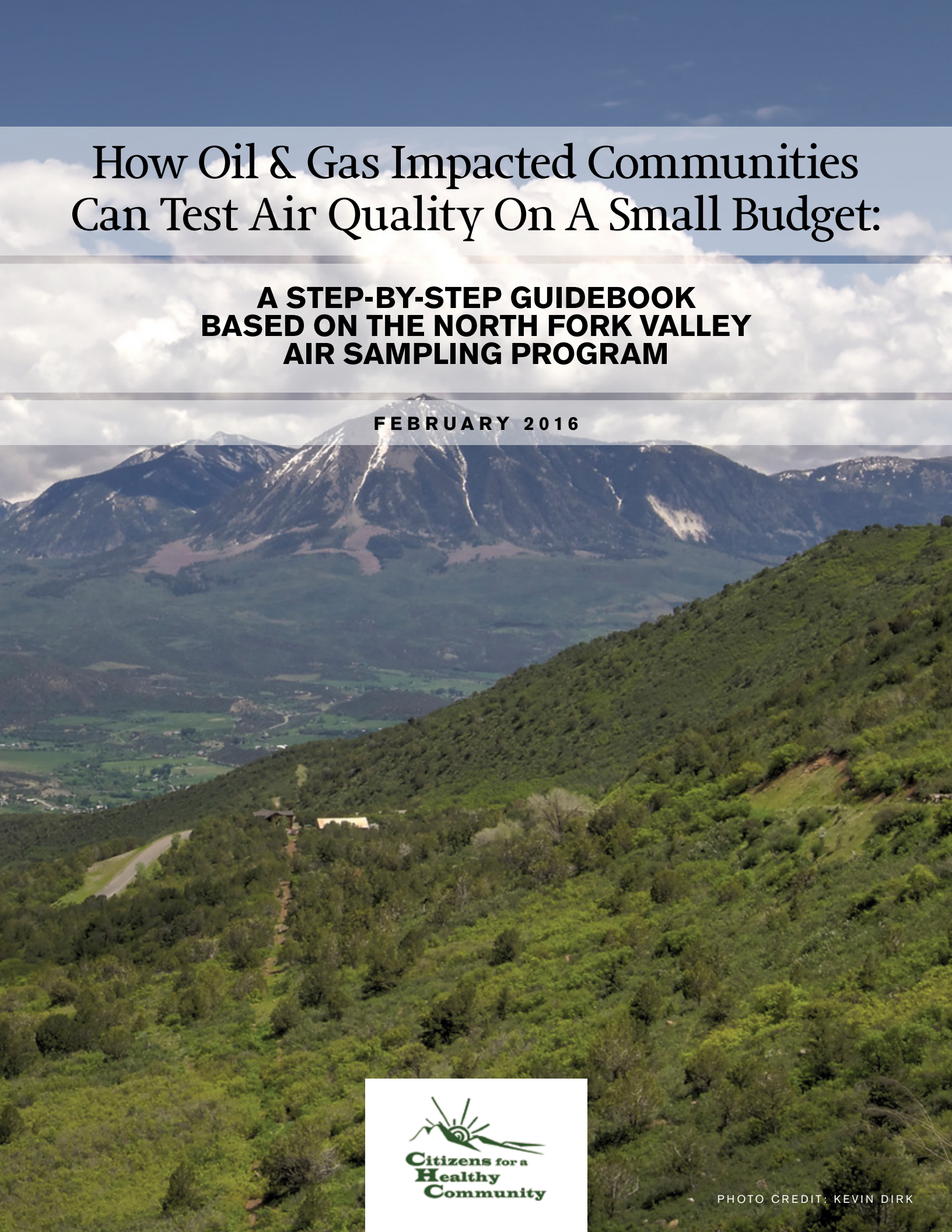
How Oil & Gas Impacted Communities Can Test Air Quality On A Small Budget:

A STEP-BY-STEP GUIDEBOOK BASED ON THE NORTH FORK VALLEY AIR SAMPLING PROGRAM

FEBRUARY 2016



Citizens for a Healthy Community

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Citizens for a Healthy Community (CHC) is a grassroots nonprofit 501(c)3 organization formed for the single, dedicated purpose to protect people and their environment from irresponsible gas and oil drilling in the Delta County Region of Western Colorado. CHC is the county's watchdog for oil and gas development, conducts research and advocacy, and works with partner organizations to fight for the health and safety of citizens and implementation of safeguards to protect public health and the environment.

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Acknowledgements

This important project would not have been possible without the support of the following organizations and individuals: TEDX – The Endocrine Disruption Exchange, in particular Kim Schultz, Dr. Carol Kwiatkowski, and Dr. Theo Colborn; Citizens for a Healthy Community's (CHC) members and financial contributors including Patagonia, the Maki Foundation, a generous anonymous donor; and CHC's dedicated volunteers and members. Financial support for TEDX was provided by the Arkansas Community Foundation, Winslow Foundation, Cornell Douglas Foundation, and New-Land Foundation.

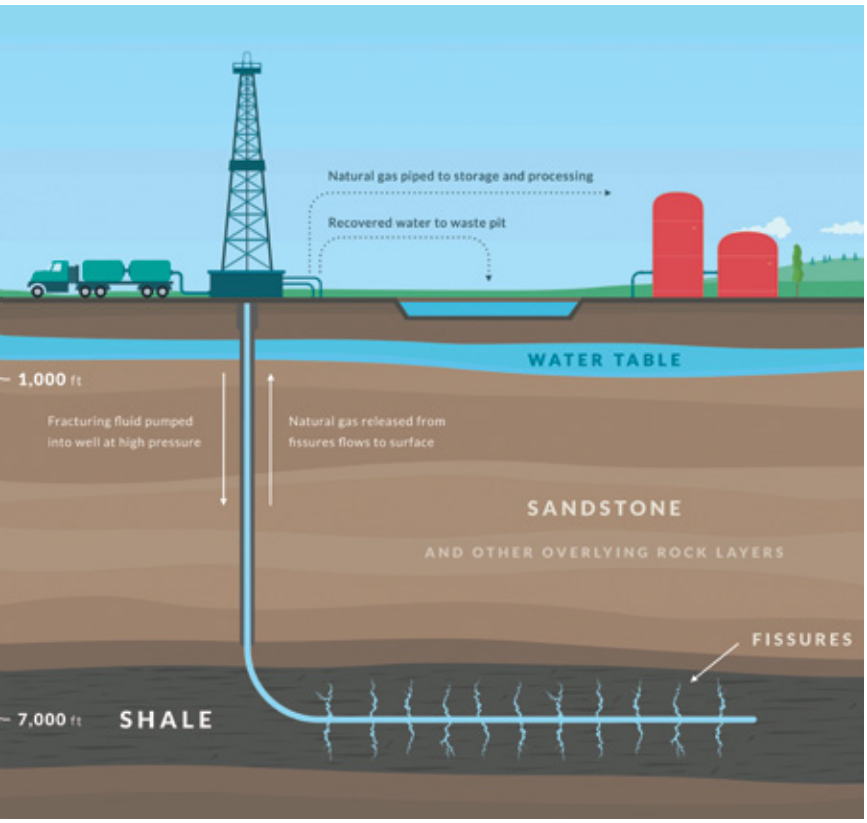
CHC's all-volunteer Board of Directors was instrumental in the success of this project. We appreciate and are incredibly grateful for the commitment, energy, and dedication of our past and present CHC Board of Directors, especially Board Chairperson Dr. John VanDenBerg.

We thank all of the air sampling and resident volunteers for the time spent in training and the collection of samples. We would also like to thank the families of the resident volunteers for volunteering their homes and property as testing locations.

CHC would also like to thank Jim Ramey, former Executive Director of CHC, for championing this project, spending countless hours bringing it to life and making it such a successful model for others to follow.

Executive Summary

Oil and gas development near homes, schools, farms, watersheds, or pristine outdoor recreational sites is a frightening prospect to many communities. Even more unsettling for long-time residents and visitors is the risk that these communities will be turned into industrial zones. Communities are fighting back; they are fighting irresponsible oil and gas development with grassroots power—by mobilizing concerned citizens through public comments, letters to the Editor, websites, and lawsuits.



Air pollution from chemicals associated with oil and gas development causes such health effects as burning eyes, dizziness, and nausea, as well as potential development of chronic diseases including damage to cardiovascular or endocrine systems. To prove that such damages are caused by oil and gas operators, and to counter industry and government arguments that such development does not unduly harm people and the environment, evidence and data are needed.

When it comes to air pollution, who is responsible for testing air quality? The conventional wisdom is such that it is or should be the responsibility of government and the responsibility of polluters. Government agencies are good at issuing standards and setting thresholds with which polluters need to comply, but generally do not conduct the testing. Polluters are good at minimizing their costs by narrowing their compliance to the bare minimum. The public tends to believe that air quality testing is expensive and complicated and therefore the domain of either government agencies, polluters, or scientists and academics.

Citizens for a Healthy Community (CHC) asked a different question. We asked who is responsible for safeguarding community health from irresponsible oil and gas development, and what role does air quality testing play?

In the State of Colorado, the Colorado Oil and Gas Conservation Commission (COGCC) regulates oil and gas. It has conflicting mandates to both promote oil and gas development and protect citizens. The Colorado Department of Public Health and Environment regulates air pollution emitted by oil and gas operators. Neither agency conducts air quality testing on chemicals associated with oil and gas operations. With respect to oil and gas development on public lands, the Bureau of Land Management (BLM), which leases oil and gas mineral rights, is required to conduct an Environmental Assessment or Environmental Impact Study of lands nominated for leasing. However, BLM is understaffed and it is unclear as to whether it has the resources to effectively conduct the required "hard look" under the National Environmental Policy Act, which includes looking at air pollution impacts. Oil and gas companies don't conduct air testing studies in advance of bidding on lease parcels, and certainly don't want to increase their acquisition, exploration, or production costs.

With no incentive on the part of the State, BLM or the industry to proactively test and monitor air quality, how can a community establish baseline air quality data to protect itself from irresponsible oil and gas development? The answer is: It must establish its own community-based air quality testing program on a shoestring budget.

CHC partnered with TEDX, The Endocrine Disruption Exchange, to conduct a community-based air quality sampling study. By partnering with a research organization, CHC and its volunteers did not need to be experts in chemistry, testing equipment, or analytical protocols. CHC equipped volunteers with mobile testing units that allowed citizen volunteers to flexibly collect samples of the air they breathed, rather than air in some fixed, remote site. The air samples were then forwarded to a lab for analysis and the results were interpreted by TEDX.

CHC conducted one of the most comprehensive test of chemicals associated with oil and gas development. We sampled 24 locations and tested for a total of 74 chemicals known to have adverse impacts on human health. This is quite an accomplishment for a grassroots nonprofit. We are proud to report that of the 45 chemicals detected they were all below Environmental Protection Agency (EPA) thresholds.

This report highlights the results of our study, but more importantly provides community nonprofits with a step-by-step guide to implementing such a program.

1. How to set up an air sampling program
2. How to interpret and communicate the results
3. How to raise money for the study
4. How to set up periodic monitoring post-baseline

We hope the work CHC and TEDX have done in the North Fork Valley of Western Colorado will inspire and encourage oil and gas impacted communities to establish their own programs. If we can do it, so can you!

A drill rig on a 16 well pad in Garfield County, Colorado.

Introduction

Citizens for a Healthy Community (CHC), a grassroots 501c3 nonprofit organization, partnered with researchers at TEDX, The Endocrine Disruption Exchange, to create a baseline air sampling program. The purpose of the program was to test the air quality in Colorado's Delta County Region for chemicals related to unconventional oil and gas development. Air quality data is needed because of adverse health effects associated with exposure to these chemicals. Such health effects include burning eyes, dizziness, and nausea, as well as potential long-term chronic illness such as damage to cardiovascular or endocrine systems.

The Delta County Region includes the three towns of the North Fork Valley (NFV) – Paonia, Hotchkiss, and Crawford, and surrounding areas, which are most impacted by existing and new oil and gas development. Currently there are very few wells operating in the region. However, many acres of public and private land have been leased for oil and gas development and future additional leasing is probable. As a consequence, an urgent community need arose to document baseline air quality before additional oil and gas development begins.

A baseline understanding of air quality was needed for six key reasons:

- To establish historical air quality data;
- To prove change in air quality caused by oil and gas development;
- To create thresholds for improved mitigations in Memoranda of Understanding between the County and operator, and at the Colorado Oil and Gas Conservation Commission (COGCC) level;
- To determine potential health impacts on human, animal, and plant health;
- To verify that energy company interests do not conflict with community interests; and
- To understand if setbacks have a meaningful protective impact on health.

Most air quality is tested in areas that are removed from an average person's daily routine. Personal mobile testing units are the solution to this problem. In this study, volunteers were outfitted with backpacks and sensors located specifically to determine what the individual was breathing—the breathing zone. This is important in the event that evidence of human exposure is needed to prove impact on human health.

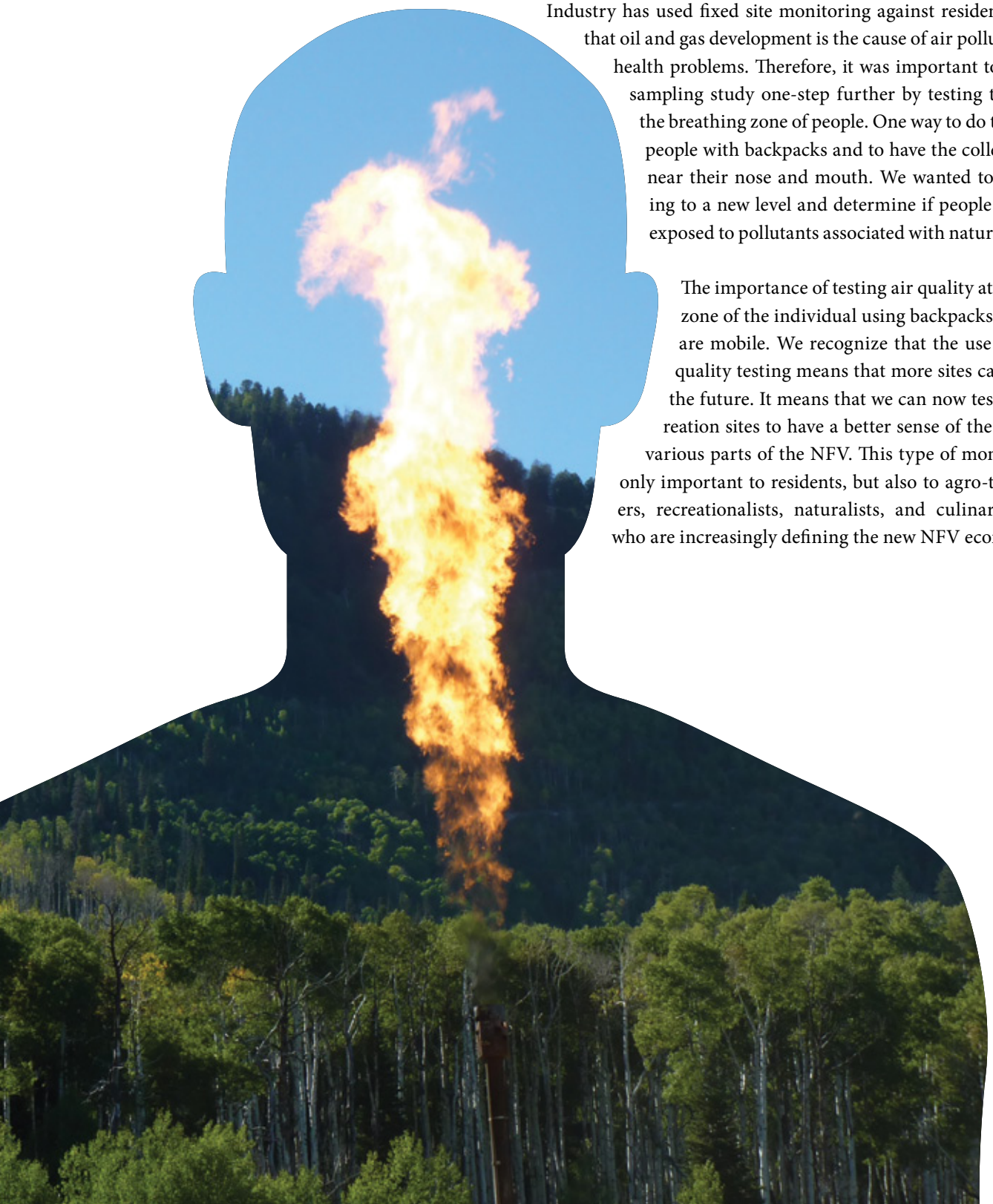
This report is intended to bring awareness not only to the importance of citizen and community monitoring of air quality in compiling evidence to fight oil and gas encroachment, but the feasibility of such programs. This report serves as a template for nonprofit community groups and communities interested in developing their own air sampling and monitoring studies. As this was an unprecedented study, there were many lessons learned, which we hope will save your community time and resources.

Part 1: The Breathing Zone Impact

TEDX conducted an air sampling study during the years 2010 and 2011 in Garfield County, Colorado using a fixed monitoring site for sample collection to determine chemicals present in the air near a home 0.7 miles away from a new pad with 16 wells under development. As a result of this research in Garfield County, TEDX recognized the limitations of using a fixed monitoring site. While stationary sampling is easier to execute and yields reliable results, it does not establish incontrovertible evidence to prove that people are actually breathing the chemical compounds in the air.

Industry has used fixed site monitoring against residents who claim that oil and gas development is the cause of air pollution and thus health problems. Therefore, it was important to take this air sampling study one-step further by testing the air within the breathing zone of people. One way to do this is to outfit people with backpacks and to have the collection devices near their nose and mouth. We wanted to take air testing to a new level and determine if people were actually exposed to pollutants associated with natural gas activity.

The importance of testing air quality at the breathing zone of the individual using backpacks is that people are mobile. We recognize that the use of mobile air quality testing means that more sites can be tested in the future. It means that we can now test popular recreation sites to have a better sense of the air quality in various parts of the NFV. This type of monitoring is not only important to residents, but also to agro-tourists, hunters, recreationalists, naturalists, and culinary enthusiasts who are increasingly defining the new NFV economy.



A methane gas flare from a well in Western Colorado.

Part 2: Air Quality Sampling At A Glance: Making the Chemical Connection

CHC recognized that with the potential pace of development in the NFV it did not have time to wait for government, industry, other environmental groups, or university research programs to show up and eventually start collecting air quality data. Community nonprofits and citizen volunteers don't need a degree in chemistry or advanced scientific training to collect air samples. However, in developing the program it helps to know what you are collecting and why, and the importance of using a broad-spectrum test instead of a narrow test to ensure that no relevant chemicals are missed. Because the volunteers collected air samples at their homes, they have a personal vested interest in knowing what chemicals are detected or undetected.

A methane gas flare from a well, and frack chemical tanks on a pad near McClure Pass. Notice the open pit on the pad.

Recent research has identified the fingerprint of chemicals associated with oil and gas as the light alkanes, which include ethane, propane, n-butane, isobutane, n-pentane, and isopentane. These chemicals will surface with methane during drilling, fracking and flowback, and are often vented or flared during natural gas production. Increasing levels of light alkanes are possible indicators of the presence of more gas related chemicals in the air.

Air samples were collected at 24 locations over roughly a year-long period. The air was tested for a total of 74 chemicals classified as volatile organic compounds(VOCs) related to oil and gas development. Many of these chemicals have been associated with adverse health impacts.

The purpose of air quality testing is to identify chemicals in the air that negatively impact human and animal health, and disrupt the environment. Indirect health impacts can result from chemically induced environmental disruption. The VOCs tested have been found to negatively impact a number of human body systems and organs, for example the nervous, immune, respiratory, circulatory, and endocrine systems, and kidneys, liver, and skin.

WHY THE TESTING PROTOCOL MATTERS

The objective of this study was to create a baseline that would give the NFV community the ability to measure change in air quality, to investigate the cause of any elevated levels, and specifically to help identify impacts from oil and gas operations. Industrial operations, along with everyday activities such as driving a car, leave a chemical fingerprint behind of compounds released into the air. In conducting a baseline air quality study it is important to test a wide range of chemicals in the air to assist in detecting the source of pollution.

UNDERSTANDING THE CHEMICALS TESTED

LIGHT ALKANES are recognized ozone precursors, which contribute to respiratory illness and global warming. Ozone precursors are chemicals that can react with nitrogen oxides and sunlight to form ground level ozone. Ozone can affect the respiratory system causing inflammation and shortness of breath especially affecting people with lung conditions like asthma and emphysema. Ozone levels, especially when snow is present, have been found above the EPA safe standard of 75 ppb in heavily drilled areas in the West. High elevations tend to have higher ozone levels.

> **ISSUE:** Readings from the upper North Fork Valley Bull Mountain Unit are already near the current EPA ozone standard.

THE BTEX CHEMICALS – benzene, toluene, ethylbenzene, and xylene– are other volatile organic compounds associated with natural gas that can surface with raw natural gas from underground. They collect as liquid condensates on the pad or are vented or flared into the air. Also, BTEX can be found in products used during drilling and hydraulic fracturing.

> **ISSUE:** BTEX are listed as Hazardous Air Pollutants by the EPA and abundant research shows all four of these chemicals have adverse human health effects at both low ***and*** high exposure levels.

Some of the **UNSATURATED VOCS**, such as ethylene, propylene, and acetylene, are most closely related to commercial and urban environments due to combustion. These chemicals have been associated with adverse health effects in multiple body systems at higher concentrations.

> **ISSUE:** Combustion emissions from increased traffic volume associated with natural gas development will raise the concentrations of unsaturated VOCs in the air. Estimated round trips from hauling equipment during well pad preparation, drilling, and completion number in the thousands.

POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) can be released from underground during drilling. It can also form as a result of incomplete combustion such as when burning wood or coal. For this reason there has been limited testing for PAHs near drilling areas.

> **ISSUE:** PAH analysis can be expensive, resulting in another reason for limited testing of PAHs near drilling areas. We included PAHs in our baseline study because very low amounts–detections in the parts per billion (ppb) or parts per trillion (ppt) range– have been shown to have serious neurodevelopmental health effects.

Chemical pollution can arise from many sources including industrial activities, diesel combustion, and off-gassing from household items like building materials or furniture. For these reasons TEDX used the most comprehensive VOC test available that was appropriate to achieve the objectives of the study. The tests conducted covered a wide range of compounds, including chemicals released during natural gas drilling as well as those more closely associated with urban environments.

Many communities have used other VOC tests, such as the EPA TO-15 (modified), which cast a wide net over VOC chemicals. Unfortunately these do not test for many of the chemicals specifically now known to be associated with oil and gas. The VOC PAMS Protocol (see page 12) enabled us to narrow down the potential sources for detected chemicals.

Part 3: Methods Used To Create A Baseline of Air Quality Data

Between November 2013 and July 2014, volunteers were equipped with mobile units to collect air samples at six different locations. Twenty-four samples were collected, six per season, at locations throughout the NFV (Figure 1). To account for seasonality, we selected two sampling dates, three weeks apart, within each of the four seasons of the year. On each date, three locations were selected, for a total of 24 samples. Samples were taken at an average distance of 30 miles from active wells, on different days to try to control for air pollution patterns such as changes in weekday and weekend traffic.

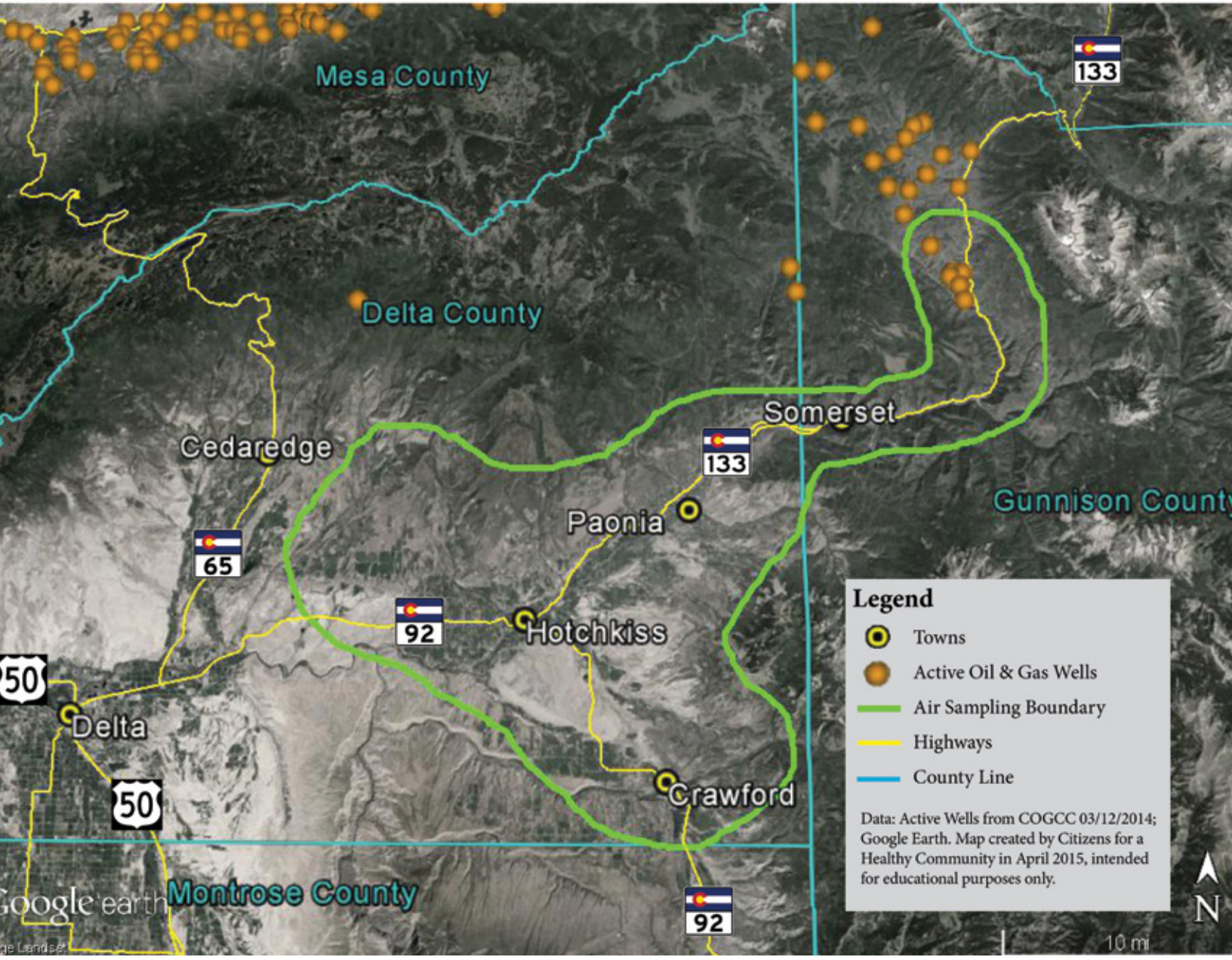


Figure 1: Air Sampling Area
The map illustrates the location of the 24 sampling sites relative to oil and gas production in the North Fork Valley.

COLLECTION

Backpack sampling was used to obtain air samples from near the breathing zone. Volunteers were recruited to wear two sampling devices and a GPS unit, all housed in one backpack for 24 hours. See Figure 2.

Figure 2: Volunteer outfitted with backpack
Backpack showing air sampling collection areas near the breathing zone.

PHOTO CREDIT: ELISE THATCHER AND ASPEN PUBLIC RADIO.

Two different groups of volunteers helped with sample collection: resident volunteers who wore the backpacks on their property, and trained sampling volunteers who took the equipment to the resident volunteers' location and operated the equipment. CHC trained the sampling volunteers on:

- How to transport the backpack to the sampling location;
- How to orient the resident volunteers wearing the backpacks to the equipment;
- How to start and stop the two sampling devices and the GPS unit at the appropriate times; and
- How to fill out the chain of custody form and prepare the samples for shipment.

Resident volunteers were selected based on the location of their residence, property details including house age and sources of heat, proximity to industrial activities, and nearby traffic conditions. Resident volunteers were asked to:

- Remain on their property in order to obtain an air sample from a relatively fixed geographic location. GPS units were included in the backpacks to verify that volunteers did not leave their property boundary.
- Refrain from many activities during air sampling including smoking, working with solvents, and running equipment powered by combustion engines. See Appendix 1, Form 1 for prohibited activities.
- Keep an hourly activity log to document general weather conditions, activities, and time spent indoors. The log could later be used to check for unintended chemical exposure, especially in samples with chemical concentrations well above the mean or samples with a high number of unique chemical detections. See Appendix 1, Form 6 for a sample activity log.

Mobile weather stations were used to collect weather data at each location. Weather data were collected using the Ambient WS-2080 Home Weather Station. These stations were set up at each location and were set to collect data at five-minute intervals for the 24 hour sample period. The stations were mounted six feet above the ground to attempt to capture the conditions near the height the samples were taken.

ANALYSIS

Polycyclic aromatic hydrocarbons (PAHs) were sampled using an AirChek XR5000 Personal Sample Pump to pull air through two filters over the entire 24 hours, beginning at 2:00 pm on Day 1 and running through 2:00 pm on the following day. These samples were sent to an accredited lab and analyzed for 16 PAHs using the NIOSH-5506 protocol. A field blank was taken on each sample date.

Summa canisters were used to collect air samples over six hours beginning at 8:00 am on Day 2 and ending at 2:00 pm. These samples were analyzed for 58 VOCs including methane using the Photochemical Assessment Monitoring Stations (PAMS) Protocol and the USEPA Method18 (modified).

A total of 74 chemicals were tested; 29 were not detected, for a total of 45 chemicals detected. See Table 1 for a complete list of chemicals tested.

Part 4: NFV Air Quality Findings

This report confirms what many NFV residents suspected: that their current air quality is considered healthy as compared to government environmental and safety standards. Of the 45 chemicals detected, they were all below EPA thresholds. Clearly, residents of the NFV want to keep it that way.

BTEX chemicals were detected at concentrations below the EPA safety threshold levels. However, it is important to note that we do not know how chronic exposure or exposure to chemical mixtures might affect our health or the environment. The data from this study are the beginning of new research on understanding the potential health hazards for individuals living in communities affected by unconventional oil and gas development.

This baseline study is the beginning of building a scientific record to identify the correlation between these chemical detections and oil and gas activity. The complete findings from the study have been submitted to a peer-reviewed journal for publication.

It is important that communities remain vigilant in monitoring their air quality. With the current data we have and with limited sampling, we are unable to pinpoint the source of detected chemicals. However, we expect that with frequent monitoring it will be easier to connect the chemicals detected with their sources, whether they are oil and gas operations or other activities in the NFV, including traffic and agricultural processes.

TABLE 1.
74 CHEMICALS TESTED IN BASELINE SAMPLING. [CHEMICALS WITH * WERE DETECTED]

1,2,3-trimethylbenzene	benzo(b)fluoranthene	m-ethyltoluene*
1,2,4-trimethylbenzene*	benzo(g,h,i)perylene	naphthalene*
1,3,5-trimethylbenzene*	benzo(k)fluoranthene	n-butane*
1-butene*	chrysene	n-decane*
1-hexene	cis-2-butene*	n-dodecane*
1-pentene	cis-2-pentene	n-heptane*
2,2,4-trimethylpentane	cyclohexane*	n-hexane*
2,2-dimethylbutane	cyclopentane*	n-nonane*
2,3,4-trimethylpentane	dibenzo(a,h)anthracene	n-octane*
2,3-dimethylbutane*	ethane*	n-pentane*
2,3-dimethylpentane*	ethylbenzene*	n-propylbenzene
2,4-dimethylpentane	ethylene*	n-undecane*
2-methylheptane*	fluoranthene	o-ethyltoluene*
2-methylhexane*	fluorene	o-xylene*
2-methylpentane*	indeno(1,2,3-cd)pyrene	p-diethylbenzene
3-methylheptane*	isobutane*	p-ethyltoluene
3-methylhexane*	isopentane*	phenanthrene
3-methylpentane*	isoprene*	propane*
acenaphthene	isopropylbenzene	propylene*
acenaphthylene	m-xylenes *	pyrene
acetylene*	p-xylenes*	styrene
anthracene	m-diethylbenzene	toluene*
benzene*	methane*	trans-2-butene*
benzo(a)anthracene	methylcyclohexane*	trans-2-pentene*
benzo(a)pyrene	methylcyclopentane*	

Part 5: Step-by-Step Guide To Designing A Community Air Quality Sampling Program

It is feasible for grassroots nonprofits with small budgets to conduct comprehensive air quality testing and establish critically important baseline air quality data for their communities. A major goal of this project was to thoroughly document our process and methods to share what we learned with other communities. This commitment and our lessons learned have resulted in this step-by-step guide to inspire and encourage oil and gas impacted communities to test for personal air pollution exposure. Community-based air quality testing is a way to build on the growing body of evidence that chemicals from development are not only in the air but are also entering our bodies.

We learned a few things along the way, which we hope will inspire you:

1. You can—and we did—come in under budget;
2. Your volunteers will amaze you with their dedication;
3. The researchers, the acronyms, and the science are not as intimidating and scary as you might think; and
4. Funders are very receptive to this type of proactive grassroots initiative.

Get Started! To obtain the best possible data from your sampling program we recommend you start planning well before sampling begins.

1. HOW TO SET UP A BASELINE STUDY

a. Outline the Project

Be clear on your objectives—what you want to test and why, timelines, sampling area, and scope of the project in terms of volunteers needed.

b. Budget & Funding

Once the project is outlined, it's time to do a budget for staff time and resources, equipment, and lab analysis. The budget should be simple, yet comprehensive, which is critical to successfully introducing the project to potential funders and volunteers. See Appendix 2 for estimated and actual budget for this project.

c. Identify an appropriate test for the objective of the study

Many communities have used other VOC tests, such as the EPA TO-15 (modified), which cast a wide net over VOC chemicals, but unfortunately do not test for many of the chemicals specifically now known to be associated with oil and gas.

As referenced earlier, recent research has identified the fingerprint of chemicals, associated with oil and gas, such as light alkanes, which include ethane, propane, n-butane, isobutane, n-pentane, and isopentane. These chemicals surface with methane during drilling, fracking and flowback, and oil and natural gas production. This is the reason TEDX used the VOC Photochemical Assessment Monitoring Stations (PAMS) Protocol, to ensure that these chemicals would not be missed. The VOC PAMS Protocol enabled us to narrow down the potential sources for detected chemicals.

PAHs are generally not tested in oil and gas impacted communities. TEDX chose to test for PAHs because they were detected in Garfield County at levels shown to have health effects. PAHs were tested in Garfield County upon recommendation of the lab. PAH testing is substantially more expensive then VOC testing, but worth using to establish a baseline. This helps in developing an appropriate on-going monitoring protocol, which meets community needs and budget constraints.

We were generally pleased with the suite of chemicals we sampled for (methane, VOCs, and PAHs), but additional options include particulate matter, carbonyls, hydrogen sulfide, NORM, and ozone. CHC chose to use a Summa canister to sample for methane and non-methane hydrocarbons. Different media are available for this kind of sampling, including the Tedlar bag used by groups like Global Community Monitor in their Bucket Brigades.

d. Identify a Lab

Identifying a lab to process and analyze your samples is critical, and can make or break the quality of your study. Criteria for evaluating a prospective lab:

i. **AN ACCREDITED LAB THAT CAN ANALYZE THE TEST APPROPRIATE FOR YOUR STUDY.** We had to use two different labs to analyze the VOCs and the PAHs. Accreditation examples include National Environmental Laboratory, Accreditation Conference, and California State Environmental Laboratory Accreditation Program; The Lab must be able to report quality control data;

i. **EQUIPMENT SENSITIVITY.** The lab should be equipped with highly sensitive instruments capable of detecting low levels of chemicals. Low detection capability is important because we still don't know the impact of chronic low-level exposure to these chemicals. Collecting low detection level data will facilitate this research.

The lab can answer questions about methods and procedures that need to be followed, and provide information for special handling or shipping instructions (e.g. PAH samples needed to be placed on ice in an insulated cooler pack for shipping to the lab). If the person who will be communicating with the lab is not a scientist, it is important to find a lab that is easy to communicate with and willing to answer questions from a layperson.

e. Identify Experts for Analysis of Lab Results

The lab reports include the list of chemicals, the reporting limits, and the levels of detection. An expert is needed to help analyze and interpret the raw data so that meaningful results can be reported back to individuals and the community. Experts should be experienced in interpreting laboratory data from volatile chemical analysis, and should have conducted and published studies of air quality.

f. Location Selection

Develop a location selection plan. Numerous criteria, including distance from roads, oil and gas operations, neighbors, etc., were considered when choosing the locations, dates, and times of sample collection. We took three samples at the same time in different locations across the Delta County Region. We sampled during different days of the week to avoid bias that could result from certain activities occurring on the same day of the week. Sampling VOCs early in the day is preferable because air pollutants tend to undergo photo degradation with increased sunlight and temperature. CHC chose to look at the data from each round of sampling in order to select the locations for the next round. This results in inherent sampling bias. Random sampling in an area is an option to avoid sampling bias.

g. Sample Collection

i. **DECIDE ON FIXED OR MOBILE SITE SAMPLING, OR A COMBINATION.** CHC decided to use backpacks so that the sampling equipment traveled with the resident volunteer. However, on rainy or gusty days, the volunteers were primarily inside, which resulted in air sampling primarily from indoors. We recognize that any sampling that occurs indoors will capture off-gassing from consumer products. A potential remedy to this problem would be to collect two samples concurrently with one outdoors and the other contained in a backpack on a person. Generally, we believe that the more samples that could be collected, the better.

ii. **KEEP AN EXTRA SET OF EQUIPMENT ON-HAND IN CASE OF EQUIPMENT FAILURE.** Collection of PAHs required a pump to actively pull air through a filter to catch the PAHs attached to particulates in the air. Despite testing the PAH pumps ahead of time, we experienced a malfunctioning pump during one of the sampling periods, which resulted in collecting the sample a day late.

iii. **EQUIPMENT PROTECTION.** In order to utilize sensitive equipment inside of a backpack, we had to package the equipment with padding in order to keep the equipment from being jostled about during sampling.

iv. **GETTING SAMPLES TO THE LAB. PLAN FOR PROPER PACKING.** Our remote location made overnight shipping of the PAH sample media to the lab challenging. This could be remedied by adjusting sample collection times as to provide for enough time for volunteers to return the samples to the coordinator for proper packaging and shipping.

h. Weather Station

Weather data, especially wind direction, can provide information on pollution sources. Therefore it is important to consider local weather data when analyzing lab results. Use existing weather data sources if available in your area. Due to our remote location, existing professional weather stations were not available. For example, Weather Underground, a personal weather station network, provides local weather in most areas but quality can be inconsistent. CHC utilized portable weather stations for each sample that was collected. A trained volunteer set up and started each station the day before sampling, but there were occasions when the weather stations malfunctioned making the data unavailable. Air flow in our valley is affected by time of day, elevation, and physical land masses, which made the wind data so variable that we could not determine a prevailing wind direction by site, date, or season.

i. GPS

Location accuracy is critical to the integrity of the study. GPS units were used to make sure the sampling occurred on the property where it was intended, and to verify that the individual wearing the backpack did not leave the property during sampling. This GPS data is also beneficial to ensure that follow-up samples are collected from the same location.

j. Volunteers

i. **DEVELOP VOLUNTEER SELECTION CRITERIA.** Variables in determining the most ideal sampling locations included property location (noting that there are many different micro-climates in the Delta County Region), the willingness of volunteers to participate, and the general competence level and trustworthiness of volunteers. A challenge for our sampling project was to identify resident volunteers who were available and capable to assist with the sample collection. For instance, people who worked during the week were unable to participate in sample collection because they were not at home during the sampling times.

ii. **DETERMINE TYPES OF VOLUNTEERS NEEDED.** We used two types of volunteers to help with the collection of samples: sampling volunteers (individuals who operated the sampling equipment and distributed equipment to the resident volunteers) and resident volunteers (individuals who wore backpacks to collect the samples at their property).

iii. **TRAINING OF VOLUNTEERS.**

1. We held training sessions for the sampling volunteers on equipment operation, set up and shut off, and troubleshooting potential problems. Holding refresher trainings was important after we went a couple of months without conducting sampling.
2. Resident volunteers wore the backpacks but did not operate any of the equipment. They received an orientation to the process and equipment from the sampling volunteers, but did not need extensive training handling the equipment.

iii. **BACK-UP VOLUNTEERS.** It is helpful to have at least one or two sampling volunteers signed up as a back-up on the sampling day, in case of emergencies or illness of the sampling volunteer originally signed up to help on that day.

iv. **DESIGNATE THE PERSON RESPONSIBLE FOR EQUIPMENT SET-UP, CALIBRATION, AND PROPER CONNECTION OF EQUIPMENT WITHIN THE BREATHING ZONE.** The Executive Director was responsible for pump calibration and assembly of the sampling train to connect the pump to the filters located on the front strap of the backpack near the breathing zone. The Summa canister was also set up even though it would not be started until the following morning. The backpack was ready to go with both pieces of equipment and the GPS unit installed when the sampling volunteer arrived at the office to take the backpack to the resident volunteer's home. A sampling volunteer could be trained in the backpack setup rather than relying on the Executive Director.

v. **DEVELOP AN ACTIVITY AND WEATHER REPORTING LOG FOR VOLUNTEERS.** Resident volunteers were required to complete an activity log that described their daily activities, general weather conditions, and time spent indoors, hour by hour. More details should have been collected on this form, as some of the resident volunteers listed only cursory information about their activities. Additional information could have been collected about time spent indoors versus outdoors, if windows were open in the house, or other activities occurring on the premises that could impact the sampling. A detailed activity log helps when checking for unintended chemical exposure, especially in samples with chemical concentrations well above the mean or with a high number of unique chemical detections. See Appendix 1, Form 6 for a sample activity log.

vi. **REPORT BACK TO VOLUNTEERS.** It is very important to report back to the resident volunteers who assisted with the project in a timely manner, and provide them with a copy of their individual results. CHC told the residents up front that the sampling would take place over one year, and they would not receive their results until analysis was completed. An exception would be if levels were high enough to warrant a health concern. Each participant received an individualized report with their air results, along with the mean concentrations detected across samples for frame of reference. The report included the different classes of chemicals tested and links to government chemical data sheets for further information when available.

2. HOW TO INTERPRET AND COMMUNICATE THE RESULTS

When communicating the results of the a baseline study it is important to communicate its purpose, its limitations and how the information should be used. Baseline studies are the beginning of building an air quality record. They are also the beginning of correlating chemicals detected with specific industrial activity. It is important to explain to the community how a baseline study fits into a long-term vision and strategy.

3. HOW TO RAISE MONEY FOR THE STUDY

a. **Apply for grants;**

b. **Partner with other like-minded organizations;**

c. **Develop a targeted fundraising campaign for the project.**

4. HOW TO SET UP PERIODIC MONITORING POST-BASELINE

a. **Determine the interval monitoring periods.** We believe that annual monitoring is critical in areas with significant oil and gas development, and prudent if the objective is to identify sources of pollution. An atmospheric expert recommended monthly outdoor stationary testing over one year to build on our baseline. This would help distinguish outdoor from indoor air pollutants, and trigger alerts for indoor air testing when outdoor levels start rising significantly.

b. **Document when new oil and gas development occurs** and any other industrial activity that may impact the chemical levels. Align testing with various stages of activity when possible.

c. **Raise awareness of the importance of community monitoring.**

d. **Develop a way to incentivize the community to participate or even fund regular air quality monitoring.** Point out that we often take the air we breathe everyday for granted. There isn't an air utility like a water or electric utility that delivers an air service. If communities want to protect their airsheds they are going to have to find ways to fund regular air quality monitoring.

Part 6: Conclusion

For the first time, baseline air quality data are now documented for the Delta County Region. We hope that this information can encourage best practices with regard to protection of public health in oil and gas impacted areas, as well as provide an opportunity to hold industry accountable for changes in air quality should drilling begin in the future. Oil and gas impacted areas include communities with existing oil and gas operations and infrastructure, or where such operations are being proposed.

Air sampling collection volunteer.

By employing this unique backpack sampling method we are able to document personal exposure to the chemicals detected. This is ground-breaking in our fight to protect our airshed, and every community's fight to protect theirs. We plan to conduct follow up sampling to broaden our data set and to observe and document how the air quality in our area might change over time. We hope sharing our process and experience can aid other impacted communities who face encroaching oil and gas development.

Appendix I: Air Sampling Forms & Documents

FORM 1
LIST OF PROHIBITED ACTIVITIES WHILE SAMPLING

This air sampling project will test for very low levels of chemicals that come from natural gas drilling and fracking operations, but some of those chemicals could also come from additional sources, and many of them are listed below as prohibited activities during the 24-hour sampling collection period. During the sampling period, you will need to refrain from the following activities in order to make sure that the sample is not compromised.

- Burning: pretty much anything, including agricultural, tobacco, candles, incense, fireplace, etc.
- Using internal combustion engines (e.g. lawnmower, weed eater, chain saw, snowmobile, atv)
- Standing or sitting near idling internal combustion engines (cars, trucks, tractors, etc.)
- Cooking on an outdoor grill or deep frying
- Painting (for hobby or otherwise)
- House cleaning, including dusting, vacuuming, cleaning with solvents of any kind
- Leaving your property

FORM 2
PERSONAL EXPOSURE BASELINE AIR SAMPLING STUDY

Instruction Checklist for Sampling Volunteers

DAY 1

PAH Sample Start-Up Procedure

- At 2:00 pm, begin sample collection of the PAHs sample by turning on the pump following these instructions:
  - *Press and hold * until display shows "ON".*
  - *Press [▲▼] simultaneously to begin sample collection as exact to 2:00 pm as possible.*
  - *Lock the keypad by pressing the down key [▼] 5 times quickly. Once locked, the display will show a small "L" in the lower-right corner.*
- Place the pump in the backpack, close the pack.
- Record the "Beginning Sample Information" on the PAHs Field Data Sheet (start date/time, indoor/outdoor temperature, ambient barometric pressure, and operator [your name]).
- The following morning, check the run-time and battery level on the PAHs pump. At 8:00 am, the run time should be 1080.

DAY 2

Summa Canister Start-Up Procedure

- **Begin collection of the summa canister sample as close to 8:00 am as possible following these instructions:**
  - *Turn the knob counter-clockwise until it stops to open the canister (usually less than one full turn).*
  - *Confirm that the pressure gauge has a reading (it was at 0 before you opened the valve).*
- **Place the summa canister in the backpack, close the pack.**
- **Record the "Beginning Sample Information" on the Summa Canister Field Data Sheet (start date/time, initial can pressure, indoor/outdoor temperature, ambient barometric pressure, and operator [your name]).**
- **Resident should begin checking the flow gauge beginning at 11:00 am, and every 30 minutes thereafter to ensure the gauge does not fall below -5.**

Summa Canister & PAH Sample Stop & Recovery Procedure

- **Stop the collection of the summa canister sample:**
  - *At 6 hours (2:00 pm) or when the pressure reads -5" HG remaining, whichever occurs first, stop the summa canister sample collection by turning the knob clockwise tightly until it stops.*
- **Stop the collection of the PAHs sample:**
  - *Press [▲▼] simultaneously to stop the pump from running at 1440 minutes or 2:00 pm, whichever occurs first.*
  - *Hold * until the pump turns off.*
  - *Have a zip-lock bag ready.*
  - *Remove the brown filter cassette from the sampling train, place the yellow and green plugs in either end of the filter cassette, and place the filter cassette in the zip-lock bag.*
  - *Remove the sorbent tube from the sampling train and remove the aluminum foil and set aside. Securely cap both ends of the sorbent tube with the red caps and cover the exposed glass of the sorbent tube with the aluminum foil. Place the capped and covered sorbent tube in the zip-lock bag.*
  - *Place the zip-lock bag in the cooler.*
- **Record the "Ending Sample Information" on the "Summa Canister Field Data Sheet" (stop date/time, final can pressure (i.e. the gauge reading when you turned off the summa canister), indoor/outdoor temperature, and ambient barometric pressure. Sign the field data sheet.**
- **Record the "Ending Sample Information" on the "PAHs Field Data Sheet" (stop date/time, indoor/outdoor temperature, and ambient barometric pressure. Sign the field data sheet.**
- **Pack up samples according to specifications.**

FORM 3
PERSONAL EXPOSURE BASELINE AIR SAMPLING STUDY

Resident Volunteer Information & Consent Form

OVERVIEW

Thank you for participation in [Organization Name]'s personal exposure air sampling program. This project is important because it will paint a picture of the [Name of Region]'s current air quality, and how our air may be impacted by natural gas drilling operations taking place in the [specific area] or elsewhere. As a resident volunteer, you will help us by wearing a backpack for 24 hours that contains two sampling devices. On the first day of sampling, a volunteer will arrive at your house prior to 2:00 pm, and begin the collection of the PAHs sample and turn on the GPS unit. The following morning, the volunteer will arrive at your home prior to 8:00 am to begin collection of the summa canister sample. Then, the volunteer will visit one last time prior to 2:00 pm on the second day to stop collection of both the summa canister and PAHs samples and turn off the GPS unit.

VOLUNTEER INFORMATION

NAME

EMAIL

HOME PHONE

CELL PHONE

PREFERRED CONTACT METHOD

CONSENT TO PARTICIPATE AND CONFIDENTIALITY

I agree to voluntarily participate in [Organization Name]'s air quality sampling project. I understand that:

- I will be provided with a copy of the complete analysis from the air sample taken at my property at the end of the study;
- The only instance when [Organization Name] would release data prior to the end of the study is if the lab revealed a health concern;
- Data released to the public will not reveal participants' names or exact sampling locations and will typically be in aggregated form; and
- [Organization Name] makes no guarantee or promise to conduct further sampling at my property, though at [Organization Name]'s discretion additional sampling may be conducted.

Please check one:

- ☐ I require that [Organization Name] keep my name, address, property location, and any other identifying information confidential.
- ☐ I expressly grant [Organization Name] the right to share my participation in this project publicly, including my name and general property location (e.g. "on Rogers Mesa").

SIGNATURE DATE

PRINTED NAME

FORM 4
PERSONAL EXPOSURE BASELINE AIR SAMPLING STUDY

Sampling Volunteer Information & Consent Form

OVERVIEW

Thank you for your interest in volunteering for [Organization Name]'s personal exposure air sampling program. This project is important because it will paint a picture of the [Region]'s current air quality, and how our air may be impacted by natural gas drilling operations taking place in the [specific area] or elsewhere. We will collect 24 samples during four different months roughly over the course of one year. As a volunteer, you will help us start and stop sample collection on-site at the homes of local residents who will be wearing a backpack for 24 hours. Three sets of samples will be collected during each 24-hour time period for eight sampling days over the course of the project. On the first day of sampling, you will arrive at a resident volunteer's house prior to 2:00 pm and begin the collection of the PAHs sample by turning on the GPS unit. The following morning, you will arrive at the location prior to 8:00 am to begin collection of the summa canister sample. Then, you will visit one last time prior to 2:00 pm to stop collection of both the summa canister and PAH samples and turn off the GPS unit. At this point, you will properly package the samples and deliver them to the coordinator for shipping.

VOLUNTEER INFORMATION

NAME

EMAIL

HOME PHONE

CELL PHONE

PREFERRED CONTACT METHOD?

CONSENT TO PARTICIPATE AND CONFIDENTIALITY

I agree to voluntarily participate in [Organization Name]'s air quality sampling project. I agree to keep the names, addresses, locations, and any other identifying information of the samplers – those individuals who are collecting samples using various sampling media – confidential. I am participating in this project on a volunteer basis; this volunteer agreement may be terminated at any time by myself or [Organization Name]. However, my obligation to keep this identifying information confidential will remain indefinite.

SIGNATURE

PRINTED NAME

DATE

FORM 5
PERSONAL EXPOSURE AIR SAMPLING SCREENING CRITERIA FORM

Thank you for your interest in participating in [Organization Name]'s personal exposure air sampling program. This project is important because it will paint a picture of the [Region]'s current air quality, and how our air may be impacted by natural gas drilling operations taking place in the [specific area] or elsewhere. In order for you to participate, we need to confirm certain information about where you live. Please answer the following questions as best you can.

Physical location

NAME(S)

ADDRESS

PLEASE ESTIMATE THE DISTANCE (IN FEET OR MILES) OF YOUR PROPERTY FROM THE NEAREST:

HIGHWAY (SPECIFY HWY 133 OR 92)

RAILROAD TRACKS

MINES/INFRASTRUCTURE (E.G. LOAD OUTS, METHANE VENTS)

GAS STATION

General location

APPROXIMATE DISTANCE (IN FEET OR MILES) FROM THE NEAREST:

TOWN (SPECIFY TOWN)

ROAD (INCLUDE ROAD SIZE)

TRAFFIC DENSITY INFORMATION

ROAD TYPE (E.G. PAVED, GRAVEL, DIRT)?

NEIGHBOR'S HOUSE (AND SOURCE OF HEAT IF KNOWN)

INDUSTRIAL ACTIVITY (E.G. ROAD WORK, FOUNDRY)

Property description

DESCRIBE THE GENERAL TOPOGRAPHY OF YOUR PROPERTY:

ELEVATION

VEGETATION TYPE (E.G. PASTURE, BRUSH, TREES)

YEAR YOUR HOME WAS BUILT

HAVE YOU DONE SIGNIFICANT REMODELING RECENTLY?

IF YES, WHAT DID YOU REMODEL AND WHEN?

SOURCE OF HEAT (E.G. COAL, GAS, WOOD, ELECTRIC)

TYPE OF COOK STOVE (E.G. COAL, GAS, WOOD, ELECTRIC)

DO YOU USE SPACE HEATERS?

DO YOU HAVE A GAS/DIESEL PUMP ON OUR PROPERTY?

Occupants

DOES ANYONE IN THE HOUSEHOLD SMOKE (ANY SUBSTANCE)?

ARE THERE PEOPLE FREQUENTLY COMING AND GOING FROM YOUR PROPERTY IN CARS OR OTHER MOTORIZED VEHICLES (ATVS, TRACTORS, ETC.)? IF YES, PLEASE EXPLAIN.

Extra information:

FORM 6
ACTIVITY LOG

Instructions:

Please keep an hourly log of your activities while wearing the backpack. You need not record every intricate detail of your activity, but you should record significant changes in what you are doing. For example, between 10 am and 11 am, "went for walk around property," between 3 pm and 5 pm, "worked at desk in home office," or between 10 pm and 6 am, "slept." If any of the prohibited activities inadvertently occur (e.g. someone forgets and lights a fire in the fireplace) you should note it on this form. On page 3, please include general descriptions of changes in the weather during sampling (e.g. "Sunny from 2pm to 5pm, then cloudy with rain showers overnight." OR "Cold during temperature inversion with poor visibility, partly cloudy to cloudy during sampling.")

TIME	ACTIVITIES
2:00 pm	
3:00 pm	
4:00 pm	
5:00 pm	
6:00 pm	
7:00 pm	
8:00 pm	
9:00 pm	
10:00 pm	
11:00 pm	
12:00 am	
1:00 am	
2:00 am	
3:00 am	
4:00 am	
5:00 am	
6:00 am	
7:00 am	
8:00 am	
9:00 am	
10:00 am	
11:00 am	
12:00 pm	
1:00 pm	

NOTES:

WEATHER INFORMATION:

Appendix II: Budget

BUDGET REPORT

This project had a budget of $33,666.85 and was completed nearly 14% under budget, with total expenses of about $29,000.00. The largest expense of the project, accounting for nearly 80% of the total cost, were the analysis and shipping costs to get samples to the labs. The remaining third of the cost was nearly evenly split between equipment purchase and rental. Below is a table that shows budgeted versus actual expenses.

EXPENSE CATEGORY	BUDGET	ACTUAL
Lab analysis & shipping ($5,400 per month, for 4 months)	21,600.00	22,988.11
Equipment purchase (one-time cost)	6,686.85	2,600.84
Equipment rental ($1,345 per month, for 4 months)	5,380.00	3,511.52
Total	**$33,666.85**	**$29,100.47**

We saved considerably on equipment purchase costs by purchasing more affordable weather stations and 2-meter stands instead of 10-meter towers. Actual costs for equipment rental came in at a lower quote from the vendor we used than we had originally planned. Lab analysis and shipping came in slightly over budget due to higher than anticipated shipping costs.

Estimate for ongoing monitoring is approximately $26,500 per year.

Project Overview and Budget is a template of how you can present your project to potential funders.

PROJECT OVERVIEW & BUDGET: PERSONAL EXPOSURE BASELINE AIR QUALITY SAMPLING PROGRAM FOR THE _____ COUNTY REGION

Purpose and Need

The purpose of this project is to develop a 'personal exposure' baseline air quality sampling program for the _____ County Region (_____) of Colorado. The project is intended to 1) develop a baseline understanding of air quality in the _____, and 2) gain a better understanding of the level of personal exposure to chemicals in the air that have originated from natural gas development activities. Gathering these data are critical because of the serious adverse health impacts that could occur from exposure. Such health effects include harm to the brain and the endocrine and nervous systems, organ damage, and cancer, as well as other "symptoms such as burning eyes, rashes, coughs, sore throats, asthma-like effects, nausea, vomiting, headaches, dizziness, tremors, and convulsions."

As natural gas development expands in the _____, baseline air quality needs to be established—along with additional continued monitoring—to determine how air quality changes with increased natural gas development in the area. There are currently no existing air quality data for the _____. The closest such data has been gathered from _____. Natural gas drilling has recently expanded along the _____ County border with _____, and in _____ area along _____ on the south side of _____. There are also pending proposals to drill _____ natural gas wells in the _____ are and 50 wells in _____, located in_____. Another proposal calls for potentially _____ of oil or natural gas wells in the _____, which stretches from _____ to _____. It is very important to gain a baseline reading of air quality in the _____ before natural gas drilling expands significantly.

Project Design & Methods

Community members will wear personal air monitoring devices to sample chemicals in the air that are typically associated with natural gas development. The first device is contained in a small backpack (an example is shown in Figure 1 at right), which will sample for 24 hours to better understand personal exposure to polycyclic aromatic hydrocarbons (PAHs). Additional chemicals, including methane and non-methane hydrocarbons (NMHCs) will be monitored using a personal-sized Summa canister (see Figure 2 on the following page) at the same time worn by the same individuals, collecting a six-hour sample. The project is unique because it includes chemicals often overlooked in traditional air quality monitoring, including the PAHs that are known to cause adverse health effects at very low levels, and the NMHCs, which are ozone precursors that are known to have numerous toxic effects. The project will test for natural gas signature chemicals—sometimes referred to as the natural gas "fingerprint" or "footprint"—that indicate those chemicals in the air are likely sourced from natural gas development.

Portable weather stations will be used to monitor weather and wind data during sampling at the standard meteorological height of 10 meters. Locations will be selected throughout the _____ taking into account weather and wind patterns, geography, and proximity to natural gas development and other potential emission sources. All individuals involved in the project will be trained in sampling collection using the backpack sampling kit and Summa canisters. Chain of custody procedures will be followed. Samples will be analyzed by Atmospheric Analysis and Consulting, Inc. (AAC Lab) using USEPA certified methods. Individuals wearing the sampling systems will keep a log of their activities and wear a portable GPS tracking device to monitor their location during sampling.

This project will establish a baseline across the _____ over the course of one year. Sampling will occur during three separate months of the year to account for variances in seasons, with an optional fourth month if lab analysis indicates that sampling should continue at any time. Three locations will be sampled at a time (i.e. one set of samples) and two sets will be collected during each month of sampling, for a total of six samples collected per month for four months (24 total samples). Upon receiving sampling results from the lab, the next three sampling locations will be strategically selected. After establishing a baseline, ongoing personal exposure monitoring could continue, as natural gas development increases in the _____, in order to monitor changes in the air quality. _____ will establish a data repository to make the results of sampling publicly available.

The project design has been developed in consultation with staff at _____, a non-profit organization dedicated to compiling and disseminating the scientific evidence on the health and environmental problems caused by low-dose exposure to chemicals that interfere with development and function, called endocrine disruptors. _____ staff have published scientific journal articles regarding chemicals used in, and released by, natural gas development activities. _____ will serve as the project coordinator and consult regularly with _____ on project design, selecting sampling locations, and data analysis and interpretation. _____will provide professional project development, analysis and interpretation of lab results, and ongoing consultation services to _____ as an in-kind donation.

Project Budget

OVERVIEW

The project budget includes funding for up-front equipment purchase, and ongoing equipment rental and lab analysis. The budget allows for eight sets of samples to occur in four separate months for a total of 24 samples, roughly over the course of one year. The total project budget, needed to establish a personal exposure baseline, is $33,666.85. _____ will raise the required funds for the project through a mix of grant funding and private donations. Table 1 shows the Project Budget Overview.

Tables 2, 3 and 4 show detailed description of the elements of the Project Budget Overview.

TABLE 1.
PROJECT BUDGET OVERVIEW

Eight sampling sets, at three samples per set	Cost
Lab analysis & shipping ($5,400 per month, for 4 months)	21,600.00
Equipment purchase (one-time cost)	6,686.85
Equipment rental ($1,345 per month, for 4 months)	5,380.00
	Total $33,666.85

ONE-TIME COSTS

To save on costs, most equipment will be rented at monthly rates. However, the project will require an initial investment to purchase some necessary equipment. Equipment purchase costs are shown in the table below, with one-time equipment purchase costs totaling $6,686.85.

TABLE 2.
ONE-TIME EQUIPMENT PURCHASE COSTS

One laptop computer (for data collection and storage)	~400.00
Portable weather station (3 needed at $536 each)	1,608.00
Weather station data logger (3 needed at $265 each)	795.00
Holster and belt for summa canisters (3 needed at $100 each)	300.00
Sampling pump backpack (3 needed at $58 each)	174.00
Weather station tower kit (3 needed at $800 each)	2,400.00
Shipping materials (e.g. insulation, ice packs)	~100.00
GPS tracking device (3 needed at $269.95 each)	809.85
Rechargeable batteries & charger (for GPS and weather stations)	~100.00
	Total $6,686.85

EQUIPMENT RENTAL AND LAB ANALYSIS COSTS FOR EACH MONTH OF SAMPLING

Table 3 shows the cost for equipment rental for one month of sampling (i.e. two sets, or six samples), which totals $1,345.00.

TABLE 3.
COSTS FOR EQUIPMENT RENTAL FOR ONE MONTH OF SAMPLING (I.E. TWO SETS)

PAHs sampling kit ($195 each per month)	585.00
PAHs sample calibrator ($250 per month)	250.00
Summa canister ($35 each per sample)	210.00
Flow controller ($100 each per month)	300.00
	Total $1,345.00

Table 4 shows the cost for lab analysis and shipping samples to/from the lab for one month, which totals $5,400.00.

TABLE 4.
COSTS FOR LAB ANALYSIS AND SHIPPING FOR ONE MONTH OF SAMPLING (I.E. TWO SETS)

LAB ANALYSIS	
PAHs ($425 per sample + one blank)	3,400.00
C2-C12 hydrocarbons ($200 per sample)	1,200.00
Methane ($100 per sample)	600.00
SHIPPING	
PAHs sample shipping (~$25 per set)	~50.00
Summa canister sample shipping (~$25 per sample)	~150.00
	Total $5,400.00

PHOTO CREDIT: JEREMY PUCKETT

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Citizens for a Healthy Community

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