Action: Conduct Air Monitoring Near the Omnitrans Bus Yard to Identify Potential Odor Emissions

Background and Objectives

Omnitrans is a public transit agency established in 1976 that serves the San Bernardino Valley. The Omnitrans bus yard in the San Bernardino Muscoy (SBM) community is located at 1700 W. 5th Street, in close proximity to Ramona Alessandro Elementary school and residential homes (Figure 1). This facility is used to park, service, and refuel buses on a daily basis. The buses operate on pipeline compressed natural gas (CNG). Although CNG is odorless, Mercaptans are added to introduce a distinct smell as a safety feature, in case of a leak. Odors detected by residents near the Omnitrans bus yard are a major air quality concern for the SBM community steering committee (CSC). Thus, the CSC recommended that the South Coast AQMD work with Omnitrans to determine if the bus yard and related activities are a potential source of odor emissions. This is achieved by conducting air monitoring the Omnitrans bus yard. If persistent elevated levels of pollutants are detected, South Coast AQMD will conduct appropriate follow-up investigations (e.g., on-site testing or other types of data review) and additional monitoring as needed.

Method

Mobile monitoring surveys focused on methane (a tracer of natural gas emissions) and other airborne pollutants were conducted near the Omnitrans facility to identify potential sources of odors. If elevated levels of the pollutants of interest were observed, the reproducibility of the signal was tested by driving a similar route downwind of potential sources multiple times to determine whether those elevated levels were persistent, thus confirming the presence of an emission source.

In addition to the mobile surveys conducted by the South Coast AQMD mobile platform, the South Coast AQMD contracted Aerodyne Research LLC to investigate this issue using its Aerodyne Mobile Laboratory, which is equipped with a real-time “sniffer” system and a suite of near-real-time, next-generation analytical equipment capable of detecting a variety of important pollutants, such as volatile organic compounds (VOCs) and odorous sulfur compounds. These measurements included stationary sampling of road openings, such as manholes and sewer drains, to detect any potential gas leaks in the natural gas infrastructure that can permeate through soil or collect in these underground openings and lead to odor nuisances.

Results

- Methane measurements were conducted in the SBM community and around the Omnitrans bus yard using South Coast AQMD’s mobile platform on five different weekdays between June and December 2019 (see Attachment A for details)

- Enhanced methane concentrations were observed at the southeast corner of the Omnitrans bus yard (near Medical Center Drive and 5th Street) during multiple measurement days (Attachments A and B)
- Overall, the average methane concentration near the Omnitrans perimeter was within typical ambient levels (around 2 ppm) (Attachment A)
- The Aerodyne Mobile Laboratory surveyed the area surrounding the bus yard on three weekdays (Monday 06/24/2019, Tuesday 11/5/2019 and Thursday 11/14/2019) and two weekend days (Saturday 11/2/2019 and Sunday 11/10/2019) to take air quality measurements and sample storm drains and manholes in the area (see Attachment B for details)
- The Aerodyne measurements were characterized by a chemical signature consistent with natural gas that indicate presence of potential emissions from compressed natural gas equipment at Omnitrans and/or from a high-pressure distribution pipeline running underground and along a portion of Medical Center Drive near 5th Street (Attachment B). On 06/19/2020 SoCal Gas conducted independent measurements along the same pipeline and determined that no leaks were present
- In response to elevated methane readings identified through the monitoring activities, South Coast AQMD's Office of Compliance and Enforcement conducted surveillance and an inspection of the Omnitrans Bus Yard in August 2019. No violations of air quality rules or regulations were found at the time of the inspection. Inspectors also issued a Notice to Comply to obtain records, which were provided soon thereafter. Neither those records nor the onsite inspection was able to identify the source(s) of the methane emissions

Next steps

- Continue air monitoring activities to collect additional air pollution measurements near and around Omnitrans bus yard and allow for statistically significant findings
- Continue conducting follow-up investigations at the Omnitrans bus yard facility
- Continue investigating potential emissions from the sewer, and work with SoCal Gas to verify the location(s) of any pipelines near Omnitrans bus yard and evaluate the presence of potential leaks

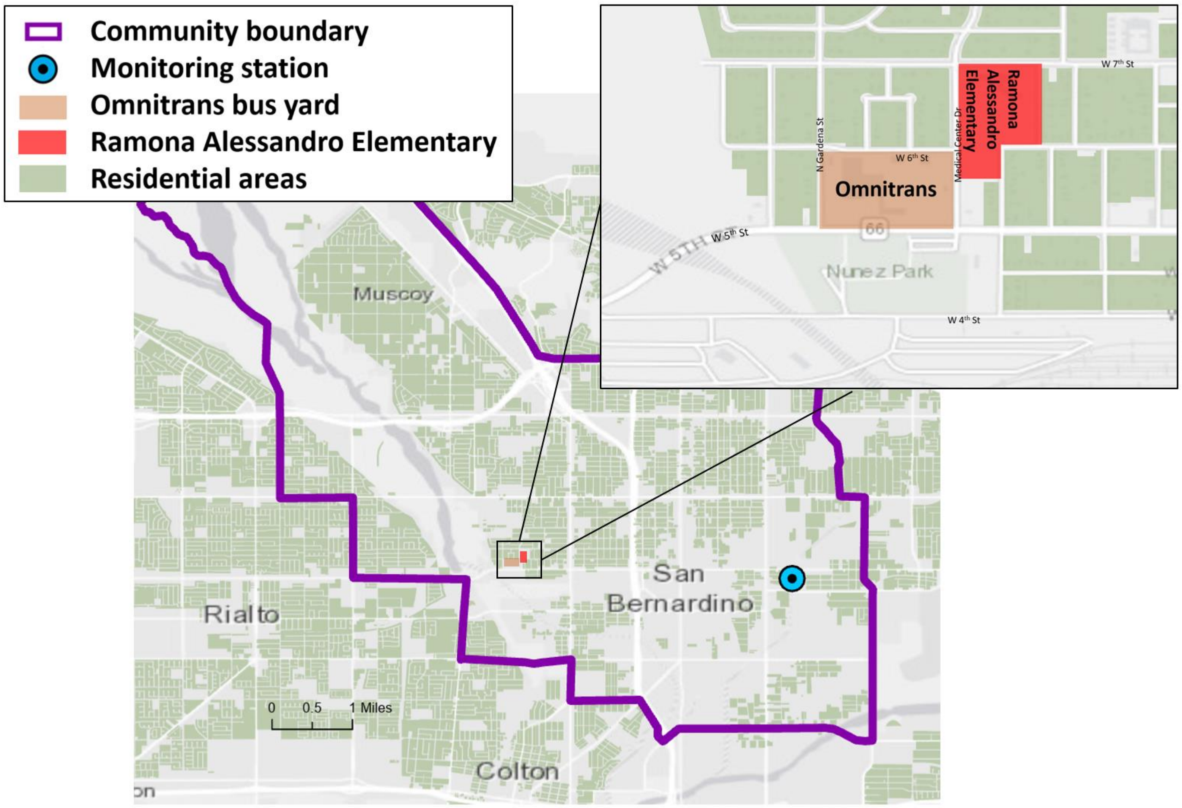

Figure 1 – Map showing the location of the Omnitrans facility and the surrounding area, as well as the location of air monitoring station for baseline measurements operated by the South Coast AQMD

Attachment A

As of June 2020, a total of five mobile surveys have been conducted by South Coast AQMD's mobile platform in the San Bernardino, Muscoy (SBM) community during the second half of 2019 to measure different air pollutants including methane (a tracer for natural gas emissions). Figure A-1 shows the duration and time window for the mobile measurements conducted at and around the Omnitrans bus yard in San Bernardino. As shown in this figure, mobile monitoring was performed at different times of the day on weekdays during the five surveys.

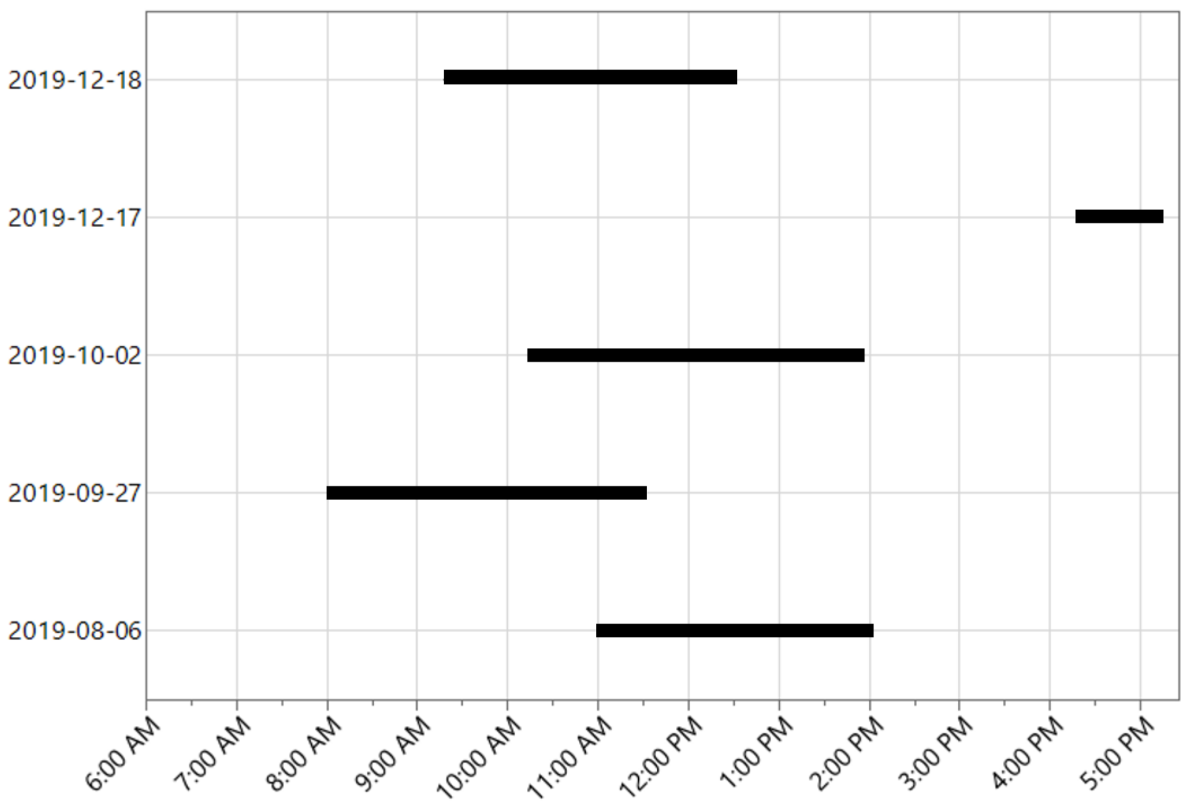

Figure A-1. The duration and time window for the area-wide mobile methane measurements performed near and around the Omnitrans bus yard in the SBM community by South Coast AQMD's mobile platform. The time windows only include hours of active mobile measurements within the community, excluding the commute time between the South Coast AQMD Headquarters and the community

Each survey included multiple passes around the Omnitrans bus yard and Ramona Allessandro Elementary school, as well as area-wide measurements in the community. Multiple passes are made to test the reproducibility of air pollution signals and identify persistent air pollution hotspots. Once an elevated level of methane is detected while driving near the potential source, the plume is mapped by driving away from and downwind of the source. This allows the field operators to perform source identification by detecting the pollution plume and triangulating from the plume back to the source using wind direction data. Figure A-2 shows the combined map for instantaneous methane monitoring near and around the Omnitrans bus yard, as measured by the mobile platform during those five days. Methane is measured in parts per million, or ppm (e.g. one part of the pollutant of interest for a million parts of air) and its background concentration in ambient air is approximately 2 ppm. Persistent readings greater than 3 ppm suggest additional sources, and persistent readings greater than 10 ppm suggest a considerable additional amount of methane is present, either due the presence of a large emission source in the area, or close proximity to an emission source.

As shown in Figure A-2, the mobile monitoring results indicated occasional instantaneous elevated levels of methane at the southeast corner of Omnitrans (Medical Center Drive and 5th Street) during multiple days. It should be noted that this is the only location where persistent elevated levels of methane were observed during multiple measurement days and at different hours, suggesting the presence of one or more potential sources of pollution.

Figure A-2. Combined map of methane concentration from five surveys around the Omnitrans bus yard from measurements conducted between August and December 2019

To investigate the representative methane levels in the area around Omnitrans, individual measurements taken within 30-meter street segments in different passes and on different days were "aggregated" by calculating their the arithmetic average, and shown as colored segments on the map in Figure A-3. The results suggest that while high concentration instances occurred more often on the southeast corner of the Omnitrans facility, the averaged concentration levels (between 2 and 2.4 ppm) varied slightly around the facility, as shown in Figure A-3.

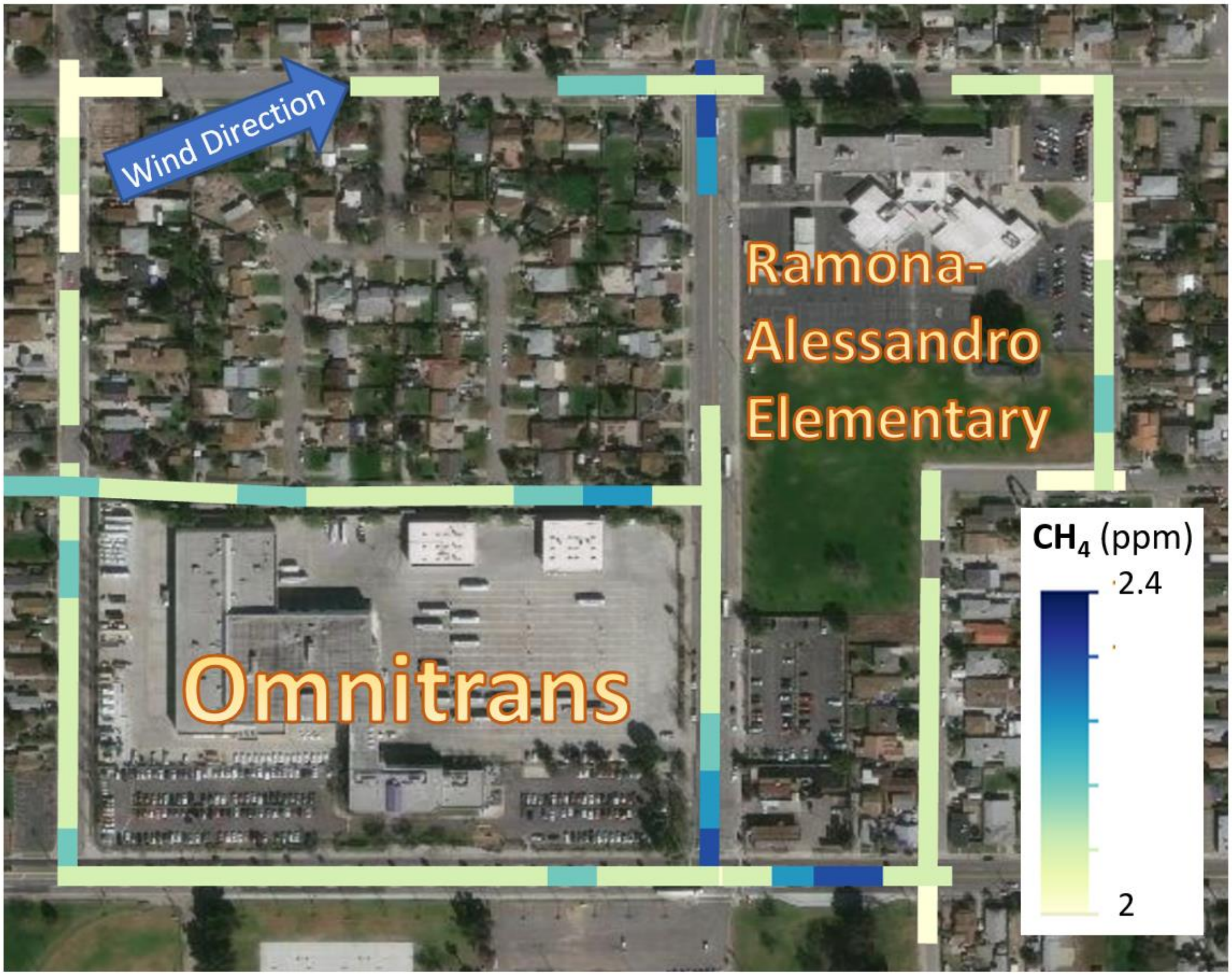

Figure A-3. Aggregated methane concentration from five surveys around the Omnitrans bus yard from measurements conducted between August and December 2019. Each segment shown in the map includes at least 10 data points

To provide context to the levels of methane measured around Omnitrans, the concentrations were compared to those measured elsewhere within the SBM community and against some other mobile monitoring studies that have been conducted by the South Coast AQMD in different parts of the Los Angeles Basin, including neighborhoods around the Los Angeles International Airport (LAX), Aliso Canyon natural gas facility, and Chino Hills. Figure 1 provides a complete picture of the distribution and statistics of the measured methane concentrations in each study. The box plots show the first quartile (Q1), median, and the third quartile (Q3). The distribution plots (shown in dark red) illustrate the distribution shape of the data. Wider sections of the plots represent a higher frequency of measurements on the given value, while the narrower sections represent a lower frequency. The black dots represent the outlying instantaneous methane measurements, while the yellow dots show the average methane concentrations during the entire study period.

Given the high time-resolution monitoring with a mobile platform (~ 3 second), instantaneous spikes in methane levels are not unusual and could be caused by a variety of sources. Mobile monitoring around Omnitrans showed a maximum instantaneous methane level of 13 ppm, which is lower than the maximum levels measured at other locations within the South Coast Air Basin (Figure A-4). It should be noted that these various mobile measurement studies were conducted to investigate different sources of methane emissions some of which, such as the Aliso Canyon natural gas leak in 2016, were very strong, last for several months and had a substantial impact on the community. Other examples in Figure A-4 are presented here only to illustrate the range of methane concentrations measured in different areas in the South Coast Air Basin and to provide context to the measurements around Omnitrans.

The spikes in methane concentrations around Omnitrans were very infrequent as shown by the distribution plots (shown in dark red in Figure A-4). In fact, the most frequent methane measurements around Omintrans and all other studies range around 2 ppm (see the wider sections of the dark red distribution plots in Figure A-4) and, as expected, the average methane concentrations in all mobile monitoring studies are around 2 ppm (see the yellow dots in Figure A-4). These results suggest that while some occasional spikes in methane have been measured around Omnitrans, its range and average concentration around the Omnitrans bus yard is well within the expected ranges measured elsewhere in the Basin.

However the objective of air monitoring is identify potential leaks and, thus, these monitoring activities mainly focused on the identification of air pollution hotspots determined based on detection of persistent elevated levels of pollutants, which could be an indication of presence of an emission source. Air measurement results will be used along with information gathered through facility inspections and outreach to guide future follow-up actions (e.g. potential enforcement actions, if needed).

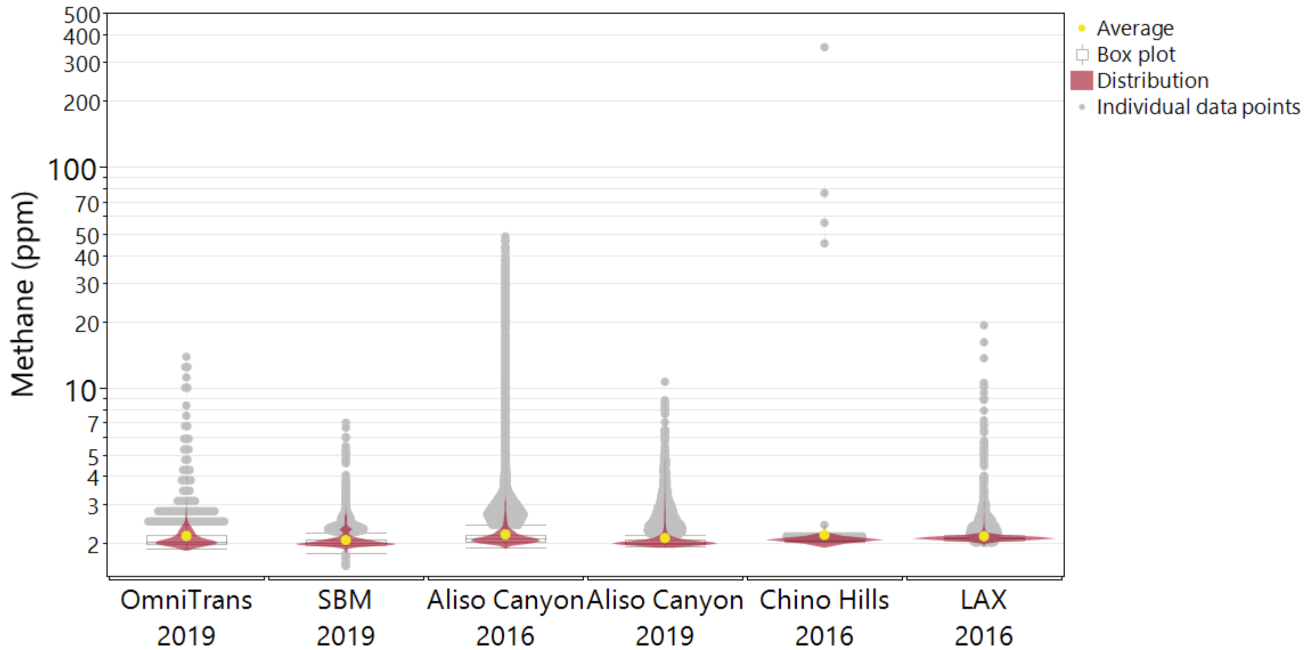

Figure A-4. Distribution and summary statistics of mobile methane monitoring around the Omnitrans bus yard and for other studies conducted by the South Coast AQMD in the South Coast Air Basin. Note that the Y axis is on a logarithmic scale

Attachment B

The Aerodyne Mobile Laboratory (AML) is a mobile platform developed by Aerodyne Research LLC (a research group contracted by the South Coast AQMD) and equipped with a suite of near-real-time analytical equipment capable of detecting a variety of important air pollutants, such as volatile organic compounds (VOCs) and air metal toxics.

Aerodyne's AML visited the area surrounding the Omnitrans bus depot at 1700 W 5th Street in San Bernardino on two weekend days (Saturday 11/2/2019 and Sunday 11/10/2019) and three weekdays (Monday 06/24/2019, Tuesday 11/5/2019 and Thursday 11/14/2019) to conduct air pollution measurements. Figure B-1 shows the duration and time window for the mobile measurements conducted by Aerodyne during these dates in the SBM community. As shown in the figure, mobile monitoring was performed at different times of the day during the surveys.

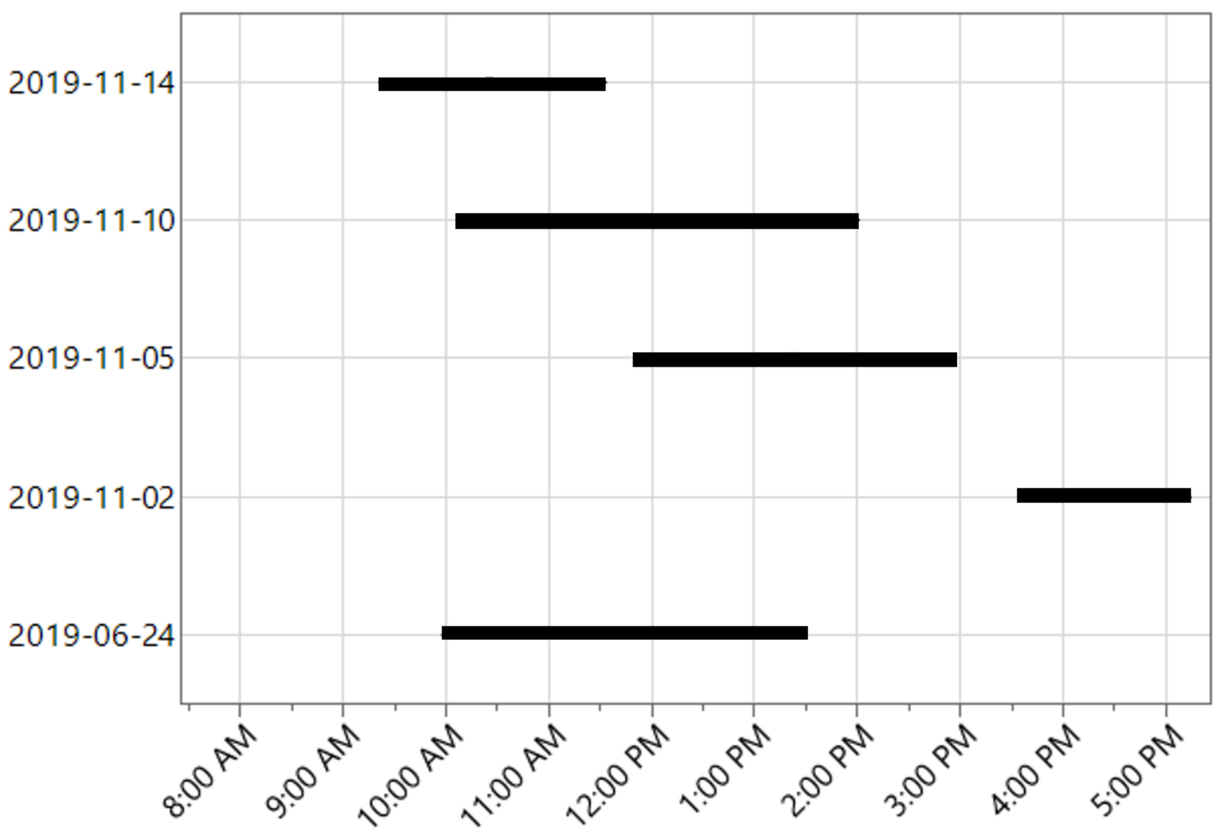

Figure B-1. Plot showing the duration and time window for the mobile methane measurements performed by Aerodyne near and around the Omnitrans bus yard in the SBM community. The time windows only include hours of active mobile measurements within the community, excluding the commute time between the South Coast AQMD Headquarters and the community

Aerodyne also sampled manholes and storm drains in the area and analyzed the chemical composition of the collected gases to determine if the sources are biogenic (i.e. sewer gas) or thermogenic (i.e. pipeline gas). The results suggest that methane gas from the manholes in this area may come from a mixture of thermogenic and biogenic sources with varying day-to-day concentration. Compressed natural gas (CNG) equipment at Omnitrans including utility meter piping and recent construction from 2014 and 2017 could be a potential above-ground source of thermogenic methane. Leaking seals and improper containment during regular use such as fuel dispensing could release methane into the atmosphere. A high-pressure distribution pipeline operated by SoCal Gas runs along a portion of Medical Center Drive near 5th Street. Based on the chemical signature of the collected data, the pipeline may be a potential below-ground source of thermogenic methane if leaks in the infrastructure were present. On 06/19/2020 SoCal Gas conducted independent measurements along the same pipeline and determined that no leaks were present. This investigation is still ongoing.

Aerodyne Research provided a comprehensive report on their air monitoring investigation which is included as Attachment C.

Attachment C

Final Report

Application of Next Generation Air Monitoring Methods in the South Coast Air Basin

Prepared for

South Coast Air Quality Management District (SCAQMD)

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May 2020

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Executive Summary

Between Friday June 14th – Wednesday June 26th and Saturday November 2nd – Thursday November 14th, 2019, air quality measurements were conducted in the greater Los Angeles area, focusing on Carson, Wilmington, Long Beach, East Los Angeles, Muscoy, and San Bernardino. The Aerodyne Mobile Laboratory (AML) was equipped with state-of-the-art instrumentation to measure a broad range of atmospheric tracers, including volatile organic hydrocarbons (e.g. benzene, a carcinogen, and methane thiol, an odor concern), combustion species (e.g. CO_2 and CO from vehicle exhaust), particulate matter size, composition and mass, air toxic metals, and many others.

This campaign has further demonstrated that the use of a well-equipped mobile laboratory is valuable for emission studies in complex urban environments.

- Mobile surveys of a neighborhood can **quickly identify emissions hotspots**.
- Mobile laboratory measurements that include instrumentation to measure combustion markers, speciated volatile organic hydrocarbons, particulate matter, and other compounds of interest are ideal for urban or industrial areas with **numerous, varied and sometimes uncharacterized emission types**.
- **Unexpected emission sources** were encountered numerous times during neighborhood surveys or during drives focused on other potential sources. This type of "by-catch" increases the productivity and value of mobile laboratory studies.
- Mobile measurements under different wind conditions help narrow down source locations in congested areas.
- Stationary measurements included **sampling unique environments using adapted configurations** (e.g. extending sampling inlets into manholes and sewers – 'snorkeling').
- The live data display and mapping in the Aerodyne Mobile Laboratory allowed scientists to **regularly brief project management** on the latest observations during the filed campaign.
- The rapid preliminary data allowed for the campaign goals to be **flexible and adaptable**.

Introduction

The Aerodyne Mobile Laboratory (AML) is equipped with a suite of near-real-time, next-generation analytical equipment, capable of detecting a variety of important air pollutants, such as volatile organic compounds and air metal toxics. Therefore, the AML can also be used as effective screening tool to identify potential sources of emissions and to evaluate community exposure levels. Conducting surveys using filter sampling is labor-intensive and time-consuming, and allows for neither continuous monitoring, dense spatial coverage, nor effective screening. Therefore, SCAQMD has a pressing need to implement an alternative approach to screening, particularly for toxic metals in the air. Recent advancements in real-time analytical techniques offer such promise. This study was therefore targeted at making significant advancements in monitoring toxic metals and volatile organic compounds in communities located near various industries and businesses.

Preparation for this study required obtaining and integrating several new instruments. Before arriving at SCAQMD for the June campaign, the mobile laboratory drove to Cooper Environmental Services headquarters in Beaverton, Oregon for installation of a Xact® 625i (energy dispersive X-ray fluorescence technique) rented for this project. Aerodyne employees were trained on the unit which had been specially adapted to report many airborne metals and their concentrations every 5 minutes as opposed to 15 minutes (fastest measurement previously available). For the November campaign, a similar unit was borrowed from SCAQMD. A small portable sensor from AethLabs (San Francisco, CA), the microAeth® MA 350, measures black carbon (BC) at 1 Hz and was also borrowed from SCAQMD during the June campaign. Data from this sensor replaced that from a Multi-Angle Absorption Photometer (MAAP) on-board (data delivered during the campaign). Another new addition, the Vocus 2R PTR-TOF, measured volatile organic compounds (VOCs) in air. This instrument, recently developed, boasts low detection limits and high resolving power. All these additions and changes demonstrate the flexibility of this platform to successfully incorporate new instruments and equipment.

The Aerodyne mobile laboratory was deployed between Friday June 14th – Wednesday June 26th and Saturday November 2nd – Thursday November 14th. Measurements were taken in the greater Los Angeles area, focusing on Carson, Wilmington, Long Beach, East Los Angeles, Muscoy, and San Bernardino. Throughout this report, individual facilities are named or drawn on a map. It is important to note that this does not indicate that they are the source of a given emission unless specifically described as such.

Experimental

Platform overview

The Aerodyne Mobile Laboratory is an instrumented box truck (Figure 1) designed to support a flexible deployment of research-grade air monitoring equipment. A schematic in Figure 2 shows the instrumentation used during this field campaign.

Figure 1. The Aerodyne Mobile Lab parked at SCAQMD in Diamond Bar, CA.

Ambient air is continuously drawn through the inlets at the front of the vehicle, which extend out on booms mounted to the roof. Every 15 minutes, clean air was delivered in excess of the intake flow for three of the inlets: the trace-gas inlet (blue, Figure 2) and the VOC inlets (purple and green, Figure 2). The air was either dry ultra-zero air or humidity-matched air from an Aadco ZA30 zero-air generator (Cleves, OH), respectively. These gas additions served to spectroscopically background select laser-based instruments, and to check zero values for the other instruments. The other inlets were dedicated to particulate matter measurements (red, Figure 2), and were manually checked for zero levels using a removable filter on the inlet tip.

Meteorological conditions and GPS-based positioning were measured on the rooftop. A Hemisphere (V103) GPS Compass (Scottsdale, AZ) was operated in conjunction with an RM Young 2D (Traverse City, MI) anemometer to determine wind speed and direction and to map vehicle location, speed and bearing during measurements. True wind was determined by vector subtraction of the mobile laboratory speed from the raw measured wind speed.

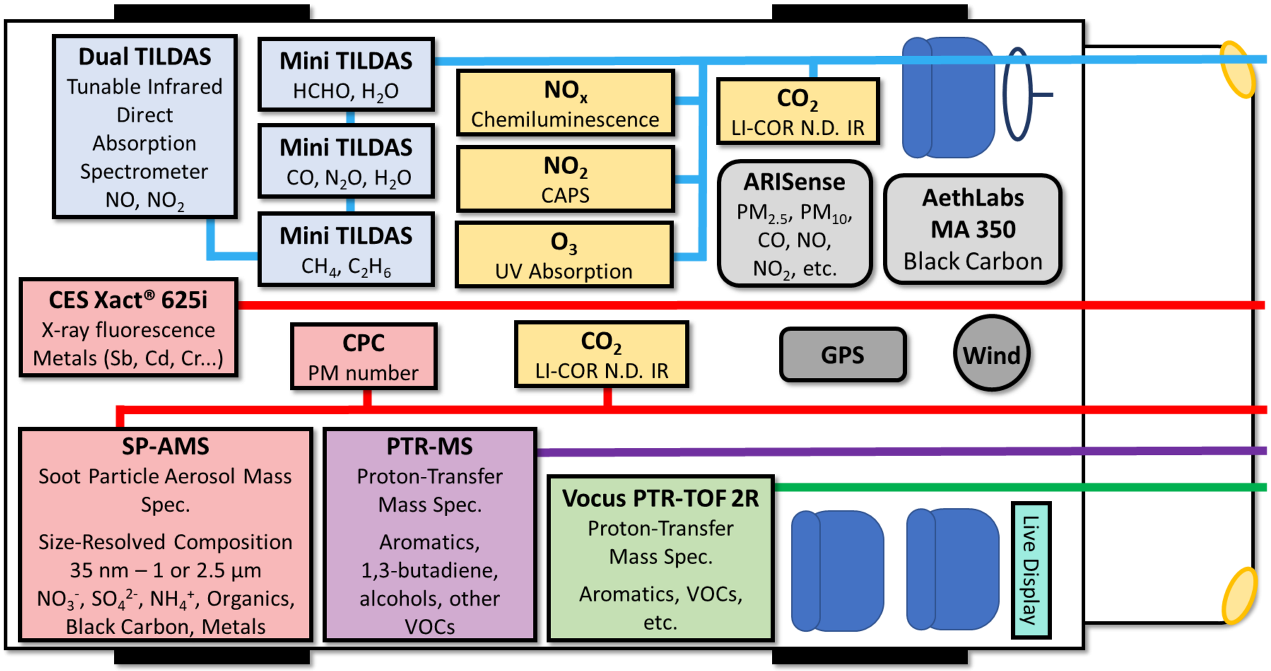

Figure 2. Schematic of the Aerodyne Mobile Laboratory during the 2019 SCAQMD field campaigns. Particulate matter instrumentation (red inlet) include condensation particle counter (CPC) and the soot particle aerosol mass spectrometer (SP-AMS). Volatile organic compound instrumentation (purple and green inlets) includes two proton transfer mass spectrometers (PTR-MS and Vocus 2R PTR-TOF). Trace gas instrumentation (blue background) includes mini or dual tunable infrared direct absorption spectrometers (TILDAS) as well as a few other commercial instruments (yellow background), all on the blue inlet. Roof-mounted sensors (grey background) include global positioning system (GPS), wind, AethLabs MA350, and the ARISense sensor.

Inside the AML, air in the trace-gas inlet is sampled by a LI-COR 6262 for CO_2 (Lincoln, NE), an Aerodyne cavity attenuated phase shift (CAPS) sensor equipped with an ozone generator for total nitrogen oxides (NOx, November only), and a 2BTech Model 205 ozone (O_3) monitor (Boulder, CO). Trace-gas monitors employing Tunable Infrared Laser Direct Absorption Spectroscopy (TILDAS) from Aerodyne Research, Inc. performed gas phase measurements of the ambient air (McManus et al., 2015). Three single laser “mini” instruments and one dual-laser instrument measured 1) formaldehyde and water (HCHO, H_2O), 2) nitrous oxide, carbon monoxide and water (N_2O, CO, and H_2O); 3) ethane and methane (C_2H_6 and CH_4); and 4) nitrogen oxide and nitrogen dioxide (NO, NO_2, June only). A mini-TILDAS measured hydrogen cyanide (HCN) and acetylene (ethyne, C_2H_2) in November. The TILDAS instruments were operated in series at pressures between 30-50 Torr, with an upstream pressure controller managing flow from a downstream scroll pump (Agilent TriScroll TM 600 - Santa Clara, CA). All TILDAS instruments were spectroscopically zeroed, except for the N_2O-CO monitor, due to residual CO present in ultra-zero air. Instrument calibrations for gas-phase species were performed by overblow of the inlet with a quantitatively blended mix of ppm-level calibration standards with a diluent (ultra-zero air or ZAG air).

A proton-transfer reaction mass spectrometer (PTR-MS) with quadrupole MS, operated in NO^+ mode and measured from the VOC inlet (purple, Figure 2) during only the June campaign. In this mode, the instrument is also called NOMS. It measured methanol, acetaldehyde, acetone and benzene. Instrument calibrations for gas-phase species were performed by overblow of the inlet with a quantitatively blended mix of ppm-level calibration standards with a diluent (ultra-zero air or ZAG air).

A time-of-flight based proton-transfer reaction mass spectrometer (Vocus 2R PTR-TOF) measured from another VOC inlet (purple, Figure 2) and measured VOCs including benzene, toluene, xylenes (C2-benzenes), acetone. Select sulfur compounds were also measured including methane thiol (CH_3SH), the sum of ethane thiol and dimethyl sulfide, dimethyl disulfide. A list of species is included in the Quality Assurance spreadsheet that accompanies the data.

An Aerodyne soot particle aerosol mass spectrometer (SP-AMS) measured particulate matter mass (PM_m μm m^{-3}) and composition. It was equipped with a high-resolution time-of-flight mass spectrometer (HR-TOF). Particulate matter sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+), chloride (Cl^-) and organic carbon ("Org") were measured with this instrument. The addition of the SP laser allowed for measuring both black carbon (BC) and metals. The metals monitored with this instrument include chromium (Cr), cadmium (Cd), aluminum (Al), Tin (Sn), and many others. The full list of output species is available in Appendix B. This instrument has an internal size cutoff (< 2.5 μm throughout the campaign) and the inlet sampled from a < 2.5 μm cyclone.

An ambient multi-metal monitor from Cooper Environmental Services (Beaverton, Oregon) called the Xact® 625i was used in both campaigns. It uses an energy dispersive X-ray fluorescence technique to analyze and detect metal in PM deposited on Teflon filter tape. This instrument was set up in a custom 5-minute sampling mode as opposed to typical longer-term sampling modes (15, 30, 60 minutes and longer). This instrument used a dedicated total suspended particle inlet with a sample flow rate at 16.7 lpm. Racks were installed to house and secure the instrument while mobile.

A condensation particle counter (CPC) measured particulate matter number (PM_n, # cm^{-3}). An AethLabs microAeth® MA 350 measured black carbon (UV-IR, μg m^{-3}), either from the roof-top or attic area (with an inlet run out the bulkheads in front). An ARISense mounted to the vehicle rooftop measured particulate matter number in 16 size bins between 0.4 –16 μm with an optical particle counter (Alphasense model OPC-N2). Subsequent analysis provided measures of integrated size-dependent particulate matter mass, like PM_2 and PM_{10} (see Appendix B). Other measured quantities include solar insolation, wind, RH, and duplicate measurements of CO, NO and NO_2. The unit was mounted flat against the roofline ("up" points forward) to prevent exceeding vehicle height restrictions, and so this unit's wind measurements were not used, and the solar insolation used only qualitatively.

Real-time data was logged and displayed on monitors in the AML, allowing scientists to rapidly detect and follow plumes of interest. Custom software was used to download, display, and update maps of the area, which were underlaid on live data graphs. Notes were recorded on the same computer and the observer defined periods of trace-gas data showing enhancements above background (plumes) while in the field.

Data Access

Aerodyne Research, Inc. visited the South Coast Air Basin for two campaigns in 2019:

June:	06/14/2019 23:00 to 06/26/2019 14:30 UTC
November:	11/02/2019 00:00 to 11/14/2019 21:00 UTC

Data was taken in the greater Los Angeles area. Two time-segments are used throughout, one each for the June and November campaign. Data reported here includes only mobile data taken 30 meters or more away from the overnight parking location at SCAQMD headquarters. There are two reasons for pairing down the data in this way:

1. Some instruments were not collecting data overnight, including particulate matter speciation data from the Aerosol Mass Spectrometer (AMS) and airborne metal data from the Cooper Xact® 625i (Cooper Environmental Services, Beaverton, OR) and the Vocus.
2. Excluding overnight data allows for the creation of comma-separated-value (.csv) files that have few enough columns to be opened in Microsoft Excel. This makes these data files easily accessible to future researchers and collaborators.

Data is stored on a shared drive specific to this project. Contact for access:

tyacovitch@aerodyne.com

Comma-separated-value files (.txt) are named as follows, where “yyyymmdd” indicates the year, month, and day of the file revision.

Aerodyne_SCAQMD2019_November_yyyymmdd.txt
Aerodyne_SCAQMD2019_June_yyyymmdd.txt

Each file starts with a column for datetime in UTC and Local time. Null data is reported as blank. All data columns are described below. Data columns begin with SS_, indicating that the data has been interpolated onto the 1-second master time for the campaign.

A spreadsheet containing data QA notes is included. The table is also reproduced below. For additional details on instruments in use, definitions of analysis product data, and QA steps taken, see Appendix B from Aerodyne’s 2018 CrVI project, “Application of Next Generation Air Monitoring Methods in the South Coast Air Basin”.

The full .h5 files for the AMS instrument, which was present on the AML for the December campaign, has been mailed to SCAQMD on a USB key. The full Cooper Xact® 625i dataset for November has also been delivered to SCAQMD.

Table 1. List of data vectors and quality assurance (QA) notes

Column Name	Long Name	Units	Instrument	Note	Data QA Note (b.)
SS_datetimeUTC	Universal Coordinated Time	Universal Coordinated Time			Data reported only when truck was >30 m away from SCAQMD parking spot.
SS_LocalTime	Local Time	PDT in June; PST in November		PDT = UTC - 7h; PST = UTC - 8h	
SS_Latitude	Latitude	decimal degrees	HemiRover Vector v103 GPS Compass		

Column Name	Long Name	Units	Instrument	Note	Data QA Note (b.)
SS_Longitude	Longitude	decimal degrees	HemiRover Vector v103 GPS Compass		
SS_Easting	Universal Transverse Mercador Easting	meters	HemiRover Vector v103 GPS Compass		
SS_Northing	Universal Transverse Mercador Northing	meters	HemiRover Vector v103 GPS Compass		
SS_Zone	Universal Transverse Mercador Zone	meters	HemiRover Vector v103 GPS Compass		
SS_Elevation_m	Truck Elevation	meters	HemiRover Vector v103 GPS Compass		
SS_truckSpeed_kmph	Truck Speed	kmph	HemiRover Vector v103 GPS Compass		
SS_truckHeading	Truck Heading	degrees clockwise from true North	HemiRover Vector v103 GPS Compass	Orientation of the truck axis	
SS_SolarElevAngle	Solar Elevation Angle	azimuthal degrees	Calculated based on truck position		
SS_wind_speed_metersPerSecond	Wind Speed	meters per second	RM Young 2D Anemometer	Unreliable at high truck speeds	
SS_wind_dir_degrees	Wind Direction	degrees clockwise from true North	RM Young 2D Anemometer	Unreliable at high truck speeds	
SS_wind_E_metersPerSecond	East component of wind	meters per second	RM Young 2D Anemometer	Unreliable at high truck speeds	
SS_wind_N_metersPerSecond	North component of wind	meters per second	RM Young 2D Anemometer	Unreliable at high truck speeds	
SS_Temperature_C	Outdoor temperature	meters per second	RM Young 3D Sonic Anemometer		

Column Name	Long Name	Units	Instrument	Note	Data QA Note (b.)
SS_Snorkel	Snorkeling Flag	unitless		0 is ambient sampling; 1 is snorkeling through an extended inlet tube	
SS_strictBackgroundMask	Strict Background Mask	unitless	Calculated based on measured CO	1 is sampling that is not affected by sharp exhaust spikes; NaN (blank data) is affected by exhaust	
SS_CO2_ppm	Carbon dioxide	ppm	LI-COR 6262	Ambient humidity	Calibrated
SS_CO	Carbon monoxide	ppb	TILDAS	Ambient humidity	Calibration factor close to 1 and within uncertainty of tank, so no calibration factor applied
SS_CO_background	Carbon monoxide background	ppb	Calculated based on measured CO	Ambient humidity	Calibration factor close to 1 and within uncertainty of tank, so no calibration factor applied
SS_N2O	Nitrous oxide	ppb	TILDAS	Ambient humidity	No calibration factor applied. Ambient concentrations agree with NOAA background concentrations for 2019 34-degree latitude
SS_NOx	Nitrogen oxides	ppb	TILDAS or CAPS-NO2	In June, NOx is sum of NO and NO2. In December, NOx is direct measurement of NOx after reaction with excess Ozone. Ambient humidity	November NOx data requires advanced QA to diagnose problem with ozone generator
SS_NO	Nitric oxide	ppb	TILDAS	No data collected in November	N/A
SS_NO2	Nitrogen dioxide	ppb	TILDAS	TILDAS in June; CAPS-NO2 in November.	No data reported
SS_H2O	Water vapor	ppb	TILDAS	Ambient humidity	No calibration factor applied
SS_O3	Ozone	ppb	TILDAS	Ambient humidity	No calibration factor applied
SS_CH4	Methane	ppb	TILDAS	Ambient humidity	Calibrated
SS_C2H6	Ethane	ppb	TILDAS	Ambient humidity	Calibrated
SS_HCN	Hydrogen cyanide	ppb	TILDAS	Ambient humidity	Calibrated
SS_C2H2	Acetylene (ethyne)	ppb	TILDAS	Ambient humidity	Calibrated
SS_HCHO	Formaldehyde	ppb	TILDAS	Ambient humidity	No calibration factor applied

Column Name	Long Name	Units	Instrument	Note	Data QA Note (b.)
SS_benzene	Benzene	ppb	Vocus (a.)		Calibrated
SS_toluene	Toluene	ppb	Vocus (a.)		Estimated response (c.)
SS_C2benzene	Sum of xylene isomers (aka C8-aromatics)	ppb	Vocus (a.)		Calibrated
SS_C3benzene	Sum of C9-aromatics	ppb	Vocus (a.)		Calibrated
SS_CH3SH	Methane thiol (methyl mercaptan)	ppb	Vocus (a.)		Estimated response (c.)
SS_acetone	Acetone	ppb	Vocus (a.)		Calibrated as acetone
SS_acetaldehyde	Acetaldehyde	ppb	Vocus (a.)		Calibrated as acetaldehyde
SS_MEK	Methyl ethyl ketone	ppb	Vocus (a.)		Calibrated as MEK
SS_isoprene	Isoprene	ppb	Vocus (a.)		Calibrated as isoprene
SS_monoTerpenes	Sum of monoterpenes	ppb	Vocus (a.)	Exact mass 137.132	Calibrated as alpha-pinene
SS_C2H5O2	Acetic acid, propanol and other isomers	ppb	Vocus (a.)	Exact mass 61.028	Estimated response (c.)
SS_C7H15O	Heptanal and other isomers	ppb	Vocus (a.)	Exact mass 115.112	Estimated response (c.)
SS_DMDS	Dimethyl disulfide, measured via ion C2H7S2+	ppb	Vocus (a.)	Exact mass 94.998	Estimated response (c.) using rate constant from Cappelin[1] and formula from Seikimoto[2]
SS_C2H7S	Sum of dimethyl sulfide and ethane thiol	ppb	Vocus (a.)	Exact mass 63.026	Estimated response (c.), calibrated as DMS (Sekimoto[2])
SS_C4H9S	Tetrahydrothiophene and other isomers	ppb	Vocus (a.)	Exact mass 89.042	Estimated response (c.) using rate constant for C4 thiols and sulfides (Sekimoto)
a. Vocus relies on mass-based detection. Interference from structural isomers are possible. See the PTR Spreadsheet. https://docs.google.com/spreadsheets/d/108MzOYtjequJHZ2N_fth1yFM7XnlGzOlQ7tPkvK5FHQ/edit#gid=0					
b. For additional QA details, see QA document from 2018 Campaign					
c. Estimated response does not account for fragmentation.					

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The chapter discussing the findings related to measurements around Rendering Facilities in the ELABHWC community is provided in the progress report for Rendering Facilities and can be accessed through the following link: http://www.aqmd.gov/docs/default-source/ab-617-ab-134/camps/elabhwc-progress-reports/elabhwc-rendering-facilities---coming-soon.pdf?sfvrsn=18#page8

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OmniTrans Bus Depot

Introduction

When visiting an urban location, the mobile laboratory surveys public roads to look for potential airborne pollutants or odor sources. Based on the wind conditions, the AML then navigates local roads downwind of the potential sources or areas of interest. With adequate road access and winds from a favorable direction, observations of elevated chemical signals will be tested for reproducibility by driving a similar route downwind of suspected sources multiple times.

Stationary sampling of road openings, such as manholes and sewer drains, can also offer direct access to gases (CH_4, N_2O, CO_2, CH_3SH) emitted in the waste water.[1] Gases (CH_4, C_2H_6) from leaks in the natural gas infrastructure can permeate through soil or collect in these underground openings. Presence of C_2H_6 with CH_4 (typically around 1-6%) indicates a thermogenic source of CH_4 gas.[2] However, CH_4 absent of C_2H_6 in combination with other gases such as N_2O, indicates a biogenic source (e.g. anaerobic bacteria digesting organic waste) of CH_4 gas.[3,4] Odorous sulfur-containing compounds, such as methyl mercaptan (CH_3SH), have been associated with the decomposition of organic material.[5] In the same family of compounds, ethyl mercaptan (CH_3CH_2SH, ethane thiol) or other sulfur compounds (tertbutyl mercaptan; tetrahydrothiophene) are added to natural gas as a safety measure to indicate leaks.[6] A mixture of these gases can be observed in manholes, suggesting multiple responsible sources.

The Aerodyne Mobile Laboratory (AML) visited the area surrounding the OmniTrans bus depot at 1700 W 5th Street in San Bernardino, CA on two week days (Saturday 11/2/2019, Sunday 11/10/2019) and two weekend days (Tuesday 11/5/2019, Thursday 11/14/2019) to measure manholes and ambient air quality.

Experimental Description

When attempting to sample road openings near the OmniTrans bus depot, the AML stopped on the side of the road, waited for traffic to reduce, and then attached an extension of tubing to the sampling inlet (a "snorkel"). Most manholes had openings that made it easy to insert the sample line into the space underneath the manhole cover (Figure 1).

Figure 1. Sampling the headspace of a manhole using an extended inlet ('snorkeling').

Each manhole was sampled for at least 30 seconds. Multiple attempts were often necessary to avoid interrupting traffic. Sampling was performed in near real-time with a few second delay due to the extended inlet. Operators waited until the gaseous composition of the headspace underneath each manhole settled to a steady value. Concentration values typically settled rapidly as there was minimal disruption or ventilation of the headspace in most cases. Elevated concentrations of nitrous oxide (N_2O), methane (CH_4), ethane (C_2H_6), carbon dioxide (CO_2), methyl mercaptan (CH_3SH), and water vapor (H_2O) were observed in most cases. Additional compounds may be identified in future analysis.

Observations

On Thursday, 11/2/2019, the AML drove loops around the OmniTrans perimeter and observed a methane emission (10 ppm CH_4) with a thermogenic signature (based on C_2H_6:CH_4 ratio) at the corner of 5th Street and Medical Center Drive (Figure 2). Similar observations were made on 6/24/2019. Given a wind direction out the NW, it seems likely that this emission originated on the OmniTrans property. According to documents publicly available on their website, OmniTrans facilities at this location include a "gasoline and compressed natural gas fueling building […] constructed in 2014" and "compressed natural gas (CNG) fuel compressor [and] generation facility constructed in 2017".[7] Near the observed emission on the border of the parking lot, exists a collection of piping and meters presumably related to distribution of natural gas onto the property. Leaks from this natural gas distribution equipment released into the atmosphere would be a source of thermogenic CH_4.

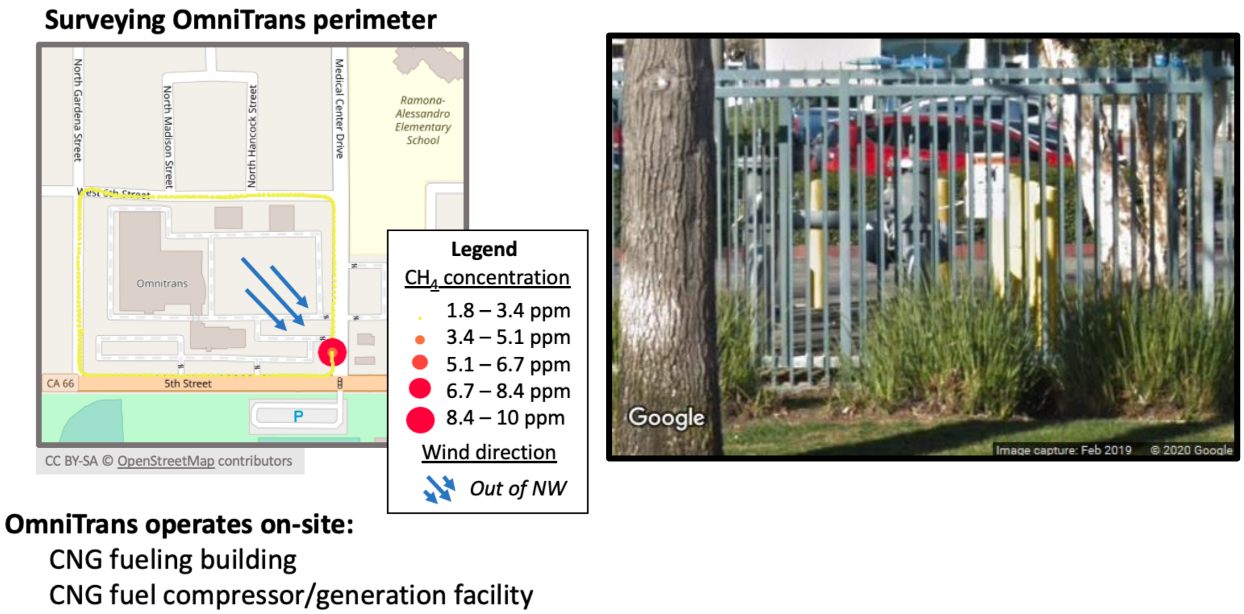


Figure 2. Observations of enhanced thermogenic methane at the corner of Medical Center Drive and 5th street near the OmniTrans Headquarters in San Bernardino (left). A nearby natural gas meter and related piping could be responsible if it had a leak (right). Data shown (left) was recorded on 11/2/2019. Similar observations were made on 6/24/2019.

On Tuesday, 11/5/2019, the AML again drove several loops around the perimeter of the bus depot encountering a couple "hot-spots" of CH_4 in the ambient air. Two manholes were sampled on West 7th Street and both contained a significantly elevated concentration of thermogenic methane. One of the manholes sampled was in front of the Ramona-Alessandro Elementary and contained the highest levels of methane (120.5 ppm) observed during this round of measurements (Figure 3).

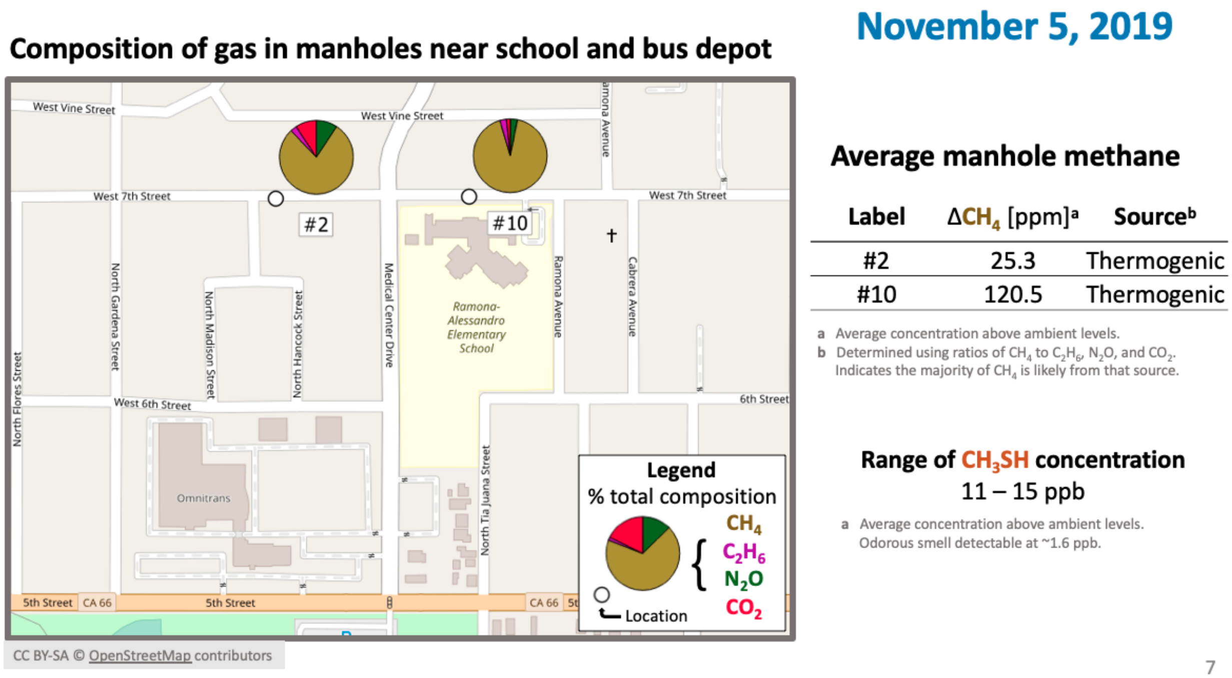
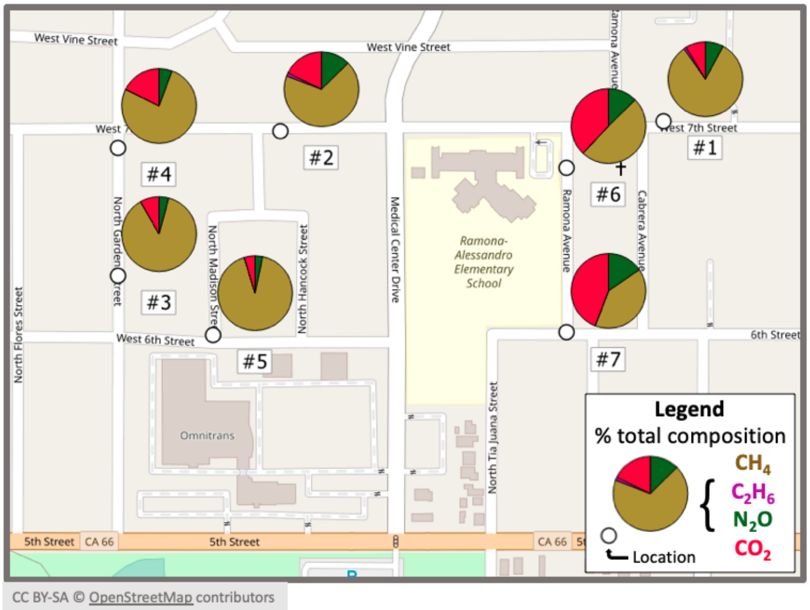


Figure 3. Pie charts showing the total composition of gases measured in the headspace of manholes scaled to 100% (left). A table depicting average methane concentrations (ppm, above ambient) at each manhole with a source attribution of either: biogenic, thermogenic, or mixture (top right). Methyl mercaptan values (ppb) from manholes are shown as a range (bottom right).

On Thursday, 11/10/2019, the AML surveyed the area but only encountered minor enhancements of CH_4. At the corner of 5th Street and Medical Center Drive, a storm drain provided small enhancements when directly sampled.

On Thursday, 11/14/2019, the AML sampled a storm drain and seven manholes in the neighborhood behind OmniTrans and near Ramona-Alessandro Elementary (Figure 4). Of the four main gases species of interest (N_2O, CH_4, C_2H_6, CO_2) there was a wide variety of chemical composition in the headspace of the seven manholes. Repeated measurements showed little change in concentration on a minute-by-minute basis. However, one of the manholes previously measured on West 7th Street on 11/5/2019 showed significantly less methane (0.4 ppm versus 22.2 ppm) and had proportionally less ethane present. Both the absence of ethane and reduced methane concentration indicate that this manhole was transiently affected by a thermogenic (natural gas) source that dissipated on the order of days. Most manholes (5 out of the 7) had methane present that seemed largely biogenic in nature.

Composition of gas in manholes near school and bus depot



November 14, 2019

Average manhole methane

Label	ΔCH_4 [ppm][a]	Source[b]
#1	7.3	Mixture
#2	0.5	Mixture
#3	34.6	Biogenic
#4	2.2	Biogenic
#5	29.5	Biogenic
#6	7.0	Biogenic
#7	1.9	Biogenic

a Average concentration above ambient levels.
b Determined using ratios of CH_4 to C_2H_6, N_2O, and CO_2. Indicates the majority of CH_4 is likely from that source. "Mixture": thermogenic and biogenic sources.

Range of CH_3SH concentration
0.4 – 9.4 ppb

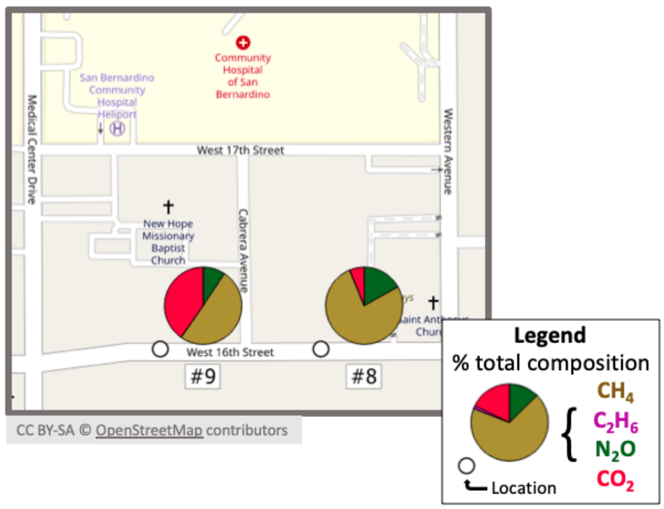
a Average concentration above ambient levels. Odorous smell detectable at ~1.6 ppb.

8

Figure 4. Pie charts showing the total composition of gases measured in the headspace of manholes scaled to 100% (left). A table depicting average methane concentrations (ppm, above ambient) at each manhole with a source attribution of either: biogenic, thermogenic, or mixture (top right). Methyl mercaptan values (ppb) from manholes are shown as a range (bottom right).

Two manholes were sampled on West 16th Street near the Community Hospital of San Bernardino. Both contained elevated levels of CH_4 with seemingly biogenic origin (Figure 5).

Composition of gas in manholes near hospital



Average manhole methane

Label	ΔCH_4 [ppm][a]	Source[b]
#8	16.7	Biogenic
#9	1.8	Biogenic

a Average concentration above ambient levels.
b Determined using ratios of CH_4 to C_2H_6, N_2O, and CO_2. Indicates the majority of CH_4 is likely from that source.

Range of CH_3SH concentration
0.5 – 24.4 ppb

a Average concentration above ambient levels. Odorous smell detectable at ~1.6 ppb.

Figure 5. Pie charts showing the total composition of gases measured in the headspace of manholes scaled to 100% (left). A table depicting average methane concentrations (ppm, above ambient) at each manhole with a source attribution of either: biogenic, thermogenic, or mixture (top right). Methyl mercaptan values (ppb) from manholes are shown as a range (bottom right).

Almost certainly, each of these manholes contained gases from a variety of sources. Source attribution for the CH_4 provided in tables in Figure 3, 4, and 5, relied on the C_2H_6-to-CH_4 ratio (> 3% - thermogenic, 1-3% - mixture, < 1% - biogenic). These designations do not suggest that all the gas derived from a single source type, but rather that most of the gas probably came from one source or another. Considering a C_2H_6-to-CH_4 ratio of 4% indicates all the gas present is thermogenic, then a ratio of 1-3% could be considered between 25% and 75% thermogenic, and a 1% ratio is largely biogenic (~75%).

Some humans can smell CH_3SH in air starting at 0.07 ppb.[9] For the ten manholes sampled during this work, including one repeat on different days, concentration of CH_3SH ranged from 0.4 ppb to 24.4 ppb (daily ranges shown in Figure 3, 4, and 5). All observations were therefore above 0.07 ppb. Human perception of odor is subjective and inherently more challenging to broadly characterize than chemical concentration measurements.

Conclusions

Methane gas from the manholes in this area appears to come from a mixture of thermogenic and biogenic sources with concentration varying day-to-day. Other observations of methane were made downwind of the OmniTrans bus depot. Compressed natural gas (CNG) equipment at OmniTrans including utility meter piping and recent construction from 2014 and 2017 could be a potential above-ground source of thermogenic methane.[6] Leaking seals and improper containment during regular use such as fuel dispensing could release methane to the atmosphere. A high-pressure distribution pipeline operated by SoCalGas runs along a portion of Medical Center Drive near 5th Street.[7] The pipeline could be a potential below-ground source of thermogenic methane if leaks in the infrastructure were present (Figure 6).

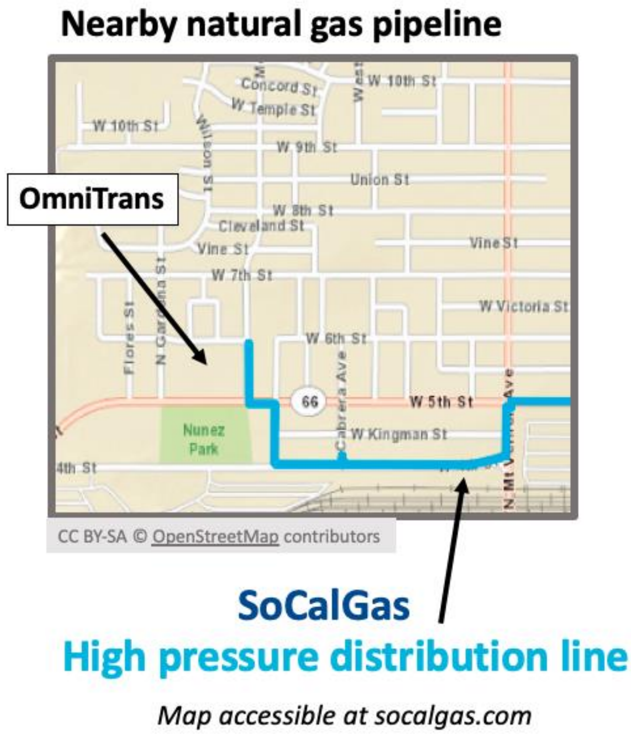


Figure 6. Pie charts showing the total composition of gases measured in the headspace of manholes scaled to 100% (left). A table depicting average methane concentrations (ppm, above ambient) at each manhole with a source attribution of either: biogenic, thermogenic, or mixture (top right). Methyl mercaptan values (ppb) from manholes are shown as a range (bottom right).

Future work to better understand the temporal variations and gaseous composition of the manholes could involve regular (daily) or long-term sampling (several hours) combined with increased sample count to allow for statistically significant findings. Access on-site to the OmniTrans facility would enable targeted sampling of equipment and potentially reveal specific leak points or unintended releases during handling of CNG equipment.

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Chromal Plating Company

Observations

On the morning of 11/12/2019, the AML drove around a collection of industrial and residential buildings near the University of Southern California Health Sciences Campus. Between Workman Street and Sichel Street off N Mission Road is the Chromal Plating Company that advertises hard chrome plating services on their website (Figure 1).

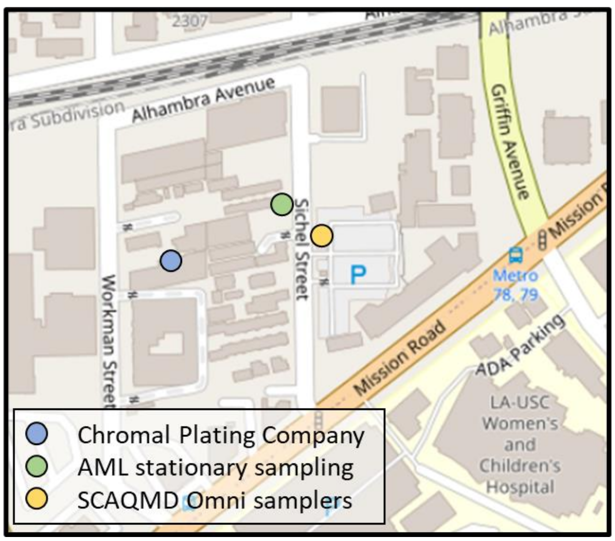

Figure 1. Location of Chromal Plating Company, stationary sampling by the AML on 11/12 and 11/13, and the SCAQMD van with Omni samplers on 11/13.

During a brief session of stationary sampling on Sichel Street between 10:05 – 10:25 AM, a peak of around 350 ng m^{-3} of chromium was observed on the Cooper Xact® 625i (Cooper Environmental Services, Beaverton, OR) in a custom 5-minute sampling mode. Measurements of Cr^{+} ions using the Aerodyne Mass Spectrometer at 1 Hz corroborated the findings. These observations caused SCAQMD management to direct longer-term measurements at this location.

On 11/13/2019, morning and afternoon measurements were made downwind of Chromal Plating Company on Sichel Street for 1-2 hours at a time. Peak observations of chromium on the

XRF instrument were ~1.1 μg m^3 in the morning at 10:25-10:30 AM and ~1 μg m^3 in the afternoon at 3:35 – 3:40 PM (Figure 2).

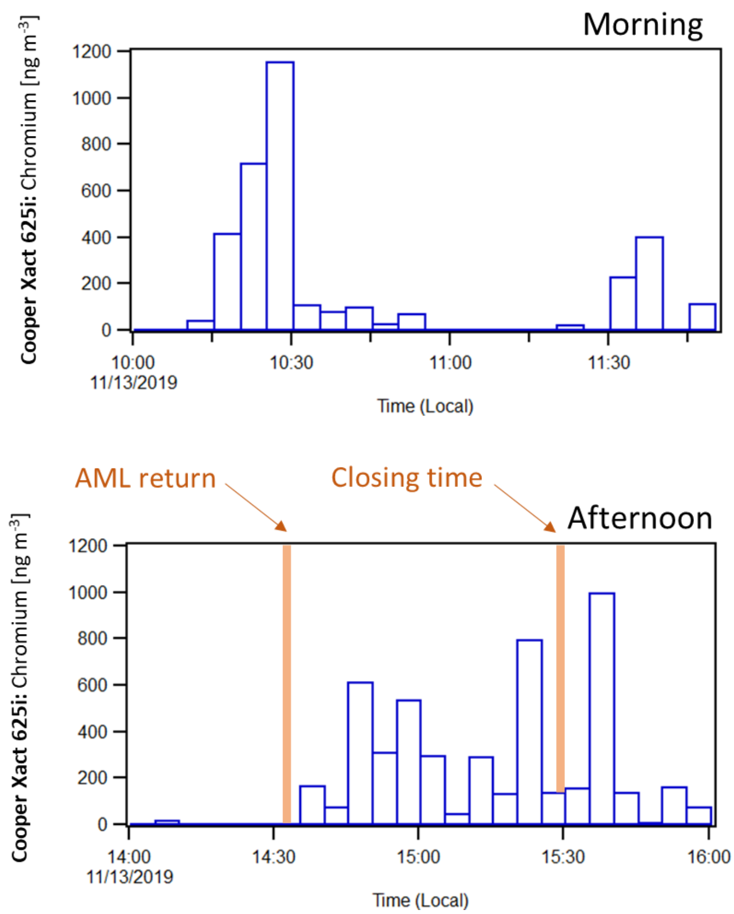

Figure 2. Measurements of chromium [ng m^{-3}] collected on-board the AML by the Cooper Xact® 625i (Cooper Environmental Services, Beaverton, OR) in a custom 5-minute sampling mode during the morning (10:25-10:30 AM) and afternoon (3:35 – 3:40 PM) of 11/13/2019.

Just prior to closing time (3:30 PM), the Vocus 2R PTR-TOF measured a notable enhancement of acetone (~60 ppb) perhaps related to clean-up efforts on-site (Figure 3). Peak chromium concentrations observed in the afternoon could also be related to cleaning or closing activities.

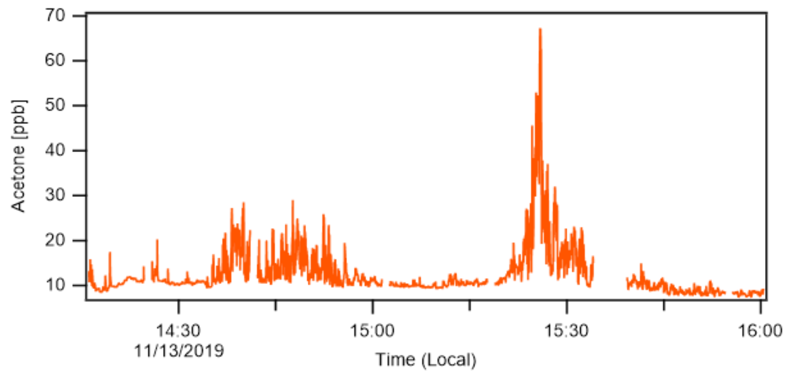

Figure 3. Measurements of acetone [m/z 59, ppb] collected on-board the AML by the Vocus 2R PTR-TOF at 1 Hz around closing time for Chromal Plating Company.

Mobile surveying identified the area and stationary sampling extensively characterized the discovery. These observations also demonstrated the value of operating the Xact® 625i in a more rapid sampling mode (5 minutes) as there were significant changes in the concentration of chromium between individual samples. Combined with the AMS and Vocus, the findings were further supported and supplemented with additional observations possibly related to on-site activity.

Ontario Ranch

Observations

On November 10th, 2019, the AML began driving towards San Bernardino on the Pomona Freeway (SR 60) intending to survey the area throughout the day. Along the way, operators began to smell a strong organic odor but could not visually identify any potential sources largely due to the noise barriers along the roadway. Shortly after the smell was noticed, concentrations of CH_4 and N_2O rose and remained elevated for approximately 10 minutes (bottom, Figure 1). Levels of C_2H_6 remained relatively low and unchanged during this time period, indicating the source of CH_4 was likely biogenic.[1] Several VOCs were also present in this plume, such as ethanol, methanethiol, and ethanethiol, tracking the other gas phase species (top, Figure 1). Some of these VOCs are associated with microbial emissions in agricultural soil and known to be malodorous.[2,3] Further analysis could likely reveal other gaseous compounds within the plume.

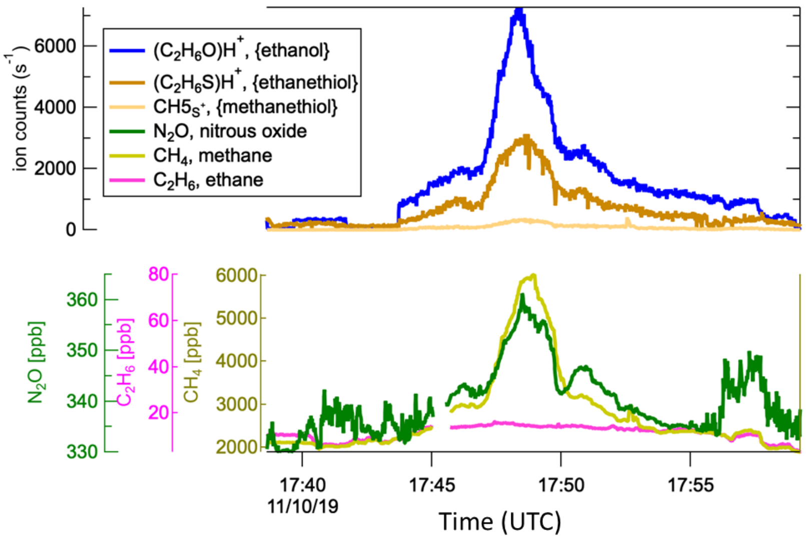

Figure 1. Time series depicting a plume of gas-phase species (CH_4 [ppb], N_2O [ppb], VOCs [counts s^{-1}]) associated with agricultural emissions recorded by TILDAS and VOCUS instruments while driving on the Pomona Freeway in Ontario, CA.

The AMS concurrently observed a plume of NH_4NO_3 (ammonium nitrate) aerosol, a product of nitric acid and ammonia reactions, previously measured in this general area (Figure 2).[4] The size mode of the NH_4NO_3 peaks at 250 nm indicating a relatively small size mode enhancing the likelihood of a local source.

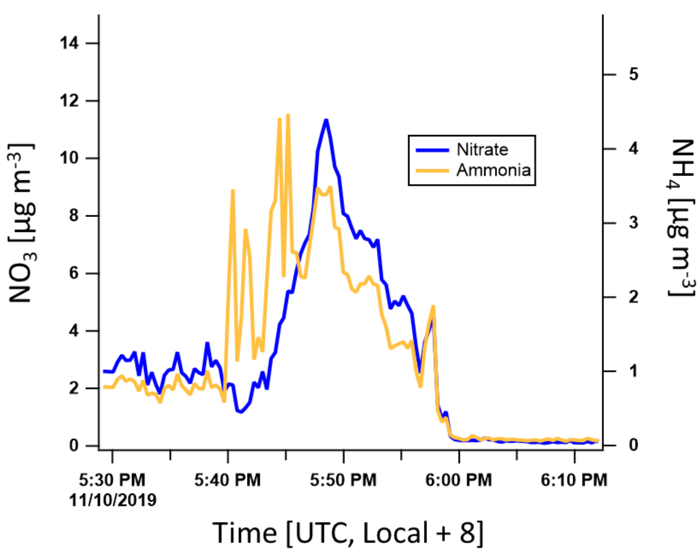

Figure 2. Time series of nitrate and ammonia [µg m^{-3}] as measured by the Aerosol Mass Spectrometer while sampling on the Pomona Freeway in Ontario, CA.

The nearby community of Ontario Ranch (Ontario, CA) is transitioning from agricultural use (primarily dairy farms) to residential and commercial development.[5] The northern border of Ontario Ranch parallels SR 60, offset by approximately 1 km, in the areas before the freeway begins to turn south. At the point of peak CH_4 enhancement, the AML was approximately 2 km away from the nearest border of Ontario Ranch experiencing a SE wind (Figure 3).

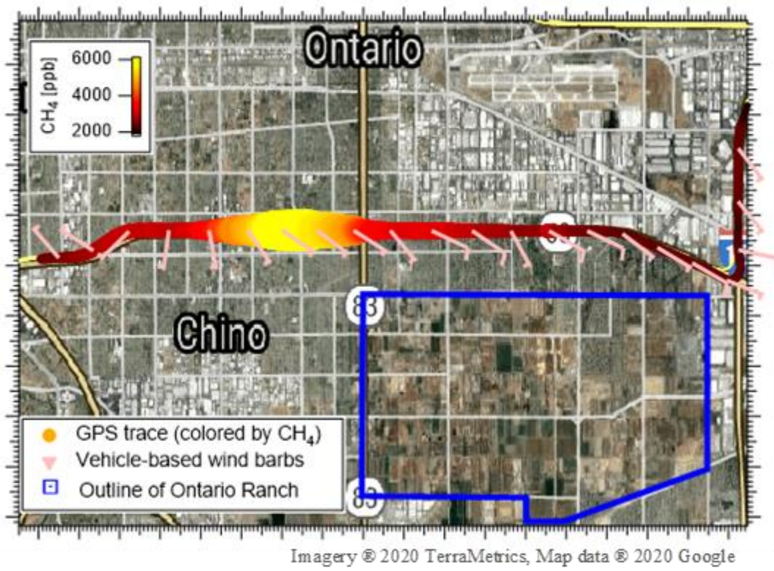

Figure 3. Driven transect of the AML (colored by CH_4 concentration) along Pomona Freeway downwind (pink wind barbs) of Ontario Ranch (blue outline) encountering elevated levels of CH_4.

The duration of the plume while at a steady highway speed shows the breadth of this impacted airmass. Given the sizable amount of land in this community previously used for agriculture, such a large plume could be expected. Monitoring downwind of this area could be an opportunity to see the effect of land use change on local air quality over time.

References

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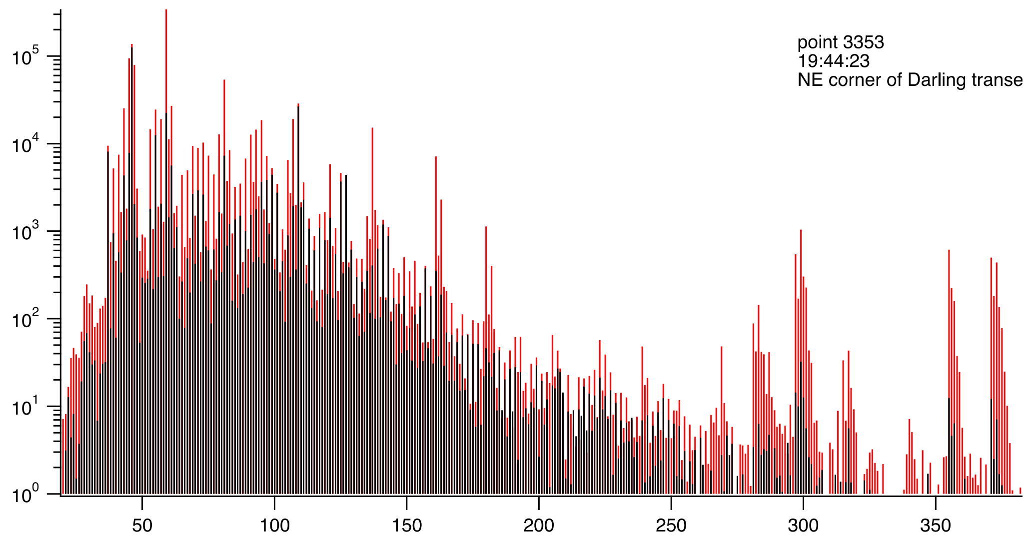
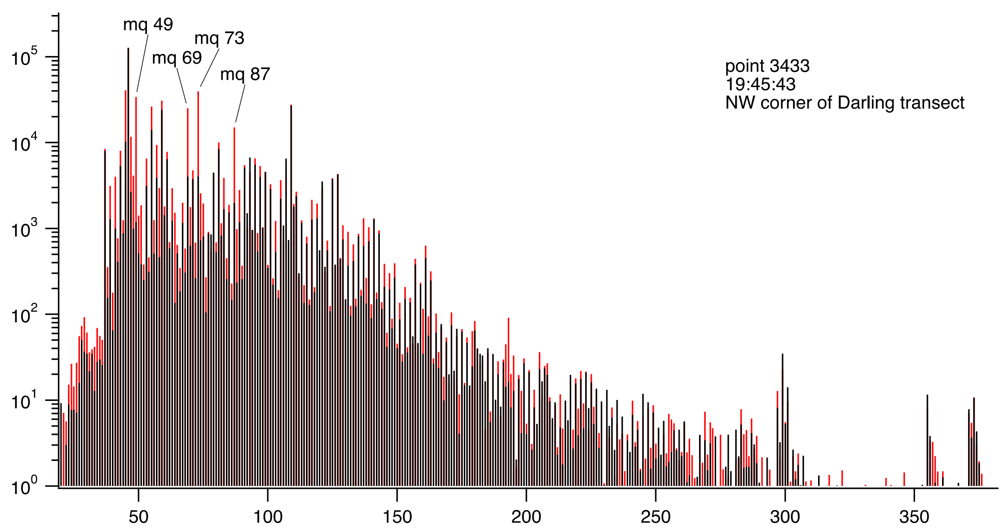
List of Appendices

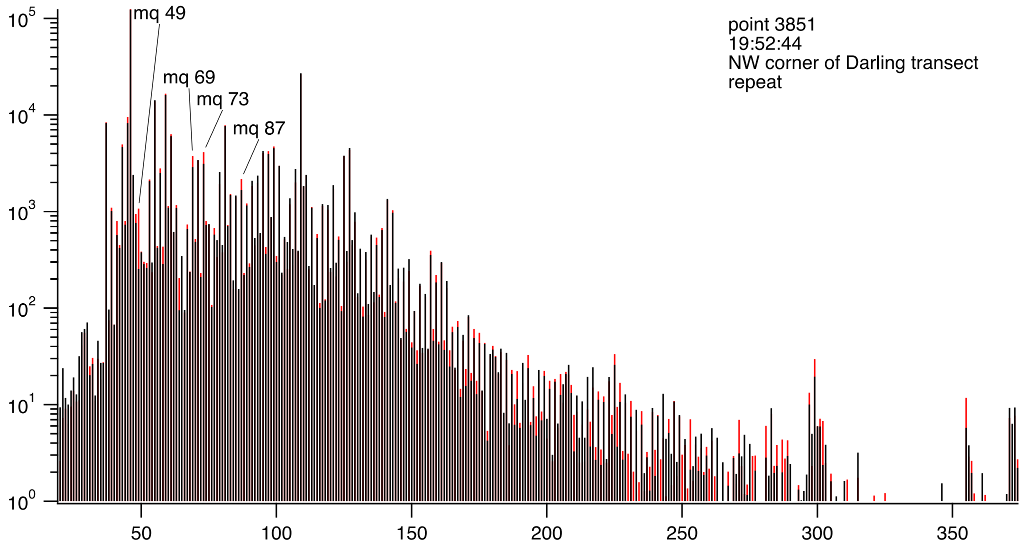
Appendix A: Mass spectra in and out of rendering area plumes,

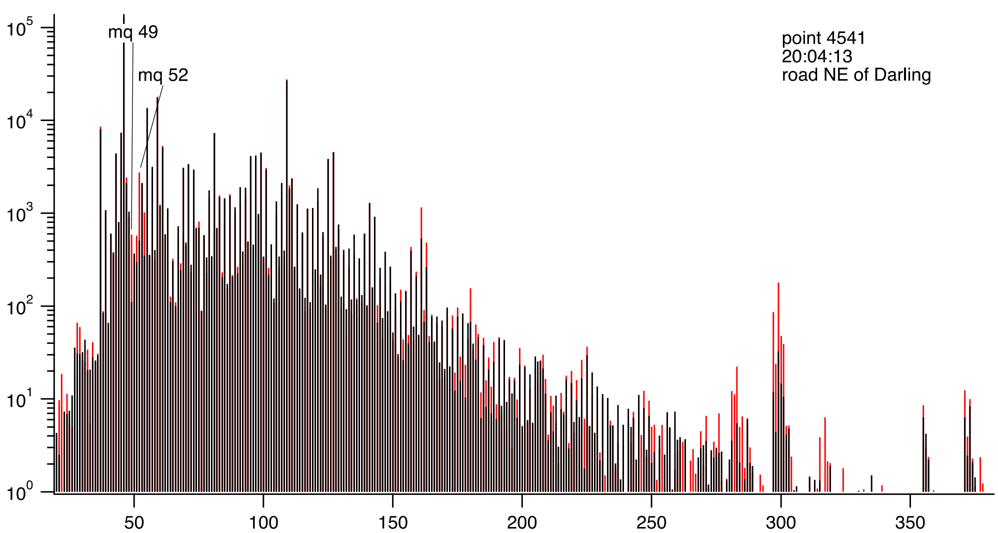
All data from June 21st, 2019

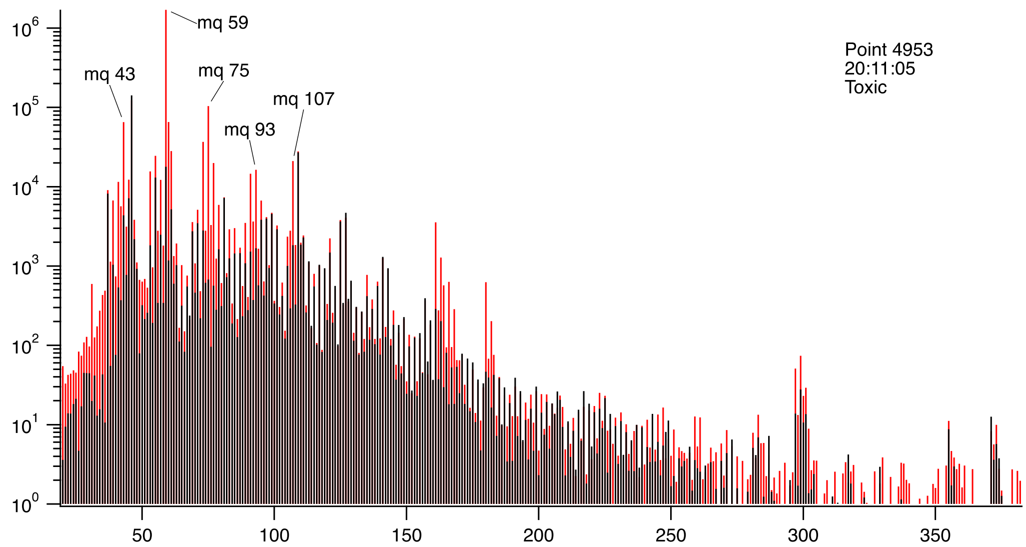
Below is a series of unit mass resolution mass spectra in which the plume is shown in red and an out of the plume background in black. The difference between the two spectra should represent the composition of the plume.

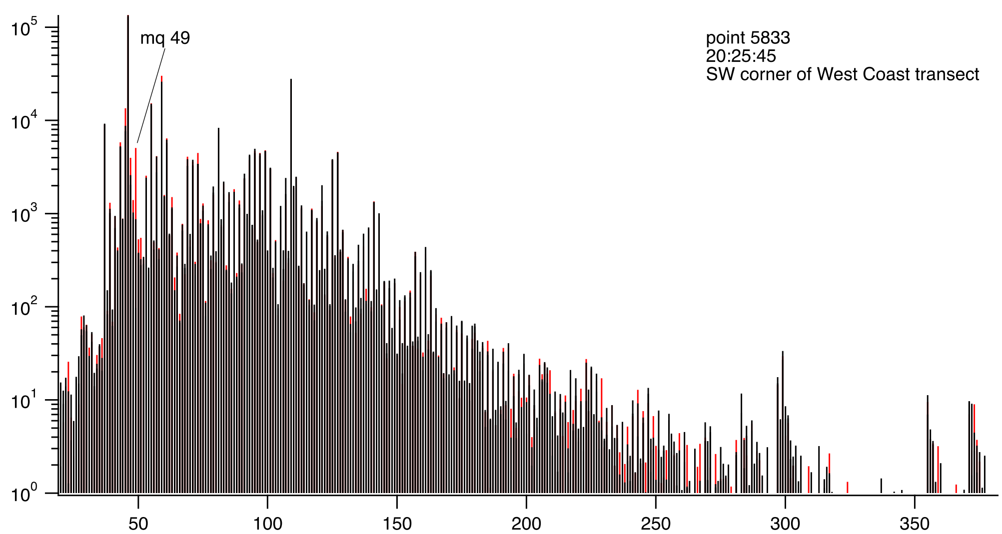


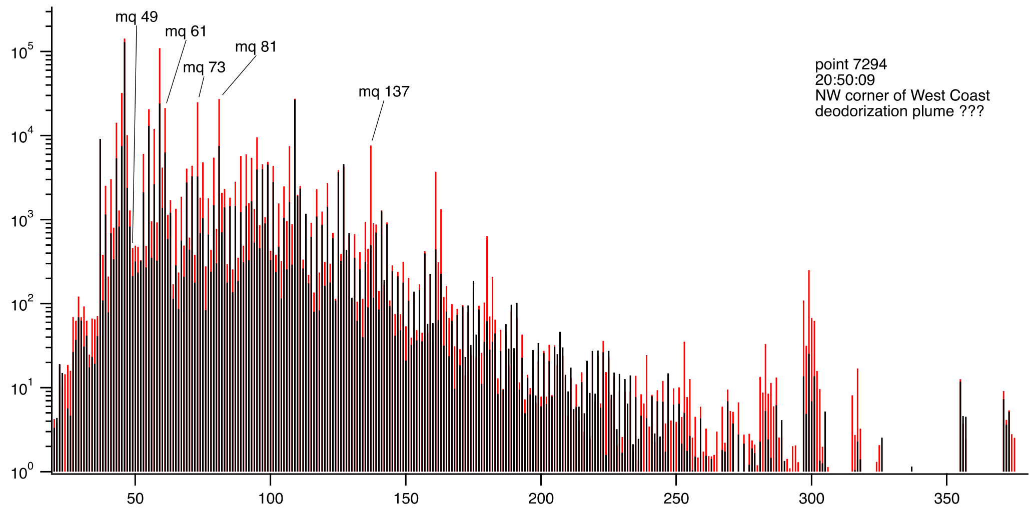



mq 49
mq 69
mq 73
mq 87
point 3851
19:52:44
NW corner of Darling transect
repeat


mq 49
mq 52
point 4541
20:04:13
road NE of Darling


mq 59
mq 43
mq 75
mq 107
mq 93
Point 4953
20:11:05
Toxic
10^0
10^1
10^2
10^3
10^4
10^5
10^6
50
100
150
200
250
300
350


mq 49
point 5833
20:25:45
SW corner of West Coast transect
10^0
10^1
10^2
10^3
10^4
10^5
50
100
150
200
250
300
350



Appendix B: SCAQMD Cr(VI) Project Quality Assurance Notes

Please refer to attached document.

References

Please refer to individual sections for relevant references.