Title: West Valley High Time Resolution Air Toxics Monitoring Campaign

Applicant Information:
Utah Department of Environmental Quality
P.O. Box 144820, Salt Lake City, Utah 84114-482
Contact Person: Brad Johnson, Deputy Director
Tel: (801) 536-4403; Fax: 801-536-0061; E-mail: btjohnson@utah.gov

Funding Requested: $355,000
Total Project Cost: $603,500 (Includes $248,500 of in-kind contributions for the use of monitoring equipment)
Project period: May 2015- May 2017
DUNS number: 8260010590000

Narrative Proposal Work Plan

The project outlined in this proposal will be conducted within the framework of community-scale Hazardous Air Pollutant (HAP) monitoring. The study will add an additional toxics monitoring site near a residential neighborhood in West Valley City to complement the State's ongoing research on HAPs distribution across the Salt Lake urban area. Most importantly, this study will provide high quality, high time resolution measurements of HAPs and related species, which were hitherto unavailable at this location. The state-of-the-art instrumentation at the site will allow for real time monitoring of air toxics as well as their key tracers with hourly to minute-scale resolution in both particulate and gaseous phases. The particulate phase air toxics include those on the current HAPs list and diesel particulate matter. Coupled with co-located measurements of meteorological parameters and a suite of other instruments, the monitoring of HAPs will produce a rich, high quality dataset that will allow for the identification of local HAPs emission sources and a better estimate of population exposure in an economically underserved area. This study will determine the relative contributions of anthropogenic and biogenic sources to aromatic HAPs, gas phase formaldehyde and acetaldehyde concentrations using source apportionment tools: a tracer-tracer correlation and EPA's Positive Matrix Factorization (PMF) model. Sources and atmospheric processes that contribute to particulate HAPs will be elucidated using hourly averaged data in a PMF analysis and a combined factor analysis of both the gaseous and particulate HAPs. Additionally, the proposed study facilitates community involvement and outreach as students and local activist groups will be invited to the University Neighborhood Programs and provided with the data. The projected duration of the sampling campaign is one year, with data analysis and source apportionment study to be completed during the second year of the project.

a) Basis and Rationale

The Salt Lake Valley (UT) on average experiences 18 days of high wintertime levels of particulate matter that exceed the National Ambient Air Quality Standard (NAAQS) for PM2.5 [Whiteman et al., 2014]. This region also commonly suffers from high levels of ozone during the summer [DAQ, 2013]. The unique topography and meteorological conditions of the Salt Lake Valley favor air stagnation that traps air pollutants for several consecutive days in winter, leading to high pollutant levels [Silcox et al., 2012; Kelly et al., 2013].

In 2013, the Utah Division of Air Quality (DAQ) analyzed observations gathered in the Salt Lake Valley between 2000~2012 at the current and historic National Air Toxics Trends Station (NATTS) in Bountiful and West Valley City. This data was compared to toxics data from Phoenix, which aided in the identification of contributions from local industries as well as truck and automobile exhaust. We identified a set of eleven gaseous organic HAPs that regularly exceeded the chronic exposure threshold concentrations including 1,3-butadiene; 1,4-dichlorobenzene; acetaldehyde; acrylonitrile; benzene; carbon tetrachloride; dichloromethane; ethylbenzene; ethylene dichloride; formaldehyde; and tetrachloroethylene. Formaldehyde and acetaldehyde displayed their highest concentrations during warm, summer months, while the other compounds peaked at the same time as high $PM_{2.5}$ during the winter.

However, because of the obsolescence of the West Valley dataset (collected between 2000 and 2002), and the low temporal resolution (24-hour samples, collected once every six days), there is uncertainty associated with the ambient levels and spatial distribution of HAPs sources. DAQ, with research funding from the Utah legislature, is conducting a

field study through 2015 that will gather HAPs data from three locations across the Wasatch Front to better characterize the spatial distribution of ambient toxics and the current population exposure levels. This study collects gaseous volatile organic compounds (VOCs) and toxic metals in PM_{10} samples in West Valley City, Bountiful (current NATTS site), and Lindon, in the Utah Valley. The data is being collected with an improved, but still less than ideal temporal resolution of once-in-three days. The proposed study greatly improves upon the temporal resolution of previous studies and provides for better characterization of sources of HAPs in Salt Lake Valley.

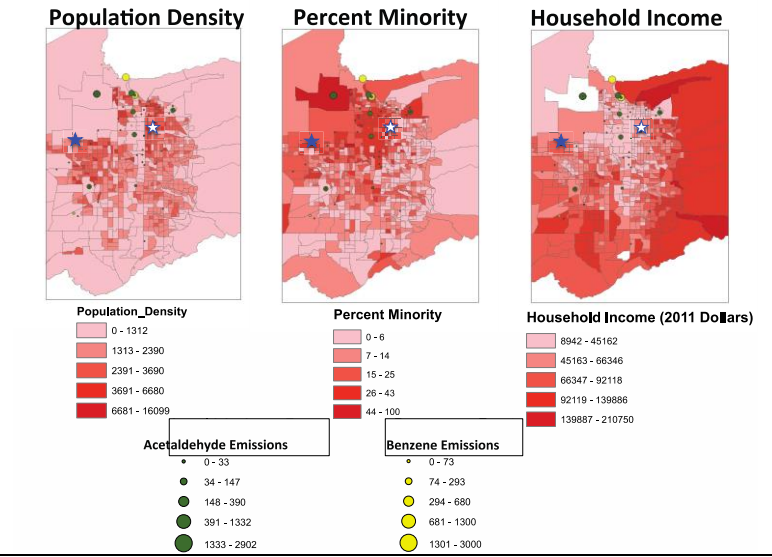

Figure 1. Map of population density, % minority, and household income in the Salt Lake Valley. The proposed measurement site in West Valley City, the Neil Armstrong Academy, is shown as a blue star. The existing key air quality monitoring site maintained by DAQ is the white star. Point sources of acetaldehyde and benzene are also indicated in green and yellow, respectively. Data: US Census Bureau.

This proposal outlines two air sampling campaigns that will be carried out in West Valley City, UT during the winter and summer months using a suite of state-of-the-art instruments. One strength of this study is the high temporal resolution provided by the suite of instruments which aids in characterizing the sources of both gaseous and particle HAPs in the Salt Lake Valley. Data from this study also allows for an estimate of population exposure to HAPs. West Valley City is a municipality with a rapidly expanding population (2nd largest in Utah) to the west of Salt Lake City, with relatively lower income, significant minority population, and potential exposure to HAPs (also see "Environmental Justice Impacts" section below). The instruments will be based at West Valley City's Neil Armstrong Academy, an elementary school dedicated to science, technology, and mathematics, thereby providing unique outreach opportunities to arise out of this project. The winter study (December-February) will emphasize the measurements of HAPs in the gas and particulate phase, including diesel particulate matter during the inversion season. During the summer (June-August), the campaign will emphasize measurement of precursor gases, formaldehyde and acetaldehyde. This approach allows for the determination of ambient levels of HAPs and toxicity assessment during the most intense pollution episodes in the region. The results of this study will provide vital information for assessing health risks and characterizing the sources of HAPs. This data is essential for the DEQ in order to formulate effective control strategies to reduce ambient levels of HAPs in both the particle and gaseous phases.

b) Technical Approach

Technical Objectives of the proposed study are to:

1) *determine the ambient levels as well as the spatiotemporal variation of HAPs in the Salt Lake and Utah Valleys, including gas phase carbonyls (formaldehyde and acetaldehyde) and polycyclic aromatic hydrocarbons (PAHs) in both gas and particle phases;*
2) *determine the chemical speciation of PAHs and diesel particulate matter in the particle phase as well as estimate the particle toxicity during high $PM_{2.5}$ pollution episodes in the winter and summer; and*
3) *conduct a source apportionment analysis using the high temporal resolution dataset of HAPs and related species.*

The objectives will be achieved by conducting two intensive gas-particle sampling campaigns during winter (December 2015 - February 2016; a period typically marked by high PM levels) and summer (June - August 2015; period with the highest formaldehyde, acetaldehyde and ozone concentrations). Both deployments will collect highly temporally resolved measurements of ambient VOCs using a Proton Transfer Reaction - Mass Spectrometry (PTR-MS) and time resolved measurements of fine particulate organic compounds including PAHs using an Organic Aerosol Monitor (OAM). In

addition, CO, NO_x, O_3, and meteorological data will be collected. An Ambient Ion Monitor (AIM) will be deployed during both sampling periods to provide both the gas phase and $PM_{2.5}$ ionic composition on an hourly averaged basis. Table 1 provides an overview of the proposed measurements. A particular strength of this study is concurrent real time measurements of HAPs in the gas and particulate phases, which is a powerful resource for source apportionment analysis, which hitherto has not been available in community air monitoring programs in this location.

Gas Phase VOCs

Measurement of gas phase VOCs will be done using PTR-MS which allows on-line detection for a broad range of VOCs with high sensitivity (ppt, lower limit of detection) and high-time resolution (second-minutes). The main advantages of PTR-MS are its fast time response; low limit of detection; and its ability to detect a wide range of VOCs of anthropogenic, biogenic and biomass burning origins [Blake et al., 2009]. For these reasons, PTR-MS is widely used for measurements of environmental VOCs on a diverse array of platforms and the instrument performance, response and specificity are well characterized for many air toxics. The PTR-MS technique was successfully used in recent studies over the Deepwater Horizon (DWH) oil spill [Ryerson et al., 2011] and Uintah Basin Winter Ozone Studies (UBWOS) in Utah [Warneke et al., 2014].

Ambient air toxics and other trace gases that can be monitored by PTR-MS include unsaturated reactive hydrocarbons such as isoprene, α-pinene and β-pinene; aromatics such as benzene, toluene and xylene; most of the oxygenated VOCs such as aldehydes, ketones, alcohols, carboxylic acids, and acetonitrile, a tracer for biomass burning emissions [de Gouw and Warneke, 2007]. Table 1 shows a list of HAPs and related species that will be monitored by PTR-MS. Measurements of related species (precursors, markers) will assist in analysis of the data. Details about the instrumentation including the gas sampling inlet system for the PTR-MS instrument have been discussed previously (Fig. 2a) [Hu et al., 2013; Hu et al., 2011; Baasandorj et al., 2014].

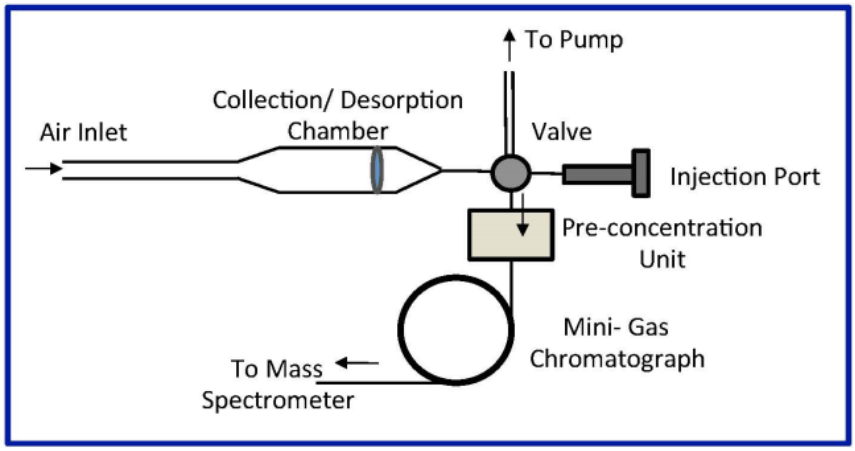

Figure 2. a) PTR-MS and the gas inlet system for VOC monitoring b) Schematic of the semi-continuous monitor for the real-time determination of fine particulate organic compounds.

Measurements of Fine Particulate Organic Compounds

This proposal introduces new instrumentation and a methodology to measure the toxic components in PM that aid in the identification of sources of these species. The OAM has been optimized during the past three years using support from Southern California Edison and Sunset Laboratories. The OAM measures the semi-volatile and non-volatile carbonaceous component in PM by first collecting particulates on an inert filter (Fig. 2b). Collection times range between 30-50 minutes. After collection, the particles are gently heated in an inert atmosphere and swept into a pre-concentrator. After pre-concentration, the molecules are swept into a miniature gas chromatograph-mass spectrometer for detection.

The analysis of the data will include a source apportionment evaluation of PAH and diesel PM and the relationship between particulate and gaseous HAPs. Source apportionment studies done in the past indicate that PAH will be produced at both sites in summer and winter due to diesel and gasoline emissions. It is also expected that diesel particulate and PAH from forest fires and winter wood burning may also be present [Grover 2006, Long 2005, Long 2002].

Several organic compounds including PAH and organic marker compounds (Table 1) have been studied in the development of the OAM. The detection limits of 1-h samples (3 times base-line noise) for the OAM are (all values are ng/m^3): Benzo[ghi]flouranthene, 4-20, DL 0.2; Levoglucosan, 300-8000, DL 1; Dehydroabietic acid, 50-500, DL 0.5; Hopane, 4-20, DL 0.2, below the expected ambient concentrations of these compounds in an urban area based on literature.

One main advantage of the OAM is its ability to monitor fine changes in chemical speciation of ambient particles. The data analysis software is linked to the National Institute of Standards and Technology (NIST) standard Mass Spectral database, which allows for rapid identification of detected compounds based on the retention time and mass spectrum. The NIST database allows for identification of about 80% of the compounds in the EPA's HAPs list. The library in the OAM software is expandable and compounds can easily be added to the system as needed.

Table 1. List of target HAPs and related species during this campaign

Species			Instrument	Resolution	Institution
Gas Phase					
VOCs	PAH	Benzene, C8 aromatics (sum of xylenes and ethylbenezene), C9 aromatics (sum of trimethylbenzenes, propyl benzenes and ethyltoluenes)	PTR - MS	~ 2 -3 min	UofU
	Carbonyl	Acetaldehyde, Acetonitrile, formaldehyde, C3-C6 ketones			
	Others	Carboxylic acids, methanol, isoprene			
Others		CO, Ozone, NOx	Various	~ 1 min	DAQ
Particulate Phase					
Organic compounds	PAHs, Others	Phenanthrene, Fluoranthene, Oyrene, Benzo[a]anthracene, Benzo[*ghi*]flour-anthene, Benzo[a]pyrene, Naphthalene, Toluene, Styrene, Phenylenediamine, Pentachloronitrobenzene, Quinoline, Levoglucosan, Dehydroabietic acid, Hopane	OAM	hourly	BYU
Black carbon (BC)			Aethalometer, Sunset Carbon Monitor	hourly	
Inorganics	Anions	Nitrate, sulfate, chloride, ammonium	URG AIM monitor	hourly	DAQ
	Cations	Sodium, Calcium, Potassium, and Magnesium			

Total $PM_{2.5}$ mass			FDMS TEOM	hourly	BYU
Meteorological Parameters by UofU (leveraging)					

c) Data Analysis

A comprehensive approach will be taken to analyze the dataset. The analysis will occur in three major steps as described below.

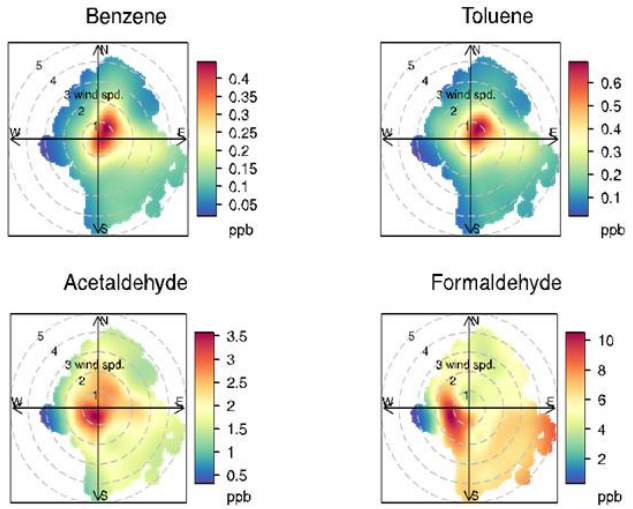

Figure 3. An example of the data analysis conducted on a similar data obtained in Baasandorj et al. This plot shows spatial distribution of sources of HAPs in St. Louis, MO. Here the aromatics are enhanced during Northeasterly winds while formaldehyde shows enhancement during Southeasterly winds, which brought biogenic precursors to the site.

1) Interpret the dataset in terms of spatial and temporal variation, and trends. The high time resolution measurements and meteorological parameters will enable us to investigate the spatial and temporal variation in the ambient HAPs levels and establish the diurnal, weekly and seasonal trend of these species.

2) Identify and characterize the sources of HAPs in and around West Valley City. The temporal variation in concentration of a particular species is driven by variations in its emission sources and atmospheric processes. Hence, we will use the diurnal and seasonal trend of HAPs to deduce whether their sources are primary, secondary or transport, and biogenic or anthropogenic in origin. Further analysis of the related species (precursors, oxidation products, markers) will help better characterize the specific source and its spatial distribution. Fig. 3 is an example of such analyses.

3) Determine the relative contribution of various source types to the ambient levels of HAPs in the gas phase and particulate matter.

3a) Formaldehyde and acetaldehyde. We will utilize two different approaches to deduce the relative contributions of primary emissions and secondary sources resulting from oxidation of biogenic and anthropogenic VOCs to the ambient levels of formaldehyde and acetaldehyde. The first approach is to use the variation patterns described above and tracer-tracer correlation. We will explore the relationship between the target species and a wide suite of chemical tracers including i) isoprene and its oxidation products (a tracer for primary and secondary biogenic sources), ii) methanol and carboxylic acids (biogenic and mixed origin), iii) methyl ethyl ketone (MEK) (mostly anthropogenic in origin; could be used as a tracer for secondary anthropogenic sources), and iv) acetonitrile (a tracer for biomass burning) and use multiple regression analysis for source apportionment. The second approach will involve PMF analysis, a variant factor analysis with non-negative factor elements [Paatero 1997, Ulbrich et al. 2009] as described below.

3b) Particulate HAP and diesel particulate matter analysis. The analysis of the particulate data will occur in 3 steps:

- **Interpretation of the GC/MS monitor data.** The OAM software will identify target compounds, based on retention time, observed spectra, and comparison with the primary compound database for: i) all identifiable PAH compounds in the sample; ii) all particulate compounds in the EPA HAPs list which are included in the NIST database or for which data from standard compounds can be added; and iii) all compounds useful in a PMF source apportionment analysis of the dataset, including compounds in Table 1 and those outlined in Lin et al. [2010].
- **PMF interpretation.** The data obtained from each sampling campaign will be used in PMF analysis as both joined and separate datasets. Other hourly gaseous and meteorological parameters collected at the site will aid in the source apportionment analysis. Drawing upon our past experience with such rich datasets [Eatough et al., 2008, 2009, 2015], we will be able to identify gasoline and diesel sources, wood smoke emissions, major secondary formation processes in the atmosphere, and specific sources based on the GC/MS marker data.

- **Factor Analysis of the Sources or Atmospheric Processes Associated with Gas Phase Toxic Compounds**. Measurements with the PTR-MS will provide a rich dataset of highly resolved gaseous HAPs. The analysis methods (1 - 3) and PMF analysis will identify many of the factors that are associated with primary and secondary sources of HAPs in this location. A factor analysis will be conducted using these hourly averaged PMF results and the PTR-MS measurements of gas phase HAPs to identify links between the particulate and gas phase HAPs.

d) Environmental Justice Impacts

The measurements will take place in West Valley City, an area of lower socio-economic status and ethnically diverse demography (Fig. 1). This community had 17.4% of residents below the poverty level between 2008 and 2012. In addition, the area's location on the Salt Lake Valley floor makes it susceptible to a buildup of extremely high levels of $PM_{2.5}$ and other pollutants during winter months. The area is impacted by the emissions from local industries and refineries located at the northern edge of the city and the several major highways running on its eastern and northern borders. The eastern part of the town is below the landing approach paths for the Salt Lake City International Airport. These conditions create a disproportionately high population exposure to air pollutants compared to the rest of the metropolitan area. Due to adverse health impacts of air toxics including higher cancer risk, and increased risk for neurological, cardiovascular, and respiratory diseases, the proposed study will be vital in determining the community exposure and assessing the risks associated with exposure to HAPs for this underserved community.

e) Community Collaboration/Outreach

Drawing upon Utah's legacy of civic engagement, this program will target two groups: the West Valley City community in general and school age children. We will aim to *i*) describe the linkages between various emission sources and their effect on air quality and *ii*) help the community learn more about health effects of air toxics through public outreach meetings. We will conduct annual outreach meetings in coordination with Univ. of Utah's University Neighborhood Partners (UNP; http://partners.utah.edu/home/), which was created with the express purpose of creating greater civic engagement with surrounding communities, such as minorities and the socio-economically disadvantaged population.

The K-12 outreach program will develop creative ways to engage students in learning about air quality and health. Activities include fun quizzes, coloring, and essay competition on solutions to reduce air pollutants (for older kids). During the community outreach meetings, we will make a presentation at the UNP center in West Valley City showing real-time air toxics data and address public concerns. We will provide information about air quality resources available to the public.

f) Environmental Results: Outcomes, Outputs, Performance Measures

The main outputs of this study include a real time, high quality, comprehensive dataset of HAPs and related species and publications on their impact on air quality and source apportionment. Specific outputs will include the following:

- Comprehensive dataset from two monitoring campaigns
- Analyses and interpretation of the monitoring data, including: Spatial and temporal variability analyses, a source apportionment (PMF) analysis, and determination of community specific impact of HAPs in West Valley City, UT and the greater Salt Lake City metropolitan area
- Publicly available HAPs data and findings via a report on the DAQ webpage
- Quarterly Reports including a discussion of technical progress, planned activities for the next quarter and a summary of expenditures
- A progress report assessing the degree to which outputs have been met, and the outlook for reaching short and mid-term outcomes
- A final report reassessing the project, and outlook for reaching all outcomes including long-term outcomes

The outcomes of this project will include:

Short-term

- Analyses based on the wind direction, time of the day and season for source characterization
- Identification of HAPs with levels above relevant health exposure thresholds in West Valley City

Mid-term

- An evaluation of relative contributions of different sources (local industries, refineries, wood burning, on-road sources and transport) to the ambient levels of HAPs
- Specific identification of diesel HAP particulate matter.
- Better understanding of the impacts of reactive PAHs on air quality in the Salt Lake Valley
- Provide baseline data for future modeling and health effects assessment
- A better informed community on HAPs issues, and community action to mitigate HAPs
- Possible State policy recommendations affecting HAPs

Long-term

- An estimation of the urban population exposure risks
- Improved community understanding of the air quality and exposure risks
- Reduced HAPs emissions
- Reduced human exposure to HAPs

Performance Measures:

In order to accomplish a thorough evaluation of the project, the following criteria will be used to determine the success of each of the following:

Data collection

- Did the quantity of data meet expectations, monitors collected data throughout the majority of the expected monitoring period?

Data Analysis

- Was each of the three analysis steps completed on schedule?

Data Summary

- Were comprehensive reports of findings developed using the data and data analyses from the study?
- Were quarterly, progress, and final reports completed on schedule?

Community Outreach

- Were steps taken to ensure community involvement in the study?
- Were data, data analyses, and reports made publicly available?

Additionally, to ensure that the project in on track and that resources are being used effectively and efficiently, at the writing of each quarterly report a brief internal examination of the project will also be carried out.

g) Programmatic Capability and Past Performance

DAQ received partial funding for an EPA Exchange Network (EN) grant for FY 2013 to upgrade and enhance the Utah Department of Environmental Quality Interactive Map. This project was begun in October, 2013 and is complete as of December, 2014. Patrick Barickman has been with DAQ for 22 years and is currently the manager of the Technical Analysis group. He will be the project manager for this proposal. Roman Kuprov has been an Atmospheric Chemist with DAQ for the past five years. His area of research involves source apportionment and characterization, speciation, carbon isotope analysis, and the analysis of Utah's HAPs monitoring data.

The University of Utah group possesses extensive experience in the measurement, modeling, and analysis of trace gases. Prof. John Lin is the leader of a state legislature-funded project on exceptional events and light rail-based measurements of greenhouse gases and $PM_{2.5}$ in Salt Lake City. Recent publications include the development of a new source apportionment method [Lin and Wen, 2014] and modeling of ammonia/ammonium [Wen et al., 2013]. Dr.

Munkhbayar Baasandorj has worked for the Chemical Sciences Division at National Oceanic and Atmospheric Administration (NOAA) for 4 years as a research scientist and worked for the University of Minnesota for 2 years as a postdoctoral researcher in atmospheric chemistry. She has expertise in ambient monitoring of volatile organic compounds by PTR-MS. She will be in charge of the deployment and operation of PTR-MS instrument, and processing and analyses of the PTR-MS data.

The research group at BYU has been involved in air sampling, instrument development and investigation of the effects of particulate matter on human health for over 30 years. Recent publications include a source apportionment study conducted in Salt Lake Valley [Kuprov et al. 2014] as well as a study on the effects of particulate water vapor on light scattering [Cropper et al., 2013]. Dr. Jaron Hansen has been researching air pollution and air pollution control for over 17 years. His research specialty includes development of new instrumentation for detection of carbonaceous material in particulate matter and the formation mechanism of aerosols. Paul Cropper, a PhD graduate student in the group of Dr. Hansen, has experience in both source apportionment analysis using Positive Matrix Factorization and has worked to develop the Organic Aerosol Monitor (patent pending).

h) Detailed Budget Narrative

A detailed description of the budget necessary to undertake and fully complete this project is given in Table 2.

Table 2. Proposed budget for project.

BUDGET DETAIL				
PERSONNEL (All Listed are 100% FTE)	**Annual Salary**	**% of Project Time for 1st Year**	**% of Project Time for 2nd Year**	**Total EPA Funding**
Environmental Program Manager	$81,700	2%	2%	$3,268
Environmental Scientist III	$62,171	13%	15%	$17,408
TOTAL PERSONNEL				**$20,676**
FRINGE BENEFITS				
Calculated based on personnel amount, and includes:				
Retirement, 401k, Social Security, Medicare, Workmans Comp,				
Unemployment Insurance, Long Term Disability, Termination Additive				
TOTAL FRINGE BENEFITS	**calculated at:**	**50%**		**$10,338**
TRAVEL				
				$0
TOTAL TRAVEL				**$0**
EQUIPMENT	**Cost/Unit**		**QTY**	
				$0
TOTAL EQUIPMENT				**$0**
SUPPLIES				
Ambient Ion Monitor Supplies				$10,600
TOTAL SUPPLIES				**$10,600**
CONTRACTUAL	**Hours**	**Rate**		**Total**
				$0

TOTAL CONTRACTUAL				**$0**
OTHER				
Building & Site Rental, Utilities, LAN/WAN, Phone, Printing /Photocopy				$1,540
Subaward to University of Utah for the measurement and analysis of gas phase PAH, carbonyls, and other organics, using Proton Transfer Reaction–Mass Spectrometry (PTR-MS)				$158,000
Subaward to Brigham Young University for the measurement of particulate phase organic compounds using a GC/MS Organic Aerosol Monitor (OAM). Perform factor analysis using the entire suit of measurements for source apportionment. $124,900				$150,000
TOTAL OTHER				**$309,540**
TOTAL DIRECT				**$351,154**
TOTAL INDIRECT (Based on OMB Circular A-87 Cognizant Agency Negotiation Agreement)		**12.40%**		**$3,846**
TOTAL PROJECT BUDGET				**$355,000**

i) Leveraging

The State of Utah DAQ as well as the Brigham Young University and the University of Utah will leverage the EPA's funding with their own in-kind contribution of monitoring equipment. The leveraging volume was adjusted for the actual deployment period of the instruments from their original costs:

1. O_3, CO, NOx analyzers $16,250
2. Ambient Ion Monitor $25,000
3. PTR-MS $175,000
4. Organic Aerosol Monitor $25,000
5. Meteorological Sensors $500
6. TEOM $6,750

Total: $248,500

The in-kind contribution from the DAQ and the local universities comes to $248,500 while the grant proposal seeks $355,000 of EPA funds to complete this project.

j) References

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