	4060.1
	Vial 8	SPS 6	---	---	44097.9
	Vial 9	SPS 6B	---	---	23119.4
	Vial 10	SPS 7	335.6	20165.3	427463.2
	Vial 11	SPS 8	384.5	28087	509384.5
	Vial 12	SPS 9	428.9	35022.8	865567.7

**Table 7: Tree Branch Blank Sample Data:** Peak Areas for the 3 different compounds (cDCE, TCE, and PCE) from the obtained blank tree branch samples from around Schuman Pound. These samples were used to compare the amount of sample the tree branches had absorbed within the dosing chamber.

Sample	Vial	Sample Name	cDCE Peak Area	TCE Peak Area	PCE Peak Area
Tree Branch (blank)	Vial 3	KCLB	---	---	---
	Vial 4	GROBEYB	---	---	---
	Vial 5	KRISTIAB	---	---	---
	Vial 6	NROB	---	---	---
	Vial 7	ASHLEYB	---	---	---
	Vial1	KEVINB	---	---	---

**Table 8: Tree Branch Sample Data:** Peak Areas for the 3 different compounds (cDCE, TCE, and PCE) from the obtained tree branch samples placed into the dosing chamber.

Sample	Vial	Sample Name	cDCE Peak Area	TCE Peak Area	PCE Peak Area
Tree Branch (dosing chamber)	Vial 8	ASHLEY	---	2859789	8501831
	Vial 9	KRISTA	---	35924.7	6616458.5
	Vial 10	GROBE	---	2467042	8250912.5
	Vial 11	MA	---	2139086	7712641.5
	Vial 12	JB	---	29680.4	5043022
	Vial 2	KEVIN	---	24936.3	3805697.5

# Tree Sampling Report

**Table 9: Calculated cDCE Concentrations Data:** Calculated Data for all samples obtained in this experiment for cDCE. The highlighted cells are the samples we collected.

Sample Name	cDCE			
	Peak Area	Log Peak Area	Calculated Log Concentration (ppb)	Concentration (ppb)
SPS 1	170.1	2.23	0.61	4.120
SPS 2	165.2	2.22	0.60	3.990
SPS 3	924.7	2.97	1.42	26.584
SPS 4	328.1	2.52	0.93	8.494
SPS 5	---	---	---	---
SPS 6	---	---	---	---
SPS 6B	---	---	---	---
SPS 7	335.6	2.53	0.94	8.708
SPS 8	384.5	2.58	1.00	10.115
SPS 9	428.9	2.63	1.06	11.408
Krista 2	---	---	---	---
ASHLEY OAK	---	---	---	---
Krista 1	---	---	---	---
KW OAK	---	---	---	---
JOHN ASH	---	---	---	---
ASHLEY ASH	---	---	---	---
KLC OAK	---	---	---	---
BLANK	---	---	---	---
MA	---	---	---	---
KLC ASH	---	---	---	---
JOHN OAK	---	---	---	---
JB	---	---	---	---
MA	108.4	2.04	0.40	2.509
ARIEL ASH	283.8	2.45	0.86	7.240
ARIEL OAK	---	---	---	---
KCLB	---	---	---	---
GROBEYB	---	---	---	---
KRISTIAB	---	---	---	---
NROB	---	---	---	---
ASHLEYB	---	---	---	---
KEVINB	---	---	---	---
ASHLEY	---	---	---	---
KRISTA	---	---	---	---
GROBE	---	---	---	---
MA	---	---	---	---
JB	---	---	---	---
KEVIN	---	---	---	---

# Tree Sampling Report

**Table 10: Calculated TCE Concentrations Data:** Calculated Data for all samples obtained in this experiment for TCE. The highlighted cells are the samples we collected.

Sample Name	TCE			
	Peak Area	Log Peak Area	Calculated Log Concentration (ppb)	Concentration (ppb)
SPS 1	946.7	2.98	-1.32	0.048
SPS 2	1938.8	3.29	-1.03	0.092
SPS 3	38030.1	4.58	0.14	1.375
SPS 4	3710.5	3.57	-0.78	0.167
SPS 5	---	---	---	---
SPS 6	---	---	---	---
SPS 6B	---	---	---	---
SPS 7	20165.3	4.30	-0.11	0.773
SPS 8	28087	4.45	0.02	1.045
SPS 9	35022.8	4.54	0.11	1.276
Krista 2	---	---	---	---
ASHLEY OAK	---	---	---	---
Krista 1	---	---	---	---
KW OAK	---	---	---	---
JOHN ASH	---	---	---	---
ASHLEY ASH	22.1	1.34	-2.80	0.002
KLC OAK	---	---	---	---
BLANK	---	---	---	---
MA	43	1.63	-2.53	0.003
KLC ASH	238.5	2.38	-1.86	0.014
JOHN OAK	---	---	---	---
JB	---	---	---	---
MA	---	---	---	---
ARIEL ASH	822.3	2.92	-1.37	0.042
ARIEL OAK	245.7	2.39	-1.85	0.014
KCLB	---	---	---	---
GROBEYB	---	---	---	---
KRISTIAB	---	---	---	---
NROB	---	---	---	---
ASHLEYB	---	---	---	---
KEVINB	---	---	---	---
ASHLEY	2859789	6.46	1.84	69.229
KRISTA	35924.7	4.56	0.12	1.306
GROBE	2467042	6.39	1.78	60.547
MA	2139085.5	6.33	1.73	53.198
JB	29680.4	4.47	0.04	1.098
KEVIN	24936.3	4.40	-0.03	0.938

# Tree Sampling Report

**Table 11: Calculated PCE Concentration Data:** Calculated Data for all samples obtained in this experiment for PCE. The highlighted cells are the samples we collected.

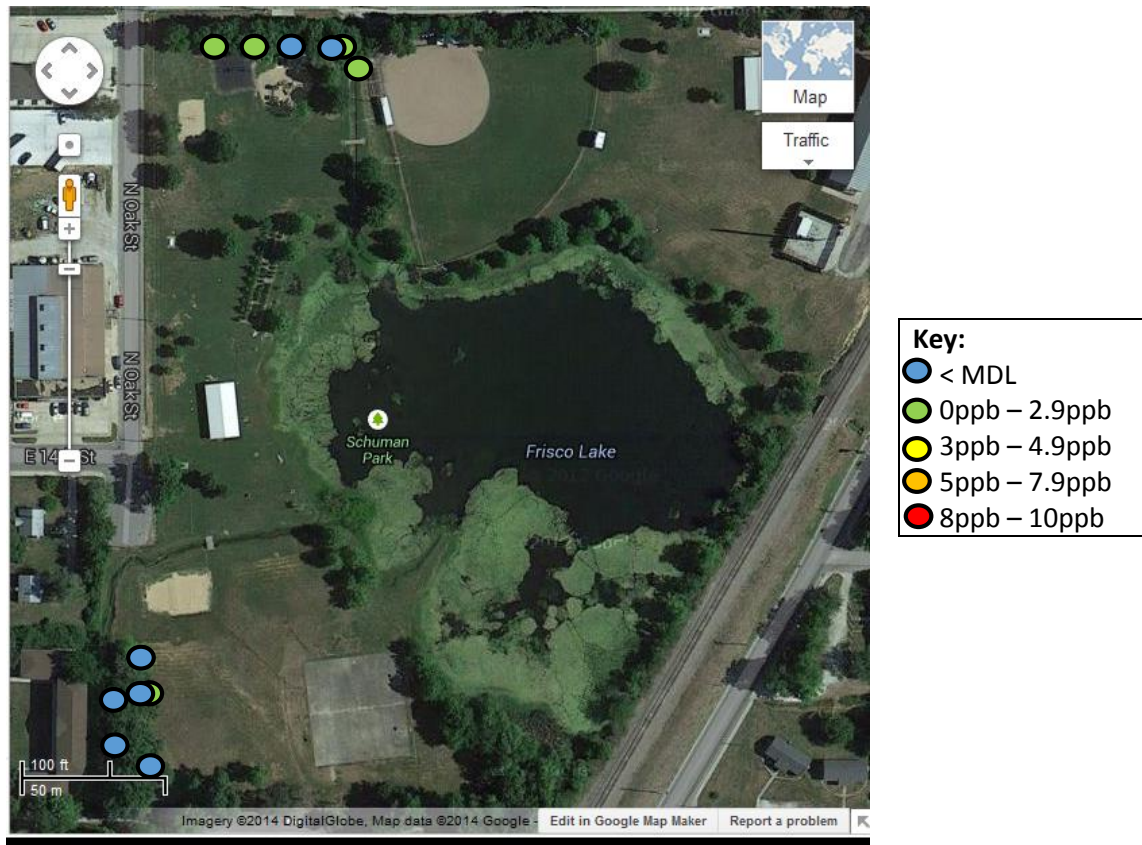
Sample Name	PCE			
	Peak Area	Log Peak Area	Calculated Log Concentration (ppb)	Concentration (ppb)
SPS 1	6991.4	3.84	-1.92	0.012
SPS 2	41068.3	4.61	-1.19	0.065
SPS 3	3431892.3	6.54	0.66	4.569
SPS 4	62791.5	4.80	-1.01	0.098
SPS 5	4060.1	3.61	-2.15	0.007
SPS 6	44097.9	4.64	-1.16	0.070
SPS 6B	23119.4	4.36	-1.42	0.038
SPS 7	427463.2	5.63	-0.21	0.619
SPS 8	509384.5	5.71	-0.14	0.732
SPS 9	865567.7	5.94	0.09	1.218
Krista 2	218.9	2.34	-3.37	0.000
ASHLEY OAK	204.3	2.31	-3.40	0.000
Krista 1	21657.9	4.34	-1.45	0.035
KW OAK	143.6	2.16	-3.54	0.000
JOHN ASH	55.9	1.75	-3.94	0.000
ASHLEY ASH	54.4	1.74	-3.95	0.000
KLC OAK	239	2.38	-3.33	0.000
BLANK	---	---	---	---
MA	7521	3.88	-1.89	0.013
KLC ASH	16082.1	4.21	-1.58	0.027
JOHN OAK	163.7	2.21	-3.49	0.000
JB	4290.5	3.63	-2.13	0.007
MA	8439.5	3.93	-1.84	0.014
ARIEL ASH	6078.1	3.78	-1.98	0.010
ARIEL OAK	218.2	2.34	-3.37	0.000
KCLB	---	---	---	---
GROBEYB	---	---	---	---
KRISTIAB	---	---	---	---
NROB	---	---	---	---
ASHLEYB	---	---	---	---
KEVINB	---	---	---	---
ASHLEY	8501831	6.93	1.04	10.915
KRISTA	6616458.5	6.82	0.93	8.580
GROBE	8250912.5	6.92	1.03	10.606
MA	7712641.5	6.89	1.00	9.941
JB	5043022	6.70	0.82	6.611
KEVIN	3805697.5	6.58	0.70	5.046

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**Figure 8: Schuman Park Map with cDCE Concentrations:** A map of Schuman Park with the locations of where Tree Cores were obtained and their associated concentrations. The color of the dot is based upon the key on the right side of the map

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**Figure 9: Schuman Park Map with TCE Concentrations:** A map of Schuman Park with the locations of where Tree Cores were obtained and their associated concentrations. The color of the dot is based upon the key on the right side of the map



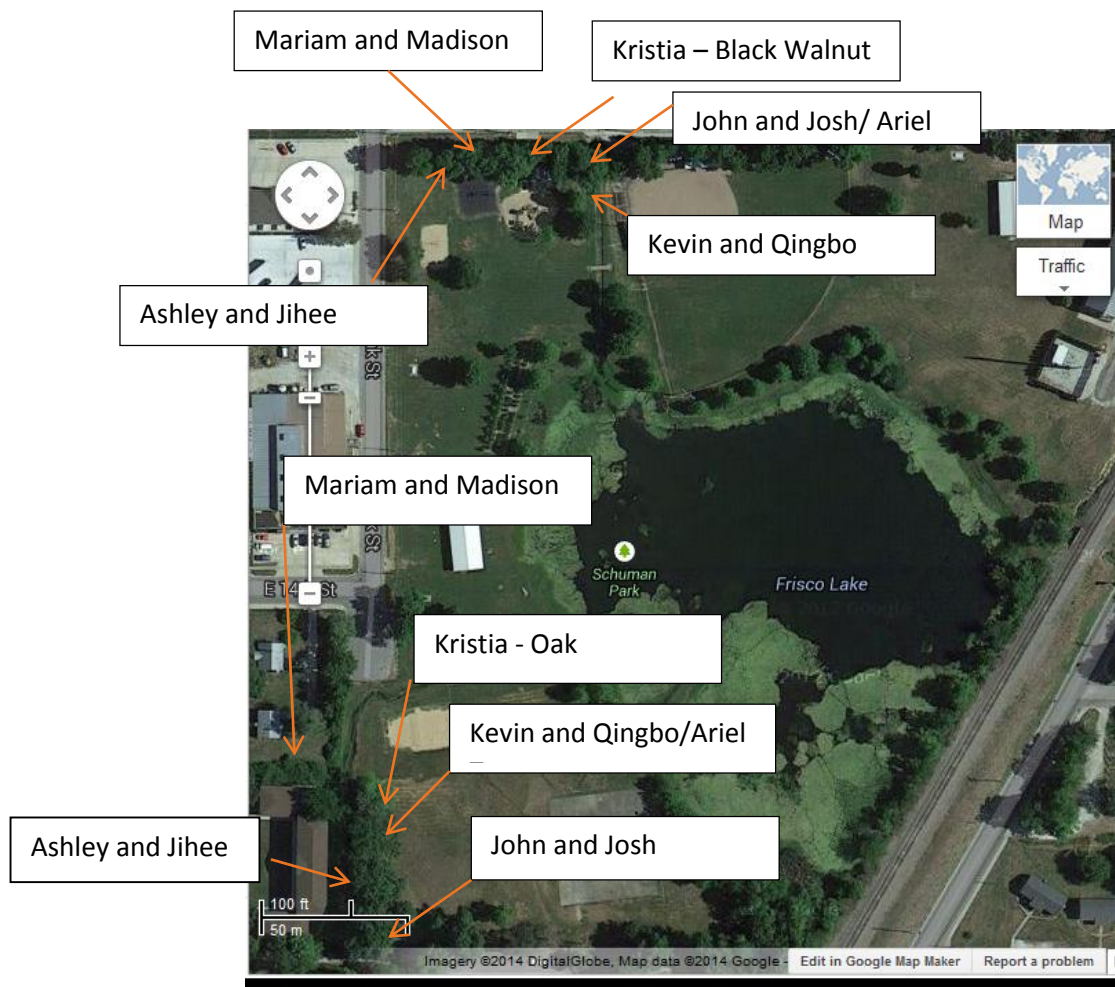
## Tree Sampling Report



**Figure 10: Schuman Park Map with PCE Concentrations:** A map of Schuman Park with the locations of where Tree Cores were obtained and their associated concentrations. The color of the dot is based upon the key on the right side of the map



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**Figure 11: Schuman Park Map with Tree Core Sample Location:** A map of Schuman Park with the locations of where Tree Cores samples were obtained and the group that collected them.



**Figure 12: Schuman Park Map with Tree Twig Sample Location:** A map of Schuman Park with the locations of where Tree twig samples were obtained and the group that collected them.

For the samples that our group collected, the results were to be as expected. We did not observe any cDCE or TCE in either of the tree core samples that we obtained (see the highlighted cells in tables 9 and 10). However in both of the tree core values we did observe a concentration. The concentration of the Oak tree was below the detectable limits although a peak was observed. The concentration in the Ash tree was found to be 0.003 ppb PCE (see the highlighted cells in table 11). Since these trees were not near the lake or the points of contamination we did not expect to see much concentration of contamination if any, which we indeed observed. Just because we did not observe any concentrations of cDCE or TCE it does not mean that there is no ground contamination with those VOCs, it just means it is too low for the machine to detect or that the tree had not absorbed enough of it to be detectable in the core sample we obtained. The samples for all groups were around the same concentration for all three compounds (see figure 10, 11, 12).

The undosed tree samples (seen in table 7) showed no observed VOCs. In the dosed tree samples (seen in table 8) no cDCE peaks were observed in any group. However, the TCE and PCE were detected. In comparison to the other groups ours was the lowest concentration concentration. This is most likely due to the type of tree that we utilized. Our tree was extremely close to Schuman Park and

## Tree Sampling Report

had recently been trimmed in order to help it survive as it was in the process of dying. This must have affected the amount of VOCs our sample absorbed within the dosing chamber.

This method of monitoring VOCs in ground water is very effective for a number of different reasons. The first is that it is cheaper to take out cores from trees as opposed to drilling into the ground and creating a sample well. It is also much easier to take multiple samples from multiple different trees since a new well would not have to be created for each sample. The other is that, although it is not a perfect representation, it is a great representation of the true ground water concentrations and thus would be sufficient for monitoring. A typical well costs between \$15-\$100 per foot with a total cost of 3,000 - \$50,000 total for each well while the tree sampling method only costs for the tree coring device and for the cost of planting trees if necessary.

## V. Conclusion

Overall cDCE was not observed in any of the samples that were obtained. In one of our samples we observed a concentration of TCE but not in the sample that was located a long distance from Schuman Park. For the third compound, PCE, it was observed in all samples that were obtained. It appears that the distance from the source of contamination, the Laundromat, affects the amount of concentrations of the VOCs found within the tree core samples. This method for analyzing the samples is more cost effective and efficient in regards to time. The method provides a good representation for the amount of ground water concentrations of the VOCs and thus is effective in terms of monitoring these concentrations in the area and determining the amount of contamination in a specific area. The contamination to Schuman Park does not appear to be widespread but it is obvious that there is contamination to the area and as such it should be continued to be monitored to ensure the concentrations are not increasing and the VOCs spreading.

## VI. Monitoring Experience

Overall this monitoring experience was very insightful. I learned a lot more about what exactly tree sampling is and what it can be used for. I also learned more about the techniques/spectrometers used to analyze samples through the research required to write this report. During the process of writing the introduction I learned a lot more about the history of tree sampling and I would like to see this incorporated into the lab somehow. I think it would also be more beneficial to do more pre lab questions or activity before conducting the lab to ensure that we have a better understanding of what we are doing while carrying out the sampling. The most helpful was having Matt around to be able to ask questions about the sampling process and having Danielle available to ask any questions about the lab. I think one thing to improve the lab overall is just to prepare us more before we actually go out into the field and collect samples.

## VII. Acknowledgements

I would like to thank the Environmental research center for providing the instruments and equipment for the experiment. I would also like to thank Danielle West for all the extra time she put into the lab in order to help us gather and analyze our data as well as for the help in understanding exactly what we were seeing. I would also like to thank Matt Limmer for taking the time to explain to us what his research group is doing and for his help in collecting the tree samples. I would also like to thank Dr. Ma for allowing us to put what we are learning in the classroom into practice. Finally I would like to thank Qingbo Yang for his help in sample collection, data analysis, and enthusiasm in conducting this experiment.



**Figure 13: Qingbo Yang:** *A picture taken after all samples had been utilized with Qingbo displaying the enthusiasm he had for this lab.*

## VIII. Pre Lab Questions

The three specific VOCs that are being analyzed in this experiment are dichloroethene (cDCE), trichloroethene (TCE), and perchloroethylene (PCE). The specific chemical properties are shown below:

**Table 12: Compound Chemical Properties:** *The chemical properties for the three VOCs being analyzed.*

Compound Name	Molecular Formula	Boiling Point (°C)	Melting Point (°C)	Partition Coefficient of Octanol/Water	Henry's Law Constant (atm m <sup>3</sup> /mol)
dichloroethene (cDCE)	C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub>	Z: 60.2 E: 48.5	Z: -81.47 E: -49.44	Z: 1.86 E: 2.06	Z: 0.00337 E: 0.00672
trichloroethene (TCE)	C <sub>2</sub> HCl <sub>3</sub>	87.2	-73	2.61	0.00985
perchloroethylene (PCE)	C <sub>2</sub> Cl <sub>4</sub>	121.1	-19	3.4	0.018

Each of these pieces of information provide a way to understand and monitor these compounds as well as distinguish them from one another. The molecular formula is the atoms tat make up the chemical compound associated with it. The boiling point of the compound is the temperature at which the compound boils. The melting point of the compound is the temperature at which the compound melts. The partition coefficient of octanol and water is the ratio of concentrations of the compound in a mixture of two phases that are immiscible at equilibrium. The two solvents, in this case, are octanol and water. Water is hydrophilic while the octanol is hydrophilic. This value provides insight as to how a compound will be absorbed into soil and thus into the trees within an area. Henry's Law Constant provides information regarding the compounds solubility. It is obtained from the ratio of pressure of the solutes to the concentration of the solutes. Henry's law constant is entirely dependent upon the solute, solvent, and temperature.

All of these chemical properties allow us to understand the order in which each compound will be dedcted, specifically in terms of the partition coefficient of octanol/water and the henry's law constant. Based upon these two values it can be assumed that the PCE will be detected first, followed by TCE and then cDCE.

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## **Monitoring Indoor and Outdoor Air Contamination of Volatile Organic Compounds with the use of Passive Air Sampling Techniques and Analysis with Gas Chromatography – Mass Spectrometry**

**John Armstrong and Josh Grobe**

**Department of Chemistry, Missouri University of Science and Technology**

### **I. Objective**

The purpose of this experiment is to overall gain exposure to air monitoring techniques and determination of air quality, according to VOC content, in several different locations. First, we will obtain an air sample in a predetermined indoor location. Once the indoor air sample is obtained, it will be analyzed with the use of gas chromatography and mass spectrometry. Next, we will obtain an air sample from an outdoor location. The outdoor location analyzed is an On-The-Run Mobile gas station. The air sample will be returned to the lab and analyzed with GC-MS. Both the indoor samples and outdoor samples will be analyzed for 13 different VOCs. The VOCs of interest are benzaldehyde, nonanal, octanal, 2,3,3 – trimethylpentane, ethylacetate, benzene, acetone, 2,2,4-trimethylhexane, Acetophenone, D-limonene,  $\alpha$ -pinene, decanal, toluene and 2,3,4 – trimethylpentane. The data produced from the GC-MS will be interpreted to determine what VOCs are present and then we can make predictions about where the VOCs may have come from, and how these VOCs influences the air quality.

### **II. Introduction**

The Clean Air Act of 1990 has established and provides a standard for air quality in the United States. Enforcement of the clean air act by national, state, and local efforts ensure that the criteria of the CCA are met by implementing strategies and establishing specific operating requirements to control the emission of pollution from industrial, automotive, and other sources. There are many different sources of air borne pollution and a variety of different types of pollution. The EPA has been able to categorize the most harmful pollutants into a six categories, known as the criteria pollutants.<sup>4</sup> These six categories are lead, sulfur dioxide, nitrogen oxides, particulate matter, carbon monoxide, and ground level ozone. Even though these are the major pollutants focused on by the EPA and regulated accordingly to the CCA, there are other air pollutants that are important to monitor, such as VOCs. VOCs stands for volatile organic compounds, and many of these VOCs can be toxic and even carcinogenic. VOCs are regulated by OSHA and US Department of Labor because they can detrimental to quality of health. VOC concentration in air is important to monitor because it is an indication of the quality of the air. Also, VOCs can be directly responsible for the formation of ground level ozone, which is one of the criteria pollutants. This is several of the reasons why VOCs are important to monitor.

In this experiment we will determine the VOC content of indoor and outdoor air samples. We will be using a passive method for sampling air. There are two different categories for air

sampling methodologies. There is active air sampling and passive air sampling. Active air sampling is basically a sampling method that relies on an input of energy to acquire the air in the process of sampling. In active sampling, a pump is typically involved, that is used to force air into a capture vessel or through a sampler containing an adsorbent material.<sup>2</sup> The other category for air sampling is passive air sampling. Passive sampling relies on the diffusion of air through an absorbent material such as thermal desorption tube in order to collect the analytes contained in the air sample.<sup>5</sup> Passive sampling is typically less complex and more resilient, so this technique was used for our sampling. We used a thermal desorption tube sampler, that was filled with conditioned Tanex TA absorbent. The absorption material was only exposed to the atmosphere of interest when it was at the sampling site.

The analytes of interest were VOCs so the method and adsorption material used was suited for VOCs detection. There are many different air pollutants that could have been analyzed such as heavy metals, particulate content, or even bacteria, but the sampling method and analysis method would have to be changed. Our thermal desorption tubes work particularly well for obtaining VOCs from the air, if we were interested in another contaminant then we would have to choose a sampling medium that is suited for that analyte, such as a cellulose ester membrane filter for particulate contamination or heavy metal content analysis. Also, if we decided monitor a different analyte; we would have to use an analysis technique best suited for detection of that contaminant, such as atomic absorption spectroscopy for determination of lead contamination in air. We decided to use Gas chromatography coupled with mass spectroscopy. This method is extremely effective for accurate determination and quantification of many different VOCs. Even though the method was coupled with mass spectrometry, the mass spectrometer was only used for determining the retention time of the standards after they passed through the GC. The experiment sample analytes were determined purely according to retention time. This method for determining the compound is effective if only your compounds of interest exist in the sample, if not, a different compound could have the same or similar retention time and produce a false positive. GC-MS is one of the easiest and most effective methods for determining VOC content. Unfortunately the methodology and sampling technique does not allow us to provide a quantitative value for the contaminant levels in the air. Since this method did not provide a standard curve, and the sampling technique did not monitor a specific volume of air, or the sampler is easily influenced by factors such as exposure time, air movement, and temperature, we cannot provide a concentration with the contaminant. The methodology used is beneficial primarily for determining whether a contamination is present or not.

We environment that we monitored can be separated into 2 different categories, indoor environment and outdoor environment. Each student had the opportunity to choose their own indoor environment to monitor, while the outdoor environment was predetermined. Studies have shown that indoor levels of VOCs contaminants are 2 to 5 times greater than outdoor levels of VOCs.<sup>6</sup> The Indoor environments chosen by the students ranged from laundry rooms to car interiors, to living rooms, this provided an array of different indoor environment for evaluation and would provide a thorough indication of possible VOCs present indoor. Students



would take the sampler to the destination, uncapped the sampler, and leave it undisturbed for 48 hours. The students would recap the sampler and then return it to the lab for analysis with GC-MS. There are many different synthetic or organic products present indoors that would be responsible for VOCs, such as paints, solvents, lubricants, detergents, plastics, and etc. The outdoor sampling location was organized so 6 different passive samplers would obtain air samples in 6 specific locations around the On-The-Run Gas Station. The samplers would be uncapped at the site and then a sample would be obtained over a 40 minute time period. This testing site should yield some interesting results considering the different possible VOCs expected to be present at a gas station. Gasoline itself is made up of many different components of hydrocarbons such as 2,3,4 –trimethylpentane, or 2,3,3 – trimethylpentane, which are two VOCs that we are interested in. Also, we have to consider the VOCs produced from the combustion of the gasoline and the all of the chemicals involved in the operation of a car, such as lubricants and oil. In an area of such high amount of traffic, it is expected that high concentrations and a variety of different VOCs will be prevalent. The results of testing the indoor site and the outdoor site will allow us to provide a comparison between the two environment and we can extrapolate the condition of air quality for both.

### **III. Experimental Procedures and Chemical Reagents**

This experiment procedure can be divided into three specific section, sampler preparation, air sampling, and analysis of air sampler.

#### **Sampler Preparation**

The sampler used was a passive type of thermal desorption tube. The thermal desorption tube was an outer diameter of ¼ in. by length of 3 ½ in. stainless steel thermal desorption tube with brass end caps, they are distributed by Sigma-Aldrich. The tubes were packed with Tenax TA adsorbent by Danielle West. The tubes were packed with adsorbent material in the center with a wire mesh screen and a torsion spring on each side to keep the adsorbent material in place. The tubes were then heated in an oven to condition the adsorbent material and ensure that no VOCs were present in the material before taking samples. The tubes were closed with brass caps directly after conditioned and then distributed to students. All tubes have a unique serial number associated with each one.

#### **Air Sampling**

The site used for indoor air monitoring was decided by each individual student. Each student received a single sampler tube. The tube would be taken to the sampling site and the brass caps would be removed. The sampling tube would then be placed in an area for approximately 48 hours. The tube would remain undisturbed for the 48 hours. After 48 hours the tube would be recapped and returned back to the lab for analysis. The sampler number was recorded by each student to keep track of the data produced.

The site used for outdoor sampling was a local gas station; students were allowed to take air samples at various locations outside on the property of the gas station. Students were devised into groups of two people per group; each group would receive a single sampling tube. The tube was taken to the gas station and the caps were removed. The sampler was placed on a surface for approximately 40 minutes and undisturbed for the time period. The tubes were recapped and returned back to the lab for analysis. The sampler number was recorded by each student to keep track of the data produced.

### Analysis of Air Sample

The air samples were analyzed with gas chromatography and mass spectroscopy. The gas chromatograph use is an Agilent 6890N Gas Chromatography. Helium was the carrier gas. Operation of the GC-MS consisted of a sampler placed in the GC, the sampler was heated and thermal desorption occurred. The VOCs were desorbed from the sampler and held in the trap of the GC for 5 minutes before being injected into the column. The VOCs of interest eluted from the column within 12 minutes. All VOCs were eluted from the column before the next sample was analyzed. Detection of the compound was performed by mass spectrometry. The mass spectrometer used was an Agilent 5973N.

Compounds were detected according to retention time of standard samples of VOCs. The detection of a compound at a specific retention time would indicate whether the compound was present or not. The samples were analyzed for benzaldehyde, nonanal, octanal, 2,3,3 – trimethylpentane, ethylacetate, benzene, acetone, 2,2,4-trimethylhexane, Acetophenone, D-limonene,  $\alpha$ -pinene, decanal, toluene and 2,3,4 – trimethylpentane. The retention time is displayed in table 1. Another possible operation parameter of GC-MS to determine VOCs in an air sample is outlined in Method TO-15 for the EPA.

Table 1.

Retention Time	Analyte
1.34	Acetone
1.44	Ethyl Acetate
1.54	Benzene
1.82	2,3,4-Trimethylpentane
1.92	Toluene
1.96	2,2,4-Trimethylhexane
3.35	$\alpha$ -Pinene
3.85	Benzaldehyde
4.67	Octanal
5.37	D-Limonene
6.78	Acetophenone
8.36	Nonanal
11.91	Decanal

#### IV. Results and Discussion

Table 2. Location of Indoor Air Sampling

Name	Location
Kevin	My Car
Ashley	My Room
John	My Basement
Qingbo	Mass-Spec Lab Exhaust
Madison	My Car
Ariel	My Living Room
Kelly	Sig Tau Lounge
Kristia	Laundry/Storage Room
Mariam	My Living Room
Joe	My Room
Josh	Laundry Room
Belinda	My Closet

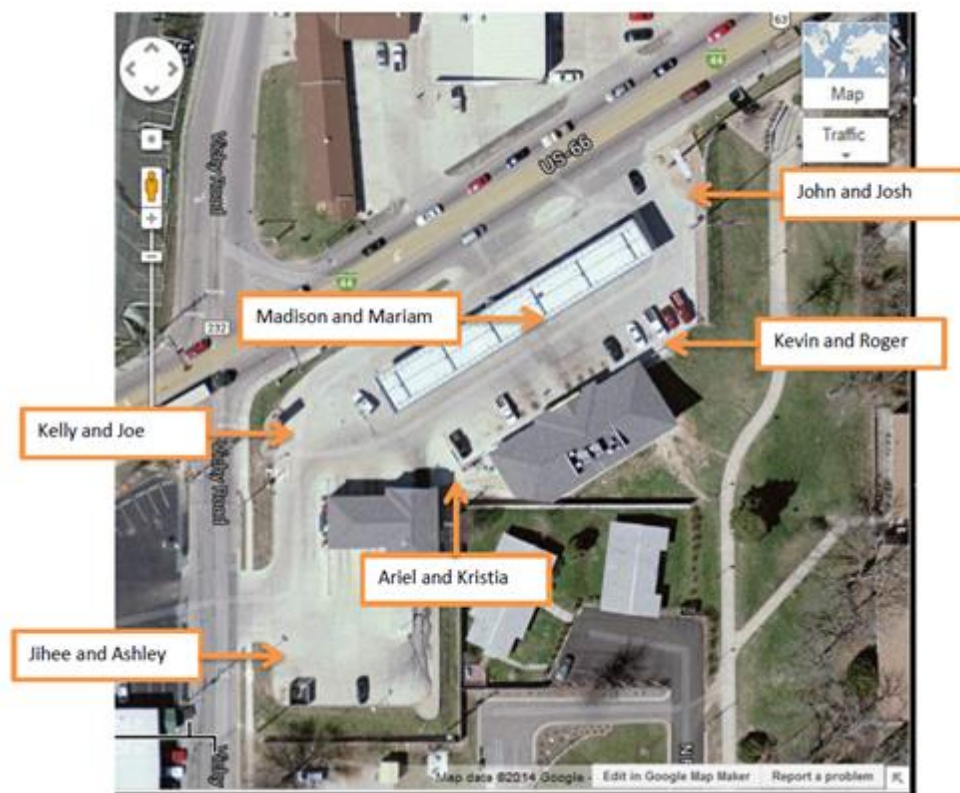


Figure 1. Location of Outdoor Air Sampling

## Air Monitoring Report

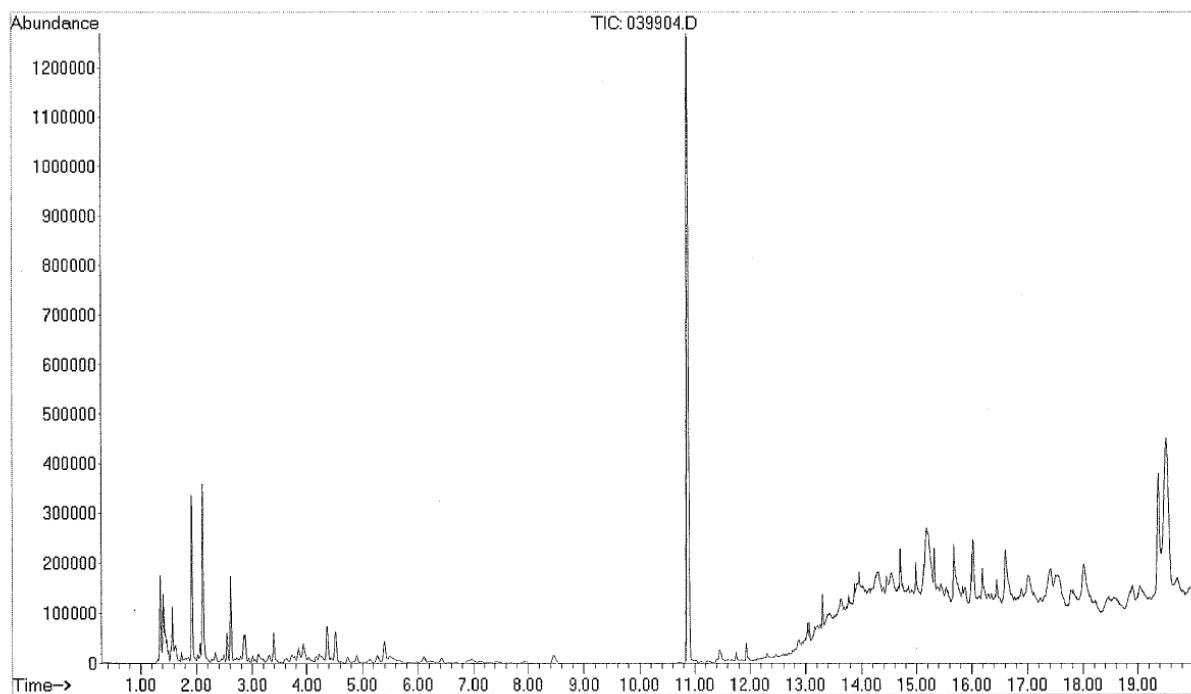


Figure 2. Chromatogram of Indoor Air Sample for John's Basement

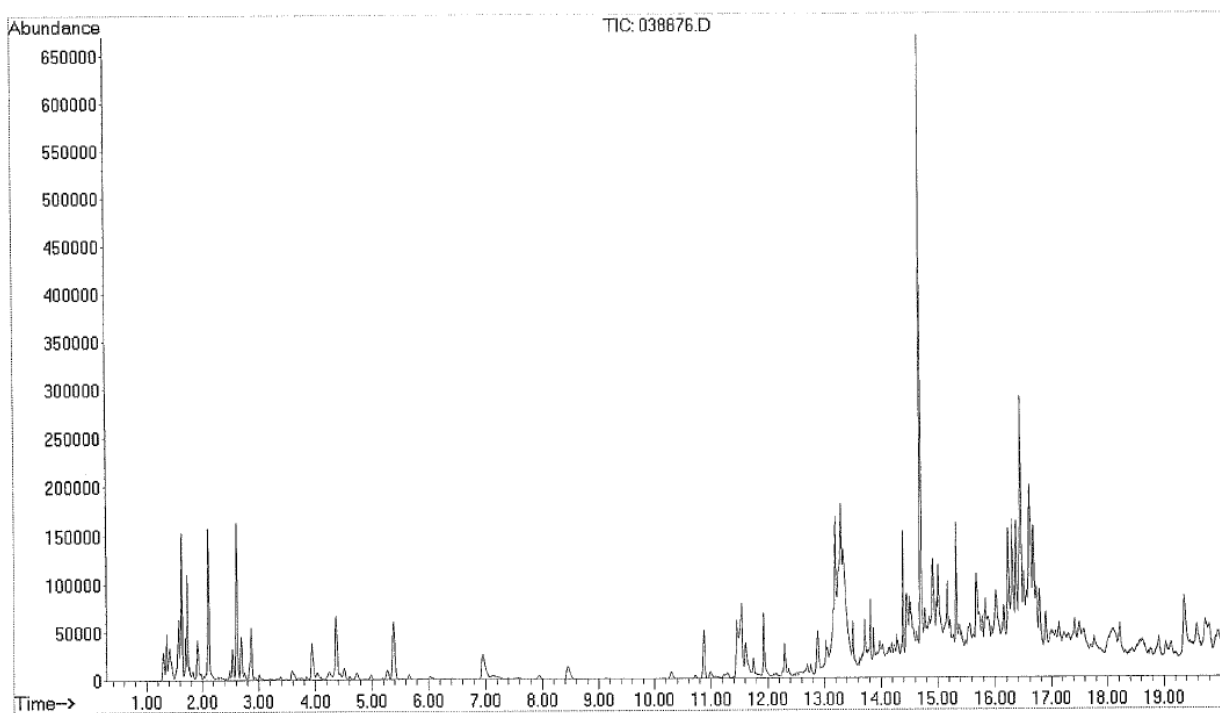


Figure 3. Chromatogram of Outdoor Air Sample for John and Josh

## Air Monitoring Report

Table 3. Standard Deviation of Toluene Retention Time

Reference	Compound	Time (minutes)
	Toluene	1.92

Tube #	Compound	Time (minutes)
38735	Toluene	1.921
38740	Toluene	1.933
38952	Toluene	1.915
38854	Toluene	1.927
38869	Toluene	1.921
38876	Toluene	1.932
39506	Toluene	1.921
39508	Toluene	1.921
39510	Toluene	1.915
39904	Toluene	1.921
51334	Toluene	1.921
51379	Toluene	1.933
81741	Toluene	1.921

Average	1.923230769
Standard Deviation	0.006139406

Table 4. Chromatograph Intensity Values for Analytes detected in Indoor Air Samples

Analyst	Indoor Location	Analyte (Corr. Area)													
		Acetone	Ethyl Acetate	Benzene	2,3,4-Trimethylpentane	2,3,3-Trimethylpentane	Toluene	2,2,4-Trimethylhexane	α-Pinene	Benzaldehyde	Octanal	D-Limonene	Acetophenone	Nonanal	Decanal
John Armstrong	Basement of my House	0	0	0	0	0	4993009	0	0	366674	0	0	0	0	0
Ashley Upschulte	My bedroom	0	0	0	20263329	0	158015304	0	0	0	0	0	0	0	18747598
Kristia Parker	Laundry / Storage Room	3021932	2861648	939380	41626	0	9590872	0	0	90774	0	9734877	0	0	1700114
Madison Rector	Car	2068566	1129494	2074613	0	0	1060427	0	0	0	0	1552428	0	0	1522902
Mariam Allami	my living room	798800	852380	482927	0	0	566217	0	0	0	0	2606536	0	0	1854438
Ariel Donovan	My bedroom	1518205	1549094	0	0	0	1019125	0	0	242365	0	2051786	0	0	1207323
Jihee Choi	My Closet	0	0	0	0	0	2584789	0	0	258073	0	0	0	0	0
Kevin Clark	My Car	1273245	522152	3301962	0	0	1288712	0	0	0	0	0	0	0	2280385
Joshua Grobe	Laundry / Storage Room	1142324	1118842	48601	0	0	847551	0	474142	89008	0	505259	0	0	1292398
Qingbo Yang	Mass-Spec Exhaust	2925155	4747028	0	7270175	0	20826065	6692049	0	0	0	0	35172452	9885820	42442350
Joseph Bossi	My bedroom	1360172	1588086	884170	0	0	1204484	0	747953	0	0	663910	0	0	1982598
Kelly Walsh	Lounge	426541	242928	1101854	0	0	263822	0	0	0	0	0	0	0	1721560

Table 5. Analyte Detected in Indoor Air Samples

Analyst	Indoor Location	Analyte (Corr. Area)													
		Acetone	Ethyl Acetate	Benzene	2,3,4-Trimethylpentane	2,3,3-Trimethylpentane	Toluene	2,2,4-Trimethylhexane	α-Pinene	Benzaldehyde	Octanal	D-Limonene	Acetophenone	Nonanal	Decanal
John Armstrong	Basement of my House	0	0	0	0	0	0 X	0	0 X	0	0	0	0	0	0
Ashley Upschulte	My bedroom	0	0	0	0 X	0	0 X	0	0	0	0	0	0	0	0 X
Kristia Parker	Laundry / Storage Room	X	X	X	X	0	0 X	0	0 X	0	0 X	0	0	0	0 X
Madison Rector	Car	X	X	X	0	0	0 X	0	0	0	0 X	0	0	0	0 X
Mariam Allami	my living room	X	X	X	0	0	0 X	0	0	0	0 X	0	0	0	0 X
Ariel Donovan	My bedroom	X	X	0	0	0	0 X	0	0 X	0	0 X	0	0	0	0 X
Jihee Choi	My Closet	0	0	0	0	0	0 X	0	0 X	0	0	0	0	0	0
Kevin Clark	My Car	X	X	X	0	0	0 X	0	0	0	0	0	0	0	0 X
Joshua Grobe	Laundry / Storage Room	X	X	X	0	0	0 X	0 X	X	0	0 X	0	0	0	0 X
Qingbo Yang	Mass-Spec Exhaust	X	X	0	0 X	0	0 X	X	0	0	0	0 X	X	X	X
Joseph Bossi	My bedroom	X	X	X	0	0	0 X	0 X	0	0	0 X	0	0	0	0 X
Kelly Walsh	Lounge	X	X	X	0	0	0 X	0	0	0	0	0	0	0	0 X

## Air Monitoring Report

Table 6. Chromatograph Intensity Values for Analytes detected in Indoor Air Samples

Outdoor Sampling														
Analyst	Analyte (Corr. Area)													
	Acetone	Ethyl Acetate	Benzene	2,3,4-Trimethylpentane	2,3,3-Trimethylpentane	Toluene	2,2,4-Trimethylhexane	$\alpha$ -Pinene	Benzaldehyde	Octanal	D-Limonene	Acetophenone	Nonanal	Decanal
John and Josh	0	0	0	0	0	805403	0	0	0	0	1600406	0	0	0
Ashley and Jihee	0	0	0	0	0	1028957	0	0	0	0	0	0	0	1619896
Kristia & Ariel	118484	189604	422635	0	0	42938	0	0	0	0	0	0	0	723347
Madison & Mariam	368112	12522	436762	0	0	177095	0	0	20480	0	0	0	0	968316
Kevin & Qingbo	198356	159143	443830	0	0	48110	0	0	0	0	0	0	0	1139587
Joe & Kelly	228364	447186	478863	0	0	58952	0	0	44166	0	0	0	0	1075406

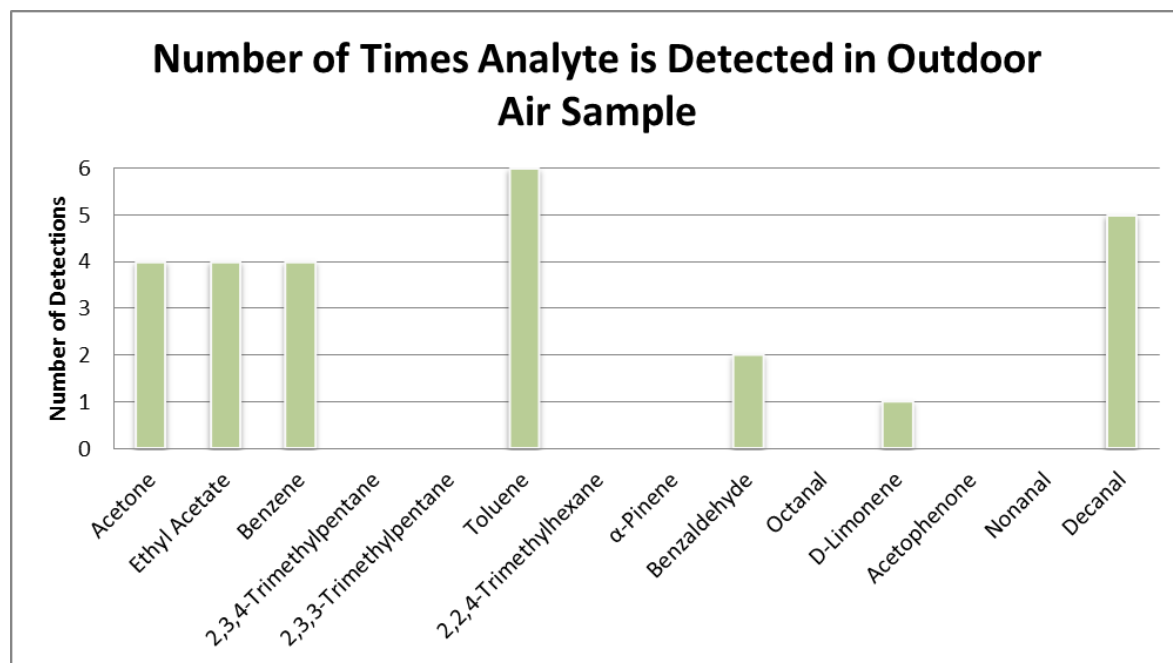


Figure 4.

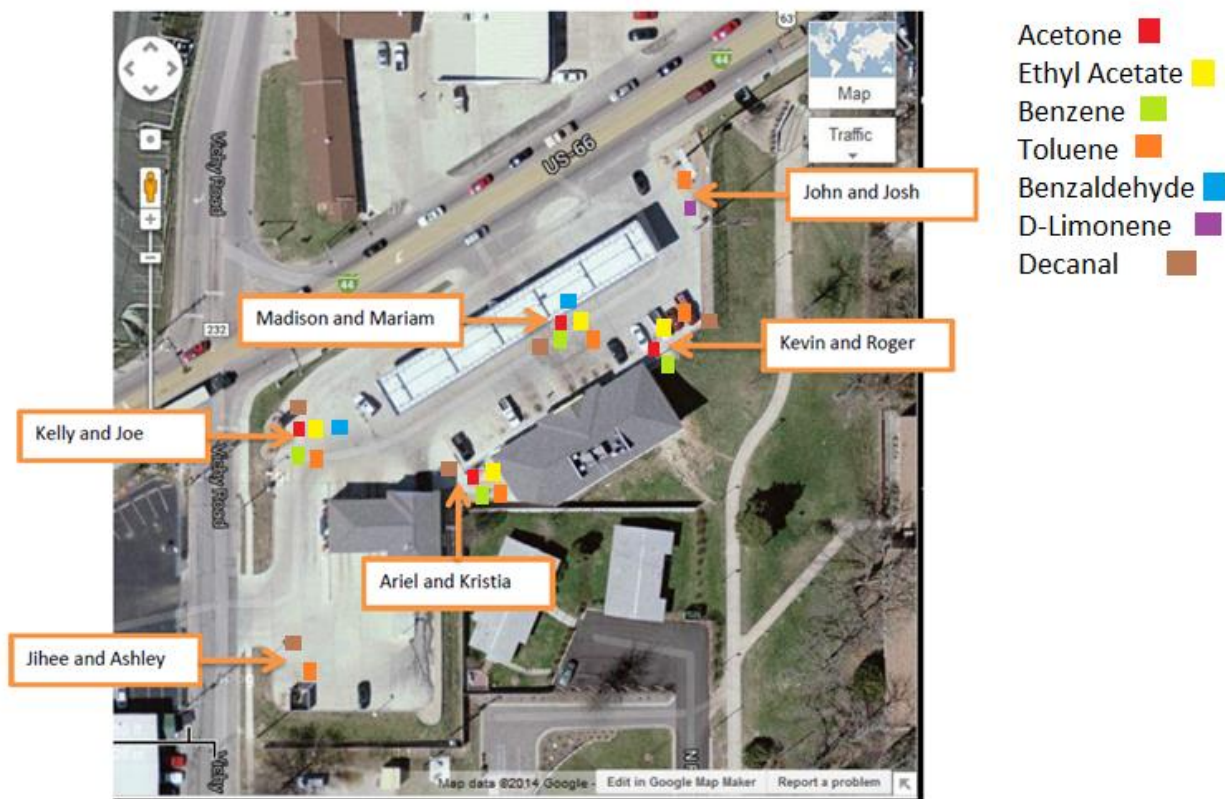


Figure 5. Color coded map of Analytes Detected at On-the-Run Gas Station

Table 7. EPA regulation of VOCs contained in air analyzed in experiment

Compound	EPA Regulated
Acetone	No
Ethyl Acetate	No
Benzene	No
2,3,4-Trimethylpentane	No
2,3,3-Trimethylpentane	No
Toluene	No
2,2,4-Trimethylhexane	No
$\alpha$ -Pinene	No
Benzaldehyde	No
Octanal	No
D-Limonene	No
Acetophenone	No
Nonanal	No
Decanal	No

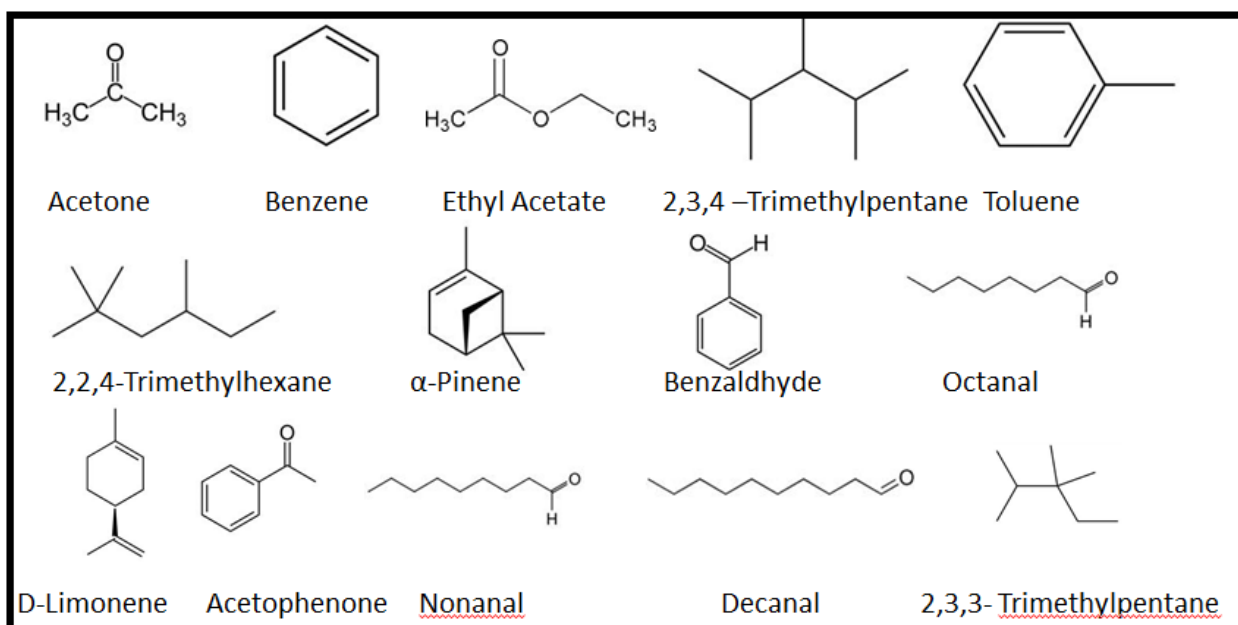


Figure 6. Structures of VOCs of interest

The results of this experiment yielded many different aspects of the quality of indoor and outdoor air sources. First, we will examine the VOCs contained in indoor air. Air samples were taken from a variety of different indoor environments, such as basements, bedrooms, living rooms, car interiors, laundry rooms, and mass spectroscopy exhausts hoods. In assigning analyte detection in our air samples in reference to our standard analyte retention times, I had to determine an appropriate range to conclude that the retention time of a VOC in the air sample is in fact one of the analytes we are interested in. Unfortunately, the best method for determining if the analyte eluding from the GC is one of the analytes of interest is best determined with the use of the mass spec, but I did not retrieve the mass spec data for each analyte eluded from the GC, so analyte detection is based on retention time. I calculated the standard deviation for the elution time of toluene in each air sample demonstrated in **Table 3**; this would provide a general idea of how great of a range the elution time can deviate. The standard deviation of the retention time of toluene is .0061 minutes; I rounded up the standard deviation to +/- .01 minutes. So when I assigned GC retention time peaks, they were within .01 minute of the reference value.

The indoor air samples all contained some VOC content according to the produced from testing. The detection of specific VOCs in different environments is shown in **Table 5**. All air sample contained toluene. Toluene is a VOC commonly found in many different products such as paint, paint thinner, detergents, rubber, lacquers, adhesives and printing ink. There are many



different sources toluene in this indoor setting, such as gasoline in the car interiors, or paint which is found in all of the indoor environments. Toluene is toxic at high levels, but not particularly harmful at low concentrations, so I do not believe that finding toluene in these environments is unexpected or problematic. Benzaldehyde was also found in many of these environments, such as the bedrooms, basements, and laundry rooms. Benzaldehyde is found in many household products such as shampoos, conditioners, shaving cream, and some plastic products, in fact benzaldehyde is found in cinnamon and almond flavoring. This explains why it is found in bedrooms or laundry rooms, because often personal care products and detergents are found in these areas, although the source of benzaldehyde is not obvious in the basement location. Another interesting result of testing indoor air is that almost all locations that detected acetone, ethyl acetate and benzene were also detected. This suggests that they came from a similar source. All three of these VOCs can be found in solvents, paint, glues and adhesives. Finding acetone and ethyl acetate in the indoor environment is not unexpected but finding benzene is unexpected. Benzene is toxic and carcinogenic; any concentration of benzene in an environment is undesired. Benzene content in household products is heavily regulated, if not banned all together due to its toxicity. This leads me to believe that the benzene must come from another source. I believe that the benzene comes from the exhaust of burning hydrocarbons, such as a car, or from cigarettes. D- limonene was found in many different environment as expected, since it is used in many different cleaning supplies, and fragrances to provide a citrus smell to the products. Also, alpha pinene was not commonly found in many different environments, this was a surprise. Alpha pinene is found in many different cleaning detergents and cleaning supplies, I expected it to be found in many different locations or at least in similar locations as D-limonene. Perhaps Alpha pinene is not as commonly used in cleaning supplies as D-limonene. Decanal is often used as a scent or flavoring in many different products to such as perfumes, colognes, and flavoring extracts, so it is expected to be commonly found since many people were some type of fragrance. I am surprised that nonanal and octanal was not more prevalent in more environments since it is used in similar applications as decanal. Nonanal and octanal are often used as flavoring or fragrance agents. Acetophenone and the three alkane hydrocarbons were not found in many different environments, with the exception of the mass spec exhaust. I do not equate the mass spec exhaust to be indication of the indoor air quality because the mass spec exhaust should be vented from the room. Surely it would be extremely harmful to constantly inhale mass spec exhaust on a daily basis. One exception to the hydrocarbon alkanes is the presence of 2,3,4-trimethylpentane in the laundry room or the bedroom, perhaps these VOCs are from a garage. Overall, we find that a lot of VOCs in indoor air are most likely due to paints and fragrance products, because the most commonly found VOCs in our samples are often found in paints and fragrances which are in many of our indoor environments.

The results of the testing of outdoor air sources near a gas station yielded particularly interesting results. The results of outdoor air monitoring are displayed in **Table 6, Figure 4, and Figure 5**. We expected the gas station air to contain hydrocarbon alkanes, but the results of the testing say otherwise. Also, the results of the testing of the gas station air are very consistent,

where almost all of the same analytes were found in each sampler tube. Acetone, acetate, benzene, toluene and decanal were found in almost all samples. These chemicals are all additives, combustion products, or involved in car care in some manner, so finding these chemicals are not surprising to find at a gas station. I believe that all sample tubes contained these VOCs but the acceptance range for retention times of VOCs varied from group to group when assigning peaks. The particularly surprising compound to find at the gas station is D-Limonene. This was found in John and Josh's sampling area. It is possible that the D-limonene came from a laundry mat exhaust found directly below the gas station, and then blew in John and Josh's direction. Another possibility is that D-limonene traveled the nearby car wash since the car wash uses cleaning solutions and detergents. I believe that the most probable cause of the D-limonene is due to some sort of glass cleaner or cleaning solvent used on a nearby light fixture. When acquiring the sample in this area John and Josh placed their sampler tube on a light fixture while taking an air sample, I believe the D-limonene was contained in the cleaning products used to clean this light. Finding D-limonene in a single air sample is very surprising and there must have been a unique source of the chemical. Another surprising aspect of the results of the testing is that no 2,3,4-trimethylpentane, 2,3,3-trimethylpentane, or 2,2,4-trimethylhexane was found in any samplers. These compounds are often added to gasoline or found in gasoline as a modifying agent. Perhaps the lack of finding these VOCs is an indication of the quality of the gas found at this gas station. Since the chemical composition of gasoline consists almost entirely of a variety of different hydrocarbons, I found the lack of these VOCs very surprising.

The results of testing both were only for a specific list of VOCs, there are many more in the environment than we tested for, such as the presence of naphthalene and anthracene found in my indoor air samples of my basement, which comes a bit of surprise since no benzene was found but these compounds similar to benzene were found. According to the results, there are two VOCs found in my basement toluene and benzaldehyde. Toluene does have potential to be dangerous at higher concentrations, some harmful health effects of toluene is cardiac arrhythmia reported in human acutely exposed to toluene<sup>1</sup> and CNS dysfunction, typically depression of the CNS, and narcosis<sup>1</sup>. Also, benzaldehyde was found in my basement air sample, fortunately benzaldehyde is only mildly toxic, some health effects of benzaldehyde is that direct exposure may cause dermatitis<sup>2</sup>, and inhaling high concentrations may cause respiratory failure<sup>3</sup>.

The outdoor air samples are somewhat representative of air quality of the gas station. According to the data the concentrations of ethyl acetate, decanal, toluene, and acetone vary greatly depending on the position of the sample site at the gas station. It is necessary to take many more samples in order to provide a more representative sample, but for our purposes, I feel that 6 samples are sufficient. Also, we should use a mechanism that prevents the wind current from influencing the amount of air that passes through our sampler, as this will affect the observed VOC concentrations, and skew the results.

Comparison between the intensity of the signal produced from the indoor air samples and outdoor air samples, it is obvious that time and exposure to an environment has a huge influence on the VOC absorption. Unfortunately we cannot normalize both to make an indication about VOC concentrations in each environment.

There are several aspects of this experiment that could be improved, specifically the quality control and quality assurance methods used in acquiring data. The first major adjustment in this experiment that would significantly improve the reliability of the results is that the mass spectrum for each peak was distributed with the chromatograph, to ensure we are correctly matching peaks to the correct analyte. Also, it is possible that another compound, not of interest, would elute at the same time as the VOCs of interest and produce a false positive; the mass spectrum of the compound would prevent this error. Since the mass spectrums were not given out with each compound and we relied on the retention time of the analyte in reference to the standard to determine the VOCs, we should have collectively determined an appropriate range of acceptance for each VOC. Some groups chose small ranges, while other chose wide ranges, thus consistency of reporting VOCs may have not been reliable. According to another group, the GC retention times for all of the compounds had a peak shift; this may have been responsible for some irregularities in the results. Another aspect of the experiment that could have been improved the quality of the results is the use of 2 different tubes at the same sampling site, this would provide information about the reliability of the technique used. Overall, this experiment could have been improved by distributing guidelines regarding peak matching, or distributing the mass spectrums for the peaks. It would have been interesting to use a method that would allow us to observe the concentration of the VOCs in the environment as well.

## V. Conclusion

We can conclude from the testing several interesting aspects about the quality of indoor air and outdoor air. First, the indoor air appeared to wide variety of different possible VOCs from many different sources. It appears that toluene is found in almost all indoor air, regardless of location, at some concentrations, while almost none of branched chain hydrocarbon alkanes of interest are found, specifically 2,3,4-trimethylpentane, 2,3,3-trimethylpentane, or 2,2,4-trimethylhexane. Also, it is probable that acetone, benzene, decanal, and ethyl acetate are often found in the indoor air. Benzaldehyde and D-lemonene are found depending on the specific sources located in an environment. According to the VOCs we analyzed, it appears that air samples from cars are similar in contents to an air sample from the interior of a house. In comparison to the outdoor air samples, the indoor air has a greater likely hood of containing more types of VOCs.

The results of the outdoor air sampling are also, very surprising. Even though 2,3,4-trimethylpentane, 2,3,3-trimethylpentane, or 2,2,4-trimethylhexane, are common components or additives to gasoline, we were not able to detect any of these VOCs at the gas station. In

addition, we were unable to detect, octanal, alpha pinene, acetophenone or nonanal. We did detect D-limonene with a single sampler, and I believe that the possible sources of the contaminant came from glass cleaner, laundry mat fumes, or car wash detergents. At the gas station it is common to find decanal, acetone, benzene, ethyl acetate, and toluene, which is very similar to finding about indoor air contents.

#### **VI. Monitoring Experience**

This was a great experience to learn about air monitoring. I liked the exposure with the actual sampling method, and the exposure to other sampling methods used when taking air samples. I wish that we would have established a better method for assigning chromatographic peaks to the analytes, or if the mass specs for each peak were distributed to the groups. It is necessary to establish a guideline for evaluating each group's data so the results are more consistent. I also enjoyed the fact that we got to take air samples from a familiar source such as our home or our car because it provides awareness of the quality of the air that we are breathing on a daily basis.

#### **VII. Acknowledgements**

I would like to Acknowledge Dr. Ma and Danielle West for providing the opportunity to conduct this experiment. I would like to especially thank Danielle West for all the work and effort put into helping us acquire and analyze air samples. I would like to thank Environmental research Center for provide the facilities to prepare and analyze the air samples collected.

#### **VIII. References**

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# Tree Core Sampling Method for Determination of Ground Water Contamination

John Armstrong  
Josh Grobe

## Objective

- Obtain tree core samples from various trees located within Schuman Lake Park.
- Determination of volatile organic compounds in tree core samples; specifically cis-Dichloroethylene, Trichloroethylene, and Perchloroethylene.
- Determine the partition coefficient of VOCs in tree core sample.
- Determine ground water contamination from tree core samples
- Map local concentrations VOC contaminants in tree core samples throughout Schuman Lake Park.
- Gain practical environmental monitoring exposure.

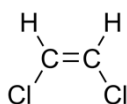
## Introduction

- Groundwater contamination determination is traditionally determined by directly drilling a well into the groundwater source.
- The process of drilling is expensive and potentially damaging to the environment.
- Tree core sampling is a possible alternative method to drilling
- Tree core sampling is quick, cheap, and easy.
- Trees absorb groundwater, thus trees will contain groundwater contaminants.
- Analysis of tree core reveal ground water contaminant level

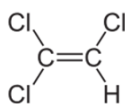
## Introduction

- Schuman Lake ground water contamination is due to improper disposal of dry cleaning solvents by local dry cleaning business.
- By removing tree core samples at different locations in the park ground water contamination can be assessed.

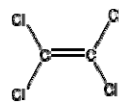
VOCs of interest



cis-Dichloroethylene



Trichloroethylene



Perchloroethylene

## Objective

- Schuman Lake Park tree core sampling locations



## Objective

- Once tree core samples are obtained analysis will be performed with the use of Solid Phase Micro-extraction followed by Gas Chromatography.
- Concentration of analytes will be determined with the use of an Electron Capture Device.
- Electron Capture Device is a GC detector that is particularly sensitive to halogenated compound.



## Experimental Procedure

- First tree need to be picked at Schuman Lake park for tree core sampling.
- Tree core sample are removed from each of the trees with the use of an tree core increment borer.
- The increment auger is screwed into the tree until a 2 inch sample is obtained.

Tree Core Sample

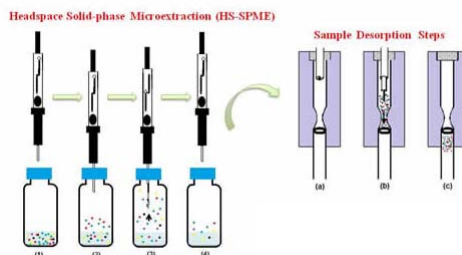


Tree Core Increment Auger



## Experimental Procedure

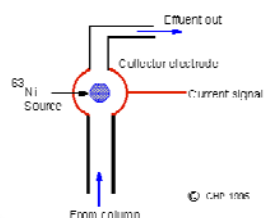
- Tree core samples are placed in a glass vial and capped to allow VOCs to equilibrate within headspace of the vial.
- Once VOCs equilibrate, VOCs are extracted from the vial with the use of a solid phase microextractor.
- Solid phase microextraction is a small fiber containing a stationary phase which allows the VOCs to partition into the fiber.



www.chrom-china.com

## Experimental Procedure

- The Solid phase microextraction fiber containing the analytes is placed into GC injection port where desorption of analytes occurs.
- Gas chromatography is performed on the sample and quantification is measured with the use of an electron capture detector.
- The GC used was an Agilent Model 7890 and the autosampler was a CTC Analytics COMBI PAL.
- Concentration of analytes in vial headspace are determined with the use of a standard curve.



Electron Capture  
Detector Schematic

Chem.unl.edu

## Experimental Procedure

- The relationship between the concentration of VOCs in the vial head space in comparison to the concentrations of the core sample is known as the partition coefficient.
- The partition coefficient is necessary to determine the VOCs in the ground water from the concentration of the VOCs in the vial's headspace.
- Partition Coefficient is determined with the use of a dosing chamber.

## Experimental Procedure

- A dosing chamber is a sealed vessel containing a known concentration of a particular analyte.
- A sample medium (tree branch in our case) is placed into the chamber and allowed to equilibrate with the analyte in the chamber.
- The sample is removed from the dosing chamber, placed in a new vial and allowed to equilibrate again
- The head space of the equilibrated sample vial is analyzed with GC.

## Experimental Procedure

- The dosing chamber used in procedure contained  $1\text{mg/m}^3$  PCE,  $25\text{ mg/m}^3$  TCE, and  $700\text{ mg/m}^3$  cDCE in 60 ml of Polydimethylsiloxane oil.
- 2, 1.5 inch maple tree branch samples were used. One sample was placed in the dosing chamber, and the other sample was analyzed with GC-ECD to determine initial VOC content.
- The dosed branches were then analyzed with GC-ECD using the same sample preparation technique as the tree core samples.

## Experimental Procedure

- Partition Coefficient Calculation

$$= \frac{\text{conc. of dosed sample headspace} - \text{conc. of undosed sample headspace}}{\text{Conc. of dosing chamber}}$$

		cDCE	Conc. Value 1.76 ppb	TCE	Conc. Value 4655 ppb	PCE	Conc. Value 147 ppb
Tree Type	Sample Name	Concentration (ppb)	Partition Coefficient	Concentration (ppb)	Partition Coefficient	Concentration (ppb)	Partition Coefficient
1 Willow	ASHLEY	---	---	69.22906	0.014871979	10.91508	0.074252216
3 Maple	GROBE	---	---	60.54670	0.01300681	10.60564	0.072147245
4 Willow	MA	---	---	53.19813	0.011428169	9.94057	0.067622896

The partition coefficient will help provide correlation between tree core VOC concentration and ground water VOC concentration.

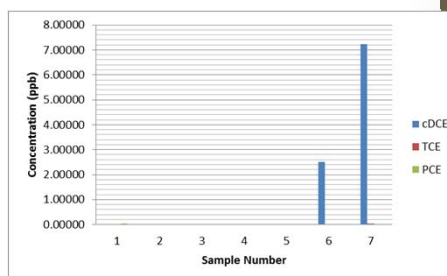
## Results

High concentrations of cis-dichloroethylene are found in the tree core samples near 16<sup>th</sup> Street. At sample site 6, 2.50 ppb of c-DCE were found, and at sample site 7, 7.24 ppb of c-CDE were found.

Location of Sample



Concentration of Contaminant for 16<sup>th</sup> Street Tree Core Samples



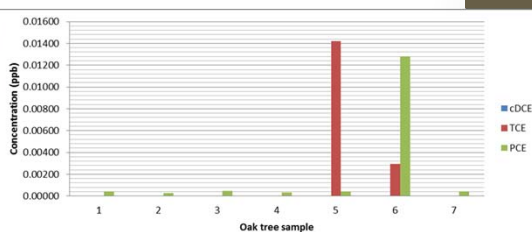
## Results

TCE and PCE were the most prevalent contaminant found in the tree core samples near the 12<sup>th</sup> street area. All c- DCE levels in the tree core did not exist or were below detection limit at this site.

Location of Sample



Concentration of Contaminant for 12<sup>th</sup> Street Tree Core Samples



## Results

Distribution of Tree Core Sample VOC Levels for contaminants over .01 ppb in Schuman Lake Park



Concentration

- .01-1ppb
- 1-2 ppb
- 2-3 ppb
- 3-4 ppb
- >5ppb

Type of Chlorinated Solvent

- 1 - cDCE
- 2 - TCE
- 3 - PCE

## Conclusion

- Tree Core Sampling indicates ground water contamination exist at Schuman Lake Park.
- Tree core samples near the 16<sup>th</sup> street area showed greatest concentration of contaminants.
- Cis-Dichloroethylene is most prevalent at the 16<sup>th</sup> street area where 2 tree core samples measured greater than 3 ppb in the tree core samples.
- 12<sup>th</sup> street area indicated some contamination but not as much as 16<sup>th</sup> street area.
- Data from direct ground water testing should be provided to indicate the validity of our technique.

## Water Sampling Objectives

- Learn about water collection and monitoring methods
- Learn about the tap water disinfection process, complications (with DBP's, etc.)
- Collect and analyze water samples from Schuman Lake and a tap water location using the learned QA/QC methods
- Analyze characteristics of water, including pH, turbidity, conductivity, temperature, free chlorine (FC), total chlorine (TC), NPOC, and total nitrogen (TN)
- Draw conclusions based on findings

## Introduction

- USEPA regulates water in the environment (CWA) and drinking water (SDWA)
- Major drinking water standards from the World Health Organization, European Union, and the USEPA

Parameter	Type	WHO	EU	USEPA
Ammonia	Social	1.5 mg L <sup>-1</sup>	0.50 mg L <sup>-1</sup>	No GL
pH	Social	6.5-8	No guidelines	6.5-8.5
Chloride	Social	250 mg L <sup>-1</sup>	250 mg L <sup>-1</sup>	250 mg L <sup>-1</sup>
Iron	Social	0.3 mg L <sup>-1</sup>	0.2 mg L <sup>-1</sup>	0.3 mg L <sup>-1</sup>
Lead	Health	0.01 mg L <sup>-1</sup>	0.01 mg L <sup>-1</sup>	0.015 mg L <sup>-1</sup>
Arsenic	Health	0.01 mg L <sup>-1</sup>	0.01 mg L <sup>-1</sup>	0.01 mg L <sup>-1</sup>
Copper	Health	2.0 mg L <sup>-1</sup>	2.0 mg L <sup>-1</sup>	1.3 mg L <sup>-1</sup>
Fecal Coliform bacteria	Health	0 counts/100 mL	0 counts/100 mL	0 counts/100 mL

## EPA Regulations – Drinking Water

Compound	MCL (mg/L)	Hazards	Sources	Goal (mg/L)
<b>D</b> Chlorine (as Cl <sub>2</sub> )	MEDL=4.0 <sup>1</sup>	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MEDLG=4 <sup>1</sup>
<b>IOC</b> Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
<b>IOC</b> Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1
<b>OC</b> Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thyroid gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
<b>M</b> Turbidity	TT <sup>1</sup>	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause short-term symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a

## Likely Sources of Ions/Contaminants

Source	Particulate constituents		Ionic and Dissolved Constituents		Gases and Neutral Species
	Colloidal	Suspended	Positive ions	Negative ions	
Contact of water with minerals, rocks, and soil (e.g., weathering)	Clay Silica ( $\text{SiO}_2$ ) Ferric oxide ( $\text{Fe}_2\text{O}_3$ ) Aluminum oxide ( $\text{Al}_2\text{O}_3$ ) Magnesium dioxide ( $\text{MnO}_2$ )	Clay, silt, sand, and other inorganic soils	Calcium ( $\text{Ca}^{2+}$ ) Iron ( $\text{Fe}^{2+}$ ) Magnesium ( $\text{Mg}^{2+}$ ) Manganese ( $\text{Mn}^{2+}$ ) Potassium ( $\text{K}^+$ ) Sodium ( $\text{Na}^+$ ) Zinc ( $\text{Zn}^{2+}$ )	Bicarbonate ( $\text{HCO}_3^-$ ) Borate ( $\text{H}_2\text{BO}_3^-$ ) Carbonate ( $\text{CO}_3^{2-}$ ) Chloride ( $\text{Cl}^-$ ) Fluoride ( $\text{F}^-$ ) Hydroxide ( $\text{OH}^-$ ) Nitrate ( $\text{NO}_3^-$ ) Phosphate ( $\text{PO}_4^{3-}$ ) Sulfate ( $\text{SO}_4^{2-}$ )	Carbon dioxide ( $\text{CO}_2$ ) Silicate ( $\text{H}_4\text{SiO}_4$ )
Rain in contact with atmosphere			Hydrogen ( $\text{H}^+$ )	Bicarbonate ( $\text{HCO}_3^-$ ) Chloride ( $\text{Cl}^-$ ) Sulfate ( $\text{SO}_4^{2-}$ )	Carbon dioxide ( $\text{CO}_2$ ) Nitrogen ( $\text{N}_2$ ) Oxygen ( $\text{O}_2$ ) Sulfur dioxide ( $\text{SO}_2$ )
Decomposition of organic matter in environment	Various organic polymers	Cell fragments	Ammonium ( $\text{NH}_4^+$ ) Hydrogen ( $\text{H}^+$ ) Sodium ( $\text{Na}^+$ )	Bicarbonate ( $\text{HCO}_3^-$ ) Chloride ( $\text{Cl}^-$ ) Hydroxide ( $\text{OH}^-$ ) Nitrate ( $\text{NO}_3^-$ ) Nitrite ( $\text{NO}_2^-$ ) Sulfide ( $\text{HS}^-$ ) Sulfate ( $\text{SO}_4^{2-}$ )	Ammonia ( $\text{NH}_3$ ) Carbon dioxide ( $\text{CO}_2$ ) Hydrogen sulfide ( $\text{H}_2\text{S}$ ) Hydrogen ( $\text{H}_2$ ) Methane ( $\text{CH}_4$ ) Nitrogen ( $\text{N}_2$ ) Oxygen ( $\text{O}_2$ ) Silicate ( $\text{H}_4\text{SiO}_4$ )

## Location



Tap water collected from library basement

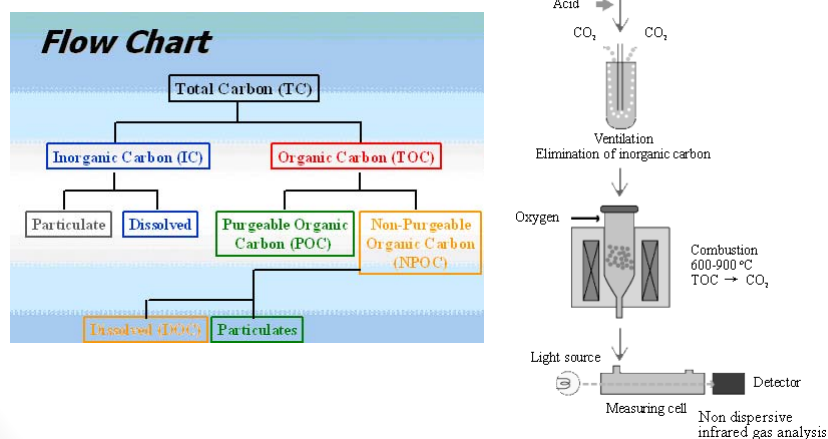


## Analysis Methods

- TC/FC – use pillow kit for colorimeter measurements
- Temperature – thermometer/thermocouple
- pH – careful 2 or 3 point calibration in buffer solution before measurement with probe
- Turbidity – Turbidimeter
- Conductivity – Conductivity meter
- Non-purgable Organic Compounds (NPOC) – See instrumentation (Thank you Danielle for calibration (using  $\text{KNO}_3$  for TN and  $\text{C}_8\text{H}_5\text{KO}_4$  for TOC))
- Total Nitrogen – See Instrumentation

## Instrumentation NPOC and TN

- NPOC Analyzer



## Water Results

Sample	Temperature (°C)	pH	Turbidity (unit)	Conductivity (unit)
Tap FB	21.3		8.36	0.05
Tap	19.9		7.4	0.08
Tap Dup	20.9		7.48	0.16
% RPD Tap	0.049019608	0.010752688	0.666666667	0.002285714
SL FB	20.2		7.71	0.15
SL	16		7.06	1.42
SL Dup	18.5		7.01	1.56
% RPD SL	0.144927536	0.007107321	0.093959732	0.009983361

Sample	FC (unit)	TC (unit)	NPOC (unit)	TN (unit)
Tap FB	0.01	0.03	0.7012	0
Tap	0.18	0.4	0.7634	0.05281
Tap Dup	0.28	0.25	0.9009	0
% RPD Tap	0.434782609	0.461538462	0.165234633	N/A
SL FB	0.01	0.02	0.7526	0.06099
SL	0.02	0.48	0.6363	0.01271
SL Dup	0.05	0.29	3.408	0.2476
% RPD SL	0.857142857	0.493506494	1.370669832	1.804694403

## Conclusion

- Schuman Lake sample one was an accidental double analysis of our Schuman lake blank. All analysis of Schuman lake is from our duplicate
- Likely sources of contamination in Schuman lake include dumping of trash, contamination from roads and the near-by dry-cleaners
- Free chlorine in water is likely from disinfection processes (especially in tap). Total chlorine is the measurement of organic compounds containing chlorine (solvents, DBPs, etc.).
- Conductivity measured from ions in water
- Tap water within EPA regulations for drinking

## References

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- 3. Annual Book of ASTM Standards. "D 2579-85: Standard Test Methods for Total and Organic Carbon in Water" (American Society for Testing and Materials, Philadelphia, PA, 1985).
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- 5. Annual Book of ASTM Standards. "D 4779-93: Standard Test Methods for Total, Organic and Inorganic Carbon in High Purity Water by Ultraviolet (UV) or Persulfate Oxidation, or Both, and Infrared Detection" (American Society for Testing and Materials, Philadelphia, PA, 1993).

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# Environmental Air Monitoring

Kelly Walsh and Joe Bossi

## Objectives

- Determine the presence of volatile and semi-volatile organic compounds
- Determine source of analyzed compounds

# Introduction

- Familiarize with Passive Air Sampling
- Personal exposure assessment
- Cost and ease of use
- Site background



<http://www.interchim.eu/catalogue.php?ref=119&varombre=25&var0=1&limite=150>





## Experimental Procedure

### Packing

- Tenax TA (poly(2,6-diphenyl-p-phenylene) oxide)
  - Applications (optimum performance)
    - Aromatics
    - Apolar Compounds (B.P. > 100 °C)
    - Polar Compounds (B.P. > 150 °C)
    - SVOCs including chemical warfare agents

- Conditioning
  - twice at 300 °C
  - Add screen, don't compress Tenax
  - Record tube #, date, Tenax Mass
  - Condition at 300 °C for one hour
  - Cool tube, seal with teflon caps



## Indoor Sampling

- Each classmate was given one thermal desorption tube pre-packed with Tenax TA on 4-18-2014
- Indoor locations were independently chosen by each member.
- Brass ends were taken off at recorded times on 4-18-2014
- Desorption tubes were sealed using brass ends after 48 hours of indoor air exposure

Analyst	Indoor Location	Acetone	Ethyl Acetate	Benzene	2,3,4-Trimethylpentane	2,2,3-Trimethylpentane	2,2,4-Trimethylhexane	Toluene	$\alpha$ -Pinene	Octanane	D-Limonene	Acetophenone	Ethyl Acetate	Nonanal	Decanal
John	Basement						X			X					
Ashley	Bedroom				X		X								X
Kristia	Laundry Room	X	X	X	X		X			X		X			X
Madison	Car	X	X	X			X					X			X
Mariam	Living Room	X	X	X			X					X			X
Ariel	Bedroom	X	X				X			X		X			X
Belinda	Closet						X			X					
Kevin	Car	X	X	X			X								X
Josh	Laundry Room	X	X	X			X		X	X		X			X
Roger	Mass-Spec Exhaust	X	X		X		X	X					X	X	X
Joseph	Bedroom	X	X	X			X		X			X			X
Kelly	Lounge	X	X	X			X								X

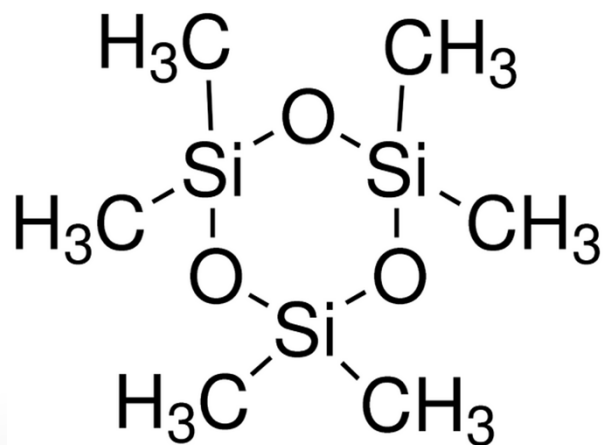
Indoor Sample - Kelly Walsh					
Data from Data Path: C:\MSDChem\1\DATA\Danielle\4.21.14\ Data File: 051379.D					
Detected Compounds	Reasonable Sources	Detected Compound	Retention Time	% Probability	Potential Sources
Acetone	paint, varnish, lacquer, human breath, cigarette smoke	benzaldehyde	3.95	65.1	fragrances and flavoring, detergent/dryer sheet exhaust treated wood prod.
Ethyl Acetate	varnish, lacquer, man fragrance				
Benzene	vehicle exhaust, paint, cigarette smoke	acetophenone	6.97	52.4	Paint and varnish removers
Toluene	vehicle exhaust, paint, cigarette smoke	nonanal	8.46	81.7	carpets, counter tops linoleum floor
Benzaldehyde	man fragrance, treated wood products	decanal	11.93	71.3	fragrance and flavoring
Decanal	man fragrance				



poly(2,6-diphenyl-p-phenylene) oxide



Compound	% Probability
hexamethylcyclotrisiloxane	81.9

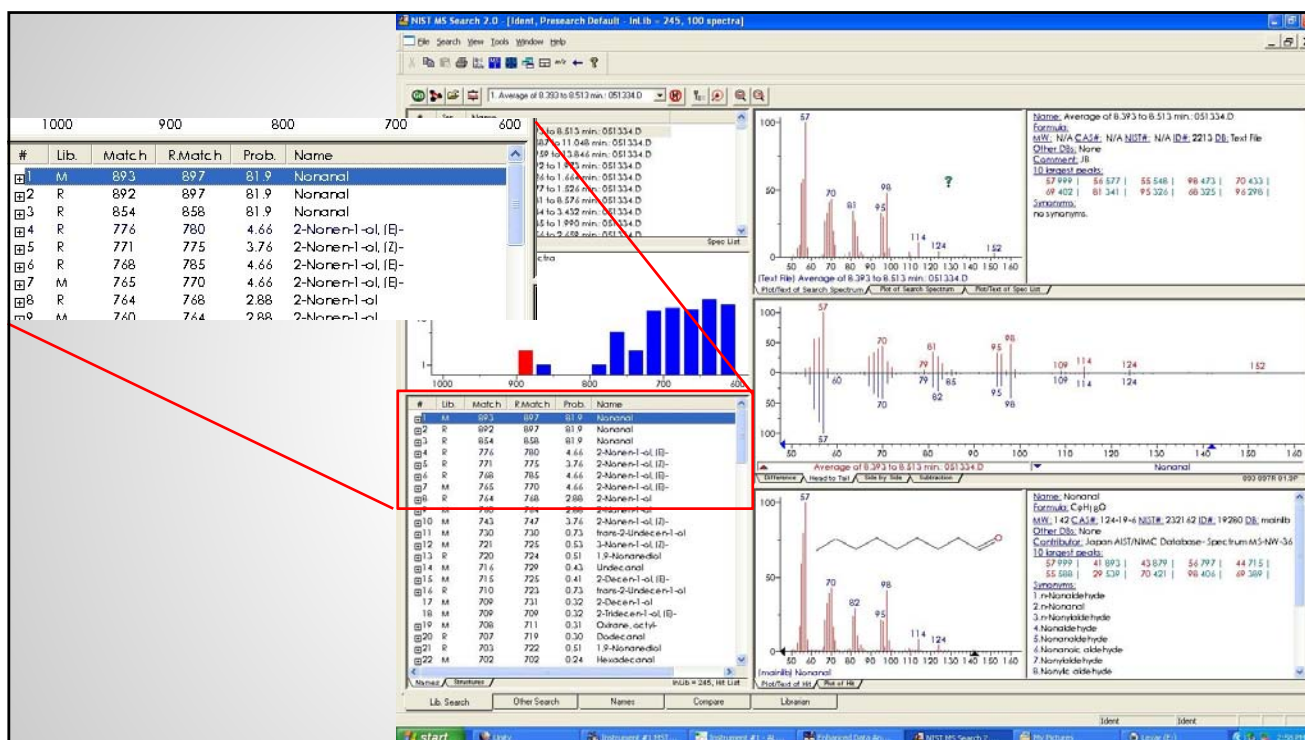


## Indoor Sample- Joseph Bossi

Data from data file 051334.D, data path  
C:\MSDCHEM\1\DATA\Danielle\4.21.14\

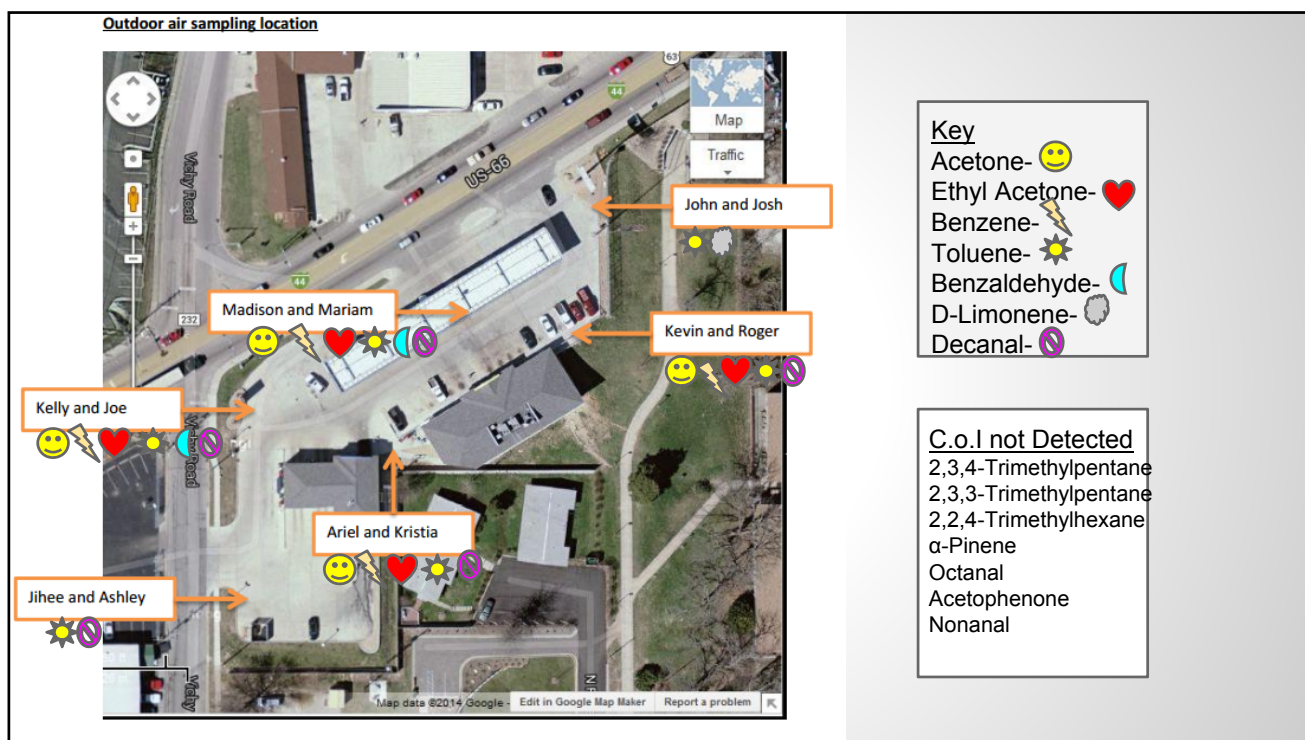
Data from personal analyzation of percentage  
compound probability

Detected Compound	Possible Source	Detected Compound	Possible Source
Acetone	paint, varnish, lacquer, breath, cigarette smoke	Nonanal	flavor and fragrance agent
Ethyl Acetate	varnish, lacquer, fragrance		
Benzene	vehicle exhaust, paint, cigarette smoke		
Toluene	vehicle exhaust, paint, cigarette smoke		
$\alpha$ -Pinene	fragrance products		
Acetophenone	fragrance, flavoring agent, solvent		
Decanal	fragrances and flavoring		



## Outdoor Sampling

- Six desorption tubes were given to groups of two on 4-23-14
- Sampling for all groups was done on the parking lot of Mobil on the Run located at 1710 N. Bishop Rolla, MO
- Outdoor air exposure lasted 45 minutes



## Outdoor Air Sampling

Detected Compounds	Possible Sources
Acetone	dryer sheets
Ethyl Acetone	solvent for many manufacturing products
Benzene	tailpipe and gasoline vapor emissions, dryer sheets
Toluene	tailpipe and gasoline vapor emissions, dryer sheets
Benzaldehyde	dryer sheets
D-Limonene	dryer sheets
Decanal	oxidation of decanol which comes from lubricants

## Possible Sources of Error

- Tube conditioning not complete
- Brass ends not sealed tightly enough
- Use of a trip and field blank
- For indoor sampling, opening a window can cause indoor air and outdoor air to equilibrate
- Not allowing enough time of exposure (outdoor samples)

## Retention Time Shifts

- Changes in column dimensions vs previous columns
- Leak in injector or blockage in the gas line
- Large change in sample concentration
- Inaccurate purge time
- Column temperature
  - flow rate, temp settings, hold time, ramp time

## Future Experiments

- Enough positive readings from outdoor samples warrant a quantitative test
- Acetone, ethyl acetone, benzene, toluene, decanal were found at 4 of 6 sampling locations.
- These 4 locations outline the main parameter of the gas station
- Further testing may prove levels exceeding ambient air quality standards

## References

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- Salthammer, T. (1999). *Organic indoor air pollutants: occurrence, measurement, evaluation*. Weinheim: Wiley-VCH.
- Wang, Hong, and Glenn Morrison. *Field and laboratory investigation of ozone-indoor surface reactions: secondary emissions inventory and implications for indoor air quality*. Rolla, Mo.: University of Missouri-Rolla, 2007. Print.

# Pre-course Survey



Initial Report

Last Modified: 01/27/2014

1. The data you provide in this anonymous survey will be used for a research project on the instructional methods of Chemistry 375 -- Principles of Environmental Monitoring. Although the data is anonymous, researchers would like to be able to match data from pre-course to post-course through an identifier which you create. Please create this identifier using the first three letters of your mother's maiden name followed by two digits of the month of birth. (For example, your identifier if your mother's maiden name was Jean Smith, born in January, would be SMI01.)

Text Response	
TOW05	
LEE05	
RAC06	
SEA01	
CLA01	
ZHA09	
GAG04	
JAB01	
ULL07	
Statistic	Value
Total Responses	9

2. Please rate your proficiency in the following areas being as truthful as you can regarding your current knowledge. (Note: You are not expected to have any knowledge of the items below prior to taking this class):

#	Question	Not proficient	Somewhat proficient	Proficient	Very proficient	Total Responses	Mean
1	How to collect real environmental samples for environmental monitoring	7	3	1	2	13	1.85
2	How to select sampling sites for environmental modeling	6	5	0	2	13	1.85
3	How to integrate QC/AQ into real environmental modeling	8	2	0	3	13	1.85
4	How to use state-of-the-art instruments for environmental modeling	5	4	2	2	13	2.08
5	How to report analysis following U.S. EPA guidelines	8	1	1	3	13	1.92
6	How to present data I have analyzed from my experiments to my peers	2	3	5	3	13	2.69
Statistic	How to collect real environmental samples for environmental monitoring	How to select sampling sites for environmental modeling	How to integrate QC/AQ into real environmental modeling	How to use state-of-the-art instruments for environmental modeling	How to report analysis following U.S. EPA guidelines	How to present data I have analyzed from my experiments to my peers	
Min Value	1	1	1	1	1	1	

Max Value	4	4	4	4	4	4
Mean	1.85	1.85	1.85	2.08	1.92	2.69
Variance	1.31	1.14	1.64	1.24	1.74	1.06
Standard Deviation	1.14	1.07	1.28	1.12	1.32	1.03
Total Responses	13	13	13	13	13	13

3. What is (are) your majors?	
Text Response	
MS in Environmental Engineering	
Chemistry	
Chemistry	
environmental engineering	
Chemistry	
Chemistry with Pre-med emphasis	
Chemistry and Biology	
Analytical Chemistry	
Bachelor in Chemistry	
Water Resources Engineering Environmental Engineering	
Chemistry	
Water Resources Engineering Environmental Engineering	
Statistic	Value
Total Responses	12

4. What is your academic seniority?				
#	Answer	Bar	Response	%
1	Junior	<div></div>	1	8%
2	Senior	<div></div>	8	67%
3	Graduate student	<div></div>	3	25%
	Total		12	
Statistic			Value	
Min Value			1	
Max Value			3	
Mean			2.17	
Variance			0.33	
Standard Deviation			0.58	
Total Responses			12	

5. Why are you interested in an environmental monitoring class ?	
Text Response	
I want to pursue a career in consulting and I believe this class will help further the knowledge needed to make be a good candidate with a consulting company.	
SOMETHING NEW	
I am interested in seeing all aspects of chemistry and I think this class will be interesting.	
The usefulness of information provided for future career	
Career Outlook	
It is a direct and practical application of chemistry.	
Seems relatively interesting and need an additional chemistry elective.	
I want to know more about the principals of monitoring and about the environment in which I live. I want to understand how to better monitor and understand the environment we have been given.	
I'm pretty interested in how actual environmental assay related experiments were done, and how currently accepted environmental testing standards (such as EPA) be sufficient or insufficient for both natural and social resources maintaining and monitoring?	
I plan to work in environmental chemistry, and I hope to learn more about the field.	
I think this class gives a great opportunity to learn more about methods and techniques used to detect and monitor environmental pollutants in different environments such as air, water, and soil.	
In field use of analytic techniques	
Statistic	Value
Total Responses	12

6. Have you had any background or experience with environmental monitoring? If so, please describe briefly:	
Text Response	
Yes. I worked as an analytical chemist for a company that analyzed air samples and consulted with their clients to obtain permits and/or maintain compliance with their permits. They also do a lot of work with the EPA on large scale monitoring programs such as PAMS (Photochemical Assessment Monitoring. Stations).	
N/A	
No.	
none	
Not particularly, I worked in Dr. Whitefield's areosol research laboratory when I was a freshman, but I did not become overly involved in enviromental monitoring aspect of the aerosol research project.	
I do not have any background experience.	
No	
I've being doing research on some nanoparticles caused health problems, though mostly focused on in vitro fundamental study, which in a broader point of view, is related to environmental monitoring. But other than that, I have no first hand experience on environmental related sampling and analyzing works.	
Yes, I have worked with water samples from water facilities and have done characterization.	
I had a background with environmental monitoring from some classes such as environmental modelling, Phytoremediation, and public health engineering. Such as detecting and monitoring some contaminants in groundwater by trees.	
None	
Statistic	Value
Total Responses	11



7. What parts of environmental monitoring are you interested in (choose as many as apply):

#	Answer	Bar	Response	%
1	Water	<div></div>	12	100%
2	Air	<div></div>	7	58%
3	Soil	<div></div>	7	58%
Statistic			Value	
Min Value			1	
Max Value			3	
Total Responses			12	

8. What do you expect to learn from this class? Please be as detailed as you can:

Text Response	
I have worked a lot with air and would like to learn more about soil and water environmental monitoring.	
I'm not sure what I expect to learn. I've never taken any enviromental class so I hope to learn as much as possible.	
I expect to learn how to locate, observe, obtain, and analyze natural samples using technology that firms today use	
I am interested in government and EPA regulations in regard to enviromental monitoring. Also, I am interested in how to properly take samples from the enviroment, so far my prior experience has provided me with techniques on how to test samples and produce data from the samples, but interpretation of the data and the guidelines behind determining what is acceptable, I am unfamiliar with.	
I don't have any background experience in enviromental monitoring so most of the information will be new and worth learning.	
How to effectively use instrumental analysis and effectively collect samples.	
How to actually and practically carry out an environmental testing on specific issues, such as air and water. What in detail the most concerning parameters within these fields, such as what small harmful molecules are mostly appeared in water (especially drinking water) samples, what is PM2.5 and what is the chemical composition of such harmful particles, what method could be use to screen out these stuff from air, etc.	
I expect to learn how to sample and analyze different environmental samples.	
Learning current and methods and techniques used to detect and/or monitor contaminants in air, water, and soil. Being able to define the environmental problems on site, and monitor pollutants as well as giving solution to attenuate such problems.	
How to properly collect and analyze data from the field and apply it towards research or a report	
Statistic	Value
Total Responses	10

9. Please rate your agreement or disagreement with the following statements:

#	Question	Strongly disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Total Responses	Mean
1	I prefer to have lectures combined with field trips as opposed to only lectures when doing sample collections	0	0	0	3	9	12	4.75
2	I feel that in-class lectures provide a sufficient learning experience for a class such as environmental monitoring	0	2	9	0	1	12	3.00
3	I have had positive experiences in other courses that have used hands-on approaches	0	0	1	1	10	12	4.75

	to learning						
Statistic	I prefer to have lectures combined with field trips as opposed to only lectures when doing sample collections	I feel that in-class lectures provide a sufficient learning experience for a class such as environmental monitoring	I have had positive experiences in other courses that have used hands-on approaches to learning				
Min Value	4	2	3				
Max Value	5	5	5				
Mean	4.75	3.00	4.75				
Variance	0.20	0.55	0.39				
Standard Deviation	0.45	0.74	0.62				
Total Responses	12	12	12				

# Post-course Survey



Initial Report

Last Modified: 05/16/2014

1. Please use the identifier you created for the pre-course survey before filling out this questionnaire. (Reminder: The first three letters of your mother's maiden name followed by the first two digits of her birth month.)

Text Response	
lee03	
GAG04	
zha09	
RAC06	
Cla01	
Per10	
JAB01	
Tow05	
sea01	
zha09	
UII04	
Statistic	Value
Total Responses	11

2. Please indicate your agreement with the following statements about Chemistry 375 "Principles for Environmental Monitoring" class:

#	Question	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total Responses	Mean
1	I was motivated to participate in the field trips	10	5	0	0	0	15	1.33
2	The field trips helped me master the concepts taught in the class	10	4	1	0	0	15	1.40
Statistic		I was motivated to participate in the field trips			The field trips helped me master the concepts taught in the class			
Min Value		1			1			
Max Value		2			3			
Mean		1.33			1.40			
Variance		0.24			0.40			
Standard Deviation		0.49			0.63			
Total Responses		15			15			

3. Comments about field trips:

Text Response
---------------

The field trips worked well for me because I didn't have a class immediately after Chem 375.	
I cannot directly evaluate how much I learnt from this class, but I do know that I would not know and learn so many things if there was no field trips. These three field-trips really helped me to practically get in touch with environmental monitoring, and from the data we could actually detect the contamination status of the surrounding environment where we live, which really impressed me. I think the class designed with these brief but important field trips worth whatever it costs, and should be maintained for the upcoming students.	
They really helped with understanding how the sampling techniques and QA/QC methods were used in the real world. I learned more from these experiments than I think I did from the lectures.	
Overall the field trips were very beneficial in terms of putting what we were learning in class into practice.	
The field trips were very hands on which helped with the learning process.	
Field trips helped a lot in enhancing our knowledge about water, air, and trees sampling as well as monitoring contaminants in such environments.	
I felt like the field trip to collect samples for the tree experiment was somewhat helpful in seeing the different ways that the samples could be obtained but the water and air sample collection field trips were very basic and didn't really teach or show me anything new or different	
Pretty good planning and design. Needs better supplementary packets. Dr. Kapila has pretty good ones to model off of.	
This field trip design series were very necessary and helpful, it not only gave us chances to review what we learn from classroom, but also deepened our knowledge as well as practical experience of environmental monitoring.	
Great idea and preparation, but handouts need a little bit of work. Kapila has great handouts that you may want to model yours off of.	
Statistic	Value
Total Responses	10

4. Please indicate your agreement with the following statements about Chemistry 375 "Principles for Environmental Monitoring" class:								
#	Question	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total Responses	Mean
1	I was motivated to participate in the experiments offered in the class	10	5	0	0	0	15	1.33
2	The experiments helped me master the concepts taught in the class	11	3	1	0	0	15	1.33
Statistic	I was motivated to participate in the experiments offered in the class			The experiments helped me master the concepts taught in the class				
Min Value	1			1				
Max Value	2			3				
Mean	1.33			1.33				
Variance	0.24			0.38				
Standard Deviation	0.49			0.62				
Total Responses	15			15				

5. Comments about experiments:	
Text Response	
The air sampling and tree core sampling were new methods that I hadn't seen or discussed before. Enjoyed them the most. I understand the significance of proper water collection but felt more time learning about HPLC operation would have been of more use.	
The experiment setup was closely correlated with the field-trips, once samples were collected, we took them back and measure different parameters either by ourselves or with TA's help, and each experiment setup will be followed by a detailed report from each students. I think this is an excellent way of transferring what we learned in classroom to what we did in practice. Also the experimental reports further	

made this learning process fruitful.	
The water experiment was my favorite due to the amount that we were able to do, analytically. Air was my second favorite because we could see what was in our place of choice.	
The experiments were very well done and executed, although, a little more prep work would be nice so that we could have a better understanding of what exactly we were doing before conducting the experiments.	
The experiments were very hands on as well. These taught essential skills in the use of equipment utilized in the analysis of the samples	
The experiments gave great opportunity to know so many things about samples collection, samples analysis using different techniques, and how we can use the results to get an idea about level of contamination of some pollutants in the environment.	
I felt like the experiments were all rushed and somewhat chaotic. Due to limited time we were not really able to do much of the experiments ourselves such as sample collection preparation or analysis. For exampl in the water lab we had to rely on the TA to have everything prepared for us and we went out and put water into bottles. We were able to perform some analysis but it was very crowded and chaotic where we were trying to perform the analysis. I think the experiments would be more beneficial if we only did one "monitoring" experiment that lasted for a majority of the semester where we prepared collection containers, collected samples and performed sample preparations and analysis if time permitted.	
Great work teaching QA/QC and analytical methodology	
Nice and clear design. The experiments are divided into different parts with different level of hardness, although we ought to finish all of them, but step by step design with different field trips really gave us chance to learn and master these concepts and instruments better.	
Statistic	Value
Total Responses	9

6. Please indicate your agreement with the following statements about Chemistry 375 "Principles for Environmental Monitoring" class:

#	Question	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total Responses	Mean
1	I was motivated to participate in the data reporting portions of the class	8	6	1	0	0	15	1.53
2	The data reporting helped me master the concepts taught in the class	9	3	3	0	0	15	1.60

Statistic	I was motivated to participate in the data reporting portions of the class	The data reporting helped me master the concepts taught in the class
Min Value	1	1
Max Value	3	3
Mean	1.53	1.60
Variance	0.41	0.69
Standard Deviation	0.64	0.83
Total Responses	15	15

7. Comments about data reporting:	
Text Response	
The reports should be due after we present because we learn so much from just the presentations themselves.	
The data reporting was somewhat useful but it was difficult to pay attention during others presentations as it was the same thing for every single group.	
Data reporting helped in understanding the results that we got from samples analysis, and how we link these results to the level of contamination of certain pollutants in the environment.	
We did not have any data to compare our results to. I felt like I was just trying to come up with stuff to talk about in the reports. I think it	

would be more beneficial if we had data from the same sources to compare results from say the beginning of the semester to the end of the semester.	
Use of powerpoint presentations to present data is the best format	
Only through data reporting, we have chances to organize and review all the things we learnt from class, and also for better illustration, we need further searching for a lot more references to fully support our data as well as develop our conclusion. So I think the data reporting processes were really important, and interesting.	
Powerpoint is ideal for this. Good job.	
Statistic	Value
Total Responses	7

8. Please indicate your agreement with the following statements about Chemistry 375 "Principles for Environmental Monitoring" class:

#	Question	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Total Responses	Mean
1	Overall, I was satisfied with the format of the course	8	6	0	0	0	14	1.43
2	Overall, I was satisfied with the content that was covered in the course	11	3	0	0	0	14	1.21

Statistic	Overall, I was satisfied with the format of the course	Overall, I was satisfied with the content that was covered in the course
Min Value	1	1
Max Value	2	2
Mean	1.43	1.21
Variance	0.26	0.18
Standard Deviation	0.51	0.43
Total Responses	14	14

9. Comments about your satisfaction/dissatisfaction with the course:	
Text Response	
The hands on experience of the different labs will help me retain what was taught more so than just lectures ever would.	
The class became more organized towards the end which was very helpful. Spreading out the labs a little more might be more helpful.	
The course was very interesting. I learned a lot about the environmental monitoring and sampling process. It has spiked a new interest in the field of chemistry for me. It has also strengthened my presentation skills. The only dissatisfaction I have with the course is how rushed the experiments were. I think if in the spring semester the experiments were in order of air, tree, water while in the fall semester the order was water, tree, air. This would help eliminate postponing experiments due to weather conditions.	
375 was a really good class. I'm glad that I had this class. This class is covers good information about environmental monitoring. Dr. Ma is a great teacher, and Danielle was a great assistant. I hope Dr. Ma continues giving this class with Danielle assistance, and strongly encourage students who interested in environmental monitoring to take this class.	
I really liked the course but I think the experiments should be reevaluted. Experiments are beneficial but in this case it seemed like we rushed through portions of the class so that we could fit all of the experiments in. I would like the class better without any experiments or with only one experiment that lasted for the entire semester.	
In total, the format and content that the whole class (and field trips) has covered were well organized and very informative. We not only learnt lots of concept, knowledge, regulations, instrumentations and techniques, but also got enough experiences on analysis of different materials. The only better thing could be done is a better order of the class and field trip, for instance, the water and tree testing reports were a little bit too close with each other, while the air testing report gave us much less data handling time.	

Statistic	Value
Total Responses	6

10. Please rate your current proficiency in understanding how to collect real environmental samples for environmental monitoring:

#	Answer	Bar	Response	%
1	Not proficient		0	0%
2	Somewhat proficient	<div></div>	1	7%
3	Proficient	<div></div>	8	57%
4	Very proficient	<div></div>	5	36%
	Total		14	
Statistic			Value	
Min Value			2	
Max Value			4	
Mean			3.29	
Variance			0.37	
Standard Deviation			0.61	
Total Responses			14	

11. The most helpful things I learned about collecting real environmental samples:

Text Response	
QA/QC for sampling and analysis.	
QA/QC is needed! Also, always have duplicates and take notes while performing the experiment.	
How to properly collect samples as well as analyze the data and disseminate the results.	
QA/QC measures, as well as the different techniques that could be used in each different monitoring situation.	
collecting representative samples, carefully collecting the samples to prevent any contamination, and QC/QA samples.	
The appropriate preparation work necessary before entering the field for sampling	
I feel comfortable with collecting air and water samples, but not soil. What was helpful was doing presentation along with reports, this solidified my understanding	
how samples are collected, how to prepare for collection, and how many/area to collect. As well as QA/QC	
Field blanks, and even trip blanks, personally I did thought about how to maintain a comparable control for each sampling, but I really didn't thought about such easier but still workable way.	
QA/QC and analytical methodology	
Statistic	Value
Total Responses	10

12. Please rate your current proficiency on how to select sampling sites for environmental modeling:

--	--	--	--	--

#	Answer	Bar	Response	%
1	Not proficient		0	0%
2	Somewhat proficient	<div></div>	3	21%
3	Proficient	<div></div>	4	29%
4	Very proficient	<div></div>	7	50%
	Total		14	
Statistic		Value		
Min Value		2		
Max Value		4		
Mean		3.29		
Variance		0.68		
Standard Deviation		0.83		
Total Responses		14		

13. The most helpful things I learned about selecting sampling sites:	
Text Response	
I learned how to select strategic locations for sampling.	
You need a wide variety to get a representative sample.	
Knowing the parameters being monitored and the analytic methods.	
selecting sampling sites that I can get representative samples from, and select multiple sites in the contaminated area.	
How to take a representative sample	
Selecting the appropriate sampling site is very important in ensuring that the data will be representative	
sampling sites are very important to provide representative data, depend on different purposes, there should be not only one way of doing so, it is either sporadic or more causal-related design, also a three dimensional consideration for sampling site choosing may still be important.	
Statistic	Value
Total Responses	7

14. Please rate your current proficiency of how to integrate QC/QA into real environmental modeling:				
#	Answer	Bar	Response	%
1	Not proficient		0	0%
2	Somewhat proficient	<div></div>	1	7%
3	Proficient	<div></div>	8	57%
4	Very proficient	<div></div>	5	36%
	Total		14	
Statistic			Value	
Min Value			2	
Max Value			4	
Mean			3.29	



Variance	0.37
Standard Deviation	0.61
Total Responses	14

15. The most helpful things I learned about integrating QC/QA into real environmental modeling:

Text Response	
I learned how to incorporate QA/QC into sampling and sample analysis.	
Field blanks are needed to have accurate data.	
Knowing how to prepare and used field blanks and use of a spike matrix and spike analysis.	
the necessity of collecting field blanks along with the collected samples, and spike recovery samples.	
Different types of QA/QC parameters that can be integrated into the experiment to produce more reliable results	
Without QA/QC your results could be considered invalid.	
Probably the most applicable skill to a job. QA/QC should continue to be afocal point in this class.	
Quality control and quality assurance are very important for environmental monitoring, and a well developed QA strategic plan as well as good quality control data collection are must for each running.	
The blanks, calibration, MDL, etc. Great info on this.	
Statistic	Value
Total Responses	9

16. Please rate your current proficiency in using state-of-the-art instruments for environmental modeling:

#	Answer	Bar	Response	%
1	Not proficient	<div></div>	1	7%
2	Somewhat proficient	<div></div>	4	29%
3	Proficient	<div></div>	7	50%
4	Very proficient	<div></div>	2	14%
	Total		14	
Statistic			Value	
Min Value			1	
Max Value			4	
Mean			2.71	
Variance			0.68	
Standard Deviation			0.83	
Total Responses			14	

17. The most helpful things I learned about using state-of-the-art instruments:

Text Response	
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I learned how to use thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS).	
Calibration of the instruments is needed to make sure your data is very accurate.	
How to use instruments to analyze environmental samples	
Some familiarization with software and instruments. More exposure to instruments/software/method development would be great.	
For instrumentation part, I have to say that I'm willing to learn more, but actually there was very limited time to practically for everybody to join the operation processes. Like mostly used GC-MS system, maybe in the future it is possible for students to join more and learn more about how to operate the instruments by themselves.	
Statistic	Value
Total Responses	5

18. Please rate your current proficiency in reporting analysis following U.S. EPA guidelines:

#	Answer	Bar	Response	%
1	Not proficient	<div></div>	1	7%
2	Somewhat proficient	<div></div>	1	7%
3	Proficient	<div></div>	9	64%
4	Very proficient	<div></div>	3	21%
	Total		14	

Statistic	Value
Min Value	1
Max Value	4
Mean	3.00
Variance	0.62
Standard Deviation	0.78
Total Responses	14

19. The most helpful things I learned about reporting analysis following EPA guidelines:	
Text Response	
Make sure there are field and trip blanks. Data reporting is necessary so everyone knows what is going on.	
reporting trustable data and compare this data with the values regulated by EPA	
The methodology for following EPA guidelines has to be absolutely exact	
The classes taught us lots of information about historical and current EPA regulations and they are really helpful, especially when we had our data and looked back to the EPA regulation to see whether there was any exceeding read.	
Statistic	Value
Total Responses	4

20. Please rate your current proficiency in presenting data to your peers:	

#	Answer	Bar	Response	%
1	Not proficient	<div></div>	2	14%
2	Somewhat proficient		0	0%
3	Proficient	<div></div>	7	50%
4	Very proficient	<div></div>	5	36%
	Total		14	
Statistic		Value		
Min Value		1		
Max Value		4		
Mean		3.07		
Variance		0.99		
Standard Deviation		1.00		
Total Responses		14		

21. The most helpful things I learned about presenting data to my peers:	
Text Response	
I learned how to present data in an understandable and efficient way. Practicing data presenting was key to this success.	
You learn from eachother.	
Becoming more confident while present the data to my peers as well as debating what I'm presenting	
Great design of course to be centered around presentations.	
I learnt that a clear report, not only includes good figures, proper information, well developed conclusions, but also needs concise speaking, eye contact with audience as well as good control of the speed. But anyway, a thoughtful data illustration is the most important thing.	
Statistic	Value
Total Responses	5

22. Which field trip and/or experiment did you enjoy the most and why?	
Text Response	
Tree core because extracting the core sample was something I have never done before.	
I enjoyed the tree core sampling trip and experiment the best. This experiment gave me to opportunity to understand how to monitor contaminations in solid samples and how to analyze these samples.	
Ground water contamination monitoring via tree core sampling. Multiple instruments were used and sample collection was unique.	
Water because we were allowed to run so many tests. We didn't just have to put it into a machine, we actually ran most of the tests which gave me a better understanding.	
The tree lab because of the real world application especially since we were able to collect data for an experiment that was already going on.	
Air experiment because I knew exactly what I was doing (due to have already complete two other experiments) and I enjoyed sampling my choice location and seeing the VOCs contained with in that location.	
The three field trips were interesting, I enjoyed everything new I learned in each one.	
Tree core sampling, because it is totally unique, and until that experiment, I was unaware that tree core sampling could be used for ground water monitoring	
I enjoyed the tree core sampling the most. The idea behind using capillary action was interesting and insightful.	
The tree one. It seemed to be the one where we had more hands on and we had more data to compare when preparing the report.	

Air experiment was my favorite for no reason in particular	
Tree core sampling, it is an interesting technique for determining ground water contamination. Also, I enjoy gaining exposure to other research projects being conducted by other departments around campus, such as Matt Limmer's research.	
tree collection. Because it was the first one we've went through, and it was really great, I can tell that everybody were feeling exciting and fresh, including me. This is the way that practical knowledge should be taught, I think.	
Statistic	Value
Total Responses	13

23. Do any of the field trips or experiments require major improvement? If so, how can they be improved to be more effective learning experiences?	
Text Response	
More hands on experiments because those truly helped understand the main concept of the class.	
All of the field trips and experiments require a little more polishing. More information about what the experiment will actually consist of should be given out before the experiment.	
The air monitoring experiment needs the most work. The material for this experiment would be just as easily covered in class or read in a textbook. Learning how to pack samples or operate the GC/MS instrument would be useful. It was nice to have the option to spend some time identifying peaks though.	
No	
The air monitoring lab as it was impossible to actually compare the outdoor air samples collected to the indoor air samples collected as they were completely different areas. The other thing is none of the indoor samples were collected in similar areas so it was impossible to compare.	
I think the field trips and experiments would go a bit smoother if there is a rubric. The first two experiments I was not really sure about what I was doing and the information I should record. Where as, by the time the third experiment came around, I knew exactly what I was doing and what all information I needed to know.	
Giving them more time, especially outdoor air sampling and monitoring field trip to get enough time to collect the outdoor samples.	
The air sampling experiment, we should use a method for determining quantitative measurements of the analytes. Also, the accuracy of the retention times needs to be given a range so people don't assign peaks to wrong analytes.	
Learning how to use the machines properly would be a great improvement	
I feel like there are too many experiments since there is not a dedicated lab portion to the class. I think that any of the experiments could be helpful just by the student being able to do more hands on by just doing one experiment in which the student was able to choose a sampling location where they could maybe monitor water, trees and air all in the same location throughout the semester and review the results from the whole semester instead of doing each one individually and at different locations just once. If it is suppose to be a monitoring experience then only one sampling event does not demonstrate what goes into a monitoring program.	
A large supplementary packet would be great for each of these to learn from and reference.	
How the data is distributed amongst groups, some people don't distribute their data until the last possible moment, we need to have earlier deadlines for data distribution. Also, determination of the retention times for the analytes in the air sampling experiment should have a determined range for acceptable values, or the mass spectrums should of been distributed.	
They are very fresh and interesting to us, that part, great. I think we can get more prepared before we head out, so that nobody have to stand in the wind and listen to somebody talking for 10 minutes, this should really be done in classroom. Sample collecting wise, the grouping should also be done before we go; Also more representative samples should be taken, because we hardly had any duplicate or triplicate data for this semester, thus all our data were kind of qualitative while not quantitative. Finally but not the least, please give more time for students to get hand on the main instruments, like GC-MS, other wise, the data analysis and reporting processes would be less interesting and almost like Chem251 or Chem355.	
Statistic	Value
Total Responses	13

24. Would you recommend this class to friends interested in environmental monitoring or to other chemistry majors? What would you tell them to interest them in taking this class?	

Text Response	
I would recommend this class to my peers. It provided a good hands-on approach to environmental monitoring.	
I would recommend this class to friends. The experiments, with their hands on approach and sample collection, would interest them the most.	
Yes! This class is very different than any other chemistry class due to the fact that you get to look more into the environment and see how QA/QC is involved. That is where a huge part of the chemistry comes in.	
Yes especially if they have any interest in understanding environmental monitoring and improving their ability to communicate results to their peers.	
Yes, I would tell them it is a great learning experience with hands on experiments and opens your mind to a different area in chemistry that is not readily talked about.	
Yes. I strongly recommend this class to any student interested in environmental monitoring. The class is great and rich with helpful information, and Dr. Ma is a great teacher.	
Yes, you get real world exposure to enviromental monitoring techniques, and it is very interesting to gain new perspective about enviromental monitoring.	
Yes. I would say that you feel comfortable in the field of environmental monitoring and that you can seriously consider it as a career option.	
Yes! There is a lot of good information presented in this class when it comes to how to develop a monitoring program from how to collect samples to how to determine how to analyze the samples. Overall it was a great course.	
Absolutely. Great professor and course design. You learn a lot without the class seeming hard.	
Yes, you are able to be involved in all aspects of conducting an monitoring experiment, such as sample prep, sample collection, analysis, and etc. For these reasons, this is a very effective class.	
Of course, it was really great experience throughout the whole semester~! We do real environmental sampling, and we can report the real status of the environment we are living in, which is awesome.	
Statistic	Value
Total Responses	12

25. My satisfaction with								
#	Question	Highly dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Highly satisfied	Total Responses	Mean
1	How the class met my expectations	0	0	0	4	10	14	4.71
2	How the class prepared me for my future career	0	0	0	8	6	14	4.43
3	How the class incorporated real life examples into the lecture material	0	0	0	3	11	14	4.79
Statistic	How the class met my expectations	How the class prepared me for my future career		How the class incorporated real life examples into the lecture material				
Min Value	4	4		4				
Max Value	5	5		5				
Mean	4.71	4.43		4.79				
Variance	0.22	0.26		0.18				
Standard Deviation	0.47	0.51		0.43				
Total Responses	14	14		14				