Application to the VIU Regional Initiatives Fund Committee

Date of Call:	November 15, 2018
VIU Researchers:	Jon Davidson, Nick Davey, Chris Gill, and Erik Krogh
Principle Investigators:	Erik Krogh and Chris Gill
Community Partners:	French Creek Pollution Control Centre, Regional District of Nanaimo
Cash Sponsors:	Regional District of Nanaimo, Engineering Services Department
In-kind Sponsors:	Applied Environmental Research Laboratories, Advanced Diploma GIS, Bohdan Hrebenyk (retired Climatologist and Odour Specialist)
Amount Requested:	**$20,000**
Project Title:	***French Creek Odour Mapping Project***
Project Timeline:	Jan, 2019 – March, 2020

Executive Overview

This project is aimed at identifying the sources and distribution of volatile organic compounds (VOCs), with particular attention to those associated with odours in and around a wastewater treatment facility operated by the Regional District of Nanaimo. The release of VOCs can have both direct and indirect impacts on air quality. In particular, odourous compounds can have a negative impact on the quality of life of residents in the surrounding areas [1,2].

Researchers at Vancouver Island University's Applied Environmental Research Laboratories will work with operators and engineers at the French Creek Pollution Control Centre (FCPCC) using the mobile mass spectrometry lab (Figure 1). This research-purposed vehicle, is equipped to make continuous real-time measurements of volatile organic compounds, greenhouse gases (including methane), particulate matter, nitrogen oxides, and ground level ozone and can be operated while stationary or while driving. The resulting data can be visualized and interrogated as independent layers on neighborhood scale maps, displaying the geospatial distribution of atmospheric constituents impacting the local area.

VOCs can arise from point and diffuse sources, and their concentrations can vary widely over time and space due to variable emission rates and atmospheric dispersion resulting from localized weather and topography. Odourants can arise from a variety of human (anthropogenic) and natural (biogenic) sources [3] and their influence on the local area can vary dramatically with the season [4]. This project will examine odourant sources, including those at several stages in the wastewater treatment process, as well as unrelated sources in the surrounding region with the objective of using mass spectrometry to provide unique chemical fingerprints. We will then map the distribution of various odour profiles and several targeted chemical concentrations in time and space.

This project will provide both quantitative and qualitative molecular level information to identify the sources and distribution of odourants, as well as their seasonal variability in the French Creek region on eastern Vancouver Island. In addition to supporting unique student training opportunities, this project will provide baseline data that can be used to compare the treatment plant's impact to the local area before and after the proposed expansion. The resulting data can be used to depict how atmospheric chemical concentrations and compositions vary over time and space. The science described here supports evidence based strategic planning and will be used to inform sustainable policy initiatives.

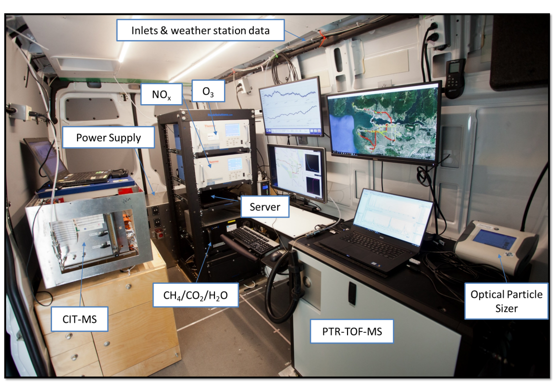

Figure 1: AERL Mobile Mass Spectrometry Lab

Regional Relevance

Recent growth on Vancouver Island has resulted in higher density developments and in some cases a closer proximity between residents and industrial operators. This can lead to concerns about potential environmental impacts and their effects on quality of life. Over the past several years there appears to be a growing number of odour complaints from residents in the vicinity of the FCPCC. Nuisance odours can arise from a number of human activities, including wastewater treatment [5], composting [6], fish processing, pulp mills, and agriculture [7] as well as natural processes including biomass decomposition occurring in swamps, estuaries and soils [4].

This project focuses on mapping VOCs associated with odours in the French Creek area on eastern Vancouver Island (Figure 2). The research is aimed at providing background information to the department of engineering services at the Regional District of Nanaimo as they examine options for expansion and possible odour control measures. We will measure and map the concentration of VOCs over several multi-day deployments over the course of the year. In addition, we will develop new data analytics aimed at identifying complex mixtures that can be associated with specific sources of odour complaints [8-9].

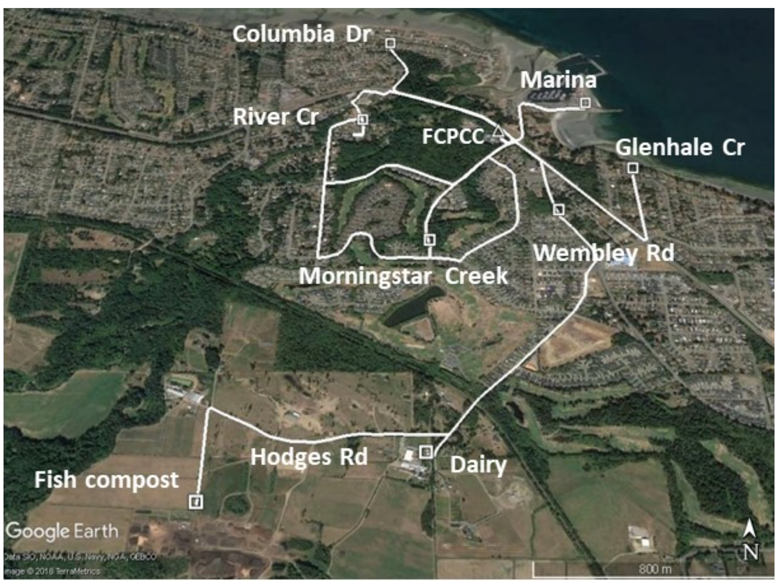

Figure 2: Overview of proposed sampling route for French Creek Pollution Control Center and surrounding area. White boxes on the figure indicate proposed sites for stationary monitoring.

Project Objectives

This project will employ advanced instrumental methods to identify the potential sources and concentrations of VOCs associated with odours at a wastewater treatment facility and the surrounding community. This work will involve the use of mobilized mass spectrometry to analyze molecular fingerprints associated with specific odourants and map chemical concentrations of a set of target compound classes including reduced sulfur compounds, amines, hydrocarbons and volatile fatty acids.

- Identify odour compounds at a wastewater treatment facility and determine how concentrations vary over time and location within the FCPCC site.

- Identify other potential sources of odourant VOCs, including near shore marine environments, green waste facilities, fish processing plants, agricultural sources and freshwater creeks and ponds within a 5 km radius of the FCPCC.
- Produce geospatial maps of target odour compounds in the French Creek area.
- Determine the seasonal variability of targeted compounds and odour plumes.
- Assist regional government partners in implementing odour control measures when and where they are needed.
- Support research and development initiatives that are aimed at using real-time mass spectrometry to identify and apportion sources of volatile organic compounds, and contribute to atmospheric dispersion models.
- Encourage meaningful scholarly connections that respond to community needs in promoting sustainable growth, and protection of the environment.

Academic Context

Our group has pioneered several important developments in the field of direct sampling mass spectrometry (MS) with applications to physiochemical processes [10], bio-analytical chemistry [11], and environmental science [12-13]. This work positions us at the leading edge of the research and development that enables real-time, *in situ* measurements. This approach has several important advantages including providing information 'when' and 'where' it is needed to enable real-time decision support, observe variations over time and space at unprecedented resolution, and inform adaptive sampling strategies to be used in combination with conventional monitoring methods.

We have made substantial progress in our ability to directly measure volatile organic compounds using mass spectrometry in both stationary and mobile laboratory deployments [14]. This includes advances in the design and implementation of a temperature controlled membrane interface and in-line permeation chambers for continuous calibration via stable isotope dilution [15]. These systems have been further modified for in-field use with battery power for remote and mobile applications, miniaturized gas handling systems, and customized software applications for on-line data analysis and real-time visualization [16]. These modifications give us the ability to simultaneously measure and quantify multiple targeted contaminants as well as measure a wide range of VOCs for non-targeted analysis in a moving vehicle.

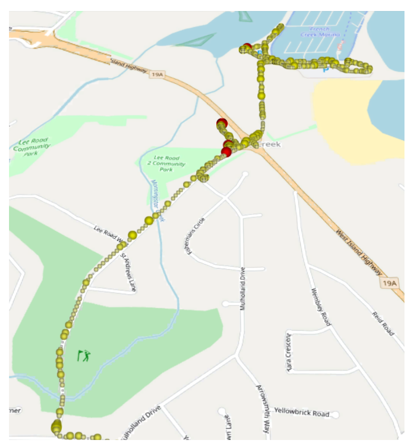

Figure 3: Preliminary data depicting the relative concentration of dimethylsulfide in the French Creek area. Data from 2017 Regional Air Quality Mapping Pilot Project.

The screenshot in Figure 3 shows typical analytical results, illustrating geographically referenced concentration time series visualized in Google Earth™. The MS data track for one of ten measured compounds is shown. The data file can be viewed in real-time by the operators and interrogated later. Metadata including wind speed and direction can also be displayed as well. This work represents a significant milestone in the evolution of environmental analysis from the lab to the field, demonstrating mobile MS as an approach to assess the distribution of trace VOCs.

Research Methodology

Consultations and Planning Sessions (Jan – Feb, 2019)
Consultations with FCPCC operators and RDN engineering staff will take place to review sampling routes, schedules and stationary locations. These interactions will guide both route planning and scheduling of sampling. Consultations will occur through a combination of teleconferencing, face-to-face meetings and on-site surveys.

Preliminary trials and site surveys (Mar, 2019)
Preliminary sampling trials will be conducted in early 2019 to characterize our instrument response times and sampling pump rates. These trials will establish site accessibility to specific locations within the treatment plant facility. To determine the odourants associated with a process or location within the FCPCC, we propose pumping air to the mobile mass spectrometry (MMS) laboratory with a small air pump and ¼ inch Teflon tubing. This approach allows for sampling at specific locations within the site that are inaccessible to the research vehicle. In addition to providing a site survey, this data will allow us to identify specific VOC to target for calibration in subsequent data collections.

Data collection (April, July, October 2019 and Jan 2020)
Four multi-day field sampling campaigns are planned for this project to cover seasonal variability. Odour in April can be impacted by near shore marine biomass degradation associated with the spring herring spawn. Warmer temperatures in July can be associated with increased microbial activity and odours within the FCPCC. Sampling in October 2019 and Jan 2020 will complete the seasonal variability. We propose a sampling protocol that consists of a central site (FCPCC) and several satellite sites (e.g., French Creek Marina, Morningstar Creek, Hodges Rd) as depicted in Figure 2. Each route will begin with the mobile lab driving around the central site and sampling the air for 20-30 min. The mobile lab would then be driven through the surrounding neighborhoods with ~20 min stops at the various satellite sites. Field campaigns will include daytime and evening data collections as odour complaints often tend to occur between 5:00 to 6:00 PM.

Data analysis (Aug, 2019 – Jan, 2020)
The direct mass spectrometry measurements of trace organic compounds will be employed to map targeted compounds and employed to fingerprint complex mixtures of odourants. We will apply multivariate statistics to discriminate odourous air samples based on the full scan mass spectral data (Figure 4). Pairing MS data with GPS location will be used to display individual concentrations and odour classifications as a data layer on a Google Earth map. Analysis of each time series will generate several statistical outputs, including ranges, means, and distributions. Geospatial maps will be analyzed to identify potential point sources volatile organic compounds. Combined with the additional on-board air quality and meteorological sensors, we will determine if we can classify air sample composition and identify dominant sources of influence in the French Creek area.

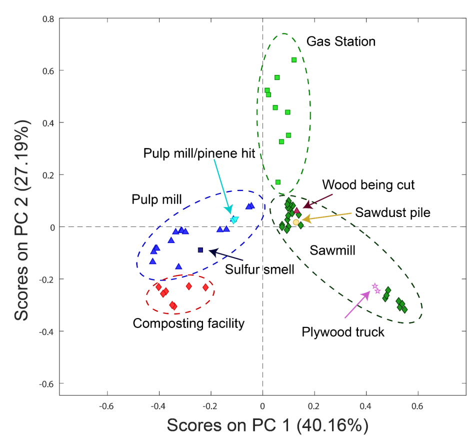

Figure 4: Principle component analysis of direct sampling mass spectra obtained from a proton transfer time-of-flight mass spectrometer operated in moving vehicle. Data obtained in Nanaimo and surrounding areas in 2017.

Stakeholder workshops (Aug, 2019 and Feb, 2020)
We anticipate holding two stakeholder workshops with funding partners and the VIU research team. The first of these is scheduled for Aug 2019 and will provide an opportunity for participants to report progress and receive feedback. The second is scheduled near project completion, which will include a presentation of preliminary results.

Community presentations (Feb-Mar, 2020)
The VIU research team will be available to attend and share information with the public in consultation with and at the invitation of RDN staff. These will be held in a central location at the VIU Parksville campus and or RDN facilitiy.

Reporting (Mar, 2020)
A short report summarizing the data including a series of representative maps depicting the geospatial distribution of major volatile organic compounds will be generated along with box plots showing ranges, means, and the statistical distribution in concentrations. Data can be visualized by project partners as an interactive digital 'kml' data file that can be interrogated on a Google Earth™ platform for meta data including location and time of sampling. Examples of geospatial air quality maps similar to those anticipated in this proposed project are shown in Figures 3. A meeting with project partners will be planned to further discuss the results of the project.

Knowledge Mobilization

Krogh and Gill have a shared vision of the importance of knowledge mobilization and the training of highly qualified personal ranging from the early exposure of undergraduate students with a research environment to graduate student projects and post-doctoral researchers. The AERL facility is closely integrated with experiential learning opportunities provided by Vancouver Island University.

This project is an excellent example of science in the public interest. The work will be guided by public servants in regional government, and contribute original scientific data that supports evidence based public decisions. Consequently, knowledge mobilization is an integral component of the project. Project partners will be invited to participate in bi-monthly conference calls to set strategic priorities, discuss logistics and review progress. Two face-to-face workshops are planned at the mid-point and upon completion of the project. These will be held at the Parksville – VIU campus, which is centrally located within 45 minutes travel time for all project partners.

Project partners will facilitate public outreach events and the principal investigators will be available to present information to the general public through town hall discussions, open house events, and open board meetings. Finally, the mobile mass spectrometry lab is itself a powerful community engagement tool. The high-tech nature of the equipment and highly qualified personnel involved provide for numerous impromptu conversations on topics ranging from the specifics of air quality to the role of science in society more generally.

Community Project Partners Providing Funding

Regional District of Nanaimo – Mike Squires, AsT, Project Engineer, Engineering Services, and Chris Kerman, Chief Operator FCPCC. The RDN is supporting this applied research activity to inform strategic planning and community engagement related to expanding the wastewater treatment facility at the French Creek Pollution Control Centre. The research described here will fingerprint volatile organic compounds associated with odour complaints at the neighborhood scale. A $20,000 funding contribution is confirmed for 2019 and a letter of support is appended to this proposal.

Project Partners

Bohdan (Dan) Hrebenyk, M.Sc., is a Climatologist and Senior Environmental Scientist involved in air quality monitoring and assessment, air pollution dispersion modelling and environmental impact assessments. He has conducted numerous studies involving ambient odour emissions monitoring and/or modelling, and has completed odour evaluations on wastewater treatment plants in the Greater Vancouver Regional District and remains as a consultant to Metro Vancouver on odour issues.

Brad Maguire – VIU, Department of Geography, Advanced Diploma in GIS Applications (ADGISA). This project will result in the generation of geospatial data layers that contain a variety of molecular level chemical information. These data sets can be displayed on landscape maps, such as keyhole markup language files visualized on Google Earth. We will work with GIS experts at VIU and the RDN to involve ADGISA student interns.

Proposed Budget RIF

Summary of Project Revenues

Project Partner	External Cash Contributions	Internal Cash Contributions	In-kind Contributions
RDN	$20,000 (confirmed)		✔
VIU RIF		$20,000	
VIU in-kind			$21,100
Dan Hrebenyk			✔
Totals	**$20,000**	**$20,000**	**$21,100**

✔ additional in-kind contributions; technical advice, background and/or meeting space.

Summary of VIU In-kind contribution

Expense	Budgeted
VIU Admin Support ($50/hr x 50hr)	$2,500
VIU Meeting Rooms ($100/d x 6d)	$600
VIU Vehicle Use ($100/d x 16d)	$1,600
AERL Instrumentation ($250/d x 16d)	$4,000
Student Office Space ($600/desk/mth)	$2,400
Faculty (hours)	$10,000
Totals	**$21,100**

Summary of Project Expenses

Expense	Budget
Undergraduate students	$8,120
Graduate Student	$8,000
Research Associate	$15,000
Supplies & Maintenance	$3,794
Travel and Food	$2,586
Knowledge Mobilization	$2,500
Totals	**$40,000**

Budget Justification

Undergraduate Student Researcher: We will hire one full time undergraduate student to work on the project for 16 weeks in the summer of 2019 and two part-time students in the Fall of 2019 at a base rate of $15/hr. After additional contributions (EI, CPP vacation), the cost to the project is $16.80/hr. We anticipate receiving a Canada Summer Jobs wage subsidy for the summer position, which contributes $4/hr ($2,240). We will also apply for two Work-Opportunities students to work part-time during the semester. The cost to top them up to $16.80 is an additional $476 per semester. We have a strong track record of receiving support for projects related to environmental protection, such as proposed here. The total cost to the RIF project for undergraduate students is therefore anticipated to be $8,120.

Graduate Student Researcher: One graduate student will be directly involved in this project over the course of the project. Graduate students receive research stipends ranging from $4,000 - $8,000 per semester depending on other academic activities (scholarships and teaching assistantships). We have budgeted two semesters of graduate student stipend at $4,000 for a total of $8,000.

Research Associate/Technical Support: This project requires considerable technical support in maintenance, repairs, and upgrades of instrumentation, software, and hardware. We have budgeted for 300 hours at rate of $50/hr for this support, for a total of $15,000.

Supplies and Maintenance: All major equipment and instrumentation for this project, amounting to over $1M of infrastructure, are in place with the Mobile Mass Spectrometry Lab (CFI Project 32238). Supplies associated with calibration standards, high purity gases, and sampling are anticipated to cost $2,294. We have also included an additional $1,500 for software licenses, pro-rated contribution to vehicle insurance costs, and a contingency for minor instrument repairs. The total supplies and maintenance budget associated with the project is $3,794.

Travel: This project involves extensive field-work and associated travel costs including approximately 1280 km of driving the mobile lab and support vehicle with a crew of three people. We anticipate 12 full days of sampling throughout, plus an additional 4 days of sampling in response to specific events/meteorological conditions. We have budgeted a total of $2,585 in travel costs for this project.

Vehicle costs: $665 (1280 km x $0.52/km)
Per Diem Food costs: $1,920 ($40/d x 16 d x 3 crew)

Knowledge Mobilization: We will work with the RDN to coordinate public outreach and knowledge mobilization, including two events to be held at VIU (Parksville campus). These costs are anticipated to be $5,000, but will be cost shared through in-kind contributions. We budgeted $2,500 to support this activity.

VIU in-kind contributions are based on In-Kind Valuation Guidelines for VIU Service, Equipment and Facility Fees at:
https://isapp.viu.ca/VIUWEB/commViewer/docShow.asp?doc_id=34716&app_id=LCQSFOGKVZPXAGAXMXFG2632670

Lead Project Personnel

The research team has direct experience developing and field-testing instrumentation in harsh environments including heavy oil production and upgrading facilities in Alberta, Canada, and transportation corridors in the Pacific Northwest (Seattle-Tacoma, Fraser Valley). The faculty co-applicants have an excellent complement of skills and experience that creates a rare opportunity for advances and innovations relevant to the protection of human and environmental health. Gill and Krogh are recognized as leaders in Canada in the area of environmental mass spectrometry, chemical analysis, and environmental chemistry. They are co-directors of the CFI funded (#2122) Applied Environmental Research Laboratories and co-PIs on the Mobile Mass Spectrometry Lab (#32238) at Vancouver Island University. They have held NSERC Discovery grants since 2004, co-authored 30 peer reviewed publications, over 100 conference presentations, and numerous technical reports for external project partners. Together, they have supervised well over 100 undergraduates, 10 graduate students, and 3 post-doctoral researchers.

Trevor Michalchuk – AERL Undergraduate Student
Trevor is senior undergraduate student completing a B.Sc. Major in Biology and Minor in Chemistry. Trevor has been involved in several mobile field sampling campaigns.

Jon Davidson – AERL Graduate Student
Jon Davidson is a MSc candidate in Chemistry at the University of Victoria, conducting his research in the AERL at VIU. His project focuses on the development of mobile mass spectrometry for air quality assessments and their applications to human health.

Nick Davey – AERL Post-doctoral Research Fellow
Dr. Nick Davey is a part-time research associate in the AERL with an interest and technical expertise in mobilizing instrumentation for high precision chemical measurements. Davey has been directly involved in numerous field campaigns and is uniquely qualified to make significant contributions to this project.

Chris Gill – VIU Faculty member, Chemistry (Co-Director, AERL)
Dr. Gill has specific expertise in analytical instrumentation development, laser spectroscopy, and mass spectrometry. He has worked on the development of MS for the *in-situ* measurement of ultra-trace analytes in air and water at low parts per trillion levels. Gill's longstanding experience and expertise with analytical instrumentation development and mass spectrometry has been central in the advancement of direct sampling MS strategies and mobile mass spectrometric systems.

Erik Krogh - VIU Faculty member, Chemistry (Co-Director, AERL)
Dr. Krogh has expertise in physical organic and environmental chemistry that relates to the understanding of the fate and distribution of contaminants in the environment, including both air and water quality. He has contributed insight to mass transport in membranes and applied MS to the *in-situ* monitoring of reaction dynamics of trace organics in natural waters and the atmosphere. His experience and expertise has contributed to improved analytical performance characteristics, adapting on-line techniques for mobile monitoring, and the application of chemometrics to environmental chemistry.

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APPENDICES

Appendix 1: Timelines & milestones for Regional Air Quality Mapping Pilot Project (Jan 2019 – Mar 2020)

Phase	Task	Timeline	Responsibility	Output
PROJECT DEVELOPMENT	Partner Consultations (multiple)	Jan-Feb 2019	EK, CG	Review priority pollutants and locations
	Preliminary Trials & Site Survey	Mar 2019	TM, JD, ND	Identify key pollutant and odour sources
	Planning Meeting	Mar 2019	EK, CG, JD, ND	Review sampling plan with partners
PROJECT IMPLEMENTATION	Data Collection I	April 2019	TM, JD, ND	Collect full suite of Air Quality data
	Data Collection II	July 2019	TM, JD, ND	Collect full suite of Air Quality data
	Data Collection III	Oct 2019	TM JD, ND	Collect full suite of Air Quality data
	Data Collection IV	Jan 2020	TM, JD, ND	Collect full suite of Air Quality data
ANALYSIS, REPORTING & WRAP-UP	Data Analysis Spring/Summer	July 2019	JD, ND	Generate maps and chemometrics
	Stakeholder Workshop I	Aug 2019	EK, CG, JD, NG	Report on progress
	Data Analysis Fall/Winter	Jan 2020	JD, ND	Generate maps and chemometrics
	Stakeholder Workshop II	Feb 2020	EK, CG, JD, NG	Report on progress
	Community Presentations	Feb – Mar 2020	EK, CG, JD, ND	Public outreach on request
	Final Report	Mar 2020	EK, CG, JD, NG	Maps and interactive digitized data

TM = Trevor Mickalchuk (undergraduate student)
JD = Jon Davidson (MSc student)
ND = Nick Davey (research associate)
CG = Chris Gill (PI)
EK = Erik Krogh (PI)

Appendix 2: List of Potential Target Analytes Associated with Wastewater

Odour Compound	Proton Affinity (kJ/mol)	PTR-MS	CIT-MS	GHG analyzer	Ozone analyzer
Acetaldehyde	768	ü			
Ammonia	854	ü			
Dibutylamine	969	ü			
Dimethylamine	923	ü			
Dimethylsulfide	839	ü			
Ethylmercaptan	798	ü			
Hydrogen sulfide	712	ü			
Methane	552			ü	
Methylamine	896	ü			
Methylmercaptan	784	ü			
Ozone	-				ü
Pyridine	924	ü			
Propylmercaptan	795	ü			
Sulfer dioxide	676		ü		
Trimethylamine	942	ü			
Benzene	795	ü	ü		
Toluene	784	ü	ü		
Ethylbenzene	788	ü	ü		
1,1,1-Trichloroethane	-		ü		
Vinyl chloride			ü		
Phenol	817	ü	ü		
Acetone	823	ü			
Hexanes	-		ü		
2-Butanone	827	ü			
Carbon tetrachloride	-		ü		
Bromoform	-		ü		
Chloromethane	-		ü		
Bromomethane			ü		
Acrolein	797	ü			
Phenyl mercaptan	-	ü			
Acetic acid	784	ü			
Propanoic acid	797	ü			
Butanoic acid	-	ü			

Appendix 3: List of Air Quality Instrumentation in Mobile Laboratory

Ozone
Thermo-Fisher 49i UV photometric Ozone Analyzer. Measures ground level ozone (O3) in low parts-per-billion range.

Nitrogen oxides
Thermo-Fisher 42i Chemiluminescence NO-NO2-NOx Analyzer. Measures both nitric oxide (NO) and nitrogen dioxide (NO2) in low parts-per-billion range.

Greenhouse Gases
Los Gatos Research Near Infrared Integrated Cavity Optical Spectroscopy Fast Greenhouse Gas Analyzer – 40r. Measures Carbon dioxide, Methane and Water vapour.

Particulate Matter
TSI OPS 3330. Optical Particle Sizer counts particulate matter in up to 16 user defined size distribution bins ranging from 0.3 – 10 microns. Output can be correlated to PM1, PM2.5 and PM10.

Volatile Organic Compounds
Griffin ICX-400 cylindrical ion trap mass spectrometer with an in-house constructed membrane introduction sampling system. Measures whole air samples and is well suited for non-polar volatile organic compounds, such as benzene-toluene-ethylbenzene-xylenes (BTEX) and is capable of tandem mass spectrometry for improved selectivity. Detection limits in low parts-per-billion.

Ionicon PTR-TOF 1000 Proton Transfer Reaction Time-of-Flight Mass Spectrometer. Measures whole air samples for volatile organic compounds and is well suited for polar and non-polar compounds down to levels of parts-per-trillion.

Additional on-board accessories include a weather station recoding, ambient temperature, barometric pressure and humidity; sonic anemometer measuring wind speed and direction; and high resolution global positioning system for accurate locational information.