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# DIY Oil Testing

## Progress toward community oil pollution analysis

## The Public Lab

The Public Laboratory for Open Technology and Science is a 501(c)3 nonprofit organization which supports a growing community in developing and applying open-source tools for environmental exploration and investigation. By democratizing inexpensive and accessible "Do-It-Yourself" techniques, Public Lab creates a collaborative network of practitioners who actively re-imagine the human relationship with the environment. For more information visit: www.publiclab.org

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This document is a snapshot in the life of an ongoing design process, and was written in January 2016. Even between that date and publication, we've learned new things, and found errors in our designs and assumptions.

This document lives on in the Public Lab website as a wiki page, which anyone may edit. As the work continues, you can see updates to the document at:

https://publiclab.org/wiki/diy-oil-testing

You can also follow continuing work as it happens at:

https://publiclab.org/tag/oil-testing-kit

Thanks to everyone who's helped to make this document possible!

**— the Public Lab staff**

# CONTENTS

We've compiled this collection of writing in order to present an overview of the Oil Testing Kit program, synthesizing four main topics:

# PROGRESS TOWARD COMMUNITY OIL POLLUTION ANALYSIS

## Introduction

As one of the core initiatives of Public Lab's Homebrew Sensing Project, the Oil Testing Kit is an effort to address one of the original challenges Public Lab faced after its founding during the Deepwater Horizon oil disaster — that of identifying oil pollutants after a spill.

Public Lab believes that the co-development of tools and methods by and with people who directly face pollution is key to developing accessible and appropriate solutions. In that light, we've strived in this project to build open collaborations, to engage partners involved in oil pollution response, and to prototype and pilot a process which addresses local needs and remains legible and open to participation, from problem identification through field testing. To varying degrees, we have succeeded at some of these aims and not succeeded at others, and here we intend to document the project so that others may build on what we've done.

Through the Homebrew Sensing Project and in this report, we have attempted to address community needs and site-specific environmental issues with affordable, co-designed, open source tools, and to collect data which provide compelling information about key questions regarding pollution. Over two years, we've had opportunity to try different strategies, to succeed and fail, to regroup and redesign.

## History

Public Lab was founded just after the Deepwater Horizon oil disaster, and many of the tools we are developing focus on oil pollution and its effects. As one of the earliest, but longest-term projects we chose to focus on, Do-It-Yourself spectrometry has also been one of our most popular, with thousands of people constructing and using their own from various kits and instructions since 2010.

While the open source approach to tool design resulted in wide adoption, it did not produce a lot of interest in the specific problem of identifying or distinguishing oil pollutants. With this in mind, we set out to launch a new project in 2013-4 to launch a more focused — but still open and collaborative — effort to distinguish oil pollutants. We chose to explore using ultraviolet fluorescence: the principle that different oils fluoresce different colors, measureable by a spectrometer, when illuminated with ultraviolet light. This involved a series of progressively more difficult challenges, which we will discuss in this document.

Images by Shannon Dosemagen (@shannon)

## Who is this document for?

We're writing this for multiple audiences, who have varied interests and experiences with oil and spectrometry. We're hoping that everyone finds information useful to them within this document and that the case studies, event models, and analysis on our process will be helpful to anyone who seeks to:

- join and further Public Lab's oil testing program
- understand the history and current state of the Oil Testing Kit
- conduct experiments using DIY spectroscopy
- develop their own community technology development project
- advocate for accessible oil testing

In this document we've tried to keep the technical language to a minimum, and have included a glossary for some potentially unfamiliar terms.

## Project goals

Some of our goals were:

- pilot DIY differentiation of oil pollution samples (using UV fluorescence)
- refine and simplify DIY spectrometer construction
- develop and test DIY sample collection and analysis methods
- improve software for easy analysis of samples
- prototype open and collaborative patterns for technology/methods development
- create and refine community engagement models for such development
- develop a tool to assist people in narrating their experience with oil

Our more specific goals as we conclude this program include:

- assess DIY fluorescence spectrometry open hardware kit design
- evaluate DIY fluorescence spectrometry analysis methods

### What's next?

**Continue to Chapter 1: Questions, Motivations, & Best Practices**

# 1

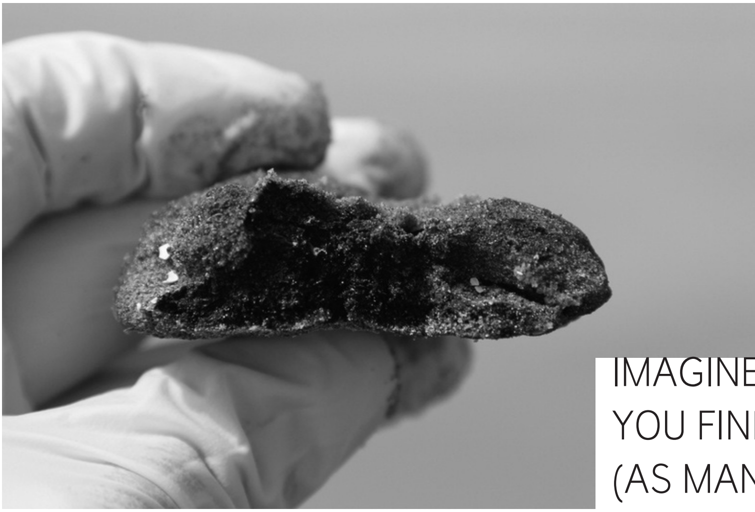
# Questions, Motivations, & Best Practices

## INTRODUCTION

Public Lab's Oil Testing Kit program has sket out to develop *a low-cost, Do-It-Yourself kit for differentiating oil pollution*, building on the DIY spectrometry kit Public Lab has designed and distributed since 2011.

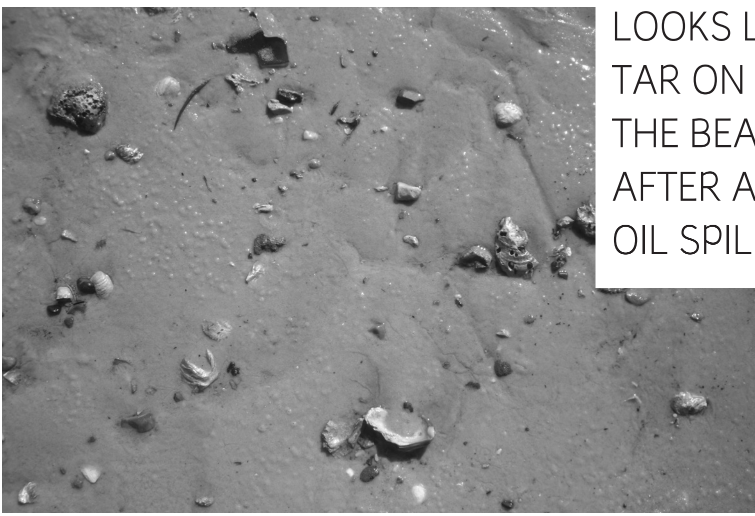
There are many different questions which such a kit might attempt to answer, and it's important to address them carefully and individually. Asking questions is how we started Public Lab, and questions are at the heart of Public Lab's process of research and development. We've collected many common questions here — many, but not all of which, we can now answer. Here, we have tried to order each group of questions with increasing difficulty or complexity.

## IN THIS CHAPTER



A tar ball, photo by @eustatic

IMAGINE YOU FIND (AS MANY OF US DID) WHAT LOOKS LIKE TAR ON THE BEACH AFTER AN OIL SPILL...



Oil residue on a beach following the BP Oil Spill; photo by Shannon Dosemagen (@shannon)

# QUESTIONS ABOUT FINDING POLLUTION

## How do I tell if it's oil or something else, like a piece of a tire or asphalt, or mud?

The technique we're using, called steady-state ultraviolet fluorescence spectroscopy[1], has been shown to be able to distinguish between different weights of oil — such as crude oil versus motor oil or diesel — in a laboratory under certain conditions (e.g. Pantoja et al, 2011). The kit we're developing also attempts to differentiate categories of oil, without laboratory facilities and instrumentation. To do this, there are many unknowns remaining; including:

- the effects of weathering
- false positives[2]

There are also other materials which fluoresce, such as various types of organic matter. Fluorescence alone cannot be used as evidence of petroleum: rotting vegetation or even olive oil or beer will fluoresce, but because the spectrum of each will be different, the theory is that a spectrometer will help you tell plant matter apart from a petroleum sample. However, as of January 2016, this has yet to be clearly demonstrated in our community, and we hope that the refinement of the testing kit itself will make such tests easier to perform.

It's important to note that, while different kinds of oils have been distinguished by a given user using their specific instrument, not every user has been able to do so, and the results have not always been consistent among different spectrometers. Thus, as of January 2016, we are still working to improve the reproducibility of our method, which is fundamental to being able to distinguish grades of oils, or oils from non-oil fluorescing materials[3].

## How do I tell if it's oil from the spill in question?

Matching an individual source of oil, such as crude specifically from the Deepwater Horizon spill, is known as "spectral fingerprinting," and according to the scientific literature, the technique we are using ("steady state ultraviolet fluorescence spectroscopy") does not produce spectra that are unique and specific enough to distinguish samples from one source from another if they are very similar — say, to distinguish between two different crude oils.

However, if there is only one source of crude oil in an area, and you wish to collect evidence that a sample is from that source, as opposed to being motor oil or diesel, or some other pollutant, then this is the test we are attempting to reproduce with a DIY kit[4].

## What does oil pollution mean for my health?

This is a complex question. Oil pollution can have a variety of impacts on a person's health, or the health of an ecosystem. In addition to birds and other wildlife getting covered by an oil slick which can result in hypothermia or suffocation, oil is comprised of several toxic compounds that can have severe consequences. Polycyclic aromatic hydrocarbons (PAHs[5]) in oils can impair reproduction, physiological and neurological development in marine organisms, and some PAHs are likely to be carcinogenic in humans (e.g. Pelletier et al, 1995, Samanta et al, 2002). Other volatile components of oil may induce headaches, nausea, and respiratory difficulty during even short exposures (e.g. Solomon and Janssen, 2010).

IMPORTANT LINKS

For more information about studies investigating the human health effects of exposure to oil, please visit http://www.atsdr.cdc.gov/csem/csem.asp?csem=13&po=11 and http://www.cdc.gov/niosh/topics/oilspillresponse/studies.html , both hosted by the national Centers for Disease Control. Also see the Hazards section of the Oil Testing Kit page.

## What do I do if I see oil?

Before handling any oil, make sure that you are equipped to do so safely. Oils contain toxic and carcinogenic components, and several volatile organic compounds, so be sure to wear gloves and stay in well-ventilated areas. See health effects, above.

### Contact local response agencies

When you see what seem to be spilled oil or tar balls, the first people to contact will be the environmental response team for the county, parish, or municipality where you observe the suspected oil. In many counties, the response team will be part of the Environmental Engineering Department or Ecology Department. If you are unsure who to call, often a detailed Internet search (e.g. "King County Washington report oil leak") can lead you to the proper website and phone number. If an Internet search does not yield the necessary information, calling the county government's main office may help you find the appropriate department to contact. When you do get in touch with the environmental response team, if possible, you will want to provide the following information:

- location
- what types of environment are or might be impacted (e.g. crop land, river, ocean, etc)
- what does it look and smell like?
- take a picture
- can you see the source of the oil?
- does it appear as though more is spilling or leaking?
- can you estimate how much oil is spilled?
- is there a particular activity occurring that is causing the spill or impacting it?
- are there other hazardous materials there?
- is there risk of fire?
- include: photographer name, date, time, site location, site description, number the photo, and record this in a logbook or other place that could be referenced
- If there is any immediate safety risk, such as potential for a fire, contact the local fire department and police department at once.

If the oil you observe is in marine waters, call the US Coast Guard National Response Center.

## Collect a sample for laboratory analysis

In addition to calling and reporting the oil you observe to a local or national agency, if it is possible to do so safely, you could collect a sample of the oil. If you are interested in having the oil tested to determine the type (and potential source of the oil) by a laboratory, it can be helpful to decide which laboratory you will send the sample to before collecting that sample. To find an analytical laboratory, you can either call the county government environmental department and ask their recommendations (as they often need to out-source their lab work), or do a series of Internet searches to find an appropriate accredited lab in your area. You can also email the main discussion list at Public Lab, where thousands of community members from around the world may be able to help you find the appropriate resources. (Likewise, if you can help, please offer assistance to others who ask.)

When you find a laboratory to use, it will be important to learn the collection techniques that are required for the method they are planning to use. Since most methods require very specific bottle preparation (generally including a final step of baking glassware to 450 Celsius for four hours, since by that temperature most organic matter should have combusted), you might want to ask to see if they will send you an appropriate collection container. Note that improper pre-cleaning of sampling containers might be the primary reason that many citizen-collected samples are thrown away by official labs, so cleaning bottles according to specific methods, or obtaining cleaned bottles from laboratories, is important. Different methods may require specific sample collection techniques, but here we include some general sample collection principles to help you prepare.

For samples that you want to analyze for organic compounds, such as oils, you generally want to use amber glass vials — note that you do NOT want to use plastic bottles[6], as those will contaminate the sample, and it is best to use a UV filtering glass (such as most amber glass vials) because several compounds in oils are sensitive to UV. If you do not have amber glass bottles, plain glass, such as a mason jar, will work if you keep the jars in a dark box out of the sunlight — but be aware that many official guidelines require amber glass, so if you're planning to submit a sample to a lab, this is important.

If you are collecting straight oil or oily solids (e.g. sand, soil), the collection container should be large enough for a minimum of 5 grams of sample plus 10 mL water, which will likely be a 40 mL vial, or larger. The analytical method the laboratory will use will indicate whether a PTFE-lined solid cap is sufficient or if you need a cap with a septa (used when the sample vial cannot be opened, and is directly pierced by the analytical instrument).

When collecting solid oil or oily solids samples, you want to avoid using any plastic scoops, and rather, use a stainless steel scoop or spatula that you have rinsed with water and wiped with isopropyl alcohol. When collecting water samples with an oil sheen or emulsion, you want to collect the sample upstream from any disturbance you have caused, with the bottle open to the current in a river, and fill the sample container completely such that there is no headspace.

Samples should be stored cold, on ice, attempting to reach 4 Celsius (39 Fahrenheit), or colder if the analytical methods requires it. For samples that must be stored colder than 4 Celsius, you can purchase dry ice. If you purchase dry ice, be careful when handling it, as it can burn bare skin and be a respiratory irritant. Samples should be transported from the field in a cooler and transferred into a refrigerator or freezer of the appropriate temperature as soon as possible.


Suspected oil samples, kept in a cooler; photo by Scott Eustis (@eustatic)

Scanning suspected oil samples; photo by Scott Eustis (@eustatic)

When collecting a sample for third-party laboratory analysis, to submit to a local government agency, or to analyze yourself, it is important to establish a Chain of Custody of the sample to ensure there is a responsible party for it. Information to include in the Chain of Custody are:

- Name and contact information of sample collector
- Sample code (if applicable)
- Date and time of collection
- Location of collection
- Type of media (e.g. soil, sediment, water)
- Environmental conditions
- Collection method used
- How it is stored or transported
- Type of preservation (if applicable)
- Analyses requested

## Analyze your own sample

In addition to collecting oil samples to provide to local agencies or independent laboratories, you could collect samples and scan them using a Public Lab DIY spectrometer and oil testing kit it to see if your samples resemble known types of oil (such as crude vs. motor oil)[7].

Discerning if your samples are oil, and potentially what kind of oil they are, can be useful for a variety of reasons[8]. One reason is to help local government officials to respond to the oil pollution through action channels more quickly, and potentially contain or mitigate some of the environmental impacts of the spill or leak. While analyzing your own samples will not lead to diagnostic evidence[9], it can demonstrate a likelihood that a sample is or is not oil, and be an excellent visual component of community education or advocacy.

## SECTION NOTES

1. See glossary on page 138.
2. "Could there be a "false positive" in my oil fluorescence test?" on page 32.
3. "Testing your Hypothesis" in Workshop 1, on page 88.
4. "How do I tell if it's oil or something else, like a piece of a tire or asphalt, or mud?" on page 13.
5. See glossary on page 138.
6. "How should I store samples?" on page 34.
7. Follow the instructions in Workshops 2, 3, and 4 on page 102 and onwards.
8. "Chapter IV: Data and Action" on page 65.
9. "What kind of oil testing data is useful in talking to regulators? To lawyers?" on page25.

## YOUR OBSERVATIONS

# TESTING QUESTIONS

## What tests exist, and what are available to me?

Here we'll discuss a few different tests described in the scientific literature, as well as used in lab analysis of field samples — but they are not accessible or affordable to people outside those spheres. These descriptions involve some technical language, which we have avoided in other parts of this document; however, part of the reason for Public Lab's Oil Testing Kit program is to address this very issue, and we feel it's important to discuss the status quo of oil testing even if it's not easy to do so for non-scientists.

Currently the most common methods used for "environmental forensics" related to oils involve the use of gas chromatography in tandem with mass spectrometry (GC/MS). Gas chromatography is a method that separates volatile (gaseous) compounds based on certain characteristics, such as their vapor pressure and hydrophobicity, causing different compounds to "elute", or come out of the gas chromatography column, at different times. As the different molecules elute, they then enter a mass spectrometer, which can determine the masses of the molecules that entered (actually mass to charge ratios). By pairing these two techniques, it's possible for a laboratory to identify what kinds of molecules they are. GC/MS is used for identification of a lot of the individual components of oils, such as alkanes, sterane, triterpane, and other polycyclic aromatic hydrocarbons (PAHs[1]). Molecules like sterane and triterpane are often called "biomarkers" because they are molecules derived from the living organisms that created the original source rock and its oil. GC/MS is generally conducted after extensive sample preparation using organic solvents, and requires a laboratory setting, but the results are widely recognized. At Louisiana State University, Dr. Ed Overton has used a combination of qualitative and statistical techniques to discern oil sources from GC/MS spectra (e.g. Henry et al, 1993).

Gas chromatography followed by flame ionization detection (GC/FID) is also used to analyze organic molecules, such as components of oils. GC/FID also starts with gas chromatography (described in the preceding paragraph), and the molecules elute to meet a hydrogen flame, which can pyrolyze the molecules to form ions, and create a current running between two electrodes. The current measured is related to the concentration of the molecules eluted. Like GC/MS, GC/FID requires considerable sample preparations involving hazardous chemicals and is performed in laboratory settings.

Fluorescence spectroscopy is also commonly used to analyze oils and other organic compounds with conjugated carbon ring structures. Spectroscopy in general involves observing the relationship between matter and light. Fluorescence spectroscopy involves irradiating a molecule with light that has high enough energy to excite an electron to another orbital, and then observing the light that is emitted when that electron relaxes (fluoresces) back to its normal state. Many organic molecules are excited by ultraviolet light (~200-400 nm), and then fluoresce in the visible range (~400-700 nm). When using a single excitation energy, emissions peaks can be broad and sometimes difficult to distinguish different organic compounds. More recently, people have used excitation-emission matrices — using a variety of excitation energies and observing the emissions energies and intensities for each — adding a dimension to assist in molecule identification. Fluorescence spectroscopy usually requires less sample preparation, is not destructive to the sample during analysis, and is generally less expensive than GC/MS or GC/FID.

Infrared spectroscopy can also be used to identify features of oil, helping to determine oil categories and weathering or wear. Infrared spectroscopy involves irradiating molecules with energy in the infrared part of the light spectrum (outside the range of our device), which is lower energy than ultraviolet or visible light, and observing the energies that are absorbed by the molecules. The energies that are absorbed correspond to rotational and vibrational energies of chemical bonds, which relate to the bond strength and atoms present. This technique allows you to discern different "functional groups" which are the most reactive regions of a molecule, and are different in refined versus crude products, and impacted by weathering. Like fluorescence spectroscopy, infrared spectroscopy is less expensive and less difficult than the GC/MS or GC/FID methods.

## How much do different tests cost?

According to the Surfrider group[2], which sent many oil samples to different labs over the course of the BP oil spill response, "When we were doing our oil study, we ran batches of ten samples using the 8272 modified solids GCMS method @ $295/sample so, $2995 a set. This was with the understanding that we would be running a lot of samples, so may not reflect the usual pricing." This is how the per-sample cost broke down from the lab analysis for a lab contracted to run samples in batches:

- $340 for PAHs including alkylated homologues.
- $1000 for petroleum biomarkers[3].
- $160 for high resolution GC/FID.
- $2 for sample disposal.

- $700 for data interpretation and reporting.
- Total cost per sample would be *$2202.00*

Costs for oil testing vary widely, to as much as $2000 a sample for dispersant testing (according to Surfrider) and as as much as $10,000 for testing with PACE labs[4] according to Scott Eustis (@eustatic) of the Gulf Restoration Network.

## What can each test tell me?

Gas chromatography - Mass spectrometry (GC/MS), described in the question "*What tests exist, and what are available to me*", can elucidate the different organic molecules present in a sample. Oils are mixtures of many different kinds of organic molecules, originating from when the oil was actually living organisms millions of years ago. Petroleum biomarkers are molecules that are generally not as volatile or reactive as many other molecules, and can provide a record of the type of oil and its source rock. However, even biomarkers are prone to react during weathering processes, so the European Committee for Standardization (CEN) promotes the use of "diagnostic ratios" of biomarkers rather than pure concentrations of certain biomarkers[5]. Diagnostic ratios of petroleum biomarkers are the best "fingerprinting[6]" of oil types and sources that are currently available, and at best, can distinguish oils from different wells.

Certain organic molecules can be identified using GC/FID (described in a previous question), but not as selectively as GC/MS biomarker or PAHs analysis.

The downsides of any of the GC methods are the financial costs, length of time for sample preparation and analysis, and the highly skilled nature of the work requiring professional training and experience. Spectroscopy is much less expensive, less time-consuming, and has lower skill-thresholds necessary for operation. Some commercial fluorescence and infrared spectrometers can even be taken into the field for on-site analysis.

Fluorescence spectroscopy is useful for distinguishing oils by grade or API weight[7], but not fingerprinting an oil source explicitly — so, not for distinguishing between crude oils from different wells, for example. Fluorescence spectroscopy also can be impacted by weathering and sample preparation or dilution, which is discussed in some following questions. Infrared spectroscopy is useful for identifying the functional groups of various molecules within the oil sample, which can be indicative of both oil type and the extent of weathering or wear it has undergone, but is generally not used to identify a specific source of oil.

Some remote hyperspectral imaging, using visible and near-infrared wavelengths, can be useful in rapidly assessing the extent of an oil spill from satellite or aircraft. However, these techniques cannot be used to discern the type or source of oil.


Preparing samples of crude oil and diesel for DIY testing; photo by Cindy Regalado (@Cindy_ExCites)

## What can Public Lab's tests tell me, and with what confidence?

As of January 2016, Public Lab's Oil Testing Kit is a prototype undergoing further development; we are working to assess data it produces and both improve the kit and methods, as well as evaluate their present utility for analyzing samples.

The tests currently being conducted are with *known* samples of motor and crude oil, as well as diesel. We asked members of the Oil Testing Kit Beta Program to scan five known, labeled samples of different types of oils, and one unlabeled sample which contains the same kind of oil as one of the five knowns. This was, in effect, a test of the test, in multiple dimensions — to see if people could assemble the kit, use the software, differentiate spectra of the known samples, and successfully identify the unlabeled sample. The data quality of spectra differed among users, likely due to construction, optical alignment, and incident light intensity differences. Likely due to these factors, the spectra of known samples were substantially different among users, such that inter-user comparisons are currently not sufficient for categorizing an unknown oil sample. However, we focused on tests on a single device; for this reason we shipped reference samples of oil to each tester so that they could be scanned on the same device.

We are improving the hardware design to make inter-user results more consistent, but our primary goal is to pilot testing against references on a single instrument. That is, *we hope our test will enable people to tell whether an unknown sample is crude, motor oil, or another type of oil.* For the above tests, spectra obtained by individual users on a single spectrometer were consistent and reproducible for many users, and for those who correctly assembled and calibrated their devices, the spectra of at least crude oil and diesel were distinguishable, and were in some cases distinguishable from intermediate grades. The spectra of our "intermediate grades" (5W30, 20W50, and 80W90) were not substantially different enough to be considered distinguishable.

User tests have demonstrated a substantial effect of oil concentration on their fluorescence spectra, larger than would be expected based on published literature. The observed differences between different concentrations of the same oil (diluted in mineral oil) are actually larger than the observed differences between different types of undiluted oils, and so it is very important to know the concentration of oil in the sample if you want to discern what type of oil it is. This may be difficult with field-collected oil samples that may be mixed with substrates such as sand or soil, and is an area of active research in the Public Lab community. As of January 2016, we are exploring the possibility of equalizing opacity of samples in order to correct for concentration[8].

As of winter 2016, fluorescence tests of unknown samples have begun as well. With the understanding that sample concentration will have an impact on fluorescence spectra, the current "unknown" tests are simply for presence or absence of fluorescent signal. Unknown samples that do fluoresce will be compared with a series of known oil samples diluted to approximately the same concentration as the unknown sample. Since the unknown sample is likely to have sand or soil agglomerated with it, simple sample weight to solution volume ratios will not be sufficient to accurately calculate true sample concentration, so these comparisons to known samples of approximately the same concentration are not very robust, but are a useful step toward classification of an unknown sample.

IMPORTANT LINK

For the most recent information on this work, see https://publiclab.org/tag/oil-testing-kit

## What kind of oil testing data is useful in talking to regulators? To lawyers?

The federal Water Quality Recommended Guidelines[9] state that waters should be "virtually free from oil and grease", so county or municipality officials should respond to reports of oil sheens or oil dumping based on citizen reports. Photographic evidence enhances the citizen reports, particularly because the situation could change between the time the report was made and when the officials are able to respond. The more data that is provided, including data obtained using a credible DIY oil testing kit, could potentially expedite the local response or other actions taken. However, note that the process of response does not necessarily include identification of a source or a responsible party. In situations where an individual or group seek a financial penalty on a company for their environmental pollution, that group may need to sue the company under the Clean Water Act.

For marine oil spills, the majority of reporting is visual, often photographic or video from aircrafts (Fingas and Brown, 2007). However, visual techniques are only appropriate for documenting or reporting the existence of an oil spill, but not for determining the type or source of the oil. Since 1972 the U.S. Coast Guard (USCG) has been tasked with developing and implementing techniques for identifying oils and hazardous substances, and the USCG has historically used a combination of spectroscopy and thin-layer chromatography (TLC) in the field and gas chromatography in the laboratory if necessary (Clow, 1977). According to the 2009 American Petroleum Institute Report, only the largest ~10% of all spills are investigated[10].

When the USCG or state or local authorities do investigate oil spills, it is common to use ASTM methods D3328 or D5739, which are qualitative methods that use GC/FID and GC/MS respectively, and compare samples with oil standards to observe similarities and differences. The methods are widely acknowledged as subjective, however, so there has been pressure to use more quantitative methods, such as using petroleum biomarkers. The European Committee for Standardization (CEN) supports the use of diagnostic ratios of petroleum biomarkers for oil spill investigations, and in the U.S., petroleum biomarker analyses by GC/MS in an accredited lab are used for large spill source identification investigations. However, in smaller cases where GC/MS analyses have not been conducted, compelling visual evidence demonstrating the leaking or spilling source, may be utilized.

## Has such data has been used to effect change? How, when, and where?

Petroleum biomarkers and diagnostic biomarker ratios[11] have been used frequently since the Exxon Valdez Oil Spill in Prince William Sound (PWS) in 1989. While much of the oil pollution in PWS was due to the massive Exxon oil spill, petroleum biomarkers were used to evaluate tarballs along the shorelines, and researchers discovered that many of the tarballs actually originated from a source in California, demonstrating the persistent and long-reaching effects of marine oil spills (Wang et al, 2007 and references therein). Petroleum biomarkers were used while investigating a destructive building fire, and it was discovered that the building had caught fire due to ignited leaked bunker oil, which also leaked into the nearby river (Wang et al, 1999). It's important to note that petroleum biomarkers and biomarker ratios can be indicative of a correlation but do not necessarily provide definitive proof of an oil source; to provide more compelling proof of a source, multiple types of analyses may be necessary.

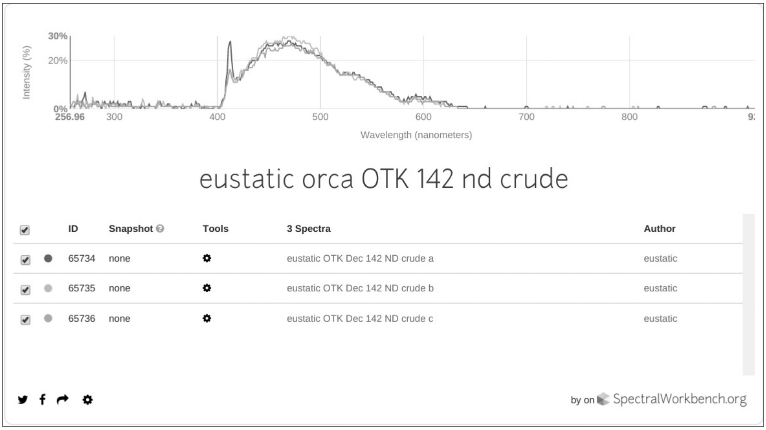
Fluorescence spectroscopy, on which we have been basing Public Lab's prototype Oil Testing Kit, has been used to investigate oil spills and their sources as well. After the Hebei Spirit Oil Spill of 2007, several methods were used to monitor the oil spill cleanup effectiveness, including a portable fluorimeter for rapid analysis of oil in pore waters (water between sediment grains). This allowed researchers to monitor oil concentrations in a large geographic spill area with substantial measurement density over several months and monitor oil attenuation (Yim et al, 2012).

Recently, fast-scanning synchronous fluorescence spectroscopy[12] has been recommended as a screening tool for oil spill source identification in the Turkish Straits, through which more than 55,000 ships travel each year, where fluorescence spectra are rapidly obtained, compared with suspected sources, and any probable matches are then evaluated by laboratory techniques (Karakoc et al, 2015). This fast-scanning screening can make illegal oil discharge or spill investigations more rapid and efficient.

Visual photographic evidence has been used to prompt investigations for decades, and is still the most common evidence included in reports of oil spills (Fingas and Brown, 2007 and references therein).

## Can results from the Public Lab Oil Testing Kit be used as evidence?

As of January 2016, there remain too many unknowns — including the effects of dilution, weathering/aging, and device construction variability — for our DIY data to be considered persuasive enough to be used as evidence yet. That is, spectra obtained using your DIY spectrometer can be informative, but may not be persuasive to your intended audience. For example, regulators will probably not recognize data from a DIY kit or other un-approved methods as diagnostic[13]. However, these low-cost methods can provide useful, if not diagnostic, information. With the Public Lab Oil Testing Kit,




Set of scans of crude oil by @eustatic; https://spectralworkbench.org/sets/2928 observing fluorescence which resembles that of a reference sample of known petroleum — is a probable indicator of petroleum compounds, and can be useful for motivating communities speaking out against oil pollution, informing neighbors about potential hazards in their environment, or prompting further investigation by enforcement or remediation agencies.

Efforts to prompt further official investigation can be greatly enhanced if you can demonstrate a correlation between your results and results of officially recognized tests. If official tests are conducted, try to collect samples at the same time and from the same location, and compare your data with the official results. If you can speak with the local or state agency who is responding to the spill, they may be willing to collect a split sample[14] for you (i.e. take a sub-sample of their sample to provide to you), especially since they will already be going out to collect samples. If any real-time data is collected in the field by officials, try to collect data simultaneously for a co-located comparison test. Read about co-located tests below. Results from these sorts of comparison tests can better inform you and the Public Lab community about the capabilities and limitations of the Oil Testing Kit, and positive results can facilitate greater impact and recognition of your unofficial tests.

## What are the advantages of co-locating tests?

By conducting tests on samples collected at the same place and time, or especially on subsamples of the same "split" sample as officially recognized tests, it's possible to evaluate if a relationship exists between your tests and those which carry much stronger legal and regulatory weight. Of course, if your own tests do not agree with the official tests, it may be difficult to establish credibility for your own testing — but if they do, this correlation can provide added credibility for your testing.

If a correlation is present between official results and your unofficial results, it may be possible to improve the spatial coverage of testing. That is, if the official tests only cover 10 spots over a 10 mile-long riverbank, but those ten tests have high agreement with a lower-cost, less-recognized test, it may be possible to use the latter test on 100 spots over the same riverbank, and "fill in" data between the official tests, for a more detailed look at pollutant distribution. This approach of filling in data gaps (also called "Data Fusion Approach") is part of the plan for US Environmental Protection Agency's (EPA) Next Generation[15] air monitoring programs, likely to be followed by other Next Generation monitoring of land and water contamination.

It is important to note that the usefulness of data from co-location tests, as with any data, will depend on how persuasive the data is to the intended audience. Any interpretation of data must be rooted from the data quality — the accuracy, precision, resolution, and reproducibility of the tests.[16] Beyond that, effective communication of those results is important. For technical audiences, communicating the data quality on a mathematical basis and demonstrating proper statistical analyses will be useful to create a platform for transparent and earnest discussions. For audiences with less technical backgrounds, while data interpretations will, of course, still be rooted in data quality, communication of results may be more effective with more visual demonstration and outlining of analogous situations.

For all audiences, very direct communication of data limitations is as important as assertions of data capabilities. This can often be a difficult balance to achieve, but if you start by clearly explaining the objectives of the test (e.g. to distinguish between different classes of oils rather than an explicit identification of an oil spill source), then explaining the scope of your results follows suit.

## SECTION NOTES

1. See glossary on page 138.
2. Visit https://emeraldcoast.surfrider.org/
3. See glossary on page 138.
4. Visit https://www.pacelabs.com/
5. Visit http://www.nordtest.info/index.php/technical-reports/item/revision-of-the-nordtest-methodology-for-oil-spill-identification-nt-tr-498.html for Technical Reports
6. See glossary on page 138.
7. See glossary on page 138.
8. For more on the effects of dilution, see https://publiclab.org/tag/dilution.
9. Visit http://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
10. See http://www.api.org/~/media/Files/Publications/2009_153_OIL_SPILLS_REPORT.pdf
11. "What kinds of tests" on page 38.
12. "What can each test tell me?" on page 22.
13. See glossary on page 138.
14. See glossary on page 138.
15. Visit http://www.epa.gov/air-research/next-generation-air-measuring-research
16. "Testing Your Hypothesis" in Workshop 1 on page 88.

# SAMPLING QUESTIONS

There are questions about how to collect and store the samples.

## How much do I need to collect? Solid vs. liquid?

As of January 2016, there is work being done by Public Lab Fellow Matej Vakula to collect useable sample volumes from sources such as sheens on the surface of water[1], and oils soaked into absorbent plastic pads[2]. These techniques aside, we currently recommend 2-10 drops of pure oil diluted in a 2.5 milliliter sample container filled with pure mineral oil (which does not fluoresce). If the samples are very transparent, dilution may not be necessary.

For solid samples, it depends on the concentration; dissolving the solid samples in a small amount of mineral oil and allowing dirt and sand to settle out can result in a pale yellow solution which can be tested[3].

## Can I touch it, and with what?

Do not touch suspected pollutants with bare hands; use gloves and other protective gear, and do not leave them unsealed except in well-ventilated areas. Oil pollutants contain volatile components which can be harmful to breathe, and carcinogenic substances which are dangerous to touch.

## What does oil pollution look like?

This depends on where and in what state you find it. Oil may be a liquid sheen on the surface of water, a dried, dirt-like residue in brown, black, or orange, or it may be dissolved in water, and not easy to see.

## Can it be mixed with sand, dirt, vegetation, etc?

Samples collected in the field can often be mixed with grit, sand, vegetation, etc. If you're dissolving a solid sample, like a piece of tar, in mineral oil or another solvent, these may settle out over a few minutes or hours, and so it can be helpful to dissolve in one container, then eye-drop the transparent solution off the top into another container for scanning.

Vegetation or plant or organic matter (like peaty soils) will fluoresce, and so should be kept out of oil samples[4].

## What happens if I dilute my sample or don't know my sample concentration?

As of January 2016, there is ongoing research in our community[5] on whether and by how much dilution affects the color of fluorescence (and specifically the position of the highest point in the spectral graph), which would potentially affect the results of the Oil Testing Kit. If dilution proves problematic, we may be able to correct for this effect using absorption spectroscopy to equalize the opacity of samples[6].

Dilution may be necessary, however, to get a spectrum from some very dark samples, like concentrated crude oil, due to issues like quenching.

## What is fluorescence quenching?

Quenching is essentially the dimming of emitted light from a sample as the light passes through the sample itself to escape the sample container — especially if your sample is too concentrated. When we illuminate an oil sample with ultraviolet light, we provide energy that excites an electron into another electron orbital. Fluorescence is the light (energy) that is emitted as the electron relaxes down to its normal or "ground" state. Quenching is the loss of energy to another molecule, rather than energy being lost as a visible light emission. So, when quenching occurs, we see less fluorescence.

Quenching can occur through several mechanisms. A common quenching mechanism involves the loss of energy through collision with another molecule. Quenching is quite common in solutions containing oxidizing agents or electronegative elements (such as halogens), which can gain electrons into their molecular or atomic orbitals. Another type of quenching commonly observed is "Forster Resonance Energy Transfer" (FRET), in which the energy of one molecule's fluorescence excites another molecule (the emission energy of one molecule is the excitation energy for another molecule in the sample). FRET broadens and lowers the intensities of the observed fluorescence spectra. An observed reduction in fluorescence intensity (though not technically fluorescence quenching) can also be due to molecular shielding and steric effects hindering the excitation of molecules in the sample. All of these types of fluorescence quenching are more pronounced in more concentrated solutions, and can be be mitigated through sample dilution.

It is important to note that all fluorescence involves the loss of energy, which is why fluorescence emissions are at longer wavelengths than their excitation energies. This phenomenon is known as Stokes shift, and is simply the loss of vibrational energy as the excited electron settles from its maximum absorption excited state to a lower energy excited state prior to fluorescing back to its ground state. Jablonski diagrams[7] offer a visual representation of fluorescence, including vibrational energy loss and potential energy transfers.

## Could there be a “false positive” in my oil fluorescence test?

Although various polluting oils fluoresce, one reason we can’t rely on fluorescence in itself as an indication of oil pollution is that several organic compounds fluoresce in the UV-Visible range. Generally, most compounds with carbon ring structures can be excited by UV light and fluoresce in the visible spectrum. Common materials that fluoresce, and may fluoresce with a similar fluorescence peak shape and energy include, but are not limited to:

- Other oil types
- Vegetation - humic acid
- Organic matter - beer
- Amino acids, bodily fluids like urine — crime scene
- Vitamin E in mineral oil
- Containers - gel capsules, for instance

## Cuvettes

Spectrometers (including our DIY Oil Testing Kit) are usually set up to scan samples placed in small containers called cuvettes, which can be made of different types of plastic or glass, depending on what you want to store in them, and what kind of light you want to shine through them.

In the lab, cuvettes are considered temporary, and often disposable, especially if plastic[8].Some problems we’ve encountered with cuvettes are that some plastic (polystyrene, a common cuvette material) will dissolve if used to store more corrosive samples like diesel, and that cuvettes with square lids will leak if not kept constantly upright.

Ultra micro cuvettes; photo by Jeff Warren (@warren)


Several cuvettes in a row, demonstrating the way light should pass through them; photo by Jeff Warren (@warren)

A good sample container has flat sides, so you can shine light (or a laser) through it without lots of reflections, which could go into your spectrometer and affect your data. It's also good to have the light travel through a consistent amount of the sample — many cuvettes (traditional spectrometry sample containers) are 1cm x 1cm, so the light always goes through 1cm of the sample. Some cuvettes are designed for smaller amounts of liquid, such as "micro" or "ultra micro" cuvettes — these taper towards the bottom, so you don't need as much sample material to scan. This also means you can shine light through less sample material; it's thinner. For fluorescence tests, like in the Oil Testing Kit, quenching (see above) can happen in a concentrated solution, especially with a long light path encountering more molecules. Thus, making the light path through the sample shorter, some quenching and molecular shielding is lessened, yielding better results.

The different plastics cuvettes are made of are often designed to be super transparent in the intended type of light, as well as to be resistant to corrosion or dissolving from the contents of the sample.
Some cuvettes also have surface treatments like a textured or slightly opaque "diffuser" surface, or a fluted surface, on some sides to affect how light enters or exits the cuvette. For the Oil Testing Kit, we've found that if you're using a laser, you should shine it through the completely clear sides, but that diffusers on the surface facing the spectrometer may have fluting or diffusers; as long as enough light enters the spectrometer, it's OK.

IMPORTANT LINK

Selecting what types of cuvettes are best for which samples and types of light http://www.brandtech.com/cuvette_comp.asp

## How should I store samples?

Samples for organic analyses, such as oils, should be stored in glass since their components may stick to the walls of plastic bottles or entrain some plastics components into the oil samples. Oils are comprised of lots of different organic molecules, many of which are photo-reactive, meaning they react and can change chemical or physical form when exposed to sunlight. Thus, keeping oil samples in dark containers, such as amber glass is best. In order to minimize photoactivity, samples should be stored in a dark space as well. Several components of oil are volatile, and to minimize loss of those volatile organic compounds (VOCs), samples should be kept cool — at 4 Celsius (39 Fahrenheit). If you are planning to have an oil sample analyzed by a laboratory, be sure to find out what kind of sample storage requirements they have prior to analysis, especially because often samples are only acceptable for a couple of days without risk of too much volatilization or oxidation, changing the sample chemistry.

Team members of the Gulf Restoration Network who responded to the 2010 BP Oil Spill collected samples of oiled fish and oiled soil where:

- Oiled fish in the field were wrapped in aluminum foil, placed in plastic bags, placed in coolers and overnight-mailed in cooler with dry ice.
- Soil was grabbed with EPA brown glass jars, placed in plastic bags, placed in coolers and overnight-mailed in coolers with or without dry ice.

Interestingly, oils for use (such as motor oil) are typically distributed and stored in plastic containers because they are less expensive and less breakable. In the Public Lab Beta Oil Testing Kit, known oil samples were mailing to beta testing program participants in plastic bottles for these reasons, as well as because the suppliers of these reference samples shipped them in plastic bottles in the first place. We have not observed impacts on oil spectra (obtained from Public Lab spectrometers) from being stored in plastic bottles, but we have not analyzed samples consistently over several months yet. We may need to include glass bottles in future reference sample shipments.

IMPORTANT LINK

Please review the EPA's technical manual on Methods for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analyses. For a quick list of typical storage requirements for different types of samples please visit http://www.caslab.com/Holding-Times-Container-Types/

## How long will samples keep?

There is an ongoing discussion among people interested in oil analyses about how long oil samples will retain their chemical (and, importantly, fluorescent) properties without deterioration or contamination. Most analytical procedures require analysis within a few days of sample collection to ensure sample integrity (see this quick reference, but if stored in cold and dark conditions in sealed containers, oil samples may retain their integrity longer. Organic matter, oxygen, and bacteria may all deteriorate components of oil though, so long storage should be avoided. If you need to store your samples for longer periods of time, deep freezing can preserve their chemical integrity longer.

As discussed in the previous question, samples should be stored in glass, UV-blocking (generally amber) containers, tightly sealed (and ideally without headspace), in the cold (generally 4 Celsius). This is to inhibit, or at least limit, photooxidation, bacterial degradation, and volatilization. Samples that are properly stored can be stored for longer periods of time.

Environmental samples are, of course, exposed to natural conditions including sunlight and air, in addition to water, sediment, or soil mixing. Weathering impacts oil fluorescence spectra and their biomarker or other component analyses, and elucidating specific impacts of weathering on these analyses is an active field of study.

## How do I prove where and when I collected it?

In environmental data collection, the "chain of custody" refers to the explicit documentation of the condition of the samples and the person(s) responsible for them, from collection through transport and storage, and finally analysis. To start the Chain of Custody, document:

- Name and contact information of sample collector
- Sample code (if applicable)
- Date and time of collection
- Location of collection
- Type of media (e.g. soil, sediment, water)
- Environmental conditions
- Collection method used
- How it is stored or transported
- Type of preservation (if applicable)
- Analyses requested,

If possible, take a photo with a cellular phone to obtain an official time-stamp and GPS coordinates. It is also useful to take supplemental photos featuring distinguishable landmarks.

## SECTION NOTES

1. Please visit https://publiclab.org/wiki/diy-oil-testing-questions#Can+I+test+sheens+from+the+surface+of+water?
2. Please visit https://publiclab.org/notes/Matej/12-21-2015/first-pig-oil-only-absorbent-mat-pad-test
3. Please visit https://publiclab.org/wiki/diy-oil-testing-questions#What+happens+if+I+dilute+my+sample+or+don't+know+my+sample+concentration?
4. Please visit https://publiclab.org/wiki/diy-oil-testing-questions#Could+there+be+a+"false+positive"+in+my+oil+fluorescence+test?
5. Please visit https://publiclab.org/tag/dilution
6. Please visit https://publiclab.org/tag/dilution
7. Please visit http://chemwiki.ucdavis.edu/Physical_Chemistry/Spectroscopy/Electronic_Spectroscopy/Jablonski_diagram
8. Pleasevisithttps://publiclab.org/wiki/diy-oil-testing-questions#How+should+I+store+samples?

## YOUR OBSERVATIONS

# SITE-SPECIFIC QUESTIONS

There are also questions about the specific site you're concerned with:

## How could data I collect relate to existing data?

There are other similar situations where some kind of oil testing would be helpful, and we think it's important to address these independently.

## Can I test sheens from the surface of water?

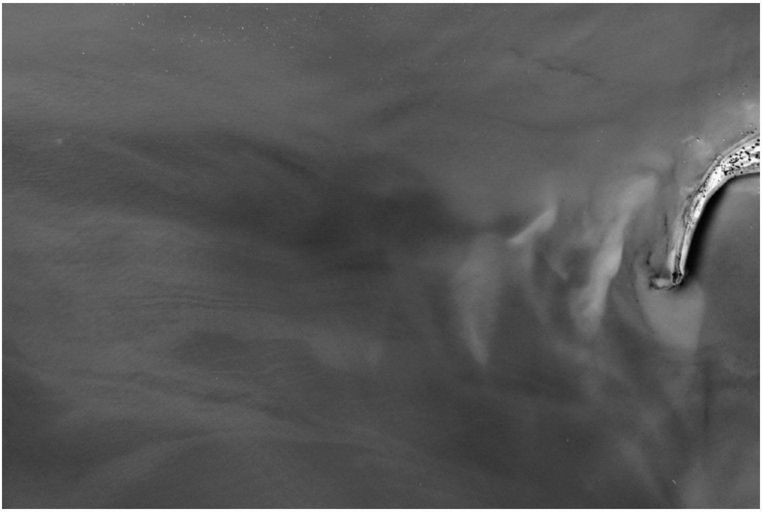
Sheens form from the distribution of oil across the surface of water — oil being lighter than water, it tends to spread out and can appear brown or orange, or even black if thick. But if it's very spread out, it often forms a rainbow colored, iridescent sheen, which can be so thin that scooping up a small amount can yield only extremely small amounts of oil.

As a result, Public Lab fellow Matej Vakula (@matej) has been investigating Do-It-Yourself techniques for collecting, concentrating, and analyzing surface sheens over the winter of 2015-16. You can read about his work here: https://publiclab.org/tag/sheen; as of January 2016, he has been exploring the use of plastic that preferentially absorbs oil, as well as the freezing of oil/water mixtures, in an attempt to separate water and oil, and to recover enough to be scanned in an Oil Testing Kit.

## Can I tell how old oil is?

Weathering, especially exposure to air, sunlight, and microbes, can affect the composition of oil samples. Many of the components of oils are photo-reactive, meaning they will undergo chemical reactions when exposed to sunlight, and many organic molecules are volatile and will evade from the samples, particularly under warm or hot conditions. Microbes may be able to metabolize certain compounds in oil, again affecting the overall chemical composition of oils. While it is well known that weathering affects oil compounds in these ways, quantifying the extent to which an oil has "weathered" is challenging.

In order to navigate these complications, the European Committee for Standardization (CEN) suggests using petroleum biomarker ratios (see what kinds of tests, above ) rather than the concentration of any one biomarker to mitigate the impacts of weathering on "environmental forensics" of oil samples. For methods such as spectroscopy that do not quantify biomarkers, it is challenging to determine the age of an oil sample or the expected impacts of weathering on its fluorescent spectra. We need more research to address this question and how best to navigate the related issues of impacts on spectra. One approach would be to repeatedly analyze a single sample as it ages in a natural, but controlled environment, and document the changes observed over time.



Oil sheen in the Chandeleur Islands after the BP Oil Spill

# CONCLUSION

In general, we've attempted to answer questions with a lower threshold first, and many of the above questions remain unanswered or partially unanswered at the time of writing. We continue to address outstanding questions with our research, development, and application, and if you feel you can contribute, please feel free to improve this document and reach out on the Public Lab discussion lists.

SECTION NOTES

For a full list of references, please view page 140

YOUR OBSERVATIONS

What's next?

**Continue to Chapter 2: Working with Communities**

# 2
# Working with Communities

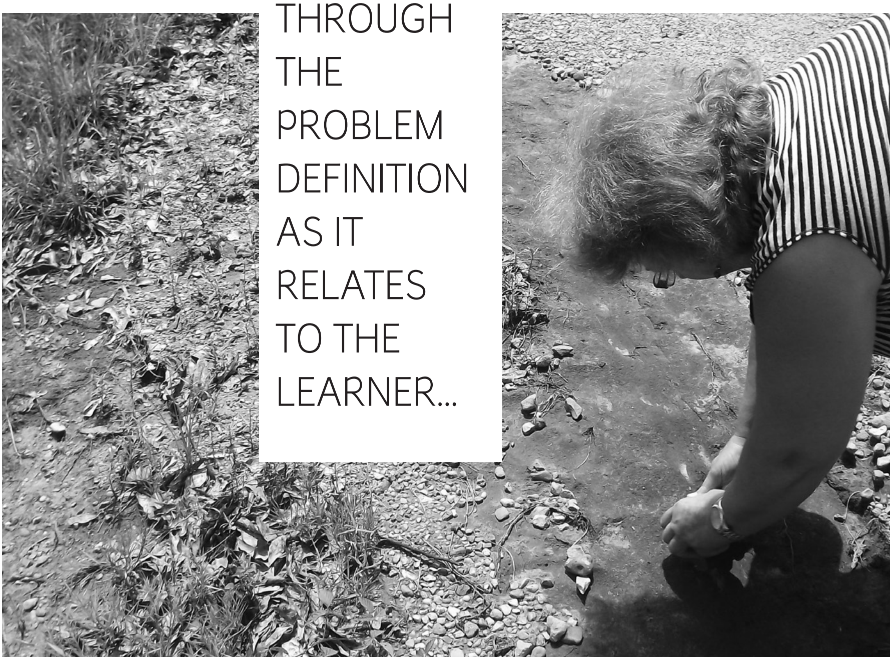
## INTRODUCTION

Part of the Public Lab approach is to build collaborations with people and community groups directly facing environmental problems. During the Homebrew Sensing project we did outreach to both online and offline groups. The section will explain some of our methods, results and further observations on the outreach strategies we employed. Taking this project into the future, we've developed a workshop series that outlines what it looks like to work with a group through the oil testing process.

## IN THIS CHAPTER

- Community Outreach
- Online Outreach
- Open open hardware

IT WAS MORE SUCCESSFUL TO WALK THROUGH THE PROBLEM DEFINITION AS IT RELATES TO THE LEARNER...



Community sampling of neglected oilfield site in Tangipahoa Parish, north of New Orleans; photo by @eustatic

# COMMUNITY OUTREACH

Over the course of the project we identified several community groups who were interested in the Oil Testing Kit. However, a group's level of involvement in the project was based on several factors, distinguished by urgency and ability.

A community group had a degree of urgency in the problem if there was an imminent threat to their health or environment from something the kit addresses. This means their interest in learning and using the kit was important to them and often times personal.

The second factor that influenced a group's involvement in the project was ability. Ability here is defined in terms of resources and outcomes. The group was able to work on the project if they had:

- time to wcommit,
- energy to learn, and
- a desired outcome was achieved when they learn or use the kit

Although the degrees of urgency and ability varied in the groups we worked with, they generally broke down into these categories:

| | URGENT | NOT URGENT |
|---|---|---|
| ABLE | Will work on the project and can use it in their community or work setting. | Will work on the project for interests other than their specific environmental concerns. |
| NOT ABLE | Will not work on the project based on project limitations but has the most need for what the kit could do in the future. | Will not work on the project. Could potentially use the kit, but does not have resources to dedicate to it or a direct need for the kit as it exists. |

## Groups who will work on the project

### Urgent/Able

We worked with two groups during the project who feel under the category "Urgent/ Able." One of these groups was a non-profit "committed to uniting and empowering people to protect and restore the natural resources of the Gulf Region." They were interested in the kit for its ability to be used in its current state as a detection tool and in its potential use in accountability and reporting. Their involvement in the project was mostly conducted through a Public Lab organizer who works for the organization and had a vested interest in tool development and the tools use.

The other group we worked with who fell in this category was a community group that has organized against the threat of fracking in their parish. They have done work lobbying their local government, exposing the issue to the media, and educating local people about the threat of fracking. Their interest in the kit in detection and the kit's potential use in the fight against fracking. They have had one training of 15 people on the kit and plan to train 15 more. They also plan to work with the kit as it develops and is more able to address their community interest.

### Not Urgent/Able

We worked with two groups who fell into this category. One group was an education based organization where students spend a semester exploring environmental issues and pathways for science and environmental careers. Their interest in the project was mostly academic, and saw the oil testing kit as a good use of science in education. They were also interested in use cases for the kit around their community. While there was not an urgency for them to use and understand the kit, their interest in exploring it has allowed us to use them as a sounding board for tool development and in experimental design.

The second group we worked with in this category was a group who had an early interest in the kit based on their experiences during and after the BP oil spill. They had spent a lot of money sending oil samples to the lab for testing and saw the kit as a screening tool in that process. Their urgency on the kit is not currently great, but their interest in learning about it and their ability to dedicate time to training on it has led them to take the kit into the classroom.

## Groups who would not work on the project

During the project we worked with two groups who initially learned about the kit, what it could do and what it could not do and decided against taking their work on the project to the next level.

### Urgent/Not Able

We worked with one group in this category. They are the group who has most to benefit from a kit like this, but is stretched the thinnest for resources and would not get desired outcomes from working with the kit as it is. The group we worked with has been dealing with a facility that has been taking hazardous chemical waste and processing it in open pits for many years. The plague of this facility on the community has brought about concerns for human health, daily nuisance of chemical odor, dumping in the waterway, and flooding waste ponds into the ditches and roads during rain events. They have the urgency of health, well being well beyond any other group we worked with for this project. However their ability to work with the kit was limited several factors. They had a lack of time to dedicate to using the kit. They identified that they did not have the technical computer skills that were needed to use the kit in it's current state. They identified that the kit in it's current state would probably not help them collect information that would push their community towards the outcomes they desired.

### Not Urgent/Not Able

The group we worked with who fell in this category identified that the current state of the kit limits their urgency and ability to take it on as a project. This group works with both fenceline communities and advocacy as well as water issues as their staff are also River Keepers. The limitations on their urgency with the kit is that it does not currently answer to a enough of their pressing issues. Their limitations on ability to work with the kit is the time it would take to learn and use it, and the lack of desired outcomes from using it. For them, desired outcomes would be the kit's ability to positively identify oil and scan samples taken from water.

# Conclusion

If the kit develops in a way, as desired, to answer more environmental questions, take less time to learn, and produce more results that are actionable, we will see an increase in the number of community groups who have an ability and an urgency to learn and use the kit.

## Sharing Space

Over the course of this project we identified that while there were a number of groups who were interested in working on developing the Oil Testing Kit and groups who were interested in using the kit for their own purposes of environmental exploration, the two did not naturally paths on the project development trajectory. This is something Public Lab has been working on for a number of years. However, it should be noted that despite this sometimes inevitable divide between users and developers, something quite different happens when people from these two groups share the same physical space.

One example of this is at the 2015 Public Lab Barnraising where both developers and users of the kit shared the same space. This physical act of sharing a space facilitated a knowledge sharing among the groups that dosen't seem to happen on the wiki or on the google groups. We could observe developers situating the Oil Testing Kit in the narrative of a community story, and community members recognizing the needs and challenges of tool development. This sharing personalized the project and process for many people and is an excellent tool that should continue to be used.

## Workshops and the learning process

In environmental exploration the learner must understand the reasons, uses and limitations of a tool in order for the learning process to be effective. The tool must also be made accessible by providing educational experiences that satisfy the learner's unique learning preferences. Finally the tool must be situated in a problem that the learner can understand and explore.

During the course of this project, the most successful learning strategy was not to place the kit in front of someone and have them explore tool development itself as a process. Rather it was more successful to walk through the problem definition as it relates to the learner, before exploring how people sought to answer the problem.

## IMPORTANT LINKS

For more information on the workshops, please visit: https://publiclab.org/wiki/oil-testing-workshops

## YOUR OBSERVATIONS

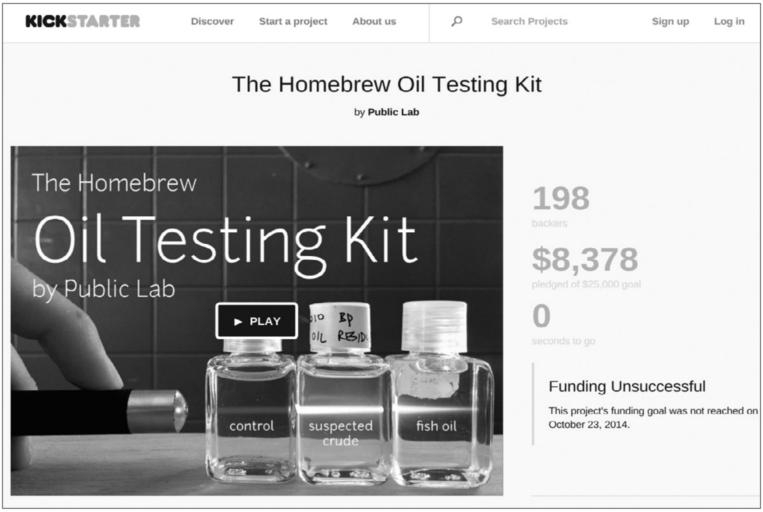
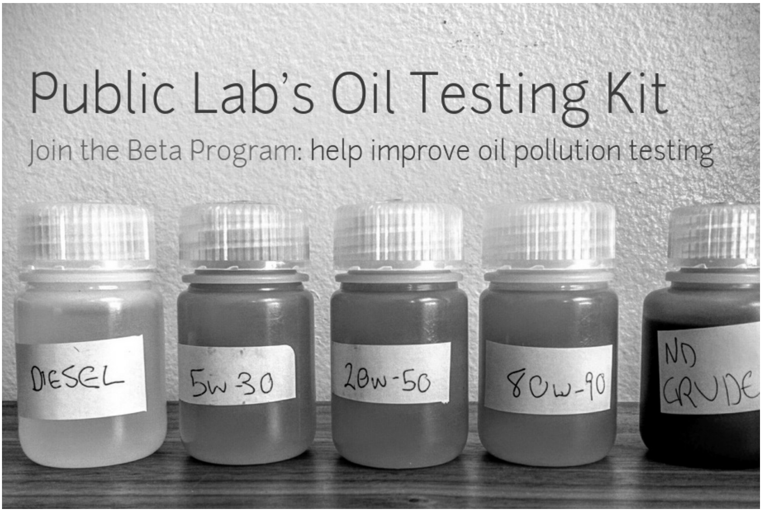



Image from the Oil Testing Kit's Kickstarter campaign




Promotional image for the Publi Lab's Oil Testing Kit Beta Program

# ONLINE OUTREACH

## Spectral Challenge

Over two years, we've had the opportunity to pilot a number of different strategies for building community interest and involvement in technology and methods development. In 2013, we developed a competition to promote innovative work to further the analysis of pollutants with do-it-yourself tools, called Spectral Challenge. Launched at SpectralChallenge.org and announced on the Public Lab website, this was an "X-prize style competition" in two stages, the first to promote and reward good collaborative practices and excellence in documentation, and the second to reward concrete advances in analytic methods, including improvements to DIY hardware. In an additional twist, the prize was crowd-funded, meaning that anyone who wished to support these goals financially could add to the prize pool.

Ultimately, the challenge failed to attract much participation. In retrospect, we feel that the terms of the challenge were too open; rather than prescribe a specific improvement such as a precision or resolution target, the prize was left open to the team that demonstrated "identification of a sample in a real-world scenario, such as from an actual soil or water sample" — and was even more open-ended in Stage 1, which called for teams to, among other things, "refine research questions and describe & execute tests which we'll need to produce credible data - including identifying problems, but especially suggesting solutions." We feel that the prize would have benefitted from much narrower goals and more scaffolding; potential participants weren't sure where to begin. Although we value openness and diversity at Public Lab, we feel that providing strong models for participation can mitigate a tendency towards aimlessness in distributed online groups.

Still, much about Spectral Challenge represented the values we aspire to in the Public Lab community; entries were required to cost less than $200, and projects were required to post "simple, legible, open source documentation." Collaborations and locally-relevant work were especially preferred. The main legacy of Spectral Challenge is that many of these priorities have been adapted into the "Open Open Hardware" process[1] announced in fall of 2015, which aims to structure and standardize collaborative practices in order to set clear timelines and expectations for hardware projects, as well as address the "tyranny of structurelessness" by establishing roles and patterns for open source hardware development.

## Oil Testing Kit: Kickstarter

Another initiative to promote participation in the Oil Testing Kit project was a Kickstarter campaign launched in the fall of 2014, which offered a prototype kit and represented a more participatory and focused campaign than previous campaigns Public Lab has run. In contrast to previous campaigns, we focused exclusively on a single type of environmental problem — oil pollution — and asked backers to become involved in testing towards that goal.

The campaign was not successful — a surprise, given Public Lab's four previous consecutively successful Kickstarter campaigns. We believe this was due to a number of different factors, and have summarized these thoughts[2] in an update posted just after we ended the campaign. Ultimately, we concluded that while Kickstarter can be (and has been) a powerful venue for certain types of Public Lab projects, it was not a good match for the kind of campaign we sought to launch.

## The Beta Program

### What was the beta program?

The Oil Testing Kit Beta Program was designed in April/May of 2015 with the intent to move forward with design of the oil testing kit, provide proof of concept that the kit did infact allow users to distinguish oil and identify potential use case for the kit. The initial outreach materials for the program were sent out in July 2014. These advertised that the program was *"offering prototype laser-cut versions of the new Oil Testing Kit free of charge for 20 people interested in helping test and refine the kit. This is an exciting opportunity to help improve our prototype DIY methods for classifying unknown petroleum samples by weight. Our eventual goal is for this kit to be usable to test and compare oil spill residues, and we need your help! Anyone can join the Beta Program, no experience required, you just need time to assemble the kit, use it (please see obligations on the sign-up wiki) and troubleshoot."*

### How was it set up?

The requirements of the Beta program initially required all participants to have completed the program by November, 2015[3], and the program involved:

- Creating a profile on PublicLab.org (if you don't already have one)
- Joining the plots-spectrometry list

- Posting unboxing photos & tweet them with @PublicLab & #OilTestingKit!
- Building and document the beta kit and sample preparation process
- Running triplicate spectra of each known and unknown sample (the kit includes five labeled and five unlabeled samples)
- Uploading all of the spectra, tagged with “oil-testing-kit”, add them to a set, and post a research note of their tests
- Running a sample that you find locally. This can be anything from suspected motor oil residue on storm drain to the tar like substance you sometimes see by train tracks!
- Attending two meet-ups to chat with other Beta Program members

A fellowship was created to run the Beta program and analyze the results of the sets that were put on SpectralWorkbench.org. There were two main forms of communication set up for beta participants. On was through a closed email group where participants were BCCed, the other was bi weekly chats in the Public Lab chat room.


The Oil Testing Kit beta; photo by Cindy Regalado (@Cindy_ExCites)

## How did it play out?

Below is a timeline of the program as it played out:

- 7/14 Announced Beta program
- 7/22 First chat on Beta program was held before the announcement of who would be in it was made. This chat had 25 attendees.
- 8/5 Announced participants (20 selected out of 31 applicants)
- 9/14 The kits were shipped.
- 9/12 The status of the application for the Beta program was changed from "accepting current applicants" to "sign up if you're interested in future testing." 12 people applied to be apart of the beta program after participants were selected.
- 9/30 The Second Beta Chat was held, this was set after participants should have received the kits (8 people). The chat was run to address people's questions on kit construction.
- 10/7 Third Beta Chat. This chat was set to answer people's questions on Running Samples with the kit. Three attendees joined the chat.
- 10/14 Fourth Beta Chat was available to help answer any questions people had working with the kit. Three people were in attendance.
- 10/19 In the emails out to the Beta participants, we stop BCCing and directly added in people. The Fellow running the program sent out an encouraging email to participants to post research notes and start running sets.
- 10/22 Full beta program sets started coming in.
- 10/28 Fifth Beta Chat was held to answer questions and address problems people were having finishing the beta program. Two people attended this chat.
- 11/2 The Fellow running the program sent emails to those we hadn't heard from.
- 12/7 OpenHour on the OTK (20 people, no beta participants)
- 12/11 Last outreach for group we didn't hear from and outreach to new participants.
- 12/18 In person meetups and staff participated in the beta program to add 6 other full data sets.

While 9 of the 20 beta participants posted research notes about working with the kit (mainly on constructing the kit), as of January 2016, only four of the original beta participants completed the entire beta program.

Special Notes: It should be noted that between June and August, unforeseen staffing changes affected the timeline of kit production and shipping. Also, changes in a few of the materials put into the kit occured right before the kits were shipped which delayed shipping as well.

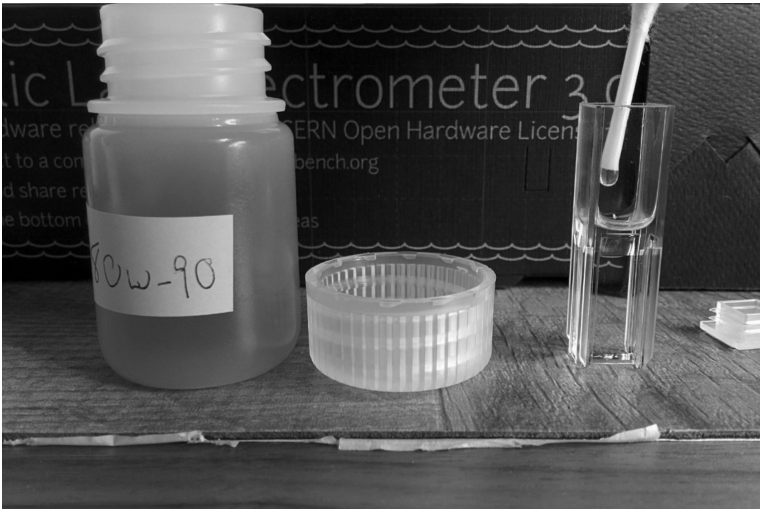
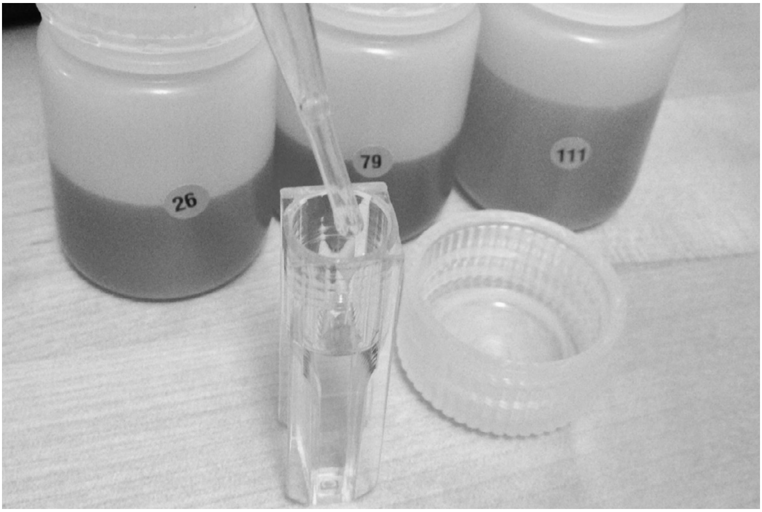


Image from the Oil Testing Kit's Kickstarter campaign




Promotional image for the Publi Lab's Oil Testing Kit Beta Program

# Reflections and suggestions

## Outcomes

There was a lot of momentum around the Beta Program when it was first announced. A lot of people participated in the first chat and contributed great ideas to how they could foresee using the kit in their scientific exploration.

There was a lot of really good feedback about constructing the kit as people began the program. There were also several good posts about people completing the beta program. Several participants in the program took their exploration further than was originally outlined. Their contributions to working on oil testing have been extremely valuable in furthering the kit design and use.

### IMPORTANT LINKS

Links about constructing the kit:

- https://publiclab.org/notes/Cindy_ExCites/10-07-2015/oil-testing-kit-beta-programme-assembly-cuvette-frame
- https://publiclab.org/notes/Cindy_ExCites/10-31-2015/oil-testing-kit-beta-programme-assembly-spectrometer
- https://publiclab.org/notes/Cindy_ExCites/10-31-2015/oil-testing-kit-beta-programme-calibration-notes
- https://publiclab.org/notes/Cindy_ExCites/11-04-2015/oil-testing-kit-beta-programme-technical-adjustments-hack
- https://publiclab.org/notes/Tofu/10-08-2015/testing-both-spectrometer-3-0-and-otk-assembly-beta-program
- https://publiclab.org/notes/RonHuber/09-17-2015/oil-test-kit-beta
- https://publiclab.org/notes/mahsa/11-09-2015/oil-testing-kit-assembly-calibration
- https://publiclab.org/notes/ethanbass/10-23-2015/oil-testing-kit-assembly-initial-calibration
- https://publiclab.org/notes/chongyukwai/10-04-2015/oil-testing-kit-failure

Links about people completing the beta program:

- https://publiclab.org/notes/Cindy_ExCites/11-04-2015/oil-testing-kit-beta-programme-scanning-otk-samples
- https://publiclab.org/notes/Cindy_ExCites/11-09-2015/oil-testing-kit-beta-programme-scanning-the-unknown-the-not-so-well-known
- https://publiclab.org/notes/eustatic/12-22-2015/oil-testing-beta-plus-grand-isle-tar
- https://publiclab.org/notes/ernestootero/10-25-2015/oil-testing-kit-collection-of-samples-from-pavement-boqueron-puerto-rico

## Communication

While the original idea to loop in beta participants on a separate email from the spectrometry google group was probably a good idea, moving forward it is best that these groups are not done with BCCs, but rather allow them to see everyone's emails. It seemed to build a sense of responsibility in completing the program.

The OpenHour was well attended by people who were interested in hearing how they Beta program went, but was not attended by any Beta participants. This could be because it was a daytime call, but also, since so few people finished the program participating in a public call on it might have felt out of their reach.

## Timelines and Deliverables

While a number of people completed part of the responsibilities of the beta program, very few finished all the tasks outlined. This could have been for a number of reasons: We advertised the program as being "for anyone", and required only that participants assemble, use and troubleshoot the kit (with a note to see the full list of to-dos on the wiki). The deliverables for those participating in the program ended up being a good bit more involved and took a lot of time to complete. Future beta program should probably include time estimates for participants. This could go so far as estimating time to complete: construction, any experimental aspects, posting back to the community, troubleshooting and participating in chats (or events such as OpenHour) on the tool.

We ran behind on shipping the kits which could have attributed to the waning participation we saw by individuals. In the future it could be a strategy to halt kit changes and development, order for the program and then announce it once the full kits are in the Portland office ready to ship.

While a number of Public Lab staff and the Fellow all worked on the Beta Program, there was not one person who was overseeing the entire program from shipping to results. In the future it would be useful to have one person manage the beta program as an overseer for the entirety of the program.

Another option moving forward would be to set up a different type of system when people get the kits to ensure more commitment from them, for example a "security deposit" to be refunded once they complete the project.

In general, we look forward to building on these lessons to develop a stronger co-design process with clearer short- and long-term goals, and entry points for potential collaborators. Toward this end, we've outlined a new workflow that addresses some of these issues; read on.

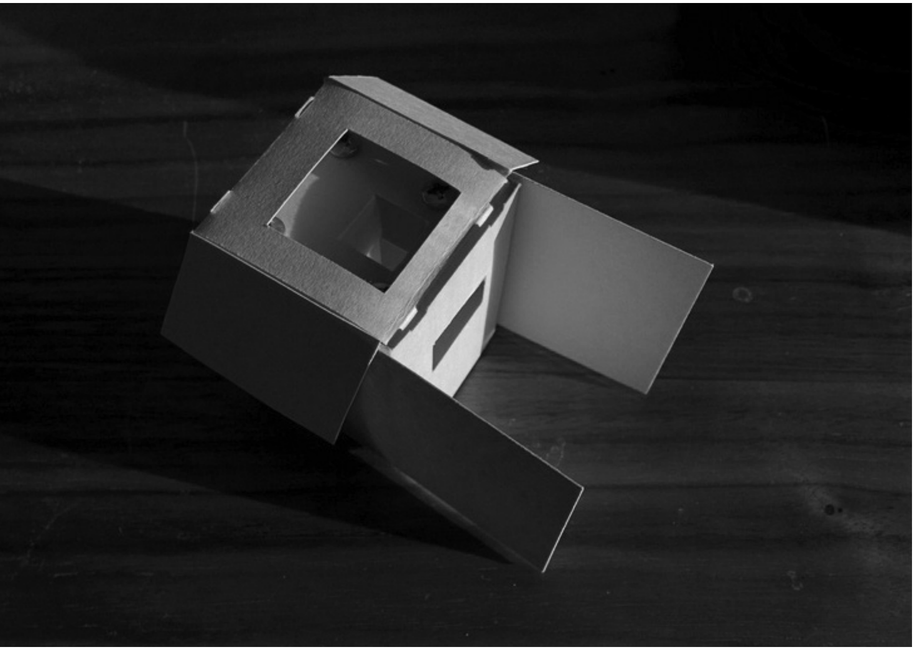
# OPEN OPEN HARDWARE

One of the outcomes of the various community outreach and engagement efforts of the project was a new format for technology and methods development, which we are provisionally calling "Open open hardware" -- a reference to the fact that many "open hardware" projects are developed in private and only published openly upon completion. By contrast, the process we've proposed and begun to adopt is one where the goals include:

- clear instructions for contributing to a design
- low barrier to entry for new contributors
- predictable revision timeline
- a transparent roadmap for reviewing and integrating changes
- regular iteration and feedback on proposed changes to help them get prepared for the next release due date
- a "maintainer" for each project who will help coordinate contributions, as well as support and promote dialogue and transparency with contributors
- a single, consistent, versioned, "baseline" design for the project, emphasizing simplicity & low cost, but upon which advanced mods may be made

While this does focus more on technical contributions, it is part of an attempt to blur the distinctions between technology and problem-focused contributions, and the barriers between contributors with different backgrounds, by establishing clear and open communication and expectations[4].

We have begun to adopt this process for the Oil Testing Kit and hope to expand its use throughout Public Lab's tools over the next year[5].



A prototype cuvette frame and UV light, based on the Oil Testing Kit Beta Program process

## SECTION NOTES

1. Visit /wiki/contributing-to-public-lab-hardware.
2. https://www.kickstarter.com/projects/publiclab/the-homebrew-oil-testing-kit/posts/1020256
3. The program details are posted at https://publiclab.org/wiki/oil-testing-kit-beta,
4. You can read more about the Open open hardware process in the original announcement at https://publiclab.org/notes/warren/11-16-2015/an-open-open-hardware-development-cycle
5. View Public Lab's hardware contributions page at https://publiclab.org/wiki/contributing-to-public-lab-hardware

## YOUR OBSERVATIONS

## What's next?

**Continue to Chapter 3: Tools and Methods: software, hardware, instructions and challenges.**

# 3

# Tools and Methods:
## Software, Hardware, Instructions and Challenges

### INTRODUCTION

Part of the Public Lab approach is to build collaborations with people and community groups directly facing environmental problems. During the Homebrew Sensing project we did outreach to both online and offline groups. The section below will explain some of our methods, results and further observations on the outreach strategies we employed. Taking this project into the future, we've developed a workshop series that outlines what it looks like to work with a group through the oil testing process.

### IN THIS CHAPTER

- Software introduction
- Hardware

# SOFTWARE INTRODUCTION

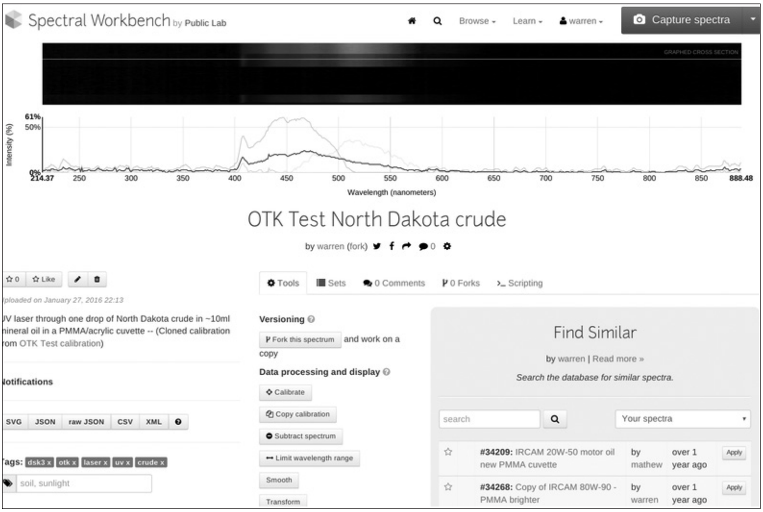
Public Lab's DIY spectrometry kit[1] plugs in with USB, and connects to the web-based app Spectral Workbench, where you can collect scans and do analysis. As part of the Homebrew Sensing Project, we've extensively rewritten and upgraded Spectral Workbench to make the analysis easier.

While data collected using Spectral Workbench may be downloaded and analyzed with the software of your choice (MATLAB, for example), we've worked to add powerful and flexible analysis features which may enable people to do not only oil comparisons, but a wide range of analyses, without needing to know how to program or to own or be familiar with programs like MATLAB. In particular, the new Operations system[2] enables tracked changes to a saved spectrum, so that it's easy to see what's been done to process or adjust data, as well as easy to replicate a set of operations on multiple spectra.

## Software procedures

The tests we did for the Oil Testing Kit Beta Program were to determine if different types of known oil samples could be distinguished: both similar oils like varying weights of motor oil (5W20, 20W50, and 80W90), diesel fuel, and samples of crude oil. We diluted these until they were similar in opacity, illuminated them with a 405nm "Blu-Ray" laser, and measured the fluorescence they produced. The basic steps were as follows:

1. place mineral oil baseline in sample container in Oil Testing Kit attachment and illuminate with laser
2. adjust brightness to 25-75% (with no clipping) with attenuator strip and save spectrum
3. place diluted oil sample in sample container in Oil Testing Kit attachment and illuminate with laser
4. adjust brightness to 25-75% (with no clipping) with attenuator strip and save spectrum
5. repeat steps 3 & 4 for each different sample, and for best results, repeat scans of each sample multiple times
6. consistently tag and title all spectra you wish to compare, and add them to a set
7. use the "equalize height" and/or "equalize area" tools to compare curve shapes after adjusting for overall brightness




Spectral Workbench 2: spectrum analysis interface

## IMPORTANT LINKS

You can read more about Spectral Workbench and how to use it on its wiki page: https://publiclab.org/wiki/spectral-workbench

A more detailed description of the software procedure can be found here: https://publiclab.org/wiki/oil-testing-kit#Oil+Testing+Kit+Beta+procedure

## SECTION NOTES

1- https://publiclab.org/wiki/spectrometer
2- https://publiclab.org/wiki/spectral-workbench-operations

# HARDWARE

In sync with the development of the Oil Testing Kit, Public Lab's Desktop Spectrometry Kit was redesigned using a primarily cardstock-based folding design, which interlocked with the alpha and beta versions of the Oil Testing Kit, also of cardstock. Building around a pen-shaped laser pointer and a standard laboratory cuvette[1], the two made it easier to align a laser beam with the optical slit of the spectrometer, and included a sliding tab "attenuator" to dim the laser light.

Following the Oil Testing Kit Beta program[2], feedback we collected from members included the need for:

- greater rigidity in both the spectrometer and the OTK
- a height change to better align the laser -- or a means to adjust the height
- an easier way to turn on the laser while interacting with the software
- an easier way to dim/brighten the UV light

As of January 2016, a number of these are being incorporated into a followup iteration which incorporates a dimming dial, a more compact and stable frame, and a more rigid attachment to the spectrometer body.


The Beta Oil Testing Kit design

## IMPORTANT LINKS

Follow further developments at https://publiclab.org/tag/oil-testing-kit

## SECTION NOTES

1. See sampler containers: https://publiclab.org/wiki/diy-oil-testing-questions#Cuvettes
2. Please visit https://publiclab.org/wiki/diy-oil-testing-community#The+Beta+Program

YOUR OBSERVATIONS

What's next?

**Continue to Chapter 2: Working with Communities**

# 4

# Data and Action: Community Oil Testing and Advocacy

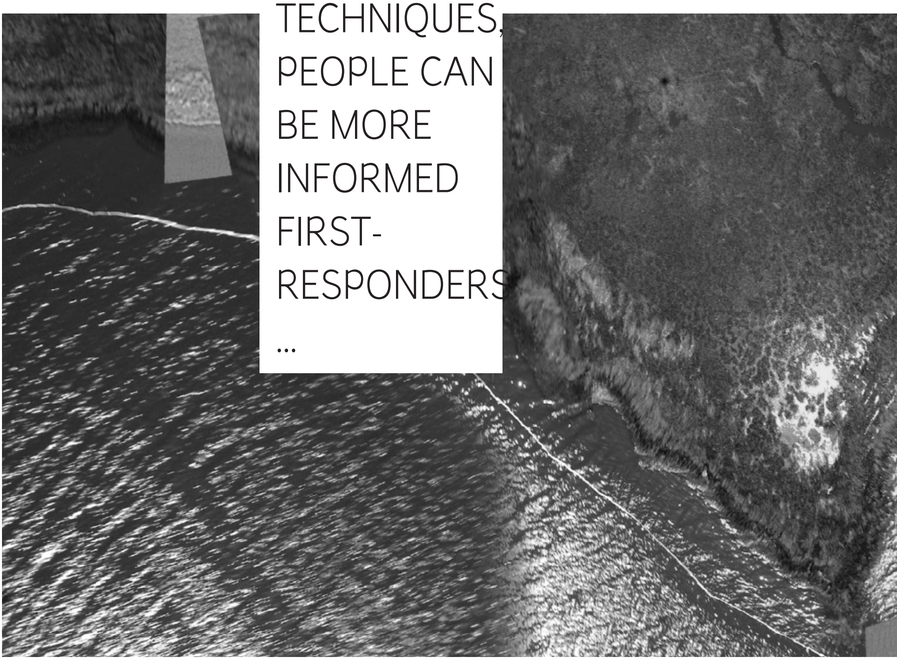
## INTRODUCTION

In parallel to our efforts to establish a collaborative design process and cooperation with community partners, we have also worked with Public Lab Fellow Ann Chen to collect and publish case studies for potential application of an affordable oil testing kit. This chapter outlines many of the stories which motivated our work, several of which came from community members involved in the project.

## IN THIS CHAPTER

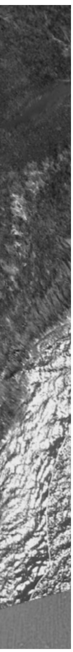
- Why is an accessible, DIY oil testing kit necessary?
- What are some specific situations where a DIY Oil Testing Kit are useful?
- How can fluorescence spectra be useful in advocacy around oil pollution?

WITH LOW-COST, OPEN-SOURCE, DO-IT-YOURSELF TECHNIQUES, PEOPLE CAN BE MORE INFORMED FIRST-RESPONDERS ...



Balloon map of oiled shores in Wilkinson Bay, Louisiana, after the BP Oil Spill.

# WHY IS AN ACCESSIBLE, DIY OIL TESTING KIT NECESSARY?



Empowering the public to explore and evaluate their own environments is essential, being beneficial to communities and to environmental stewardship. When leaks, spills, and other environmentally hazardous situations occur, it is often community members who discover the problem first, and the more information they can obtain about the situation, the more prompt and appropriate the response can be.

With low-cost, open-source, do-it-yourself (DIY) techniques, communities can be more informed first-responders, and also more informed and powerful advocates for their own environment. Communities doing DIY oil testing can also contribute to official testing and evaluation by serving as a screening or indicator step prior to more costly officially-recognized analyses, or by serving to fill in existing gaps in data, such as testing with denser geographic coverage. Even local agencies who officially respond to reports of oil pollution could utilize low-cost tests to use in the field as a screening method. For personal use, DIY oil testing kits can provide useful information at a fraction of the cost of third-party laboratory testing for home analyses, such as discerning potential sources of leaked or spilled oil in a yard or basement or evidence of any leaking oil tank. Thus, for personal autonomy, community stakeholdership, rapid environmental response, and in support of governmental monitoring, access to tools such as Public Lab's DIY spectrometer and oil testing kit is useful, and even necessary.

# WHAT ARE SOME SPECIFIC SITUATIONS WHERE A DIY OIL TESTING KIT ARE USEFUL?

Conceptual understanding of the utility of low-cost DIY tools, and of spectroscopy as a means to elucidate information about oil, is important. Perhaps equally important is learning about real, specific examples of where and how this kit could be applied.

# Discerning likely source of oil sheen near industrial landfill

Image from Louisiana Environmental Action Network

The community in Oakville, Louisiana has dealt with the nearby Industrial Pipe Landfill for the past 30 years, including several legal engagements regarding the improper zoning of the landfill, illegal reporting omissions of fires in the landfill, and persistent activities threatening the health of the community. The Industrial Pipe Landfill accepts a variety of wastes, including building and construction materials and oily wastes from washing drilling equipment. The landfill is unlined, extends below the water table, and is in a floodplain, increasing the likelihood that contaminants from the landfill will be mobilized into the adjacent Oakville township and wetlands. Community members have observed visible oil sheens in ditches and low-lying areas near the landfill, and are concerned that it is oil waste leaching from the landfill. If the oil testing kit can adequately distinguish between crude oil waste residue and roadway runoff motor oil or gasoline, Oakville community members could have more evidence to support their appeals for closure of the landfill.

## NOTES

1. For more information about the Oakville and Industrial Pipe environmental justice concerns, please see:
2. A review by clinical instructor at the Tulane Environmental Law Clinic: http://law.loyno.edu/sites/law.loyno.edu/files/Van%20Dalen-Final.pdf
3. A court case: http://caselaw.findlaw.com/la-court-of-appeal/1612065.html
4. A 2014 post-trial brief: http://www.tulane.edu/~telc/assets/briefs/10-24-12_Post-Trial.pdf
5. A newspaper article: http://www.nola.com/environment/index.ssf/2011/07/oakville_residents_face_new_fi.html
6. A Public Lab research note5 by Scott Eustis: https://publiclab.org/notes/eustatic/12-28-2015/some-gulf-coast-use-cases-for-the-oil-testing-kit-in-2015

## YOUR OBSERVATIONS

# Understanding oil pollution on coastal beach in area with oil production and transport

Tar balls at Grand Isle, Louisiana; photo by @eustatic

Grand Isle, Louisiana is a coastal beach south of New Orleans, an important landing spot for thousands of migratory birds, the seafood industry, and tourism. It is also the onshore neighbor to oil exploration and production wells, and ship patterns for crude and refined oil transport. The BP Oil Spill in 2010 devastated Grand Isle, and wildlife and their dependent economies continue to suffer[1]. Grand Isle is also impacted by persistent spills and leaks from the offshore oil drilling, with tarballs washing ashore regularly. In order to assess the continued impact of the BP Oil Spill and that of ongoing impacts of oil waste from transport spill and leaks, Grand Isle community members and workers could use a low-cost DIY device to discern different types of oils.

While the impacts of weathering on oil fluorescence spectra have not yet been determined, it is plausible that the resultant spectra of tar balls from the 2010 BP Oil Spill could be distinguished from more recent refined oil leaks from barges. While the Public Lab Oil Testing Kit cannot accomplish definitive forensic analysis (such as could be possible with a series of biomarker analyses using professional-grade equipment, discussed in the Questions section of this document), the oil testing kit screening level capability to distinguish crude oil from fuel could warrant further diagnostic investigations and aid Grand Isle workers in advocating for BP to continue cleanup and community reparations.

## IMPORTANT LINKS

For more information on the oil issues facing Grand Isle, please see:

- A article: http://www.desmogblog.com/2015/04/21/five-years-after-bp-oil-spill-gulf-coast-residents-say-bp-hasn-t-made-things-right
- A short piece: http://houston.culturemap.com/news/city-life/05-13-13-louisiana-revisited-anger-and-sadness-on-grand-isle-as-bp-oil-spill-worries-continue/
- A Public Lab research note: https://publiclab.org/notes/eustatic/12-28-2015/some-gulf-coast-use-cases-for-the-oil-testing-kit-in-2015

## NOTES

1. http://www.nbcnews.com/science/environment/report-wildlife-struggling-5-years-after-bp-oil-spill-n333326

## YOUR OBSERVATIONS

## Advocating against new drilling by demonstrating effects of past drilling

Hydraulic fracturing (or "fracking") of shale rocks has increased exponentially in the United States in the past decade, and there is interest in fracking the Tuscaloosa Marine Shale beneath the Southern Hills Aquifer. Opponents of the proposed fracking, particularly in St Tammany Parish, are concerned with the myriad environmental health consequences of hydraulic fracturing for natural gas and oil that have been witnessed in Pennsylvania and Texas among other shale-rich lands, and also the lasting impacts of drilling wells.

Louisiana DEQ has a poor record of managing decommissioned wells[1], and as of 2013 there were more than 2800 orphaned wells in Louisiana, many of them posing enviornmental hazards. Even old oilfield and drill sites that were ostensibly remediated have been purported to have not been remediated fully. In Tangipahoa Parish, old oilfields and drill pits are now being used as offroading ATV courses, which could reveal contaminated soils through the disturbances caused by racing ATVs. Community members have observed oily dirt at the ATV courses and other old oilfields. To assess the ongoing impacts of the decommissioned and remediated oilfields versus the current impacts of ATV activity would be valuable information in advocating against new drilling. Opponents to the proposed new drilling into the Tuscaloosa Marine Shale could utilize the DIY oil testing kit to distinguish crude oilfield waste from ATV motor oil.

The highly visual fluorescence spectra data obtained using the Public Lab Oil Testing Kit could be persuasive in discussing concerns over the lasting impact of oil drilling with other nearby Parishes that are allowing fracking into the Tuscaloosa Marine Shale, such as Tangipahoa Parish. NOLA[2] highlights the differences in opinion between St Tammany and Tangipahoa Parish residents, which all live above the same shale play and the same groundwater aquifer.

Perhaps highly visual data, from a tool that can be used to analyze a lot of samples at a very low cost, would be an avenue to create conversation between the communities, and potential broaden support for anti-fracking advocates. St Tammany recently won a court-ordered permit vacate disallowing exploratory drilling in St Tammany (there could be a difficult battle against hydraulic fracturing in the Tuscaloosa Marine Shale[3]).

Louisiana and Mississippi have regulations that are more favorable to oil and gas companies than most anywhere else in the United States, including extremely low taxes in Mississippi, Mississippi's "forced pooling" if the company has obtained a lease for at least a third of the mineral rights in the proposed drilling area, and the authority of the Louisiana state government to override Parish plans for pertinent issues such as waste water disposal[4]. Though a difficult endeavor, demonstrating evidence of prolonged and persistent contamination from past oil operations in the Parishes residing above the Tuscaloosa Marine Shale may bolster the community voice in their efforts to protect their land and aquifer.

## NOTES

1. http://app.lla.state.la.us/PublicReports.nsf/0/D6A0EBE279B83B9F86257CE700506EAD/$FILE/000010BC.pdfs
2. http://www.nola.com/politics/index.ssf/2014/07/fracking_embraced_not_vilified.html
3. http://www.nola.com/crime/index.ssf/2015/08/judge_vacates_helis_oil_drilli.html
4. http://www.louisianaweekly.com/drilling-for-tuscaloosa-marine-shale-impacts-rural-parishes/

## YOUR OBSERVATIONS

# Discovering leaking oil tanker trains

Tar balls at Grand Isle, Louisiana; photo by @eustatic

Transporting oil by rail has increased exponentially in the last few years as the U.S. and Canada have increased their oil export industry. Pipelines have traditionally been the primary way to transport crude oil to refineries along the coasts, but are prone to leaks and ruptures, causing large-scale oil pollution[1], and the current pipeline infrastructure is at capacity transporting crude oil from the Alberta oil sands into or through the United States. Crude oil producers have increased the use of train cars to transport product, with crude-carrying rail traffic increasing by 5100% from 2008 to 2014, and rail constituted approximately 11% of overall crude oil transport in 2014[2].

There have been several examples of train derailments resulting in large explosions from the highly flammable oil cargo[3], but even beyond those dangerous events, oil transport by rail can also damage the environment in less sensational, more persistent ways. For example, oil tanker cars often leak. According to Holland & Knight[4], approximately 92,000 tanker cars are used to transport crude oil, but only 14,000 of those cars have been built to the latest safety requirements. The DOT-111 cars that are used for this style of transport are known to puncture easily, making the potential for oil leakage quite high.

As trains travel through remote areas, leaking oil cars may go unnoticed by the public, but can pose a significant risk to wildlife and the environment. As leaking trains roll through towns, the public becomes susceptible as well. A Public Lab community member found evidence of a leaking oil train car in Minnesota, with a visible orange streak running along the tracks for miles. As this train ran along the shore of the Mississippi River and above minor trout streams, leaked oil was able to spill into waterways. In rural stretches of this train track, spilled oil in water may go unnoticed for long periods of time.

DIY oil testing could be useful in this situation for multiple reasons. First, persons encountering the oil need to know what safety implications there are, and different grades of oil have different toxic components. Second, the density and flammability differences between different grades of oil impacts their cleanup, and where you might look for oil contamination in water bodies (emulsions, surface oil, or on the sediment). Discerning what grade of oil leaked out of a train could help protect people and expedite environmental remediation.

### IMPORTANT LINKS

For more photo-documentation please visit the research note: https://publiclab.org/notes/marlokeno/02-12-2014/cp-rr-oil-tanker-leak-from-red-wing-to-winona-mn-beside-mississippi-river

### NOTES

1. https://en.wikipedia.org/wiki/List_of_pipeline_accidents_in_the_United_States_in_the_21st_century
2. https://www.aar.org/BackgroundPapers/US%20Rail%20Crude%20Oil%20Traffic.pdf
3. http://www.riverkeeper.org/campaigns/river-ecology/crude-oil-transport/crude-oil-transportation-a-timeline-of-failure/#rail
4. https://www.cacities.org/Resources-Documents/Policy-Advocacy-Section/Hot-Issues/Oil-by-Rail/Oil-by-Rail-Webinar-No-2_October-2014.aspx

## Demonstrating oilfield effects on wildlife

Oil and gas exploration and production sites can cause human and animal exposure to a variety of chemicals associated with those activities, and oilfields in particular can present multiple pathways of exposure. The American Petroleum Institute (API) has written informational brochures around this topic, including a 2006 publication, "Protecting Livestock: Answers to Frequently Asked Questions About Livestock Exposure to Crude Oil in Oilfield Operations[1]," which shows various animal exposure pathways, including direct ingestion of contaminated soil or chronic drinking of contaminated streams, among others. In certain states, oilfield produced water even can be discharged legally into surface waters that are used by livestock and wildlife. A 2002 study in Wyoming[2] found that produced water discharges often became ephemeral streams or pools in the arid Wyoming environment, and birds would mistake oilfield waste pits or discharges for real wetland habitat (see references in the same report).

When wildlife are exposed directly to oil, they may have remnants on their bodies (e.g. if a cow rolls in contaminated oily dirt, or a bird lands in an oil pit and gets oiled feather), which could potentially be sampled to provide evidence of their exposure. Additionally, waterfowl who reproduce near oilfields may transfer oil onto their eggs, or nest eggs in oil-containing materials, so eggshells could be analyzed for the presence of oil compounds. Animals that have ingested oil waste may have components of oil, such as PAHs, in their systems, and with significant sample preparation, it may be possible to identify oil components in animal tissues or secretions using methods such as fluorescence.

Demonstrating wildlife and other animal exposure to oil pollution, particularly from oilfields, could prompt more simple, responsible behavior by oilfield operators, such as putting netting up over oilfield pits and wastewater pits. A U.S. Fish and Wildlife Service bulletin[3] says that netting is one of the most effective deterrents to keep wildlife out of dangerous oil pits, but also emphasize that closed operations are safer.

## NOTES

1. http://www.occeweb.com/og/livestock_exposure_brochure_final.pdf
2. http://www.fws.gov/mountain-prairie/contaminants/papers/r6718c02.pdf
3. http://cogcc.state.co.us/Announcements/WILDLIFE_FENCING/reservepits_usfw_2000.pdf

## YOUR OBSERVATIONS

# Assessing spilled or leaked oils for home safety

In many northern states in the U.S., using heating oil is the most common way people heat their homes. Improper maintenance or storage of the oil tanks can also lead to some of the most common environmental accidents. In a 2010 report from Rhode Island Department of Environmental Management[1], the state reports that 28% of the oil spills it responded to in the past year were from home heating oil. Heating oil leaks can be extremely dangerous, as it can poison soils where children play and gardens grow, in addition to off-gassing volatile oil components.

If a person suspects an oil leak, they could use DIY fluorescence spectroscopy as a quick screening method to evaluate whether or not there is likely to be oil present. DIY spectroscopy could also be useful in real estate transactions as a screening method. Since cleanup of leaking heating oil tanks or pipes can cost up to $100,000, a site assessment is often important in real estate transactions for properties containing oil tanks. As a quick screening tool for home buyers who suspect oil, a DIY oil fluorescence test were able to indicate a likely match between a suspected oil leak and a reference heating oil, home buyers could step away from the transaction prior to the financial and time investment of hiring an official site assessment with laboratory analyses. In the case of home heating oil, DIY oil testing could save people time, money, and potential exposure if used as a screening method.

## NOTES

1. http://www.dem.ri.gov/news/2010/pr/0215101.htm

## YOUR OBSERVATIONS

# HOW CAN FLUORESCENCE SPECTRA BE USEFUL IN ADVOCACY AROUND OIL POLLUTION?

Our purpose in developing a do-it-yourself fluorescence spectrometry method is to make the collection of evidence more accessible to those without access to lab testing, and for data from such DIY tests to support community goals, be they regulatory, legal, or other. Just as the visual nature of aerial photos can make them clear and compelling, fluorescence data can support your campaign in a highly visual format, in a way that tables of data alone cannot. A well-presented comparison of rigorously collected and analyzed spectra can show similarities and differences between a collected sample, a known pollutant, or even a suspected false positive result. Using persuasive scientific data as part of a campaign can strengthen your position by communicating in a language which many community groups have been unable to make use of due to the lack of accessible equipment, knowledge and resources. Data presented in a visual format, as is standard in fluorescence spectrometry, can communicate the scientific rigor in an approachable and interpretable for people in a variety of sectors, communicating effectively across disciplines and stakeholder status.

Scott Eustis (@eustatic) collecting pollutant samples in Oakville, Louisiana

**End of the Journey!**

# Resources

# Oil Testing Workshops

## INTRODUCTION

This section will explain in detail each workshop, presented in Chapter 2: Working with Communities, and outline what it looks like to work with a group through the oil testing process. For other curriculum topics and resources please visit: https://publiclab.org/wiki/spectrometer-curriculum

## IN THIS SECTION

# INTRODUCTION

Reporting suspected oil pollution to the appropriate government agency is as easy as picking up the phone, but there's no guarantee that an agency will respond with a site visit or official investigation. Since reaching resolution (and getting cleanup action) on a pollution event can be a lengthy process that often means that a company will have to go to court, having evidence can make a more compelling case for a government agency to engage from the start.

Furthermore, in historically heavily affected industrial areas, it's critical to demonstrate that there is a new source of pollution and not simply the old pervasive pollution which may seem less urgent. Long story short, the more the community can provide good evidence, the more that the response (and possible enforcement) process will be encouraged at each threshold of escalation.

## About evidence

But what is good evidence, and how can regular people collect it? The simplest form of evidence is a verbal complaint, followed by a picture, which becomes more powerful when geotagged with location and posted publicly online. Anything beyond snapping a photo, such as figuring out what type of unknown substance it might be, has been out of reach to the public both in terms of technology (professional lab equipment is too expensive) and methodology (techniques are not documented or accessible to non-experts).

DIY tools can begin to bridge this gap, enabling citizens to provide more credible evidence of environmental pollution. Using DIY spectrometers, individuals can go beyond verbal complaints and geotagged photos to demonstrate if the unknown substance fluoresces under UV light, as well as provide a calibrated fluorescence spectrum and explanatory research note, perhaps comparing it to scans of known pollutants. This workshop will help us design experiments for appropriately using our DIY tools and understanding the capabilities and limitations of the data they produce.

# About the workshops

## What will you be able to do after completing these workshops?

- If you have an unknown substance you think might be oil, you can tell if the substance definitely isn't oil.
- If you have different oil samples, you can compare and contrast these samples (for example diesel, crude, fish, and motor oils).
- You can compare known oil samples with an unknown sample. You should be able to say if your unknown sample has a spectrum similar to or different from your known sample. Please read the Q&A regarding if results from the Public Lab Oil Testing Kit can be used as Evidence
- You can compare oily materials to tell if they are similar or different.

## What is NOT yet possible:

- Identify a substance with 100% certainty (for example you will not be able to say "this is definitely oil," or "this is this specific compound.")
- Learn much about a substance without reference samples to compare it to — for example, a sample of what you suspect it to be (i.e. crude oil), and a sample of what it might otherwise be (i.e. motor oil).
- Definitively determine if two similar looking substances are the same.
- Compare data collected using two different devices, rather than on the same device

## Upon completing these workshops you will have:

- gained the ability to design an experiment,
- developed a clear understanding of what a spectrometer is, what it does, and how to use it,
- constructed a Public Lab spectrometer kit,
- analyzed samples using spectralworkbench.org,
- worked through an experiment involving spectroscopy from start to finish,
- identified what was learned and what the next steps are,
- shared notes, questions, and ideas for improving the workshops, kits, and projects, and
- posted results and reflections to the Public Lab community.

# Oil Testing Workshop 1: DESIGN AN EXPERIMENT

## Materials Needed

- Markers, pens
- blank 8.5"x11" printer paper
- blank index cards
- blank large chart paper
- tape
- printed copies of this handou

## Things to keep in mind

### Why (The Situation)

In order to confidently answer the questions we have about our environment, we want to learn how to structure our questions, use DIY tools, conduct experiments which make use of the scientific method, and understand the capabilities and limitations of our data in comparison to any existing data. This workshop will focus on the case study of the Oil Testing Kit

### When

A 3.5 hour workshop in four sections, with a ten minute break after each section.

### Where

A room with tables and chairs, with participants sitting in small groups.

### What (the Content)

The basics of designing an effective experiment; transforming guesses into testable hypotheses; assessing precision and reproducibility; interpreting data based on data quality.

## Achievement Based Objectives

- Met others attending the workshop
- Shared with each other what motivated you to to participate
- Written down your expectations for your time
- Discussed examples of scientific questions that interest you in small groups
- Read about the elements needed for good experimental design
- Noted the important points of designing a clear experiment
- Drafted your own questions and transform them into hypotheses
- Explored the concept of proof versus likelihood (facilitated discussion)
- Discussed the importance of precision, resolution, and accuracy in any data set
- Reflected upon how experimentation relates to your own interests/work

### Setting Up

Write out the 7 steps of the scientific method written out on index cards, one set per table in scattered order:

- asking a question
- gathering background information
- developing a hypothesis
- conducting an experiment to test the hypothesis
- analyzing the experimental results
- communicating the experimental results
- retesting the hypothesis (or a new one, if necessary)

**Outline**

**Introduction**
- Who is here today? (20 mins)
- Introductions among tables (10 mins)
- Everyone asks questions, but how?
- Step by step

**Developing hypotheses**
- From observing to questioning
- Evidence versus proof
- Let's turn guesses into testable hypotheses
- Turn your own question into a hypothesis

**Testing your hypotheses**
- Address the question
- Concept of using a known sample as a baseline for identifying unknowns
- Precision and resolution, Part 1
- Precision and resolution, Part 2
- Reproducibility

**Wrap up**
- Relating all this to our real lives

# 1. Introduction

## 1.1 Who is here today?

As a whole group, take turns introducing yourself by saying your name, where you're from, and your reason for coming to the workshop today.

Facilitator's heads-up: If this is a very large group, try following this sequence: Let's take 30 seconds to think quietly to ourselves about our reasons for coming here today. Then meet in your small groups and introduce yourself and what you thought about. After a couple minutes we'll reconvene as the full group, and go around the room saying our names and one key word that best describes your motivation for coming.

## 1.2 What are we doing today?

Take a minute to read through the achievement based objectives on page 1 of your handout, and then each table should choose one person to read through the following out loud:

*You may have heard people talk about the scientific method. The scientific method is a general guideline for the steps to take in order to answer a question that is based on an observation. Historically, the scientific method originated as a knowledge production technique, and it endures into the present day as a technique you can potentially use in your work, in your community, to help take control of a situation.*

## 1.3 Everyone asks questions, but how?

Think of a situation in which have you wondered about something (how it works, why it exists, etc). How have you tried to answer your question? Think about the specific steps you have taken, and write them down.

Take five (5) minutes to make notes on your own paper, summarizing your individual thoughts as a five-step process. Share with your table. Next, each table will make a brief poster presentation back to the whole group. Finally, discuss your perceptions of how the EPA, or even law enforcement, goes about answering questions.

### 1.4 Step by step

Look at the index cards on your table, and notice that they are in no particular order.

Facilitator heads-up: do not read the steps out loud yet, instead allowing each table to order the cards themselves during the next activity.

There are seven basic steps listed for what is commonly understood as the "scientific method". It is important to note that this is not a linear, one-time series of steps, but rather, it is cyclical. For example, a given hypothesis might require several different experiments to adequately test that hypothesis, or test results may indicate that the original hypothesis is false and you need to develop a new hypothesis.

Each step in the basic scientific method is important and challenging, and deserves special attention. In this workshop we are going to focus mostly on developing a hypothesis, and designing an experiment to test the hypothesis. During this series of workshops, you will conduct an experiment, and by the end, be able to analyze and communicate your results.

A couple of important points that we want to highlight that are crucial to scientific inquiry and experimental design are:

- the concept of proof versus likelihood, and
- the importance of knowing your analyses' precision.

We'll cover these topics in the following sections.

Take fifteen (15) minutes to work through the following prompt as a group. In what order would you imagine proceeding through these steps? Place them in order, then discuss:

- Would an experiment be a straight path through these steps?
- Would you repeat certain parts, or occasionally take one out of order?
- Would you ever need to repeat the entire sequence?
- Why?

Return to what you wrote down during the previous activity (1.3) about what steps you took to answer your own question. Based on this new knowledge, name 2 or 3 things you might change about your original ideas.
Send one representative from your group to go up to the wall and tape your steps in order. Each group should line up their rows to facilitate comparison; discuss.

**------ (10 minute break) ------**

# 2. Developing Hypotheses

### 2.1 From observing to questioning

In this task, we are going to come up with research questions for our own observations. Choose one person at the table to read the following text out loud:

*Before developing a hypothesis, the very first step in a scientific inquiry is asking a question. Scientific questions usually arise from observations. For example, we might observe that "The sky is blue," which prompts us to wonder, "Why is the sky blue?" We might notice that "A lot of kids have asthma here," which compels us to ask, "Why do so many kids have asthma in this neighborhood?" If we notice that "this substance looks like oil," we ask, "Could this be oil?" These are all good questions based on an initial observation.*

On a large piece of paper, draw a vertical line through the middle to make two columns, AKA a "T Chart":

- Label the top of the left-hand column "Observations"
- Label the top of the right-hand column "Research Questions"

Individually, on sticky notes:

- Write observations that you have had about your yard, your neighborhood, your landscape, local industrial activity, etc. One per note.
- For each observation, take another sticky note & write a research question based on it.

After a few minutes, everyone can put up their sticky notes up on the "T chart" in the appropriate columns.

Review similarities and differences in the framing of research questions, and make a presentation about this to the whole group.

## 2.2 Evidence versus proof

Choose one person at the table to read the following text out loud:

*A key difference between science and mathematics is that there is no such thing as absolute proof in science.*

*In mathematics, you can have a proven theorem because you are dealing with a closed system where all of the information is available and controlled, and the proof is final. As a result, there can be a binary, "yes or no", "proven or disproven" set of logic in math.*

*In science, we don't have the luxury of an absolute proof because not all of the information is known. We discover new relevant information constantly, and never deal with a truly closed circuit where all information is known. In science, knowledge is tentative, based on the information available, and we gather evidence that suggests a likelihood that something is true.*

*Everything in science is tentative, and is based on the best available evidence, but cannot be based on absolute proof. This is extremely important for our experimental design and how we talk about results.*

Quick group check in: What is the difference between the kind of answers that are possible to arrive at for questions in the domain of math versus the domain of science?

Facilitator heads-up: Although this exceeds the scope of this workshop, it might help to point out that legal proof is different yet again from scientific proof. In legal situations, some evidence may be more persuasive than others. Consider: what does proof mean in the context of water regulations?

Based on what we just read, we can begin designing our experiments with the understanding that any answers we reach through scientific research will be evidence-based but not an absolute truth. The basic sequence is to:

- Make an observation
- Ask a related question
- From that question, develop a hypothesis that can be tested.

What is a hypothesis? Your hypothesis is an educated guess about the answer to your question, but is different from a basic guess in two important ways: first, a hypothesis is based upon existing evidence (albeit a limited amount), and second, a hypothesis can be tested such that new evidence can be gathered that directly supports or refutes the hypothesis.

The steps for turning a question into a hypothesis are:

- Starting with your observation, get as specific as possible (or as specific as you'd like to be, based on the scope of your research).
- With your specific observation, brainstorm ideas that could be the cause of what you are observing. This is your "basic guess."
- Make sure you have some evidence, or there is existing information, that supports your guess. If there is not, then familiarize yourself with the information about the issue that is available, and adjust your guess/idea accordingly. This saves you time by helping you develop a more likely hypothesis.

To turn your guess into a real hypothesis, you must have a testable statement, with tests that can be observed and measured, and/or compared against a "known" value or entity. This often will be in the form of "X is more than/less than/similar to Y", where X and Y can be observed and compared, or one of the two is already "known."

Here is an example of turning a guess into a hypothesis:

Observation: The sidewalks on this tree-lined street are cracked and bumpy.

*Get more specific*

Revised Observation: The sidewalks on this tree-lined street are more cracked and bumpy than the sidewalks on the street without trees.

*Good. Now guess why that is the case.*

Guess: I think trees made sidewalks bumpy.

*Make it more specific and testable*

Hypothesis: I think tree roots grow under sidewalks, and as they get bigger, they can push up the cement sidewalks. Thus, sidewalks near bigger trees are likely to have more cracked and bumpy sidewalks than sidewalks on streets with small trees or without trees.

## 2.3 Let's turn guesses into testable hypotheses

Individually, turn these guesses into testable hypotheses:

Guess: Cats like wet cat food.
Hypothesis: ____________________________________________________________

Guess: Breathing fumes from cleaning products is bad.
Hypothesis: ____________________________________________________________

Guess: Strip mining damages the environment.
Hypothesis: ____________________________________________________________

### 2.4 Turn your own question into a hypothesis

Each person take a look back at the observations you made in section 2.1.

- Chose one of your questions, transform it into a hypothesis, and write your hypothesis on a blank index card.
- In small groups, talk about how testing this hypothesis might or might not be helpful in your own work or pursuits.
- Consider kinds of tests are possible for this question. What tests or data are available? Which ones are used by environmental regulators?
- Write out variations on your question, like "in a worst case scenario, like a windy day" or "measure particulates" vs. "measure PM2.5" and try out "daily average" vs. "on a bad day".

**------ (10 minute break) ------**

## 3. Experimental Design – Testing your Hypothesis

### 3.1 Address the question

Individually, take five or ten minutes to read the following text:

*The first step in designing your experiment is to make sure that it will allow you to address your hypothesis.*

*Your goal is to gather evidence that either directly supports or directly refutes your hypothesis, so the more specific your hypothesis is, the more tailored and efficient your experiment can and should be, and the more clearly it can answer your question. Broader questions and hypotheses can be very useful and provide a wealth of evidence, but do require more comprehensive investigations.*

*For example, with a broad hypothesis such as "I think tomato plants grow well in sunlight," your experiment will have to encompass several varieties of tomato plants in several different potential growing conditions (e.g. different kinds of soil and watering patterns), and different sunlight exposures, and you would have to evaluate different aspects of growth (growth rate, fruit abundance, fruit quality, etc).*

*If your hypothesis were more specific, such as "I think beefsteak tomato plants growing in sandy soils under a variety of watering conditions grow faster in the sun than in the shade," then your experiment need only include a few types of beefsteak tomato plants growing in one type of soil under either sunny or shady conditions, with variable watering patterns.*

*Take into consideration that the second experimental design would be inadequate to address the first hypothesis, while the first experimental design would be excessive to address the second hypothesis. The second experiment isolates one difference between the two scenarios -- it's a comparison -- which is an easier type of experiment.*

As a group, discuss:

- Would it make sense for either of the two hypotheses written above to test eggplant growth in addition to tomato plant growth?
- Would it make sense to test growth under drought conditions?
- Would it make sense to test tomato plant growth in predominantly cloudy conditions?

Facilitator heads-up: You may want to add an example of a poorly formed testable hypothesis, one which could lead to a fallacy, maybe by neglecting a positive or negative control.

Each person should individually write:

- one alternative hypothesis with experimental design that expands the scope of the scientific inquiry.
- one alternative hypothesis with experimental design that narrows the scope of the scientific inquiry.

As a group, go around and have each person can share how they expanded or narrowed the inquiry. Discuss what kind of answer you can expect from the modified question.

## 3.2 Concept of using a known sample as a baseline for identifying unknowns

Each table should choose one person to read through the following text out loud:

*In many scientific inquiries, identification or classification of an unknown object or compound is accomplished through comparison with known compounds.*

*When designing an experiment to identify or classify unknown objects or compounds, you should choose relevant known samples against which to compare. "How will I know what's relevant?", you might ask. Well, if the question is "Is this mucky stuff actually oil?", then obtain known samples of the oil carried on nearby train tracks, pipelines, etc, as well as commonly available consumer oils such as for vehicles or machinery. Once you have relevant known compounds available, you can assess your unknown compound through comparing similarities and differences to the "knowns". You need to analyze known compounds to demonstrate that your method is valid and is able to correctly identify, classify, or quantify the known sample.*

*If your method can't tell that oil is oil, your method is not valid (for using to identify anything else).*

*The assessment of whether a compound is similar enough to a known compound that you conclude they are in the same category, will depend on your method's precision and resolution, which are discussed below.*

As a group, discuss:

- When have you been faced with an unknown substance and gone about trying to figure out what it was?
- What other thoughts and ideas do these concepts bring up for you, especially related to unknown substances?

## 3.3 Precision and Resolution Part 1

Choose one person at the table to read the following text out loud:

*In scientific experiments, we are assessing the likelihood of an assertion to be true, such as whether an unknown oily residue is in a certain class of oil. To do this, we have to know how well we know our own data. That knowledge depends on accuracy, precision, and resolution.*

Facilitator's heads-up: If the group is familiar with finding the mean and standard deviation of a set of numbers, ask them to find the mean and standard deviation of the second and third example and use those values to bolster their discussions.

Each table should choose one person to read the following situation out loud:

*mg = milligram, which is one thousandth of a gram;*

*L = liter.*

*Units of mg/L read as "milligrams per liter" are a measure of concentration.*

*You are interested in whether or not an industrial facility violated their permit by discharging more than 1.8 mg/L ammonia in their effluent.*

*Let's say your instrument measured 2 mg/L ammonia, but the resolution of your instrument is 1 mg/L, meaning that the only readings you can obtain are 0, 1, 2, 3... mg/L. Can you be certain that your measurement of 2 mg/L is definitely higher than 1.8 mg/L? Could the true value of your measurement be 1.6 mg/L and still read as 2 mg/L?*

(pause for discussion)

- *What if your tool could reliably measure 0.1 mg/L differences, and using it, you took three measurements which were 1.6, 2.2, and 1.8 mg/L. How well do you know what the "true" value is? (pause for discussion)*
- *What if your three measurements were 1.9, 1.8, and 1.9 mg/L? How well do you know what the "true" value of those measurements is?*

(pause for discussion) Each table should choose another person to continue reading:

The example above illustrates that your ability to evaluate your own data depends on:

- *knowing your instrument's resolution (resolution means the smallest distinguishable difference from a given value)*
- *knowing your method's precision (precision is the variability in values recorded for a given true value)*
- *knowing your method's accuracy (accuracy means how close a measured value is to the true value, often based on the mean of several measurements)*

*The numbers or values that our equipment give us have a specific relationship to reality, and how well we can describe that relationship is dictated by resolution, precision, and accuracy.*

*Describing your data's accuracy*, precision, and resolution are part of** determining the probability that your original assertion is true.*

**Note: that in the example above, it is assumed that your instrument was reading fairly accurate results because it had been appropriately calibrated. We will discuss calibration more in a future workshop.*

***Note: There are several factors that will influence probability, and especially in larger data sets, more statistical analyses are needed to adequately describe the data. In this workshop we are focusing more conceptually rather than mathematically. If you want to do more statistics, here is a useful introductory guide for statistical analyses: http://www.robertniles.com/stats/.*

## 3.4 Precision and Resolution Part 2

Everyone get a piece of paper and a writing implement, and get ready to draw!

Draw a few visual representations to describe what we learned above about accuracy, precision, and resolution. Draw a representation of measurements with:

- high precision but low accuracy
- low precision but high accuracy
- low precision and low accuracy
- high precision and high accuracy
- high precision but low resolution
- low precision but high resolution

Share your drawings with your group members and discuss them.

Next, as a table, refresh your memories about the ammonia concentrations measured in the effluent of the industrial facility (above).

Draw representations of the data from the example to explain whether or not you are able to determine if the discharge is above the 1.8 mg/L ammonia limit for each scenario listed (and remember to assume that your measurements are accurate).

## 3.5 Reproducibility

Each table should choose one person to read through the following out loud:

*To demonstrate the validity of your experiment and your results, you must be able to show that you can achieve same results multiple times, and that another person could achieve the same* *results by following your protocol. This reproducibility of results is important for three reasons:*

- to help you assess your own precision, as discussed above,
- to ensure that you provide enough information for other people to replicate your experiment and thus grow scientific knowledge and capacity, and
- to demonstrate the validity of the data by asserting that it is reliably reproducible.

*In cases of scientific fraud that have occurred (thankfully rarely), they have most often been caught by another researcher attempting to reproduce an experiment's results, and alerting people that the initial results must have been falsified. In Workshop 3, we will follow procedures to take each oil spectrum three times. By virtue of posting our oil spectra freely and openly to the Web, we are contributing to a massive body of experimental results, and both demonstrating and evaluating the reproducibility of those results.*

*Individually, and then as a group:*

*Think ahead towards future research projects you might have in mind. When do you think you might have to be aware of resolution, precision, and accuracy?*

**------ (10 minute break) ------**

# 4. Wrap-up

Congrats, we made it!

## 4.1 Relating all this to our real lives

Each table should choose one person to read through the following out loud:

*In our daily lives, we make observations constantly. Think about the observations you listed in section 2.1, and others that cross your mind:*

- *Have you ever noticed that grass pops up through cracks in the sidewalk in some places but not others?*
- *Have you ever been struck by an odd smell in a new house or new car?*

Your take home assignment, should you choose to accept it, is to think of something that you have observed in an environment that matters to you. Write down your observation, and come up with a hypothesis that could be tested, or at least some baseline ideas that could become hypotheses after reading relevant background information. Remember that your hypothesis must be testable, and that the outcomes of your test will offer a likelihood of an answer, but not definitive proof. For the hypothesis that you create, define how precisely you are going to need to know your answer. Also define the purpose(s) you intend to use the data you collect for.

Congratulations! You have embarked upon the process of scientific inquiry!

YOUR OBSERVATIONS

# Oil Testing Workshop 2: BUILD A SPECTROMETER

## Materials Needed

- large clean space for people to build their kits
- 2 poster boards one with the words "Notes" "Questions" "Ideas" evenly spaced down the left hand side.
- large chart paper
- markers and pens
- sticky notes
- paper research notes (page 112)
- a shallow pan
- water (enough to fill the pan with 2in of water)
- a small mirror
- a flashlight
- a piece of white paper
- one computer per person or team
- internet connection
- a power source that can support all your computers
- one Public Lab Spectrometer (version 3.0) and oil testing kit addition per person or team or the oil testing kit add-ons pieces (see page 114, 116 and 118)
- camera (to document)

## Things to keep in mind

### Why (The Situation)

We want to learn what spectroscopy is, and we want to understand the purpose spectroscopy serves in environmental science. We want to join the development community around Public Lab's prototype spectrometer and work toward realizing its promise of collecting data that will be useful in pollution cases.

### When

A 2.5 hour workshop, part of a four-part series.

### Where

A room with long tables, chairs, power outlets, water source, and internet connection.

### What (the Content)

What kinds of things can be learned from light; how to measure a rainbow; what the unit "nanometer" refers to; the working parts of a spectrometer; how to position a sample in front of the spectrometer.

## Achievement Based Objectives

- Meet others attending the workshop
- Share with each other what motivated you to to participate
- Read 4 brief stories from spectrometry experiments in environmental science
- Measure a rainbow (in nanometers!)
- Study what wavelengths belong to which colors
- Fold paper pieces into a working spectrometer
- Fold paper pieces into a holder for lasers and sample containers
- Critically review the documentation you were provided -- what worked, what didn't?
- Post your critical review as a research note on publiclab.org

### Setting Up

- Set your tables up near a power source that can be used by all the computers
- Put up the 2 poster boards on the wall. One poster board will be blank, on the other, put the words "Notes, Questions and Ideas" evenly spaced down the left hand side.
- Put post-its, markers and pens on each table.
- Put copies of the hand written research notes on each table for people to include more in depth information on what participants explored.
- Set one Spectrometer kit, one Oil Testing Kit (or the supplies for these), and one computer, on each station people will work from. (Suggested group size is 2-3 people -- you can divide your chairs, tables and participants up accordingly)

**Outline**

**Introduction**
- Who's in the room (10 minutes)
- Introduction to the event (10 minutes)

**Learning about Spectrometry**
- Seeing in color
- Explore and measure a rainbow (activity from physicscentral.com) (20 minutes)
- What we can learn from light (5 minutes)

**Use of Spectrometry in environmental science**
- Background Reading
- Defining your problem

**Build your Spectrometer**
- Tools you will need

**Wrap up**
- Reflection

# 1. Introduction

## 1.1 Who is here today?

As a whole group, take turns introducing yourself by saying your name, where you're from, and your reason for coming to the workshop today.

Facilitator's heads-up: If this is a very large group, try following this sequence: Let's take 30 seconds to think quietly to ourselves about our reasons for coming here today. Then meet in your small groups and introduce yourself and what you thought about. After a couple minutes we'll reconvene as the full group, and go around the room saying our names and one key word that best describes your motivation for coming.

## 1.2 What are we doing today?

Take a minute to read through the achievement based objectives on page 1 of your handout.

Facilitator's speaking notes: The following outline could be used by someone facilitating the workshop to include an introduction to Public Lab's open development process.

If you have not done so yet, introduce yourself:
- why you are interested in this project and
- a little bit about Public Lab.

Give an overview of the event goals and structure (at the top of this page)

Emphasize "the tools, technology and learning that happens here is always under development. One of the major outcomes of the event is to provide constructive feedback on the learning, the activities and the tool we will build in order to improve it for future participants."

Introduce the things in the room:

- Highlight the posters, markers and sticky pads available for people to put up their questions, comments, and ideas on as they work through the event.
- Identify the paper research notes for those who would like to take in depth notes on their steps for sharing back with the Public Lab community.

# 2: Learning about Spectrometry

## 2.1 Seeing in color

Choose one person to read out loud:

*"Light is made up of waves, and we see longer waves and shorter waves as different colors." - Randall Munroe in Thing Explainer: Complicated Stuff in Simple Words, 2015.*

*When light is bent (AKA refracted), each color will separate out according to its wavelength at a different angle.*

Let's explore this idea in the next task.

## 2.2 Explore and measure a rainbow (20 minutes)

Resources needed: A DVD, a pair of scissors

- Cut the DVD in half, and peel apart its layers
- Look through the clear layer at a light bulb or window, or anything very bright (not the sun!)

Choose a person at each table to read each of the following sentences out loud, pausing frequently for discussion:

*The light passing through the DVD layer is refracted, which means the DVD is acting like a prism. The light is bent by the plastic so that its colors are separated.*

Question for the group: In what order are the colors displayed? Have you ever seen a rainbow in a different order of colors?

*nm = nanometer, which is one billionth of a meter*

*Rainbows manifest from violet to red. Why? Because colors travel at specific wavelengths: violet has the shortest wavelength we can see, blue is slightly longer, and green slightly longer all the way up to red, which has the longest wavelengths that humans can see.*

*Fun fact: wavelengths can be measured ... in nanometers! Red is in the 620–750 nm range on the visible spectrum whereas violet is always in the 380–450 nm range.*

IMPORTANT LINKS

For a color chart, please visit: https://i.publiclab.org/system/images/photos/000/014/139/original/800px-Linear_visible_spectrum.png

*Although most of us can see colors with the naked eye, generally, humans are not very adept at measuring color or color intensities.*

*A spectrometer is a device which splits colors apart, like a prism, and measures the strength of each color.*

*In its simplest form, a spectrometer is an optical device, like a prism, which separates light into separate wavelengths so you can observe and measure the amount of light energy at each frequency. See an example of how a spectrometer can read their spectral signatures more precisely than our human eyes.*

Look at the example of fish oil below:

IMPORTANT LINKS

For an example of the spectral signatures please visit https://i.publiclab.org/system/images/photos/000/014/365/original/Screenshot_2016-02-17_at_4.05.06_PM.png

*Notice how much of each color this particular fish oil is giving off. The peaks and dips in the chart that show the intensity of that particular color. Consider, how can this be useful? One possible use for this is that although crude oil and synthetic gear oil (80W90) often appear to our human eyes to be the same color, they are two different substances. See an example of how a spectrometer can read their spectral signatures more precisely than our human eyes*

IMPORTANT LINKS

For an example of the spectral signatures please visit https://i.publiclab.org/system/images/photos/000/014/141/original/Screen_Shot_2016-02-08_at_11.45.16_AM.png

### 2.3 What we can learn from light (5 minutes)

*The wavelengths of light absorbed by, reflected off, or emitted by matter can be used to identify what the matter is composed of. Different materials (whether liquid, solid, or gas) that appear the same to the naked eye can actually be distinguished by the colors we can measure from them with a spectrometer.*

Discuss the following question as a group, and have a note-taker write down what people say under the "ideas" section of the poster board:

- Does the information about give you any ideas about how could a spectrometer be useful?

IMPORTANT LINKS

Check out some examples that other Public Labbers have explored with a spectrometer: https://publiclab.org/wiki/spectrometry-activities.

**------ (10 minute break) ------**

## 3. Use of spectrometers in environmental science

### 3.1 Background reading (45 minutes)

Read these short synopses about how spectrometry has been used in environmental science, and what types of data and advocacy can result from the use of a spectrometer.

*One sentence overview: Fluorescence spectroscopy is a widely useful technique. Similarly to how blood or bodily fluids at a crime scene are revealed by shining a UV light, oil also fluoresces.*

From the texbook, Oil Spill Science and Technology chapters 4, 5, 7, we learn about more about this method to identify oil in the environment:

*The combination of spectroscopy and UV lasers is used to identify oil in the environment. Oil has a "unique oil fluorescence spectral signature" (p 171); when ultraviolet light (300 to 355 nm) is shined on petrochemicals, they fluoresce (release) light in visible wavelengths that are specific to the kind of oil it is. Chlorophyll and other biological materials also fluoresce, but (fortunately) at significantly different wavelengths to avoid confusion.*

From the abstract of the 2012 article, "Findings of Persistency of Polycyclic Aromatic Hydrocarbons in Residual Tar Product Sourced from Crude Oil Released during the Deepwater Horizon MC252 Spill of National Significance" produced by James H "Rip" Kirby III, of the University of South Florida Dept of Geology, and also of The Emerald Coast Chapter of Surfrider:

*The use of ultraviolet light equipment in the field showed distinct fluorescent responses to illumination by a 370nm UV light source. UV light equipment was found to be very efficient in identifying tar product on the beach for evaluating the visual level of contamination on the beach. Fluorescent responses from tar product found in the field and laboratory created tar product were measured by fluorometry equipment.*

From the 2012 article, "State of the art satellite and airborne marine oil spill remote sensing: Application to the BP Deepwater Horizon oil spill", we learn how different methods are used in times of a spill:

*This technical article begins by stating how valuable people are in times of disaster: "experienced observers are a spill response's mainstay." Since there are few experienced observers available, and the weather and environmental conditions present access challenges to getting a holistic view of the situation, responding to the Deepwater Horizon oil disaster also involved extensive airborne and spaceborne passive and active remote sensing. An airplane carried a Visible/Infrared Spectrometer over the spill to derive oil slick thickness and oil-to-water emulsion ratios. Other equipment on planes and satellites helped extrapolate this understanding to the geographic extent of the entire spill, find the extent of burned oil carried into the air as smoke, and track oil as it sunk to the seafloor.*

There was a January 2016 discussion on the plots-spectrometry mailing list that referenced the 2011 article "Prediction of crude oil properties and chemical composition by means of steady-state and time-resolved fluorescence." by p.3600 of Pantoja, Patricia A., et al. Energy & Fuels 25.8 (2011): 3598-3604. One graph from the article shows peak shift due to dilution of crude oil.

IMPORTANT LINKS

Graph 1: https://i.publiclab.org/system/images/photos/000/014/143/original/image-1.png

*Ethan Bass (@ethanbass) has been working on a dilution test to see if diluting oil samples with mineral oil changes their spectrum, and if there's a way to adjust for that. The main gist of this article is about exactly the kind of fluorescence based oil differentiation we're attempting with the Oil Testing Kit. They use a 337nm excitation light source, not the 405nm that Public Lab has been working with, but the peaks in the graph occur at wavelengths longer than 405nm, so some active developers of the spectrometer feel this is not improbably related to the blue => red shift we're looking for in lighter => heavier oils*

IMPORTANT LINKS

Graph 2: https://i.publiclab.org/system/images/photos/000/014/144/original/image.png

As a group, discuss these brief summaries and your ideas.

### 3.2 Defining your problem

Workshop 1 covered what is required in designing a scientific experiment. So far, this workshop has presented how spectroscopy is used to detect oil in the environment. Now we will put these elements together. Below are options for what kinds of experiments are known to be possible with the current state of development on Public Lab's spectrometer 3.0 and oil testing kit. Discuss as a group which topic you would like to design an experiment around:

- If you have an unknown substance you think might be oil, you can tell if the substance definitely isn't oil.
- If you have different oil samples, you can compare and contrast these samples (for example diesel, crude, fish, and motor oils).
- You can compare known oil samples with an unknown sample. You should be able to say if your unknown sample has a spectrum similar to or different from your known sample.
- You can compare oily materials to tell if they are similar or different.

After the group has chosen which experiment they would like to design, design a hypothesis (if needed, refresh your memory by reviewing Workshop 1: 2.3 and 2.4). Record the hypothesis on the large chart paper so that everyone can see it. Discuss as a large group.

Return to small groups and work through designing the experiment. Ask yourselves, what needs to be done to test the hypothesis? Record the steps you specify for the experiment on the large chart paper.

Facilitator's heads-up: Save this chart paper for use in Workshop 3.

# 4 Spectrometer Construction

## 4.1 Tools you will need (1 hour 20 minutes)

In small groups, or individually, you will build both the spectrometers and the oil testing add on pieces by following directions and photographs online. These pieces will fit together and are your tools for oil testing. As you build the spectrometer and have ideas for how the pieces or the instructions could be improved, add your ideas to the board with sticky notes.

Begin by gathering these materials:

- Spectrometer Kit, per person or team
- Oil Testing Kit add on, per person or team and (for this part you only need the paper pieces and the laser.)
- One computer with internet connection, per person or team
- Scissors

HEADS UP! THIS IS REAL SAFETY BUSINESS: Do not turn on the laser unless it is fully enclosed in your testing frame and be sure to never look directly at the light. Read more about safety here: https://publiclab.org/wiki/oil-testing-kit-warning

HEADS UP! THIS IS REAL SAFETY BUSINESS: Even looking at the beam indirectly can be damaging to your eye.

Go online to find instructions for:

- constructing the spectrometer: http://publiclab.org/wiki/desktop- spectrometry-kit-3-0

- assembling the oil testing kit: http://publiclab.org/wiki/oil-testing-kit-construction

Enjoy building!

## 5. Reflection and Wrap up (10 minutes)

Send one person from the entire group to take notes on the poster board while everyone reflects on the day's activities through the following questions:

- what was hard?
- what was easy?
- what questions are you left with?
- what questions are you inspired to explore?
- any other takeaways you'd like to share with the Public Lab community?

Choose someone from the group to write up their experience as a Public Lab Research Note.

Facilitator's notes for after the event: Compile the notes that were left on the poster boards and your experiences facilitating this event so that others may learn from hearing about your experiences with the kit and workshop. Post them to the Public Lab wiki and put a link to it on the bottom of this page: https://publiclab.org/wiki/oil-testing-event

YOUR OBSERVATIONS

# PUBLIC LAB
## Paper Research Note

**By:** ______________________________

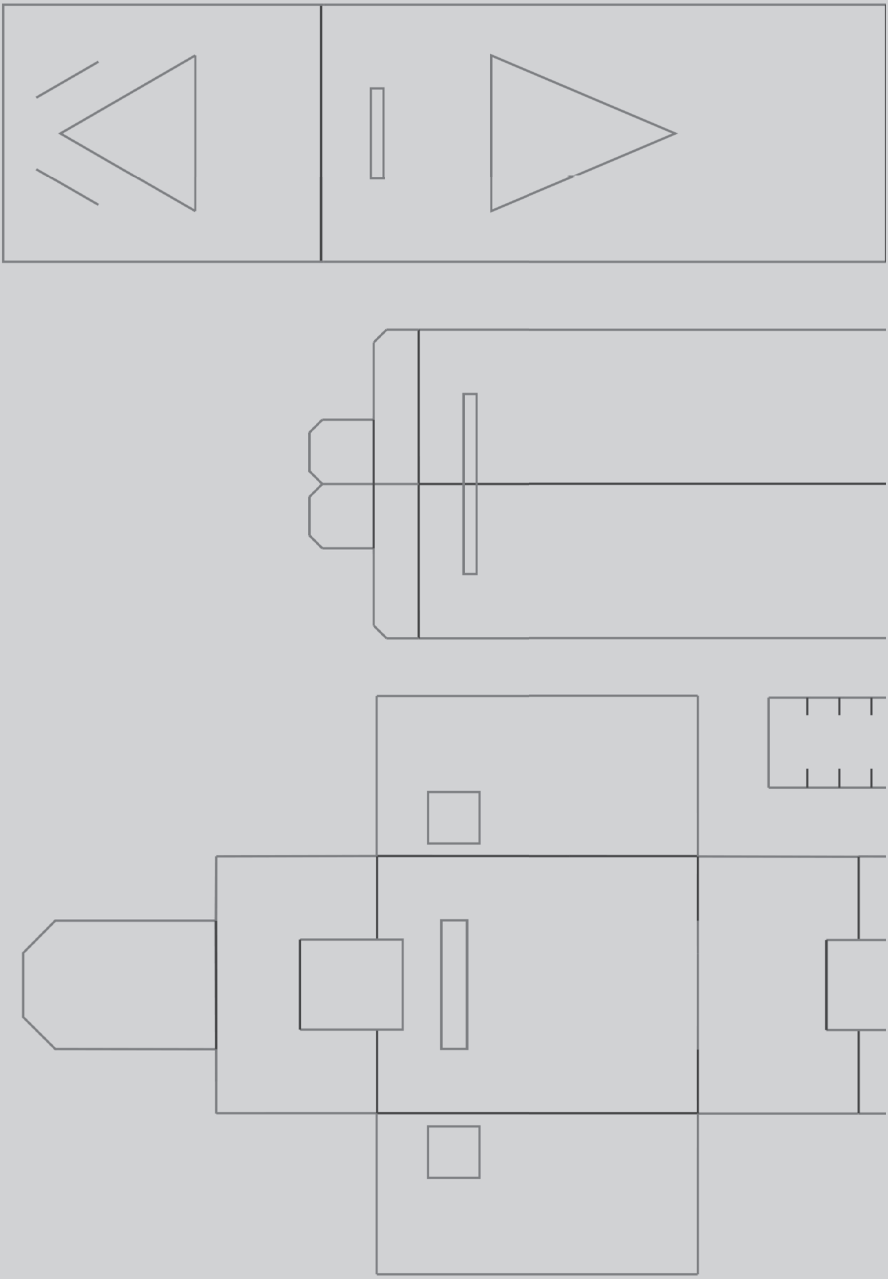
publiclab.org username or name for attribution

# PUBLIC LAB

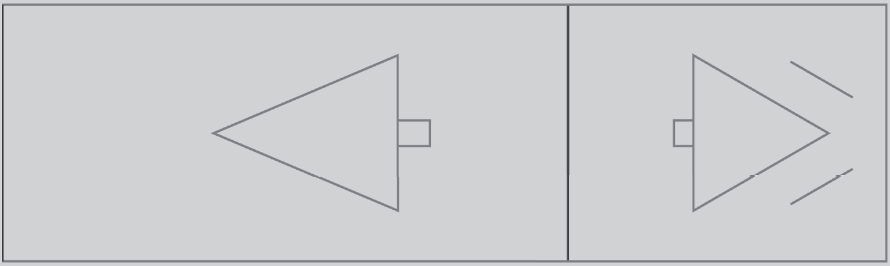
## Paper Research Note

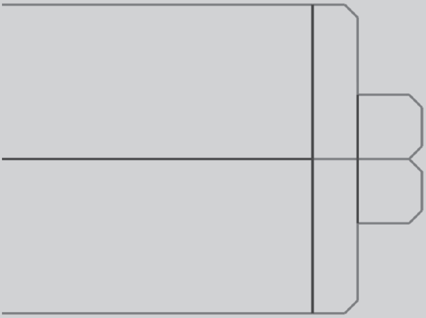
**By:** ______________________________

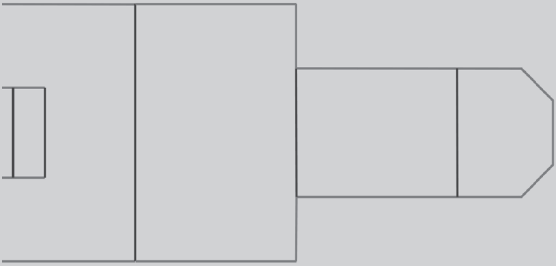
publiclab.org username or name for attribution

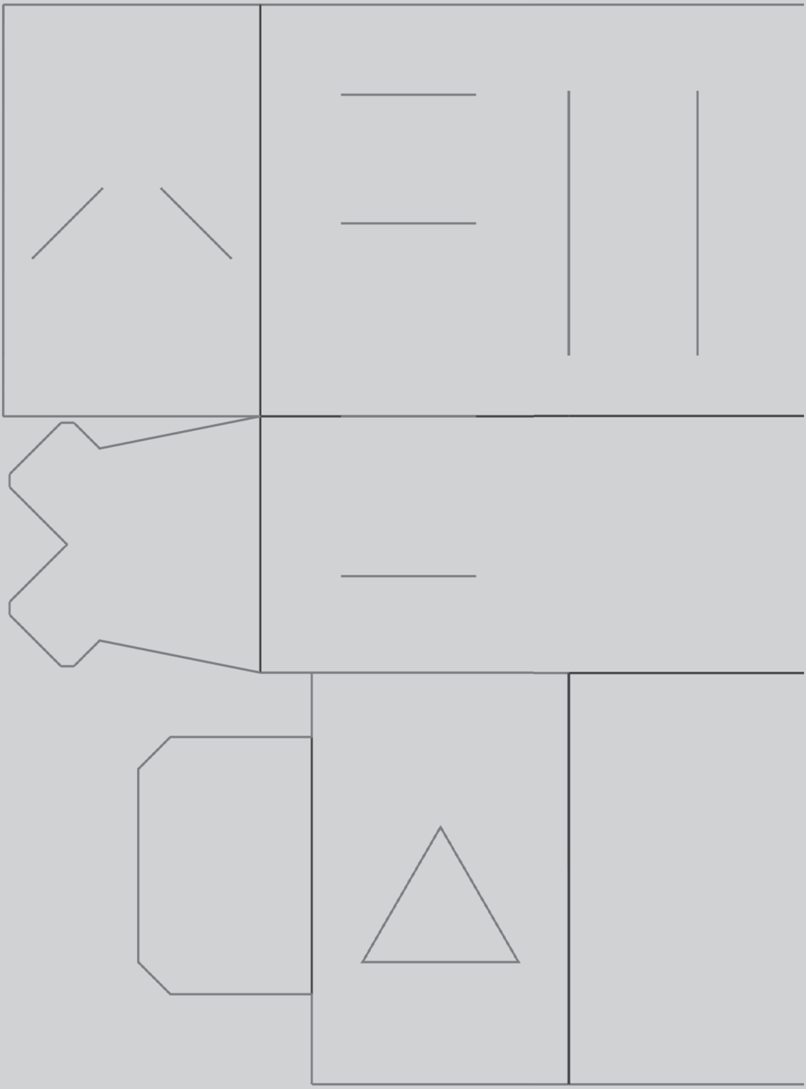


@ 85% scale. For full size: https://i.publiclab.org/system/images/photos/000/013/171/original/all-together-10-2.pdf

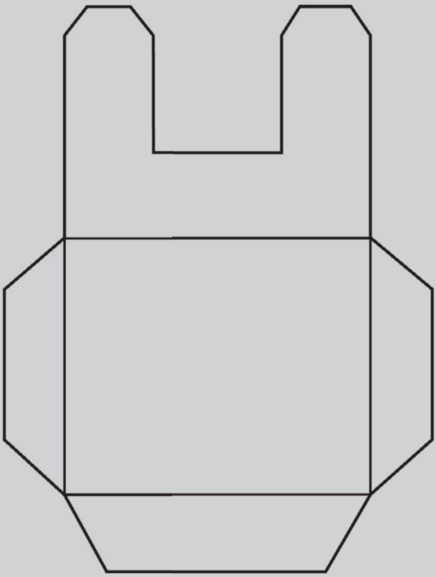








@ 85% scale. For full size: https://i.publiclab.org/system/images/photos/000/009/589/original/all-together-9-8.511.pdf



@ 85% scale. For full size: https://i.publiclab.org/system/images/photos/000/011/023/original/light-flap.svg

# Oil Testing Workshop 3:
# CALIBRATION AND SCANNING

### Materials Needed

- a large clean space for people to work (long tables work well)
- one computer per person or team
- internet connection
- a power source
- newspaper to cover the tables
- 3 poster boards
- markers and pens
- sticky notes
- paper research notes (page 128)
- a plugged in compact fluorescent light bulb
- the Public Lab Spectrometer 3.0 that was constructed in workshop 2
- the oil testing kit add on (if you do not have the add-on kit, include a 405nm blue/violet laser pen)
- cuvettes (1-2 per sample)
- droppers (1 per sample)
- protective eye gear
- gloves
- known samples such as specific oil samples, for example 80W90 and 20W50 (these also come with the kit)
- unknown sample (such as runoff water from the road, black tar like substances found on the beach etc.)

## Things to keep in mind

### Why (The Situation)

We want to calibrate the spectrometers we built. We want to prepare our oil samples for scanning. We want to learn how to use spectralworkbench.org. We want to scan known samples of oil to test the function of the equipment itself. We want to scan unknown samples and assemble their spectra into sets for comparing and contrasting with known samples to attempt categorization.

### When

A 2.5 hour workshop, part of a four-part series.

### Where

A room with long tables, chairs, power outlets, and internet connection.

### What (the Content)

Calibrate a spectrometer using a fluorescent lightbulb; safely work with ultraviolet (UV) lasers; the features of spectralworkbench.org; troubleshoot your equipment to get a clear high-quality scan;

## Achievement Based Objectives

- Meet others attending the workshop
- Share with each other what motivated you to to participate
- Connect your spectrometer to the computer using the webcam's cord & USB plug
- Login to spectralworkbench.org
- Look at a flourescent light bulb through the spectrometer
- Use spectralworkbench.org's interface to set the calibration of the spectrometer
- Squeeze eyedroppers to put oil samples into cuvettes (small tubes with square sides)
- Shine a blue laser through a small container of oil, and capture the spectra the oil emits with your spectrometer and spectralworkbench.org
- Assign your calibration to your scan of oil
- "Read the rainbow" AKA the spectrum of fluorescence produced by oil
- Gain necessary information for use in the 4th and final workshop in this series

### Setting Up

- You must have already prepared your samples
- Line your tables with newspaper
- Two of the poster boards should be prepared with the words "Notes" "Questions" "Ideas" evenly spaced down the left hand side. Each poster boards will also carry one of the titles: "Calibration" and "Scanning." Put these on the wall. Leave the third poster board blank and hang it on the wall as well.
- Set up computer stations for each working group along with the spectrometers they built in workshop 2. Provide each group with the oil testing kit add-on or materials in it.
- Put pens, markers, paper research notes and sticky notes around for people to use to take notes.

## Outline

**Introduction**

- Who's in the room (10 minutes)
- Introduction to the event (10 minutes)

**Calibrating your Spectrometer**

- Log into spectralworkbench.org
- Connect your spectrometer to your computer
- Scan your first fluorescent bulb
- Reflect on the calibration process

**Sampling**

- Setting up for safe scanning!
- Scanning samples
- Creating sets

**Wrap up**

- Reflection

# 1. Introduction

### 1.1 Who's in the room? (10 minutes)

Go around the room, with each person introducing themselves with their name, where they're from, and the reason they are interested in being here today. If there are really a lot of people, then as a large group say names only, and then break into smaller groups at tables to share reasons, hopes, and expectations for attending.

Facilitator's heads-up: If you did Workshop 2, this is the same activity, feel free to modify it, but be sure to remind people about the tools and feedback to Public Lab.

If you have not done so yet, introduce yourself:

- why you are interested in this project and
- a little bit about Public Lab.

Give an overview of the event goals and structure (at the top of this page)

Emphasize "*the tools, technology and learning that happens here is always under development. One of the major outcomes of the event is to provide constructive feedback on the learning, the activities and the tool we will build in order to improve it for future participants.*"

Introduce the things in the room:

- Highlight the posters, markers and sticky pads available for people to put up their questions, comments, and ideas on as they work through the event.
- Identify the paper research notes for those who would like to take in depth notes on their steps for sharing back with the Public Lab community.

# 2. Calibrating your spectrometer

Quick overview: Calibration turns a device for looking at rainbows into an instrument that can measure the wavelength of spectral data. We calibrate our spectrometer by looking through it at a common light source with well-known peaks -- a fluorescent bulb. Once we save this image, we can use the SpectralWorkbench.org interface to match-up two of our peaks with the corresponding two peaks in the reference spectrum. Picking these two points of correspondence scales the X-axis of our image and adds units to our graph. This is the wavelength calibration process. When using a calibrated spectrometer, we can know the true location (measured in nanometers) of the peaks and troughs of future scans we make.

Two important notes:

- We are not calibrating the intensity of the light on the Y-axis, although that is the goal of ongoing work as of February 2016.
- Whenever the physical relationship of the pieces of your spectrometer changes (if anything is bent or moved, such as the camera, the DVD, or the slit), then you must recalibrate.

### 2.1 Log into Spectral Workbench

- Ask your group if there's anyone with a publiclab.org username.
- If no one has one, choose someone to create one for themselves at https://publiclab.org/signup
- Go to https://spectralworkbench.org and log in. You will be directed through the PublicLab.org site; just keep clicking through until you are back to Spectral Workbench and your username shows up in the upper right-hand corner.

### 2.2 Connect your spectrometer to your computer via Spectral Workbench

FACTS: each spectrometer has to be calibrated before it is used.

Choose one person at the table to read the following text out loud:

*Calibration helps us to make sure the readings of an instrument are consistent. For example, if this were a scale, we would want to make sure that when it read that something weighed two pounds, the item you were weighing was really two pounds. Because we know certain colors always show up at the same place on the nanometer scale (recall from Workshop 2), the way we calibrate a spectrometer is by using a known type of light as a reference. In this case, we* *use a compact fluorescent light, where there is a clear green light peak at 546 nanometers. By shining the compact fluorescent light into our spectrometer, and graphing the color peaks on Spectral Workbench, we can measure our future samples against that known calibration of the compact fluorescent light. In this way, we know our future scans will be accurate.*

Individually, write down any questions you have about these concepts and discuss as a group. Going through the activity may help clarify, and afterwards if you still have questions, you can email plots-spectrometry@googlegroups.com.

Follow the following 4 steps to connect your spectrometer to your computer:

- Plug the cord into a USB port on your computer
- In an internet browser (we strongly recommend Chrome for reasons that will later become clear), navigate to https://spectralworkbench.org (make sure you're logged in! See 2.1)
- On https://spectralworkbench.org, click "Capture Spectra".
- Make sure it is working:
    - If you see black or just a light line of color, you will know you are using the correct camera (i.e. not the built-in one on your computer) and you are ready to proceed.
    - If you see yourself, you need to switch the input camera by using the button on the right under the picture that says "change camera."
    - If you still see yourself, use Chrome's address bar to "allow" or "enable" the camera on your spectrometer from the browser's address bar. Once you are seeing the rainbow image from your spectrometer on Spectral Workbench, you are ready to proceed.

## 2.3 Scan your first fluorescent bulb

Follow the following 4 steps to take your first scan of a fluorescent light bulb:

- Hold the front end of the spectrometer (where the slit is) towards the lit compact fluorescent light bulb. Make sure the color line that appears on your image appears straight, as in the example from the calibration page on Spectral Workbench.
    - Troubleshooting information: if the colors are really not straight, you can open up your spectrometer and try to move the angle of the DVD slightly.
- Once your color line is straight, click the middle of it to position the yellow line directly through it, as in the example.
- Click the button "begin capture", and once you do so, you (and perhaps a partner) will need to hold the spectrometer steady.

- Once you click “begin capture”, you will see a new page where the “live feed” of your spectra is coming through. You may have to work to re-align your equipment to see a clear spectra of all the colors -- then, click the blue “save” on the left of the screen.
- This will open a new page where you will see your calibration and can fill in some information about it. Title the spectra “CFL Calibration” and click the button “save and calibrate later.”
- On the new page, click the blue “calibrate” button below your sample. This will walk you through matching your sample (the above bar) to the example scan (the below bar) so the colors line up.
- Leave these pages open in your browser.

Additional calibration directions can be found on this wiki page: http://publiclab.org/wiki/spectral-workbench-calibration

**2.4 Reflect on the calibration process**

Once you have finished calibrating your spectrometers, take five minutes and brainstorm notes, questions, and ideas on the calibration process. Post these up on the poster board. These will be reviewed and compiled at the end of the workshop and posted back to Public Lab. If you still have questions, you can email plots-spectrometry@googlegroups.com.

**------ (10 minute break) ------**

# 3. Sampling

**3.1 Setting up for safe scanning! (90 minutes)**

YOU MUST REVIEW AND FOLLOW THESE SAFETY GUIDES (10 minutes)

- Do not turn on the laser unless it is in your testing frame and be sure to never look directly at the light. Even looking at the beam indirectly can be damaging to your eye.
- Always wear your safety glasses when working with oil samples, suspected oil samples and the laser.
- The materials that come in the beta kit are hazardous and should only be handled with gloves in a well ventilated area. Here are the Material Safety Data Sheet (MSDS) for each oil type included in the Oil Testing Kit: MSDS_5W30_motor_oil_Hess.pdf, MSDS_20W50_

Gulfpride.pdf, MSDS_crude_oil_sweet_Hess.pdf, MSDS_80W90_Lucas.pdf, MSDS_Diesel_fuels_Hess.pdf, MSDS_gasoline_Hess.pdf

### 3.2 Scanning samples (50 minutes)

Facilitator speaking notes Recap what you prepared ahead of time during Sample Prep https://publiclab.org/wiki/oil-testing-kit#Collect.

The Public Lab community advises to scan each sample 3 times. Following this rule, a rough time estimate would be that a first time user can achieve the scanning of 3 unique samples in an hour.

As we learned in Workshop 1 (Experimental Design), taking triplicate samples of each one of your materials will increase the accuracy of your results.

- Identify which of your oil samples are "knowns" and begin with them.
- Use the dropper to fill the cuvette with your sample to the line above where it curves in (just over halfway full)
- Place your sample in the sample holder on your oil testing kit add-on
- Place the cover over the sample
- Press and hold the button on the laser.
- Return to the open "capture" tab on spectralworkbench.org. There you will see your spectra. Ideally, you want your spectra line to fall between 25-75%.
    - Look at the top line of the graph -- Is it yellow? It turns yellow when your are peaks touching or getting cut off by this line. If the top line is yellow, you need to dim your spectra by using the physical dimmer on the oil testing kit add-on. The higher you pull the dimmer, the less light it lets in.
- Once you've captured a good spectra, click "Save" and title it the name (whatever it is you're sampling) and the number 1.
- Leave this tab open and repeat steps 1-5 with the same samples naming the consecutive ones (Sample name)2, and (Sample name)3. For example Diesel1, Diesel2 and Diesel3.

### 3.3 Creating sets (30 minutes)

- Once you have all three scans of one sample, click the "Compare" button on your most recent scan (Sample3). This will let you search for (by ID) and add your previous samples to the graph. Then use "Save as a set" under the "Compare" tab -- see https://publiclab.org/wiki/spectral-workbench-usage#Sets.
- On the New Set page that comes up, give some information about

the set you're creating. For example, you'll want to title it with the sample name, for example "Diesel Set for Oil Testing" or "Unknown Set for Oil Testing". To add additional spectra, at the bottom of the page for the new set you've just created, you can click "Add to set"
- Press the "Equalize Area" button under the cog icon below the set name, which will equalize the light intensities of your three samples.
- Take a screenshot of your graph and save it with the name of your sample in a place you will be able to find it later. We will return to these graphs in Workshop 4 to publish your results research note on Public Lab.

Follow all the steps of activity 3B for all of your samples. More notes on scanning can be found on this wiki: https://publiclab.org/wiki/oil-testing-kit#Scan)

Once you have finished scanning your samples, take five minutes and brainstorm notes, questions, and ideas on the scanning process. Have participants post these up on the poster board. These will be reviewed compiled on the end of the workshop and posted back to Public Lab

Individually, what do you remember from Workshop 1 about taking multiple samples? Why is this important?

## 4. Reflection and Wrap up

Send one person from the entire group to take notes on the poster board while everyone reflects on the day's activities through the following questions:

- what was hard?
- what was easy?
- what questions are you left with?
- what questions are you inspired to explore?
- any other takeaways you'd like to share with the Public Lab community?

Choose someone from the group to write up their experience as a Public Lab Research Note.

Facilitator's notes for after the event: Compile the notes that were left on the poster boards and your experiences facilitating this event so that others may learn from hearing about your experiences with the kit and workshop. Post them to the Public Lab wiki and put a link to it on the bottom of this page: https://publiclab.org/wiki/oil-testing-event

# PUBLIC LAB

## Paper Research Note

**By:** ______________________________

publiclab.org username or name for attribution

# PUBLIC LAB

## Paper Research Note

**By:** ________________________________________

publiclab.org username or name for attribution

# Oil Testing Workshop 4: ANALYZING AND SHARING

## Materials Needed

- one computer per team (with internet, and power sources)
- the saved screenshots from workshop 3
- markers and pens
- post-it notes
- 1 poster board

## Things to keep in mind

### Why (The Situation)

We want to calibrate the spectrometers we built. We want to prepare our oil samples for scanning. We want to learn how to use spectralworkbench.org. We want to scan known samples of oil to test the function of the equipment itself. We want to scan unknown samples and assemble their spectra into sets for comparing and contrasting with known samples to attempt categorization.

### When

A 2.5 hour workshop, part of a four-part series.

### Where

A room with long tables, chairs, power outlets, water source, and internet connection.

### What (the Content)

reading graphs of spectral information.

## Achievement Based Objectives

- Meet others attending the workshop
- Share with each other what motivated you to to participate
- Compare and contrast the samples you scanned and added to sets in Workshop 3
- Examine your results
- Walk through next steps of your project
- Share out your findings, ideas and questions with the Public Lab community via Research Notes.
- Write possible uses for spectroscopy in your own work / activism

### Setting Up

- The poster board should be titled with the word “Analysis” and prepared with the words “Notes” “Questions” “Ideas” evenly spaced down the left hand side.

**Outline**

**Introduction**
- Who's in the room (10 minutes)
- Introduction to the event (10 minutes)

**Analyzing your data**
- Visually assess your spectra
- Analyze your spectra in Spectral Workbench

**Identifying next steps**
- Finalizing your conclusions

**Compiling your data to share**
- Posting a Research Note online

**Wrap-up**

# 1. Introduction

## 1.1 Who's in the room? (10 minutes)

Take a minute to read through the achievement based objectives on page 1 of your handout.

Go around the room, with each person introducing themselves with their name, where they're from, and the reason they are interested in being here today. If there are really a lot of people, then as a large group say names only, and then break into smaller groups at tables to share reasons, hopes, and expectations for attending.

Facilitator's heads-up: If you did Workshop 2 or 3, this is the same activity, feel free to modify it, but be sure to remind people about the tools and feedback to Public Lab.

- If you have not done so yet, introduce yourself:
- why you are interested in this project and
- a little bit about Public Lab.
- Give an overview of the event goals and structure (at the top of this page)
- Emphasize "the tools, technology and learning that happens here is always under development. One of the major outcomes of the event is to provide constructive feedback on the learning, the activities and the tool we will build in order to improve it for future participants."
- Introduce the things in the room:
- Highlight the posters, markers and sticky pads available for people to put up their questions, comments, and ideas on as they work through the event.
- Identify the paper research notes for those who would like to take in depth notes on their steps for sharing back with the Public Lab community.

# 2 Analyzing your data

## 2.1 Visually assess your spectra (15 minutes)

View the graphs you saved as image files in Workshop 3, or go back to spectralworkbench.org to find your sets.

Take a close look at the spectra within each set, and assess how they look similar and how they look different.

Here are some tools to use in comparing your data (from Workshop 3).

- Equalize the height of the spectra that are on your sets.
- Equalize the area of the spectra.
- Find the graph centers.

Things to notice include:

- How close together are the "center lines" you found toward the end of Workshop 3?
- Do the shapes of the spectra look similar?
- Do the spectra overlap with each other well, or are they offset (shifted to the right or left) from one another?
- How closely aligned (i.e. how close on the x-axis, the wavelengths axis) are the incident light peaks (the laser light, at ~405 nm)? Is it shifted right or left? Is it the same size in all three spectra?

As a group, talk about the visual appearance of the sets of spectra and how similar or different spectra within a given set are.

## 2.2 Analyze your spectra in Spectral Workbench (40 minutes)

Now, support these visual observations with data in Spectral Workbench. In Spectral Workbench, open one of your saved sets. You will do this exercise for each set, one set at a time. In the first set, place your cursor in the set's spectra, and watch the legend in the upper right-hand corner, which shows the fluorescence intensities of each spectrum at the wavelength where your cursor currently is. As you move your cursor to the left or right, you will see the intensities (written as %s) change.

In your group, you will identify the wavelengths at which different things occur, and you will record those wavelengths on a piece of paper. This takes good teamwork! Have one person slowly move the cursor across the spectra, another person paying close attention to the intensities legend in the upper right hand corner, and one person recording values on the paper.

In each set, find:

- the wavelength of the center point of each spectrum in a set. Do this by clicking "More Tools" and select 'Find graph "centers" only between 410-700nm'. Center lines will appear on the spectra. Move the cursor to overlap with the center-line for each spectrum and record the wavelength where that occurs.

- the wavelength at which each spectrum has the highest intensity. Do this by slowly moving the cursor across the spectra and closely watching the intensity for each spectrum to find the highest points. Note that this can require close attention, especially if the spectra have broad peaks. For spectra with broad maxima (i.e. the same high intensity for a range of wavelengths), record the range of wavelengths for the highest intensity.

- the wavelengths at any changes in slope of the spectrum. For example, if there is a distinct dip, or a place where the curve becomes more steep, record the wavelengths at which those changes occur for each spectrum in a set.

With your group, compare your findings for each of the characteristics listed above. How far apart are the center lines? Do the spectra have similar wavelengths for their maximum intensities? Do the other characteristics of the spectra (such as valleys and slope changes), occur at similar wavelengths?

Repeat this section for the rest of your sample sets.

Remember back to Workshop 1 when we discussed precision. Since each spectrum in a set is the same oil sample, comparison of those spectra inform us about the precision of our method. How precise is our method for measuring the fluorescence spectra of oil samples? Is our method more precise for one type of oil than another? Which kinds of oils had the best precision, and which had the worst? Do you have any ideas about why that might be?

### 2.3 Possible issues

Spectra in a set don't always match up exactly. Some reasons for this are:

- The intensity of your light source was different.
- One of your samples is more diluted than another.

IMPORTANT LINKS

For more tips visit: https://publiclab.org/wiki/spectral-workbench-usage

### 2.4 Compare across sets (15 minutes)

First, visually compare the different sets. Using the same characteristics as in part 2.1, note the similarities and differences in the spectra of different kinds of oil. Discuss your comparisons as a group.

Now, reference the data you determined in step 2.2 about the wavelengths at characteristic places in the spectra. How similar are the graph centers, peak wavelengths, and slope changes in the different kinds of oil?

Look at the range of wavelengths for a given characteristic (e.g. wavelength at maximum peak intensity) within a single set, and compare that against the wavelengths for that same characteristic in other sets.

- Based on a single characteristic, can you discern the different kinds of oil?
- For example, if the only information you were given were that an oil sample had its maximum fluorescence intensity at 540nm, could you group it into one type of oil sample as opposed to another?
- What if you compared shapes and other characteristic wavelengths?

Discuss your analyses as a group.

Once you have finished analyzing your results, take five minutes to brainstorm notes, questions, and ideas on the analyzing process.

Post these up on the poster board.

These will be reviewed compiled at the end of the workshop and posted back to Public Lab.

**------ (10 minute break) ------**

# 3. Identifying next steps

### 3.1 Finalizing your conclusions (30 minutes)

Revisit the question you identified in Workshop 2.

Choose one person to type notes from the discussion. These notes will be used during the last activity of this workshop, posting a research note.

Discussion Prompts:

- What did we learn?
- Were our questions answered? If not, what would we need to do to further explore the questions?
- Did any new questions arise?
- How can the information be used?
- Who can use the information?
- Where do we want to take this project next?

High accuracy depends on calibration. What would have happened if you had improperly calibrated? HINT: the relative precision would still be the same, but the accuracy would be much different.

# 4 Compiling your data to share

### 4.1 Posting a Research Note online (30 minutes)

While you may have been posting research notes along the way on the progress of the workshops, this activity is as a final wrap up/reflection time on the project in sharing it out with the Public Lab community.

Follow these steps to post a Research Note:

- Log into PublicLab.org.
- On your dashboard you will see the most recent research notes people have posted.
- On the top left hand corner of the screen, click the button "Write a research note." You will be able to drag and drop the images of your graphs into the textbox.

## 4.2 Tips for improving your research note

Research notes can include information such as:

- Introduction: to the project and the question explored (Workshop 1)
- Methods: how participants worked to answer the question from workshop 1 (What was done in workshops 2 and 3)
- Results: The graphs and information you compiled in Activity 1 today.
- Discussion: The discussion can include anything you'd like to mention about the results or the process you went through to get them. Below are some prompts of useful information to include in the discussion:
- Experience using the oil testing kit
- Questions that arose along the way
- Ideas for improving the kit
- Ideas for future use of the kit
- Information you were able to gather about your results
- Things you learned
- Things you would like to learn more about or have questions about
- etc.

## 4.3 Make a plan for the next steps in your oil testing project

Based on the point you arrived at while writing your research note, think forward about what the very next step is that needs to happen. What about the couple steps after that? What schedule would you like to set for these steps?

Most importantly, welcome to the Public Lab community! We want to hear from you, so reach out anytime to the spectroscopy group at plots-spectrometry@googlegroups.com. All of the people who wrote this workshop are on that list, which means you already know people there!

# Glossary

### DIY
Do-It-Yourself; a tool, technique, or method that a person can do without special facilities, highly technical equipment, or formal expertise.

### Split sample
A split sample is when someone who is collecting a sample agrees to take a sub-sample of their sample to provide to you. As both are collected at the same time, they are useful for comparing the results of two different tests.

### Fluorescence Spectrometry
Also known as fluorescence spectroscopy; a type of spectrometry where samples are illuminated by a light, typically ultraviolet, which causes them to emit (or fluoresce) their own light. This is then measured using a spectrometer for comparison with other samples.

### PAH
Polycyclic Aromatic Hydrocarbons, a set of carcinogenic compounds found in petroleum pollution.

### Spectrometry
an analysis technique which examines and compares the intensities of different colors from samples, typically as illuminated by a light source. See fluorescence spectrometry for the type we have been using in Public Lab's Oil Testing Kit

### VOC
Volatile Organic Compound; a group of compounds made of carbon, hydrogen, oxygen, and/or nitrogen that have low boiling points, high vapor pressure, and can often vaporize around room temperature.

### GC/MS

Gas Chromatography/Mass Spectroscopy; see What tests exist, and what are available to me?

### Biomarkers

Molecules like sterane and triterpane are often called “petroleum biomarkers” because they are molecules derived from the living organisms that created the original source rock and its oil. Read more in Has such data has been used to effect change? How, when, and where?

### Fingerprinting

A colloquialism in scientific studies is to call something that can uniquely identify a substance a “fingerprint” since human fingerprints are unique identifiers for individual people. In oil testing, “fingerprinting” means identifying the source or specific type of oil it is, based on chemical properties (such as ratios of biomarkers) that are unique to only that source or type.

### API weight

Also known as API gravity, the American Petroleum Institute (API) grades oil based on their densities. The less dense an oil is, the higher its API weight. If an oil has an API above 10, it will generally float on water; if it has an API below 10, it will sink. Most petroleum products have API gravity of 10-70, but Canadian tar sands oils are more dense than water, with API gravity of ~8. For more information, please see this page.

### Diagnostic test

A diagnostic test is a test or series of tests that can yield enough information to provide an explanation or answer with a high degree of certainty. In the context of oil testing, a diagnostic test generally refers to a test that can indicate a specific source of oil, such as the specific geologic formation from which that oil came. Diagnostic tests are used to investigate oil pollution without a clear source, in order to identify the source of the leak or spill or illegal discharge.

# References

A range of related scientific literature has been collected on the *Oil Testing Kit Literature* page; here we list those which were cited in Chapter 1.

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## IMPORTANT LINKS

For the full literature list, please visit: https://publiclab.org/wiki/oil-testing-kit-literature

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