Characterization of Air Emissions from Open Burning at the Radford Army Ammunition Plant

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Abstract

The Radford Army Ammunition Plant (RFAAP) conducts on-site disposal of a variety of hazardous energetic wastes at the facility's open burning ground (OBG). Data on potential combustion emissions and their emission factors are available only from small laboratory and pilot scale simulations. In an effort to obtain actual open burning emissions data the U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD) performed direct sampling and calculation of the RFAAP's OBG emissions. ORD's gas and particle sensor system was attached to a National Aeronautics and Space Agency, Ames Research Center (NASA Ames) hexacopter unmanned aerial vehicle (UAV) and flown into the plumes generated from open burning of propellant and manufacturing discards at RFAAP. This effort represents the first time a UAV with a sampling payload has been used to collect data from the plume of an energetic open burn. While there are no EPA approved methods for sampling emissions from any type of open burn, equipment calibrations and analytical methods followed EPA protocols. Over a 2-week period in September 2017, the NASA/ORD team sampled 33 plumes of dry propellant burns (MK-90 rocket motors) and so-called "skid burns", comprised of a combination of process wastes from onsite production operations. Emissions factor data were determined for particulate matter (PM), metals (particularly Cr(IV)), chloride, perchlorate, volatile organic compounds (VOCs), polychlorinated dioxins/furans (PCDD/PCDF), and nitrogen-based organics. Emission factors were compared with other recently sampled aerial emission data and found to be consistent or, in some cases (for example, HCl) found to be considerably lower. $PM_{2.5}$ emission factors for MK-90s were within the range of three other previously-documented sources. The majority of the metal emission factors, 17 of 24, were lower than those emission factors used in the RFAAP Human Health Risk Assessments (HHRA). Cr(VI) emissions were 28% and 14% of the total Cr emitted from the burns of the MK-90 and skid waste, respectively. Chlorate and perchlorate emission were below detection limits. PCDD/PCDF emissions were less than 0.1% of the emission factor found in the HHRA for skid waste and were similar to those values typically reported from prescribed forest or biomass burns. Residual energetics and nitroaromatics for the MK-90s were below the detection limit. Of the 26 compounds in common between detectable VOC emissions from Radford's skid waste and the listed HHRA emission factors, 25 of the VOCs were less than the HHRA emission factor.

Results show agreement with published emission factors and good reproducibility (e.g., 11% relative standard deviation for $PM_{2.5}$). The UAV/sampler is a significant advance in emission characterization capabilities for open area sources, safely and effectively making measurements heretofore deemed too hazardous for personnel or beyond the reach of land-based samplers.

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List of Acronyms

CO	Carbon monoxide
CO_2	Carbon dioxide
Cr(VI)	Chromium VI
DOD	U.S. Department of Defense
DQI	Data Quality Indicator
EF	Emission Factor
EPA	U. S. Environmental Protection Agency
FOD	Foreign object debris
GC	Gas chromatography
GPS	Global positioning system
HCl	Hydrogen chloride
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HPLC	High-Performance Liquid Chromatography
IC	Ion chromatography
ICP	Inductively coupled plasma
LC	Liquid chromatography

LRGC	Low resolution gas chromatography
LRMS	Low resolution mass spectrometer
MCE	Mixed cellulose ester
MK-90	MK-90 rocket motors
NASA	National Aeronautics and Space Administration
NC	Nitrocellulose
NDIR	Non-dispersive infrared
NG	Nitroglycerine
NIST	National Institute for Standards and Technology
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NRE	New river energetics
OB/ OD	Open burning/Open detonation
OBG	Open burning ground
OD	Outer diameter
ORD	Office of Research and Development
PCDD/PCDF	Polychlorinated dibenzodioxin/dibenzofuran
$PM_{2.5}$	Particulate matter equal to and less than 2.5 µm
PUF	Polyurethane foam
QA	Quality Assurance
QAPP	Quality assurance project plan
RDX	Research Department Formula X, 1,3,5-Trinitroperhydro-1,3,5-triazine
RFAAP	Radford Army Ammunition Plant
RPD	Relative percent difference
SD	Secure digital
SDS	Safety Data Sheets
SIM	Selective ion monitoring
SRM	Standard reference material
SVOC	Semivolatile organic compounds
UAV	Unmanned aerial vehicle
UDRI	University of Dayton Research Institute
USB	Universal serial bus
VOCs	Volatile organic compounds
XRF	x-ray fluorescence spectrometry

1. Introduction

1.1 Brief

The Radford Army Ammunition Plant (RFAAP) conducts on-site disposal of a variety of hazardous energetic wastes via open burn pans located at the facility's open burning ground (OBG). Data on potential combustion emissions and their emission factors are available only from small laboratory and pilot scale simulations and their relevance to the RFAAP's scenario is uncertain. To resolve this issue, the RFAAP asked the U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD) to perform direct sampling and quantification of the RFAAP's OBG emissions. ORD has considerable experience sampling emissions from open burning and open detonation (OB/OD) of military ordnance and static firing of rocket motors (for example, see Aurell et al. [1]). Since 2010, ORD has worked with the Department of Defense's (DoD's) Joint Munitions Command (and their predecessor, the Defense Ammunition Center), the Army Corps of Engineers, and the Defence Research and Development Canada -Valcartier to sample OB/OD emissions at three sites in the US and Canada. ORD has developed a suite of technologies for sampling an array of OB/OD emission constituents from both aerial and ground-based sampling platforms. These sampling methods have been developed over the last five years and include novel methods employing small sensors and samplers, necessitated by the challenge of sampling within a plume located several hundred feet in the open air. To transport ORD's emission sensors/samplers into the plumes, RFAAP entered into an Interagency Agreement with the National Aeronautics and Space Agency, Ames Research Center (NASA Ames) to pilot the Center's hexacopter unmanned aerial vehicle (UAV). This effort represents the first time a UAV has been used to collect comprehensive emissions data from the plume of an energetic open burn. While there are no EPA approved methods for sampling emissions from any type of open burn, equipment calibrations and analytical methods followed EPA protocols.

1.2 Objective

The objective of this work was to characterize and quantify emissions from open burning of dry propellant burns (MK-90 rocket motors) and so-called "skid burns," which are a combination of process wastes from onsite production operations. This skid waste is generally a combination of energetic material, soil, gravel, and other foreign object debris (FOD). Skid burns are what the facility refers to as "assisted burns," where the materials are placed on wooden skids, and nested with dunnage and diesel fuel to promote burning. Quantification of the emissions includes determination of emission factors relating the amount of compound emitted to the amount present in the original material.

2 Materials and Methods

2.1 Test Site Location and Description

The sampling was conducted at the Radford Army Ammunition Plant (RFAAP) in the mountains of southwest Virginia, approximately five miles northeast of the city of Radford, Virginia. RFAAP lies along the New River in the relatively narrow northeastern corner of the valley. Approximate GPS coordinates are 37.1925 N, 80.5233 W. Figure 2-1 shows an overview of the RFAAP burn pan site.

Figure 2-1. Overhead View of RFAAP Burn Pan Site.

2.2 Waste Fuels and Test Schedule

Two waste fuel sources were sampled: dry propellant burns (MK-90) and skid waste burns (two types, described below). The test schedule is shown in Table 2-1. Knowledge of the carbon content of the waste fuel is required for determination of emission factors, as explained in 2.5.1, below.

Table 2-1. Test schedule, amount of total pan load and amount of waste burned per test day.

Test Date	Waste Fuel	Amount of burn pans	Amount of Total pan load lb (kg)	Amount of Total waste lb (kg)
09/27/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
09/28/2016	Skid waste: Type 1	3	3,254 (1,479)	1,620 (736)
09/29/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
09/30/2016	Skid waste: Type 2	2	1,589 (722)	500 (227)
10/03/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
10/04/2016	Skid waste: Type 1	3	3,254 (1,479)	1,620 (736)
10/05/2016	MK-90	5	3,000 (1,364)	3,000 (1,364)
10/06/2016	Skid waste: Type 2	2	1,589 (722)	500 (227)

2.2.1 MK-90

The MK-90 composition was constant for all burn tests. Each burn pan charge was comprised of 99% MK-90 and 1% NRE contaminated waste, by weight. The total carbon fraction is shown in Table 2-2.

Table 2-2. Total carbon fraction in "MK-90" burns.

Ordnance	Total Carbon Fraction
Total fractions from MK-90 and NRE cont.	0.25

2.2.2 Skid Waste

Two different types of skid waste compositions, derived by the RFAAP Operating Contractor, were tested as shown in Figure 2-2. The main difference between the two skid waste types were the chlorine, lead, copper, and chrome fractions. Skid waste type 1 was designed to be a high chlorine burn (0.26% Cl and 0.056% metals) and skid waste type 2 was a high metals burn (0.017% Cl and 0.361% metals), with focus on those metals that have feed limits. These compositions are not typical of those skid burns normally executed at RFAAP but, according to the RFAAP Operating Contractor, were designed at the request of the Virginia Department of Environmental Quality to represent "worst-case" scenarios. The carbon content data of the energetics material was provided by the RFAAP Operating Contractor and was not verified by EPA/ORD. The majority of the carbon in the skid waste originated from the wood pallets (Table 2-3). Both skid waste types contained the same number of wood pallets, however, skid waste type 2 contained 26% more carbon than skid waste type 1 due to a higher mass fraction of pallets (less waste mass in type 2).

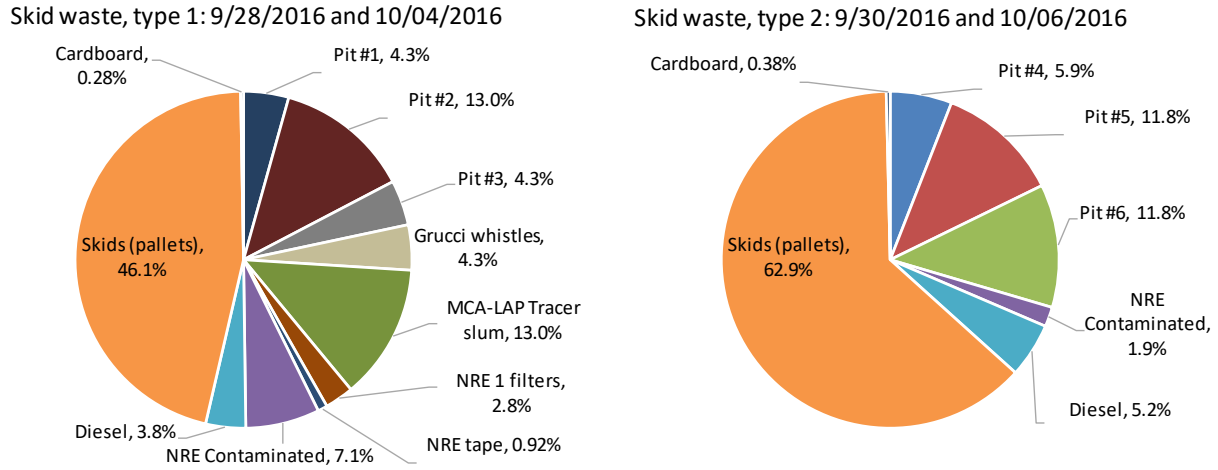

Figure 2-2. Composition of the two types of skid wastes tested, type 1 (left, total mass 3,254 lbs.) and type 2 (right, total mass 1,589 lbs.).

Table 2-3. Skid waste composition and carbon fraction

Waste type/ Test Dates	Composition	Carbon Fraction of each component	Carbon fraction in burn pan
Skid waste Type 1 09/28/2016 and 10/04/2016	Pallets 46%	0.502[a]	0.23
	Cardboard 0.28%	0.46[b]	0.0013
	Diesel 3.8%	0.86[b]	0.033
	Pit #1 4.3%	0.017[d]	0.00074
	Pit #2 13%	0.046[d]	0.0059
	Pit #3 4.3%	0.41[d]	0.0018
	Grucci whistles 4.3%	0.16[d]	0
	MCA-LAP Tracer slum 13%	0.0003[d]	0.000043
	NRE 1 filters 2.8%	0.013[d]	0.00035
	NRE tape 0.92%	0	0.00016
	NRE Contaminated 7.1%	0.046[d]	0.0032
	Total Carbon fraction		**0.28**
Skid waste Type 2 09/30/2016 and 10/06/2016	Pallets 63%	0.502[a]	0.32
	Cardboard 0.38%	0.46[b]	0.0017
	Diesel 5.2%	0.86[c]	0.045
	Pit #4 5.9%	0.052[d]	0.0031
	Pit #5 11.8%	0.038[d]	0.0045
	Pit #6 11.8%	0.056[d]	0.0066
	NRE Contaminated 1.9%	0.046[d]	0.00086
	Total Carbon Fraction		**0.38**

[a] [2]
[b] [3]
[c] Calculated using molecular formula $C_{12}H_{23}$ and density 0.832 kg/L.
[d] Analytical measured data from BAE.

2.3 Testing Procedures

2.3.1 Target Analytes and Collected Target Analytes

The target analytes are listed in Table 2-4. The full list of target VOCs and elements are listed in Chapter 2.4.5 and Chapter 2.4.3, respectively. CO_2 and CO were successfully measured continuously through all burns. The total number of target analyte samples collected for each type of waste are shown in Table 2-5.

Table 2-4. Target analytes.

Analyte	Instrument/Method	Frequency
CO_2	Non-dispersive infrared	Continuous
CO	Electrochemical cell	Continuous
$PM_{2.5}$[a]	Impactor, Teflon filter	Batch
Nitrocellulose	Glass fiber filter	Batch

Analyte	Instrument/Method	Frequency
Nitroaromatics	Glass fiber filter	Batch
PCDD/PCDF	Glass fiber filter and PUF[b]	Batch
Elements	Teflon filter from $PM_{2.5}$ batch filter	Batch
Cr(VI)	Bicarbonated-impregnated MCE[c] filter	Batch
HCl	Na_2CO_3 coated quartz filter	Batch
Perchlorate/chlorate	Quartz filter	Batch
VOCs	Carbotrap 300	Batch

[a]Fine particles in the ambient air with particles less than or equal to 2.5 µm in diameter.
[b] PUF – polyurethane foam plug.
[c] MCE – mixed cellulose ester.

Table 2-5. Collected target analytes from MK-90 and skid waste.

Analyte	MK-90	Skid waste	Total
$PM_{2.5}$	5	2	7
Nitrocellulose	2	0	2
Nitroaromatics	4	0	4
PCDD/PCDF	0	4	4
Elements	5	2	7
Cr(VI)	5	3	8
HCl	0	6	6
Perchlorate/chlorate	0	6	6
VOCs	0	4	4

2.3.2 Unmanned Aerial Vehicle Based Sampling Method

Figure 2-3 shows the sampling instrumentation attached to the bottom of the UAV. This combined system was used for collecting air emissions from propellant plumes.

Figure 2-3. UAV-Based Sampling Method

2.3.2.1 Unmanned Aerial Vehicle – UAV

Aerial sampling was conducted by a UAV operated by NASA Ames. NASA used a DJI Matrice M600 UAV (Figure 2-4). It is a 6-rotor hexacopter with a 9.1 kg weight and a 15.1 kg maximum acceptable gross take-off weight. Its maximum loaded flight time was approximately 13.5 min whereupon the remaining battery charge was 40%. The UAV can be controlled automatically or by pilot-in-command modes and provides the operator a GPS display screen of location in real time with a 2.4 GHz telemetry system. The M600 has an inertial measurement unit and GPS with a return to base function at a preset charge threshold.

Figure 2-4. NASA's UAV.

2.3.2.2 Kolibri – Sampling System

EPA/ORD's sampling system called the "Kolibri" has been developed specifically for sample collection of plumes from open combustion sources. There are two configurations of the Kolibri primarily relating to the different sizes of the pumps needed for specific analytes. There are duplicate models of both Kolibris configurations for redundancy, referred to as "Oden" and "Balder" for the smaller unit and "Tor" and "Loke" for the larger unit (Figure 2-5). Because of payload limitations on the UAV, it was not possible to sample all of the target analytes with all of the pumps on a single platform. In addition, one pump has to be used for multiple analytes ($PM_{2.5}$ or Total PM, Nitrocellulose or Nitroaromatics) and these can only be sampled separately. Hence, the full suite of analytes could only be collected using both Kolibris with sampler variations on each one (Table 2-6). In addition, energetics and VOCs required composite samples comprised of emission sampling from plumes of multiple burns. Because each of these samples has to be collected separately with composite samples, the number of repeat samples was limited. The Kolibri is capable of plotting real time CO_2 and CO data, displaying sampling time and VOC sampling volume, while performing real time calculations to estimate the total amount of gaseous carbon sampled for the energetic sample.

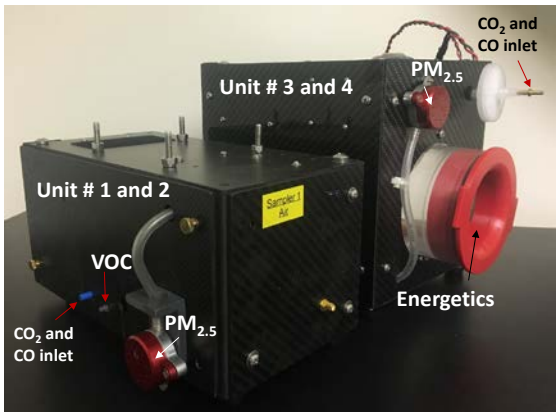

Figure 2-5. Kolibri Instrumentation, Oden and Balder model in foreground and Tor and Loke model in background.

Table 2-6. Sampling instrumentation used during each test day.

Test Date	Ordnance	Kolibri Unit[a]	Analytes Collected
09/27/2016	MK-90	Unit 4: Loke	Nitroaromatics/$PM_{2.5}$/Metals
09/29/2016	MK-90	Unit 4: Loke	Nitrocellulose/Cr(VI)
10/03/2016	MK-90	Unit 4: Loke	Nitroaromatics/Cr(VI)
10/05/2016	MK-90	Unit 4: Loke	Nitrocellulose/$PM_{2.5}$ /Metals
09/28/2016 10/04/2016	Skid waste	Unit 4: Loke	PCDD/PCDF/ HCl/Perchlorate/Chlorate
09/30/2016	Skid waste	Unit 2: Balder	VOCs/Cr(VI)
10/06/2016	Skid waste	Unit 1: Oden	VOCs/Cr(VI)
10/06/2016	Skid waste	Unit 1: Oden	VOCs/$PM_{2.5}$/Metals

[a] Unit 3 (Tor) was not used.

2.3.3 Ambient Air Background Sampling

Ambient air background samples were collected upwind of the burn pan site after any MK-90 and skid waste burns were conducted. The ambient air background samples were collected with the same instruments/methods as the emission samples shown in Table 2-7.

Table 2-7. Sampling Instrumentations used during Ambient Air Background Collection.

Test Date	Kolibri Unit	Sampling volume	Analytes Collected
10/04/16	Unit 4: Loke	0.31 m^3	HCl/Perchlorate
10/04/16	Unit 4: Loke	33 m^3	PCDD/PCDF

Test Date	Kolibri Unit	Sampling volume	Analytes Collected
10/05/16	Unit 4: Loke	0.63 m^3	$PM_{2.5}$/Metals
10/05/16	Unit 4: Loke	36 m^3	Nitrocellulose
10/06/16	Unit 4: Loke	35 m^3	Nitroaromatics
10/06/16	Unit 1: Oden	0.48 m^3	Cr(VI)
10/06/16	Unit 1: Oden	0.0058 m^3	VOC

2.4 Emission Sampling and Analytical Methods

2.4.1 CO_2

The system CO_2 sensor (DX62210/DX6220 OEM Model, RMT Ltd, Moscow, Russia) measured CO_2 concentration by means of non-dispersive infrared absorption (NDIR). The DX62210/DX6220 CO_2 concentration was recorded on a standard secure digital (SD) card at a rate of one sample per second (1 Hz). The DX62210/DX6220 was calibrated for CO_2 and checked for drift on a daily basis in accordance with EPA Method 3A [4]. The gas cylinders used for calibration were certified by the suppliers and traceable to National Institute of Standards and Technology (NIST) standards. A precision dilution calibrator Serinus Cal 2000 (American ECOTECH L.C., Warren, RI, USA) was used to dilute the high-level span gases for acquiring the mid-point concentrations for the DX62210/DX6220 calibration curves. The daily CO_2 system drift for Unit 4 (Loke) varied from -4.6% to -0.4% of the full span and +1.0% for Unit 2 (Balder), which is within the 5% acceptance limit of the sensor. Unit 1 (Oden) did not have a long enough warm up period before calibration therefore the drift of 7.9% was slightly outside acceptance limit, for this reason, the post-calibration curve was used for calculations as opposed to the pre-calibration curve.

2.4.2 CO

The CO sensor (e2V EC4-500-CO) was an electrochemical gas sensor (SGX Sensortech Ltd, High Wycombe, Buckinghamshire United Kingdom) which measured CO concentration by means of an electrochemical cell through CO oxidation and changing impedance. The sensor was calibrated for CO on a daily basis in accordance with U.S. EPA Method 3A [4]. The e2V CO concentration was recorded on a SD card at a rate of one sample per second (1 Hz). All gas cylinders used for calibration are certified by the suppliers and traceable to NIST standards. A precision dilution calibrator Serinus Cal 2000 (American ECOTECH L.C., Warren, RI, USA) was used to dilute the high-level span gases for acquiring the mid-point concentrations for the e2V EC4-500-CO calibration curves. The daily CO system drift for Unit 4 (Loke) varied from -8.4% to 2.8% and -1.2% for Unit 2 (Balder) and -4.5% for Unit 1 (Oden), which is within the 10% acceptance limit of the sensor.

2.4.3 PM and Elements

$PM_{2.5}$ was sampled with SKC impactors (761-203B) using 37 mm tared Teflon filter (obtained from Chester LabNet) with a pore size of 2.0 µm via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) of 10 L/min. Total PM was sampled using cassette with a 37 mm tared Teflon filter (Chester LabNet) with a constant air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA). PM were measured gravimetrically following the procedures described in 40 CFR Part 50 [5]. The constant flow pump was calibrated daily with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Petersburg, FL, USA). The plume samples' $PM_{2.5}$ concentrations were more than 100 times higher than the collected ambient air background sample.

Elements were determined by x-ray fluorescence spectrometry (XRF) analysis of the Teflon $PM_{2.5}$ and Total PM filters using EPA Compendium Method I0-3.3 [6]. The elements analyzed using XRF are stated in Table 2-8. Chester LabNet evaluated precision with a multi-element quality control standard (QS285) and accuracy using NIST standard reference materials (SRMs): SRM 1832, SRM 1833 and SRM 2783. The SRMs used for quality assurance/quality control (QA/QC) had a recovery of 91.9-108.6%, which is within the 80-120% acceptance criteria of the method. The plume samples' element concentrations were at least 4 times higher than the ambient air background concentration.

Table 2-8. Elements Determined using XRF.

Elements			
Aluminum (Al)	Copper (Cu)	Molybdenum (Mo)	Strontium (Sr)
Antimony (Sb)*	Gallium (Ga)	Nickel (Ni)*	Sulfur (S)
Arsenic (As)*	Germanium (Ge)	Palladium (Pd)	Tin (Sn)
Barium (Ba)	Indium (In)	Phosphorus (P)	Titanium (Ti)
Bromine (Br)	Iron (Fe)	Potassium (K)	Vanadium (V)
Cadmium (Cd)*	Lanthanum (La)	Rubidium (Rb)	Yttrium (Y)
Calcium (Ca)	Lead (Pb)*	Selenium (Se)*	Zink (Zn)
Chlorine (Cl)	Magnesium (Mg)	Silicon (Si)	Zirconium (Zr)
Chromium (Cr)*	Manganese (Mn)*	Silver (Ag)	
Cobalt (Co)*	Mercury (Hg)*	Sodium (Na)	

* On U.S. EPA's list of hazardous air pollutants [7].

2.4.4 Chromium(VI)

Chromium(VI) (Cr(VI)) was sampled on a bicarbonate-impregnated "acid hardened" cellulose filter via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) at 10 L/min. Cr(VI) was determined using a proprietary method (ChesterLabNet, Tigard, OR) based

on an EPA standard procedure [8]. The control sample had recoveries of 97.6 to 101.0% which is within the acceptance limits for the method of 75-125%. No detectable levels of Cr(VI) were found in the ambient air background collected sample.

2.4.5 VOCs

VOCs were sampled using Carbotrap 300 stainless steel TD Tube (Supelco Inc., Bellefonte, PA, USA) via a constant micro air pump with an air flow rate of 0.185 L/min (3A120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) in accordance with U.S. EPA Method TO-17 [9]. The Carbotrap 300 tubes were analyzed by ALS Environmental (Simi Valley, CA) for VOCs by thermal desorption GC/MS according to U.S. EPA Method TO-17 [9]. The target VOCs analyzed from Carbopack 300 are stated in Table 2-9. The surrogate spikes used for the QA/QC had recoveries of 85-107% for all samples, which is within the accuracy of the method; recoveries of 70-140%. Eight of sixty-one VOCs (Trichlorofluoromethane, methylene chloride, carbon disulfide, trichloroethene, 1,1,2-trichloroethane, toluene, 1,2-dibromoethane, bromoform) had recoveries slightly outside the acceptance limits for the laboratory control sample. The other 53 VOCs had recoveries of 99-118%, which is within the acceptance limit of the method; recoveries of 52-135%. The VOC method blank showed all non-detectable levels of VOCs except for carbon disulfide. The VOC trip blank showed detectable levels of ethanol, acetonitrile, and acetone. The VOC plume sample levels were 2-14 times, 22-63 times, and 6-35 times higher for ethanol, acetonitrile, and acetone, respectively, than the trip blank levels. The VOC plume samples were corrected for the trip blank concentrations as well as corrected for ambient air background concentrations. The constant flow pump was calibrated daily with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Peterburg, FL, USA).

Table 2-9. VOCs analyzed from Carbotrap 300

VOCs		
1,1,1-Trichloroethane*	2-Hexanone	Ethanol
1,1,2,2-Tetrachloroethane*	2-Propanol (Isopropyl Alcohol)	Ethylbenzene*
1,1,2-Trichloroethane*	4-Methyl-2-pentanone	Hexachlorobutadiene*
1,1-Dichloroethane	Acetone	m,p-Xylenes*
1,1-Dichloroethene	Acetonitrile*	Methyl tert-Butyl Ether
1,2,4-Trichlorobenzene*	Benzene*	Methylene Chloride*
1,2,4-Trimethylbenzene	Bromodichloromethane	Naphthalene*
1,2-Dibromo-3-chloropropane	Bromoform*	n-Heptane
1,2-Dibromoethane	Carbon Disulfide*	n-Hexane
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	Carbon Tetrachloride*	n-Octane
1,2-Dichlorobenzene	Chlorobenzene*	o-Xylene*
1,2-Dichloroethane	Chloroethane	Styrene*
1,2-Dichloropropane	Chloroform*	Tetrachloroethene
1,3,5-Trimethylbenzene	Chloromethane*	Tetrahydrofuran (THF)
1,3-Butadiene*	cis-1,2-Dichloroethene	Toluene*

VOCs		
1,3-Dichlorobenzene	cis-1,3-Dichloropropene*	trans-1,2-Dichloroethene
1,4-Dichlorobenzene*	Cumene*	trans-1,3-Dichloropropene*
1,4-Dioxane	Cyclohexane	Trichloroethene
2,2,4-Trimethylpentane* (Isooctane)	Dibromochloromethane	Trichlorofluoromethane
2-Butanone (MEK)*	Dichlorodifluoromethane (CFC 12)	Trichlorotrifluoroethane
		Vinyl Chloride*

* On U.S. EPA's list of hazardous air pollutants [7].

2.4.6 Energetics

Nitroaromatics/Nitrocellulose were sampled using two 15 cm glass fiber filters (Fisher Scientific) with a nominal rate of 500 L/min. Energetics were sampled using a low voltage MINIjammer brushless blower (AMTEK, USA). The flow rate was measured by a 0-622 Pa Model 265 pressure differential transducer (Setra, USA) across a Herschel Standard Venturi tube (EPA in-house made). The Venturi tube is specially designed to meet the desired sampling rate for the target compound. The voltage equivalent to this pressure differential is recorded on the onboard Teensy USB microcontroller board, which was calibrated with a Roots meter (Model 5M, Dresser Measurement, USA) in the U.S. EPA metrology laboratory before sampling effort.

The energetics samples were analyzed by an outside laboratory using analytical methods U.S. EPA Method 8330b [10] for nitroaromatics and U.S EPA Method 353.2 [11] for nitrocellulose, which is a nitrate-nitrite colorimetric method. The surrogate spikes used for the nitroaromatics QA/QC had recoveries of 99.9-104% for all samples, which is within the accuracy of the method; recoveries of 70-130%. The laboratory control spike recoveries for nitroaromatics were between 99.5% and 100%, which is within the accuracy of the method; recoveries of 70-150%. The laboratory control spike recovery for nitrocellulose was 108%, which is within the accuracy of the method; recoveries of 40-120%. Nitroaromatics and nitrocellulose were not detected in the ambient air background sample.

2.4.7 HCl, Perchlorate, and Chlorate

HCl was sampled using an alkali-impregnated filter following a solid perchlorate and chloride filter (ISO Method 21438-2) [12]. The sampling was conducted at a flow rate of 2 L/min using a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA). The constant flow pump was calibrated daily with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Petersburg, FL, USA). Perchlorate salts were captured as a solid on the filter, which assumes no perchloric acid formation [13]. Samples were analyzed at a New York State certified laboratory, ALS Environmental, Rochester, NY. The alkali-impregnated filter was analyzed for HCl by ion chromatography methods specified in U.S. EPA Method 26 [14]. The laboratory control spike recovery for perchlorate and chlorate was 100% and 115%, respectively which is within the accuracy of the methods; recoveries of 40-120%. The laboratory control spike

recovery for chloride was 107%, which is within the acceptance limit of the method; recoveries of 90-110%. Chlorate, perchlorate, or HCl were not detected in the ambient air background sample.

2.4.8 PCDD/PCDF

PCDD/PCDF were sampled similarly to energetics (see 2.4.6) but with the addition of a polyurethane foam plug (PUF) following the glass fiber filter. PCDD/PCDF samples were cleaned up and analyzed using an isotope dilution method based on U.S. EPA Method 23 [15]. Concentrations were determined using high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) with a Hewlett-Packard gas chromatograph 6890 Series coupled to a Micromass Premier mass spectrometer (Waters Corp., Milford, MA, USA). U.S. EPA Method 8290 [16] was used for analysis of tetra- through octa-CDDs/Fs. The laboratory control spike recoveries were within the acceptable 40-130% range for Tetra to Hexa PCDD/PCDF and 25-130% for Hepta to Octa PCDD/PCDF for most of the congeners. The HpCDF recovery was slightly outside the acceptance criteria for three of the four samples (13-23%), PentaCDD was outside the acceptance criteria in two of the four samples (155% and 178%). The collected plume samples had 10-250 and 700- >10,000 times higher levels of Total and TEQ PCDDs/PCDFs, respectively, than the collected ambient background sample.

The 2005 World Health Organization (WHO) toxic equivalent factors (TEFs) [17] were used to determine the PCDD/PCDF toxic equivalent (TEQ) emission factors (see Chapter 2.5.2 for calculations). Some of the seventeen TEF-weighted PCDD/PCDF congeners were undetected. The congeners that were not detected (ND) were considered as zero mass for the reported text calculations, however Appendix B shows both ND = 0 and ND = limit of detection mass value.

2.5 Calculations

2.5.1 Converting from mass/mass Carbon to mass/mass initial source

The emission ratio of each analyte or species of interest was calculated from the ratio of background-corrected pollutant concentrations to background-corrected carbon dioxide (CO_2) and carbon monoxide (CO) concentrations. Emissions factors were calculated using these emissions ratios following the carbon balance method [18], and presented as mass pollutant per mass of charge weight. For the two skid waste types, the charge weight was expressed both as 1) the total initial weight of the waste plus the supplemental pallet and diesel fuel ("mass pollutant/mass initial source") as well as 2) the weight of the RFAAP waste alone without the supplemental fuel ("mass pollutant/mass waste"). For the MK-90s the charge weight was the total mass of initial MK-90 source material in the pan, resulting in emission factors expressed as "mass pollutant/mass initial source" which is the same meaning as "mass pollutant/mass waste" since no supplemental fuels were added to the waste, Equations 2-1 and 2-2. Emission factors determined here are compared with the emission factors used in the RFAAP Human Health Risk Assessment (HHRA) document, specifically Table 2-13 [19].

$$EF_i = f_c \times \frac{Analyte_i}{\sum C_j} \qquad \textit{Equation 2-1}$$

where:

EF_i	=	Emission factor of target analyte i in terms of mass pollutant per mass initial source
fc	=	mass fraction of carbon in the initial source
$Analyte_i$	=	the mass emission ratio of species i,
ΣC_j	=	the background corrected mass concentration of carbon in major carbon emissions species j (carbon calculated from ΔCO_2 and ΔCO).

$$EF_{Waste} = EF_i \times \frac{IW}{IW+SF} \qquad \textit{Equation 2-2}$$

where:

EF_{Waste}	=	Emission factor of target analyte i in terms of mass pollutant per mass waste
IW	=	Initial weight of waste
SF	=	Supplement fuel (pallet, cardboard, and diesel)
IW/(IW+SF)	=	2.01 and 3.18 for skid waste type 1 and 2, respectively

The majority of the carbon emissions were emitted as CO_2 and CO. With this assumption, CO_2 and CO are the only carbon-containing compounds that were required to be measured for the emission factor calculations.

2.5.2 PCDD/PCDF Toxic Equivalent Calculations

PCDDs and PCDFs include 75 and 135 congeners, respectively. Of these 210 congeners 17 are toxic and have been assigned toxic equivalency factor (TEF) values (Table 2-10). The TEQ value is obtained by multiplying the concentration of a PCDD/PCDF congener by its TEF-value and summing the result for all 17 toxic congeners.

Table 2-10. The 2005 World Health Organization PCDD/PCDF Toxic Equivalent Factors for mammals/humans.[17]

PCDDs	**TEF**	**PCDFs**	**TEF**
2,3,7,8 - TCDD	1	2,3,7,8 - TCDF	0.1
1,2,3,7,8 - PeCDD	1	1,2,3,7,8 - PeCDF	0.03
1,2,3,4,7,8 - HxCDD	0.1	2,3,4,7,8 - PeCDF	0.3
1,2,3,6,7,8 - HxCDD	0.1	1,2,3,4,7,8 - HxCDF	0.1
1,2,3,7,8,9 - HxCDD	0.1	1,2,3,6,7,8 - HxCDF	0.1

PCDDs	TEF	PCDFs	TEF
1,2,3,4,6,7,8 - HpCDD	0.01	1,2,3,7,8,9 - HxCDF	0.1
1,2,3,4,6,7,8,9 - OCDD	0.0003	2,3,4,6,7,8 - HxCDF	0.1
		1,2,3,4,6,7,8 - HpCDF	0.01
		1,2,3,4,7,8,9 - HpCDF	0.01
		1,2,3,4,6,7,8,9 - OCDF	0.0003

2.5.3 Data Variability

Standard deviation, as well as the relative standard deviation (RSD), were used as a measure of dispersion of three or more data values, see Equations 2-3 and 2-4. RSD indicates how precise the data is, for example a RSD of 50% indicates that the data is more spread out than a RSD of 20%.

$$Standard\ Deviation = \sqrt{\frac{\sum(x-\bar{x})^2}{(n-1)}} \qquad \textit{Equation 2-3}$$

where:

x = each sample value, $\overline{x}$ = mean value of samples, n = number of samples

$$RSD\ (\%) = 100 \times \frac{Standard\ Deviation}{Sample\ Average} \qquad \textit{Equation 2-4}$$

The relative percent difference (RPD) calculation was used as a quality indicator when only two data values (duplicate samples) were obtained, Equation 2-5. RPD indicates how precise the data is, for example a RPD of 20% indicates that the data are more precise than a RPD of 50%.

$$RPD\ (\%) = 100 \times \frac{x-y}{(\frac{x+y}{2})} \qquad \textit{Equation 2-5}$$

where:

x = sample number one, y = sample number two

3 Results and Discussion

3.1 PM

The $PM_{2.5}$ emissions are reported in Table 3-1. $PM_{2.5}$ emissions were higher from the MK-90 than from the skid waste (Table 3-1). These emission factors can be compared to previous values determined by sampling with an instrument system lofted into the plume with a helium-filled aerostat. The MK-90 $PM_{2.5}$ emission factor (15.5 g/kg initial source) is similar to those determined earlier with the aerostat system from static firing of CRV-7 (16 g/kg initial source) and MK-58 (34 g/kg initial source) rocket motors [20] and lower than static firing of Sparrow rocket motors (120 g/kg initial source) [1]. The HHRA document lists no PM emission factors, precluding comparison of these site-sampled values.

Table 3-1. $PM_{2.5}$ emission factors in g/kg initial source and lb/lb initial source.

		$PM_{2.5}$	
		MK-90	**Skid Waste - Type 2**
	Unit	**n[a] = 5**	**n[a] = 2**
Average	g/kg initial source	15.5	2.3
Stand. Dev.[b]	g/kg initial source	1.73	N/A[e]
RSD[c]	%	11	N/A[e]
RPD[d]	%	N/A[e]	9.8
Average	lb/lb initial source	0.0155	0.0023
Stand. Dev.[b]	lb/lb initial source	0.0017	N/A[e]
Average	g/kg waste	15.5	7.3
Average	lb/lb waste	0.0155	0.0073

[a] Number of samples collected.
[b] Stand. Dev. – standard deviation, calculated only if $n \geq 3$.
[c] RSD – relative standard deviation, calculated only if $n \geq 3$.
[d] RPD – relative percent difference, calculated only if $n = 2$.
[e] N/A – not applicable.

3.2 Elements/Metals

3.2.1 Elements/Metals

Sixteen metals/elements were detected above instrument limits for one or both of the ordnance sources (Table 3-2). Lead (Pb) and copper (Cu) had the highest emission factors from the MK-90 burns of all the metals analyzed, 0.0102 and 0.00307 lb/lb initial source, respectively (Tables 3-2 to 3-4). Pb, chloride (Cl), potassium (K), Cu, and zinc (Zn) had the highest element emission factors for the “high metal” skid waste. The average standard deviation for the MK-90 metal/element emission factors was 29%. The average relative percent difference for the skid waste emission factors (only two samples were taken) was 55%. These relatively low values

validate the precision of the sampling method, particularly given the small number (less than five) of samples. All element values from the XRF analyses for each collected sample are shown in Appendix A.

Table 3-2. Element emission factors in $PM_{2.5}$ fraction in mg/kg initial source and mg/kg waste.[a]

Element	MK-90				Skid waste – Type 2			
	n[b]	Average	Stand. Dev.[c]	RSD[d]	n[b]	Average	Average	RPD[e]
		mg/kg initial source		%		mg/kg initial source	mg/kg waste	%
Pb	5	10,186	1,103	11	2	678.9	2,158	40
Cu	5	3,073	380	12	2	17.4	55.4	92
Cl	5	30	24	80	2	80.4	255.5	24
Ca	5	28	5.8	20	2	2.17	6.91	20
K	5	25	5.2	20	2	43.4	138.0	1.9
As	4	21	5.3	25	2	1.45	4.62	62
Fe	5	16	3.3	21	2	0.53	1.70	129
Br	5	15	2.5	17	2	1.53	4.86	45
Ge	5	11	2.7	24	2	0.66	2.09	57
Y	5	11	2.8	26	2	0.80	2.53	46
Rb	5	8	1.6	20	2	0.81	2.57	41
Ba	4	6.4	0.42	6.6	2	0.24	0.75	36
Al	3	7.3[f]	5.9	80	0	ND[g]	ND[g]	N/A[h]
Cd	5	2.0	1.2	59	1	0.19	0.62	N/A[h]
Cr	4	1.4	0.21	15	1	0.038[f]	0.12[f]	N/A[h]
Zn	5	ND[g]	N/A[h]	N/A[h]	2	7.6	24.1	121

[a] Element concentrations were 22 times higher than the ambient air levels except for Cr which was four times higher than the ambient levels. All element values from XRF analyses are presented in Appendix A.
[b] Number of samples collected with detectable levels.
[c] Stand. Dev. – standard deviation, calculated only if $n \geq 3$
[d] RSD – relative standard deviation, calculated only if $n \geq 3$.
[e] RPD – relative percent difference, calculated only if $n = 2$.
[f] Results less than three times the uncertainty level of the analyses.
[g] ND – not detected.
[h] N/A – not applicable.

Table 3-3. Metal emission factors in $PM_{2.5}$ fraction in lb/lb initial source and lb/lb waste.[a]

Element	MK-90				Skid waste - Type 2			
	n[b]	Average	Stand. Dev.[c]	RSD[d]	n[b]	Average	Average	RPD[e]
		lb/lb initial source		%		lb/lb initial source	lb/lb waste	%
Pb	5	1.02E-02	1.10E-03	11	2	6.79E-04	2.16E-03	40
Cu	5	3.07E-03	3.80E-04	12	2	1.74E-05	5.54E-05	92
Cl	5	2.97E-05	2.37E-05	80	2	8.04E-05	2.56E-04	24
Ca	5	2.84E-05	5.80E-06	20	2	2.17E-05	6.91E-06	20
K	5	2.53E-05	5.17E-06	20	2	4.34E-05	1.38E-04	1.9
As	4	2.08E-05	5.29E-06	25	2	1.45E-06	4.62E-06	62
Fe	5	1.60E-05	3.32E-06	21	2	5.34E-07	1.70E-06	129
Br	5	1.47E-05	2.49E-06	17	2	1.53E-06	4.86E-06	45
Ge	5	1.11E-05	2.71E-06	24	2	6.59E-07	2.09E-06	57
Rb	5	8.41E-06	1.64E-06	20	2	8.08E-07	2.57E-06	41
Y	5	1.07E-05	2.78E-06	26	2	7.95E-07	2.53E-06	46
Ba	4	6.36E-06	4.19E-07	6.6	2	2.37E-07	7.53E-07	36
Al	3	7.32E-06[f]	5.89E-06	80	0	ND[g] (6.11E-05)	ND[g]	N/A[h]
Cd	5	1.99E-06	1.18E-06	59	1	1.94E-07	6.18E-07	N/A[h]
Cr	4	1.40E-06	2.06E-07	15	1	3.79E-08[f]	1.21E-07[f]	N/A[h]
Zn	0	ND[g] (4.73E-07)	N/A[h]	N/A[h]	2	7.58E-06	2.41E-05	121

[a] Elements levels were 22 times higher than the ambient air levels except for Cr which was four times higher than the ambient levels. All element values from XRF analyses are presented in Appendix A
[b] Number of samples collected with detectable levels.
[c] Stand. Dev. – standard deviation, calculated only if $n \geq 3$
[d] RSD – relative standard deviation, calculated only if $n \geq 3$.
[e] RPD – relative percent difference, calculated only if $n = 2$.
[f] Results less than three times the uncertainty level of the analyses.
[g] ND – not detected, method detection limit within parentheses.
[h] N/A – not applicable.

The sampled emission factors were compared with the assumed emission factors used in the RFAAP EFs listed in the HHRA (Table 3-4) [19]. Of the twelve metals that overlapped for the MK-90s, seven sampled emission factors were lower than the RFAAP EFs and four emission factors were higher than the RFAAP EF (As, Cd, Pb, and Ag). One metal, Hg, was reported as ND so its ratio (<2.2) is not clearly greater or less than unity. For the twelve metals from the skid waste burns, emission factors for ten metals were less than estimated in the HHRA. Two metals, As and Pb, had emission factors above their respective values in the HHRA.

Table 3-4. Comparison of EFs derived in this project with EFs used by RFAAP's HHRA.

Element	MK-90 EF	MK-90 RFAAP EF [19]	MK-90 Ratio	Skid waste EF	Skid waste RFAAP EF [19]	Skid waste Ratio
	lb/lb initial source		EF/RFAAP EF	lb/lb waste		EF/RFAAP EF
Al	7.32E-06[a]	1.00E-02	0.00073	ND[b] (<6.11E-05)	5.36E-02	<0.0011
Sb	2.32E-06[a]	5.62E-06	0.41	ND[b] (<2.14E-07)	5.62E-06	<0.038
As	2.08E-05	5.54E-07	37.5	4.62E-06	5.54E-07	8.3
Ba	6.36E-06	8.80E-05	0.072	7.53E-07	8.80E-05	0.0086
Cd	1.99E-06	1.32E-06	1.5	6.18E-07	1.32E-06	0.47
Cr	1.40E-06	1.20E-05	0.12	1.21E-07[f]	1.20E-05	0.010
Pb	1.02E-02	2.06E-03	5.0	2.16E-03	2.06E-03	1.1
Hg	ND[b] (<1.65E-06)	7.38E-07	<2.2	ND[b] (<1.65E-07)	7.38E-07	<0.22
Ni	ND[b] (<3.32E-07)	1.98E-05	<0.017	8.19E-09[a]	1.98E-05	0.00041
Se	9.38E-07[a]	1.56E-06	0.60	ND[b] (<6.68E-08)	1.56E-06	<0.043
Ag	1.27E-06[a]	2.12E-07	6.0	2.06E-07[a]	2.12E-07	0.97
Zn	ND[b] (<4.73E-07)	7.55E-05	<0.0063	2.41E-05	7.55E-05	0.32

[a] Results less than three times the uncertainty level of the analyses.
[b] ND – not detected, detection limit within parentheses.

3.2.2 Chromium(VI)

The Cr(VI) emission factors are reported in Table 3-5. Analysis of the $PM_{2.5}$ solids showed that the percentage of Cr(VI) to total Cr in the emissions was 28% and 14% for the MK-90 and skid waste, respectively. Table 3-4 indicates that the total Cr emission factor from sampling was less than used in the HHRA for both MK-90 (12% of the HHRA emission factor) and skid waste (1% of the HHRA emission factor).

Table 3-5. Cr(VI) emission factors.

		Cr(VI) MK 90	Cr(VI) Skid Waste -Type 2
	Unit	n[a] = 5	n[a] = 1
Average	mg/kg initial source	0.39	0.0053
Stand. Dev.[b]	mg/kg initial source	0.13	N/A[d]
RSD[c]	%	34	N/A[d]
Average	lb/lb initial source	3.95E-07	5.31E-09
Stand. Dev.[b]	lb/lb initial source	1.34E-07	N/A[d]
Average	mg/kg waste	0.39	0.017
Average	lb/lb waste	3.95E-07	1.69E-08

[a] Number of samples collected with detectable levels. [b] Stand. Dev. – standard deviation,
[c] RSD – relative standard deviation, calculated only if $n \geq 3$. [d] N/A – not applicable.

Cr(VI) was detected in all five MK-90 samples collected but only in one of the three samples collected from the skid waste type 2 (Table 3-2). The collection time for the three Cr(VI) skid waste samples was approximately the same but the amount of carbon collected was approximately two times higher in the detected sample than the two with no detectable levels. This simply indicates a greater plume sampling efficiency (collection of oxidized carbon) during the one detectable sample.

3.3 HCl, chlorate, and perchlorate

No chlorate or perchlorate compounds were detected in any of the six samples collected from skid waste type 1 which was the "high Cl" waste (Table 3-6). The HCl emissions (0.000229 lb/lb initial source) from the skid waste were over 100 times lower than those emitted from static firing (versus open burning) of MK-58 (0.030 lb/lb initial source) and CRV-7 rocket motors (0.086 lb/lb initial source) [20]. Three of the six collected HCl samples were under the method reporting limit (no detectable levels of chloride). These compounds are not included within the Radford HHRA [19] so no comparisons could be made.

Table 3-6. HCl, chlorate, and perchlorate emission factors from skid waste type 1

		Skid Waste -Type 1		
	Unit	**HCl** $n^a = 3$	**Chlorate** $n^a = 0$	**Perchlorate** $n^a = 0$
Average	mg/kg initial source	229	ND (0.054)[b]	ND (0.054)[b]
Stand. Dev.[d]	mg/kg initial source	135	N/A[c]	N/A[c]
RSD[e]	%	59	N/A[c]	N/A[c]
Average	mg/kg waste	459	ND (0.11)[b]	ND (0.11)[b]
Stand. Dev.[d]	mg/kg waste	272	N/A[c]	N/A[c]
Average	lb/lb initial source	2.29E-04	ND (5.40E-08)[b]	ND (5.40E-08)[b]
Stand. Dev.[d]	lb/lb initial source	1.35E-04	N/A[c]	N/A[c]
Average	lb/lb waste	4.59E-04	ND (1.08E-07)[b]	ND (1.08E-07)[b]
Stand. Dev.[d]	lb/lb waste	2.72E-04	N/A[c]	N/A[c]
Average	% into air from initial source[f]	8.4	N/A[c]	N/A[c]
Stand. Dev.[d]	% into air from initial source[f]	5.0	N/A[c]	N/A[c]
Average	% into air from waste[f]	17.0	N/A[c]	N/A[c]
Stand. Dev.[d]	% into air from waste[f]	10.0	N/A[c]	N/A[c]

[a] Number of samples collected with detectable levels.
[b] ND – not detected, detection limit within parentheses.
[c] N/A – not applicable.
[d] Stand. Dev. – standard deviation.
[e] RSD – relative standard deviation.
[f] percent of Cl in skid waste going into air as HCl.

3.4 PCDD/PCDF

The PCDD/PCDF emission factor from the Type 1, high Cl skid waste (1.77±1.59 ng TEQ/kg waste) was in the same range as emission factors from prescribed forest burns (1.55±1.65 ng TEQ/kg biomass [21]) and much lower than from open burning of municipal solid waste (1,765±1,474 ng TEQ/kg waste [22]). The sampled emission factor was less than 0.1% of the value used in the HHRA. Values are shown in Table 3-7 and Figure 3-1. Emission factors for each homologue group and each TEF-weighted congener are shown in Appendix B, Tables B-1 to B-6. The MK-90s were not sampled for PCDD/PCDF due to time prioritization of other analytes.

Table 3-7. PCDD/PCDF results.

	Skid waste – Type 1					
	Unit	**Average**	**Stand. Dev.**	**RSD**	**EF RFAAP [19]**	**Ratio EF/EF RFAAP**
PCDD Total	ng/kg initial source	13.2	8.6	66%	NV[b]	
PCDF Total	ng/kg initial source	33.4	37.5	112%	NV[b]	
PCDD/PCDF Total	ng/kg initial source	46.6	41.1	88%	NV[b]	
PCDD TEQ[a]	ng TEQ/kg initial source	0.10	0.15	158%	NV[b]	
PCDF TEQ[a]	ng TEQ/kg initial source	0.79	0.71	90%	NV[b]	
PCDD/PCDF TEQ SUM[a]	ng TEQ/kg initial source	0.88	0.79	90%	NV[b]	
PCDD Total	ng/kg waste	26.5	17.4	66%	105.7	0.25
PCDF Total	ng/kg waste	67.1	75.3	112%	105000	0.00064
PCDD/PCDF Total	ng/kg waste	93.6	82.6	88%	105000	0.00089
PCDD TEQ[a]	ng TEQ/kg waste	0.19	0.30	158%	17.8	0.0107
PCDF TEQ[a]	ng TEQ/kg waste	1.58	1.43	90%	9940	0.00016
PCDD/PCDF TEQ SUM[a]	ng TEQ/kg waste	1.77	1.59	90%	9950	0.00018

[a] Not detected congeners set to zero. Appendix B shows data with not detected congeners set to the limit of detection.

[b] NV = no value.

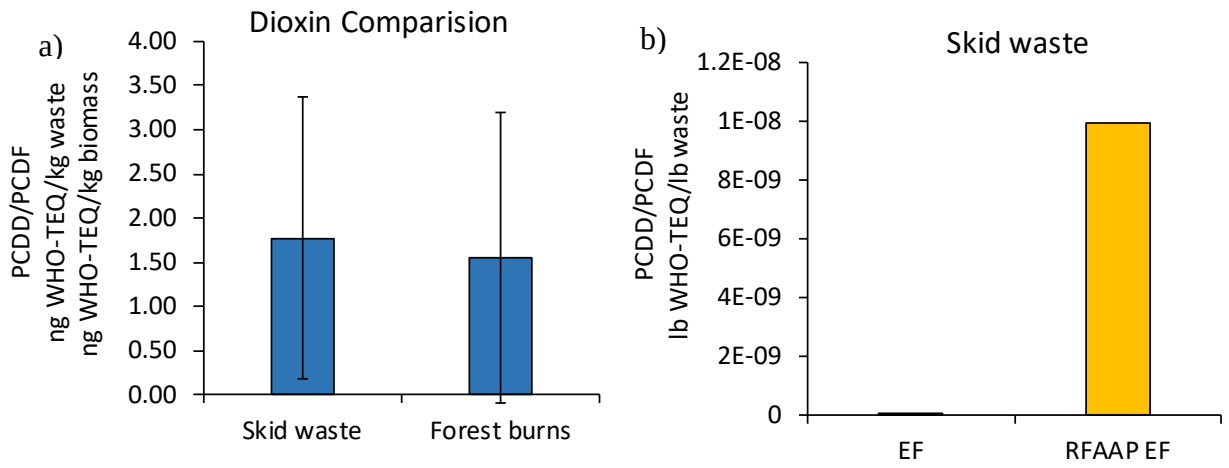

Figure 3-1. Comparison of PCDD/PCDF (Dioxin) emission factors from a) this study (Skid waste) and Forest burns [21], and b) emission factor derived from this study (EF) and emission factor used today by RFAAP (RFAAP EF) [19].

3.5 VOCs

VOC sampling was prioritized only for the type 2 skid waste due to project time limitations. All VOCs analyzed are presented in Tables 3-8 to 3-11. Toluene (3.26E-4 lb/lb waste), benzene (3.11-04 lb/lb waste), naphthalene (1.45E-04 lb/lb waste), methylene chloride (1.26E-04 lb/lb waste), styrene (5.07E-05 lb/lb waste), and xylenes (5.73E-05 lb/lb waste) were the most abundant VOCs emitted from skid waste type 2, all on EPA's list of hazardous air pollutants [7]. These emission values compare to emissions from static fire of rocket motors: toluene 4.5E-04 lb/lb waste, naphthalene 9.2E-06 lb/lb waste, and xylenes 1.2E-03 lb/lb waste [1]. Of the 26 compounds common between sampled and detectable VOC emissions at Radford and the HHRA, 25 of the VOCs were less than the HHRA emission factor (Table 3-8). Only chloromethane was found at RFAAP to be higher (2.3 times) than the HHRA emission factor.

Table 3-8. VOC Emission Factors in lb/lb waste from skid waste type 2.

Compound	n[a]	Average[b]	Stand. Dev.[c]	RSD[d]	RPD[e]	RFAAP EF [19]	Ratio
		lb/lb waste		%	%	lb/lb waste	EF/ RFAAP EF
1,1,1-Trichloroethane[f]	0	ND (8.04E-08)				1.00E-04	
1,1,2,2-Tetrachloroethane[f]	0	ND (9.38E-08)				1.04E-04	
1,1,2-Trichloroethane[f]	1	1.11E-06				1.15E-04	0.010
1,1-Dichloroethane	0	ND (3.95E-08)				2.92E-05	
1,1-Dichloroethene	0	ND (1.14E-07)				4.94E-05	

Compound	n[a]	Average[b] lb/lb waste	Stand. Dev.[c] lb/lb waste	RSD[d] %	RPD[e] %	RFAAP EF [19] lb/lb waste	Ratio EF/ RFAAP EF
1,2,4-Trichlorobenzene[f]	0	ND (2.75E-07)				3.28E-06	<0.084
1,2,4-Trimethylbenzene	4	2.72E-05	1.53E-05	56		5.09E-04	0.053
1,2-Dibromo-3-chloropropane	0	ND (1.41E-07)				NV[g]	
1,2-Dibromoethane	0	ND (6.57E-08)				NV[g]	
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	3	1.46E-07	1.51E-07	103		NV[g]	
1,2-Dichlorobenzene	0	ND (1.14E-07)				3.28E-06	<0.035
1,2-Dichloroethane	1	1.01E-07				4.31E-05	0.002
1,2-Dichloropropane	1	1.34E-06				4.31E-05	0.031
1,3,5-Trimethylbenzene	4	7.28E-06	4.13E-06	57		4.31E-05	0.169
1,3-Butadiene[f]	4	1.97E-05	5.32E-06	27		4.35E-05	0.453
1,3-Dichlorobenzene	1	1.14E-07				NV[g]	
1,4-Dichlorobenzene	1	1.73E-07				3.28E-06	0.053
1,4-Dioxane	2	6.93E-07			71	NV[g]	
2,2,4-Trimethylpentane (Isooctane)	4	7.21E-07	7.11E-07	99		NV[g]	
2-Butanone (MEK)	4	1.02E-05	6.02E-06	59		NV[g]	
2-Hexanone	1	6.43E-06				NV[g]	
2-Propanol (Isopropyl Alcohol)	1	3.95E-06				NV[g]	
4-Methyl-2-pentanone	4	1.47E-06	1.60E-06	109		NV[g]	
Acetone	4	5.55E-05	1.91E-05	34		7.44E-04	0.075
Acetonitrile[f]	4	3.47E-05	1.94E-05	56		NV[g]	
Benzene[f]	4	3.11E-04	1.85E-04	59		9.69E-04	0.321
Bromodichloromethane	0	ND (6.37E-08)				9.69E-04	
Bromoform	0	ND (9.38E-08)				NV[g]	
Carbon Disulfide[f]	1	1.07E-06				3.25E-06	0.329
Carbon Tetrachloride[f]	4	1.09E-06	1.15E-06	106		3.25E-06	0.335
Chlorobenzene[f]	1	1.71E-06				3.25E-06	0.526
Chloroethane	3	2.35E-06	1.68E-06	71		3.25E-06	0.723
Chloroform[f]	3	2.23E-07	1.55E-07	70		3.25E-06	0.069
Chloromethane[f]	4	7.58E-06	6.64E-06	88		3.25E-06	2.332
cis-1,2-Dichloroethene	0	ND (6.23E-08)				NV[g]	
cis-1,3-Dichloropropene[f]	0	ND (7.37E-08)				NV[g]	
Cumene[f]	4	3.75E-06	2.41E-06	64		NV[g]	
Cyclohexane	1	8.71E-06				2.67E-05	0.326
Dibromochloromethane	0	ND (4.56E-08)				NV[g]	
Dichlorodifluoromethane (CFC 12)	3	6.72E-06	5.64E-06	84		NV[g]	
Ethanol	4	1.06E-05	7.98E-06	75		NV[g]	
Ethylbenzene[f]	4	2.08E-05	1.00E-05	48		4.53E-05	0.459

Compound	n[a]	Average[b] lb/lb waste	Stand. Dev.[c] lb/lb waste	RSD[d] %	RPD[e] %	RFAAP EF [19] lb/lb waste	Ratio EF/ RFAAP EF
Hexachlorobutadiene[f]	0	ND (2.01E-07)		N/A		NV[g]	
m,p-Xylenes[f]	4	4.11E-05	1.91E-05	46		NV[g]	
Methyl tert-Butyl Ether	0	ND (4.69E-08)				NV[g]	
Methylene Chloride[f]	4	1.26E-04	2.37E-04	189		1.17E-03	0.108
Naphthalene[f]	4	1.45E-04	8.23E-05	57		7.87E-04	0.184
n-Heptane	4	4.70E-06	1.85E-06	39		NV[g]	
n-Hexane	4	1.63E-05	2.94E-05	180		2.56E-05	0.637
n-Octane	4	1.56E-05	6.08E-06	39		NV[g]	
o-Xylene[f]	4	1.61E-05	8.53E-06	53		NV[g]	
Styrene[f]	4	5.07E-05	3.15E-05	62		5.56E-05	0.912
Tetrachloroethene	2	6.11E-07			185	NV[g]	
Tetrahydrofuran (THF)	3	7.30E-07	2.04E-07	28		NV[g]	
Toluene[f]	4	3.26E-04	4.10E-04	126		4.75E-04	0.686
trans-1,2-Dichloroethene	0	ND (8.04E-08)				NV[g]	
trans-1,3-Dichloropropene	0	ND (7.37E-08)				NV[g]	
Trichloroethene	1	2.81E-07				6.59E-05	0.004
Trichlorofluoromethane	4	2.48E-06	1.91E-06	77		NV[g]	
Trichlorotrifluoroethane	4	1.00E-06	1.11E-06	111		NV[g]	
Vinyl Chloride[f]	0	ND (9.38E-08)				9.28E-05	
Xylenes	4	5.73E-05	2.75E-05	48		4.52E-04	0.127

[a] Number of samples with detectable levels out of 4 samples.
[b] ND – not detected. Detection limit within parentheses.
[c] Stand. Dev. – standard deviation, calculated only if $n \geq 3$.
[d] RSD – relative standard deviation, calculated only if $n \geq 3$.
[e] RPD – relative percent difference, calculated only if $n = 2$.
[f] On U.S. EPA's list of hazardous air pollutants [7]
[g] NV = no value.

Table 3-9. VOC Emission Factors in mg/kg waste from skid waste type 2.

Compound	n[a]	Average[b] mg/kg waste	Stand. Dev.[c]	RSD[d] %	RPD[e] %
1,1,1-Trichloroethane[f]	0	ND (0.080)			
1,1,2,2-Tetrachloroethane[f]	0	ND (0.094)			
1,1,2-Trichloroethane[f]	1	1.11			
1,1-Dichloroethane	0	ND (0.040)			
1,1-Dichloroethene	0	ND (0.11)			
1,2,4-Trichlorobenzene[f]	0	ND (0.28)			
1,2,4-Trimethylbenzene	4	27.17	15.31	56	
1,2-Dibromo-3-chloropropane	0	ND (0.14)			
1,2-Dibromoethane	0	ND (0.066)			
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	3	0.15	0.15	103	
1,2-Dichlorobenzene	0	ND (0.11)			
1,2-Dichloroethane	1	0.1			
1,2-Dichloropropane	1	1.34			
1,3,5-Trimethylbenzene	4	7.28	4.13	57	
1,3-Butadiene[f]	4	19.67	5.32	27	
1,3-Dichlorobenzene	1	0.11			
1,4-Dichlorobenzene	1	0.17			
1,4-Dioxane	2	0.69			71
2,2,4-Trimethylpentane (Isooctane)	4	0.72	0.71	99	
2-Butanone (MEK)	4	10.24	6.02	59	
2-Hexanone	1	6.43			
2-Propanol (Isopropyl Alcohol)	1	3.95			
4-Methyl-2-pentanone	4	1.47	1.6	109	
Acetone	4	55.47	19.12	34	
Acetonitrile[f]	4	34.65	19.44	56	
Benzene[f]	4	310.88	184.78	59	
Bromodichloromethane	0	ND (0.064)			
Bromoform	0	ND (0.094)			
Carbon Disulfide[f]	0	1.07			
Carbon Tetrachloride[f]	4	1.09	1.15	106	
Chlorobenzene[f]	1	1.71			
Chloroethane	3	2.35	1.68	71	
Chloroform[f]	3	0.22	0.16	70	
Chloromethane[f]	4	7.58	6.64	88	
cis-1,2-Dichloroethene	0	ND (0.062)			
cis-1,3-Dichloropropene[f]	0	ND (0.074)			
Cumene[f]	4	3.75	2.41	64	
Cyclohexane	1	8.71			
Dibromochloromethane	0	ND (0.046)			

Compound	n[a]	Average[b]	Stand. Dev.[c]	RSD[d]	RPD[e]
		mg/kg waste		%	%
Dichlorodifluoromethane (CFC 12)	3	6.72	5.64	84	
Ethanol	4	10.63	7.98	75	
Ethylbenzene[f]	4	20.81	10.04	48	
Hexachlorobutadiene[f]	0	ND (0.20)			
m,p-Xylenes[f]	4	41.14	19.07	46	
Methyl tert-Butyl Ether	0	ND (0.047)			
Methylene Chloride[f]	4	125.62	237.46	189	
Naphthalene[f]	4	144.54	82.32	57	
n-Heptane	4	4.7	1.85	39	
n-Hexane	4	16.35	29.36	180	
n-Octane	4	15.62	6.08	39	
o-Xylene[f]	4	16.12	8.53	53	
Styrene[f]	4	50.71	31.49	62	
Tetrachloroethene	2	0.61			185
Tetrahydrofuran (THF)	3	0.73	0.2	28	
Toluene[f]	4	326.46	409.87	126	
trans-1,2-Dichloroethene	0	ND (0.080)			
trans-1,3-Dichloropropene	0	ND (0.074)			
Trichloroethene	1	0.28			
Trichlorofluoromethane	4	2.48	1.91	77	
Trichlorotrifluoroethane	4	1	1.11	111	
Vinyl Chloride[f]	0	ND (0.094)			

[a] Number of samples with detectable levels out of 4 samples.
[b] ND – not detected. Detection limit within parentheses.
[c] Stand. Dev. – standard deviation, calculated only if $n \geq 3$.
[d] RSD – relative standard deviation, calculated only if $n \geq 3$.
[e] RPD – relative percent difference, calculated only if $n = 2$.
[f] On U.S. EPA's list of hazardous air pollutants [7]

Table 3-10. VOC Emission Factors in lb/lb initial source from skid waste type 2.

Compound	n[a]	Average[b]	Stand. Dev.[c]	RSD[d]	RPD[e]
		lb/lb initial source		%	%
1,1,1-Trichloroethane[f]	0	ND (2.53E-08)			
1,1,2,2-Tetrachloroethane[f]	0	ND (2.95E-08)			
1,1,2-Trichloroethane[f]	1	3.48E-07			
1,1-Dichloroethane	0	ND (1.24E-08)			
1,1-Dichloroethene	0	ND (3.58E-08)			
1,2,4-Trichlorobenzene[f]	0	ND (8.64E-08)			
1,2,4-Trimethylbenzene	4	8.55E-06	4.82E-06	56	

Compound	n[a]	Average[b] lb/lb initial source	Stand. Dev.[c]	RSD[d] %	RPD[e] %
1,2-Dibromo-3-chloropropane	0	ND (4.43E-08)			
1,2-Dibromoethane	0	ND (2.07E-08)			
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	3	4.60E-08	4.74E-08	103	
1,2-Dichlorobenzene	0	ND (3.58E-08)			
1,2-Dichloroethane	1	3.16E-08			
1,2-Dichloropropane	1	4.22E-07			
1,3,5-Trimethylbenzene	4	2.29E-06	1.30E-06	57	
1,3-Butadiene[f]	4	6.19E-06	1.67E-06	27	
1,3-Dichlorobenzene	1	3.58E-08			
1,4-Dichlorobenzene	1	5.45E-08			
1,4-Dioxane	2	2.18E-07			71
2,2,4-Trimethylpentane (Isooctane)	4	2.27E-07	2.24E-07	99	
2-Butanone (MEK)	4	3.22E-06	1.89E-06	59	
2-Hexanone	1	2.02E-06			
2-Propanol (Isopropyl Alcohol)	1	1.24E-06			
4-Methyl-2-pentanone	4	4.64E-07	5.04E-07	109	
Acetone	4	1.75E-05	6.02E-06	34	
Acetonitrile[f]	4	1.09E-05	6.11E-06	56	
Benzene[f]	4	9.78E-05	5.81E-05	59	
Bromodichloromethane	0	ND (2.00E-08)			
Bromoform	0	ND (2.95E-08)			
Carbon Disulfide[f]	1	3.37E-07			
Carbon Tetrachloride[f]	4	3.43E-07	3.63E-07	106	
Chlorobenzene[f]	1	5.37E-07			
Chloroethane	3	7.40E-07	5.28E-07	71	
Chloroform[f]	3	7.02E-08	4.89E-08	70	
Chloromethane[f]	4	2.38E-06	2.09E-06	88	
cis-1,2-Dichloroethene	0	ND (1.96E-08)			
cis-1,3-Dichloropropene[f]	0	ND (2.32E-08)			
Cumene[f]	4	1.18E-06	7.58E-07	64	
Cyclohexane	1	2.74E-06			
Dibromochloromethane	0	ND (1.43E-08)			
Dichlorodifluoromethane (CFC 12)	3	2.11E-06	1.77E-06	84	
Ethanol	4	3.56E-06	2.85E-06	80	
Ethylbenzene[f]	4	6.55E-06	3.16E-06	48	
Hexachlorobutadiene[f]	0	ND (6.32E-08)			
m,p-Xylenes[f]	4	1.29E-05	6.00E-06	46	
Methyl tert-Butyl Ether	0	ND (1.48E-08)			
Methylene Chloride[f]	4	3.95E-05	7.47E-05	189	
Naphthalene[f]	4	4.55E-05	2.59E-05	57	

Compound	n[a]	Average[b] lb/lb initial source	Stand. Dev.[c]	RSD[d] %	RPD[e] %
n-Heptane	4	1.48E-06	5.81E-07	39	
n-Hexane	4	5.14E-06	9.24E-06	180	
n-Octane	4	4.92E-06	1.91E-06	39	
o-Xylene[f]	4	5.07E-06	2.68E-06	53	
Styrene[f]	4	1.60E-05	9.91E-06	62	
Tetrachloroethene	2	1.92E-07			
Tetrahydrofuran (THF)	3	2.30E-07	6.41E-08	28	
Toluene[f]	4	1.03E-04	1.29E-04	126	
trans-1,2-Dichloroethene	0	ND (2.53E-08)			
trans-1,3-Dichloropropene	0	ND (2.32E-08)			
Trichloroethene	1	8.85E-08			
Trichlorofluoromethane	4	7.80E-07	6.02E-07	77	
Trichlorotrifluoroethane	4	3.15E-07	3.50E-07	111	
Vinyl Chloride[f]	0	ND (2.95E-08)			

[a] Number of samples with detectable levels out of 4 samples.
[b] ND – not detected. Detection limit within parentheses.
[c] Stand. Dev. – standard deviation, calculated only if $n \geq 3$.
[d] RSD – relative standard deviation, calculated only if $n \geq 3$.
[e] RPD – relative percent difference, calculated only if $n = 2$.
[f] On U.S. EPA's list of hazardous air pollutants [7].

Table 3-11. VOC Emission Factors in mg/kg initial source.

Compound	n[a]	Average[b] mg/kg initial source	Stand. Dev.[c]	RSD[d] %	RPD[e] %
1,1,1-Trichloroethane[f]	0	ND (0.025)			
1,1,2,2-Tetrachloroethane[f]	0	ND (0.030)			
1,1,2-Trichloroethane[f]	1	0.35			
1,1-Dichloroethane	0	ND (0.012)			
1,1-Dichloroethene	0	ND (0.036)			
1,2,4-Trichlorobenzene[f]	0	ND (0.086)			
1,2,4-Trimethylbenzene	4	8.55	4.82	56	
1,2-Dibromo-3-chloropropane	0	ND (0.044)			
1,2-Dibromoethane	0	ND (0.021)			
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	3	0.046	0.047	103	
1,2-Dichlorobenzene	0	ND (0.036)			
1,2-Dichloroethane	1	0.03			
1,2-Dichloropropane	1	0.42			
1,3,5-Trimethylbenzene	4	2.29	1.3	57	
1,3-Butadiene[f]	4	6.19	1.67	27	
1,3-Dichlorobenzene	1	0.04			

Compound	n[a]	Average[b] mg/kg initial source	Stand. Dev.[c]	RSD[d] %	RPD[e] %
1,4-Dichlorobenzene	1	0.05			
1,4-Dioxane	2	0.22			71
2,2,4-Trimethylpentane (Isooctane)	4	0.23	0.22	99	
2-Butanone (MEK)	4	3.22	1.89	59	
2-Hexanone	1	2.02			
2-Propanol (Isopropyl Alcohol)	1	1.24			
4-Methyl-2-pentanone	4	0.46	0.5	109	
Acetone	4	14.06	8.48	60	
Acetonitrile[f]	4	8.46	4.97	59	
Benzene[f]	4	97.8	58.13	59	
Bromodichloromethane	0	ND (0.020)			
Bromoform	0	ND (0.030)			
Carbon Disulfide[f]	0	ND (0.17)			
Carbon Tetrachloride[f]	4	0.34	0.36	106	
Chlorobenzene[f]	1	0.54			
Chloroethane	3	0.74	0.53	71	
Chloroform[f]	3	0.07	0.05	70	
Chloromethane[f]	4	2.38	2.09	88	
cis-1,2-Dichloroethene	0	ND (0.020)			
cis-1,3-Dichloropropene[f]	0	ND (0.023)			
Cumene[f]	4	1.18	0.76	64	
Cyclohexane	1	2.74			
Dibromochloromethane	0	ND (0.014)			
Dichlorodifluoromethane (CFC 12)	3	2.11	1.77	84	
Ethanol	4	3.34	2.51	75	
Ethylbenzene[f]	4	6.55	3.16	48	
Hexachlorobutadiene[f]	0	ND (0.063)			
m,p-Xylenes[f]	4	12.94	6	46	
Methyl tert-Butyl Ether	0	ND (0.015)			
Methylene Chloride[f]	4	39.52	74.71	189	
Naphthalene[f]	4	45.47	25.9	57	
n-Heptane	4	1.48	0.58	39	
n-Hexane	4	5.14	9.24	180	
n-Octane	4	4.92	1.91	39	
o-Xylene[f]	4	5.07	2.68	53	
Styrene[f]	4	15.95	9.91	62	
Tetrachloroethene	2	0.19			185
Tetrahydrofuran (THF)	3	0.23	0.06	28	
Toluene[f]	4	102.71	128.94	126	
trans-1,2-Dichloroethene	0	ND (0.025)			

Compound	n[a]	Average[b]	Stand. Dev.[c]	RSD[d]	RPD[e]
		mg/kg initial source		%	%
trans-1,3-Dichloropropene	0	ND (0.023)			
Trichloroethene	1	0.09			
Trichlorofluoromethane	4	0.78	0.6	77	
Trichlorotrifluoroethane	4	0.32	0.35	111	
Vinyl Chloride[f]	0	ND (0.030)			

[a] Number of samples with detectable levels out of 4 samples.
[b] ND – not detected. Detection limit within parentheses.
[c] Stand. Dev. – standard deviation, calculated only if $n \geq 3$.
[d] RSD – relative standard deviation, calculated only if $n \geq 3$.
[e] RPD – relative percent difference, calculated only if $n = 2$.
[f] On U.S. EPA's list of hazardous air pollutants [7].

3.6 Energetics

None of the energetics and nitroaromatic compounds for the MK-90 rocket motors exceeded the analytical method detection limit (Table 3-12). Energetics were not sampled for the skid waste due to time limitations. The ratio of the method detection limit (for the sampled emission factor) to that of the HHRA emission factor resulted was less than 1.1 for the eight overlapping compounds.

Table 3-12. Energetics based on method detection limit.

Energetics	MK-90 mg/kg initial source	MK-90 lb/lb initial source	RFAAP EF [19] lb/lb initial source	Ratio EF/RFAAP EF
Nitrocellulose (n=2)	< 51	< 5.1E-05	NV[a]	
1,3,5-Trinitrobenzene[b]	< 1.1	< 1.1E-06	2.28E-05	<0.048
1,3-Dinitrobenzene	< 1.1	< 1.1E-06	8.19E-06	<0.13
2,4,6-Trinitrotoluene	< 1.1	< 1.1E-06	3.48E-05	<0.032
2,4-Dinitrotoluene	< 1.1	< 1.1E-06	1.05E-04	<0.010
2,6-Dinitrotoluene	< 1.1	< 1.1E-06	9.81E-07	<1.1
2-Amino-4,6-Dinitrotoluene	< 1.1	< 1.1E-06	NV[a]	
2-Nitrotoluene	< 1.1	< 1.1E-06	NV[a]	
3,5-DNA	< 1.1	< 1.1E-06	NV[a]	
3-Nitrotoluene	< 1.1	< 1.1E-06	NV[a]	
4-Amino-2,6-Dinitrotoluene	< 1.1	< 1.1E-06	NV[a]	
4-Nitrotoluene	< 1.1	< 1.1E-06	NV[a]	
HMX	< 1.1	< 1.1E-06	2.16E-05	<0.051
Nitrobenzene	< 1.1	< 1.1E-06	3.28E-06	<0.34
Nitroglycerin	< 1.1	< 1.1E-06	3.07E-06	<0.36
PETN	< 2.7	< 2.7E-06	NV[a]	
RDX	< 1.1	< 1.1E-06	NV[a]	
Tetryl	< 1.1	< 1.1E-06	NV[a]	

[a] NV = no value.
[b]Four samples for all energetics except nitrocellulose.

4 Conclusions

Aerial sampling methods for emission quantification of demilitarization efforts have only been comprehensively in use since the development of tethered aerostats to loft sampling equipment in 2010. The logistical challenges experienced in these earlier efforts and recent developments in UAV and sensor technology prompted EPA's Office of Research and Development to create a new system applicable for sampling open demilitarization plumes that had greater flexibility of positioning within a plume than that of the tethered aerostat. Working with pilots and a hexacopter from NASA Ames, EPA/ORD demonstrated the first comprehensive test of a UAV-borne emission sampler at RFAAP's open burning grounds with this two-week sampling event. Plume sampling of open burns of MK-90 rocket motors and skid waste was successfully accomplished with the UAV/Kolibri system based on the number of plumes sampled (100%), the repeatability of the emission factors, and the comparability of the emission factors with previous aerial sampling methods.

Emissions were sampled for PM, elements including metals (particularly Cr(VI)), VOCs, chlorinated dioxins/furans, and nitroaromatics. $PM_{2.5}$ emission factors for MK-90s were within

the range of three other previously-documented sources. The majority of the metal emission factors, 17 of 24, were lower than those emission factors used in the HHRA. Cr(VI) emissions were 28% and 14% of the total Cr emitted from the burns of the MK-90 and skid waste, respectively. Emission factors were compared with other recently sampled, aerial emission data and found to be consistent or, in some cases (for example, HCl) found to be considerably lower. Chlorate and perchlorate emission were below detection limits. Dioxin emissions were less than 0.1% of the emission factor found in the HHRA for skid waste and were similar to those values typically reported from prescribed forest or biomass burns. Residual energetics and nitroaromatics for the MK-90s were below the detection limit. Of the 26 compounds in common between detectable VOC emissions from Radford's skid waste and the listed HHRA emission factors, 25 of the VOCs were less than the HHRA emission factor.

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Appendices

Appendix A: Element emission factors

Table A-1. Elements analyzed for each sample collected in mg/kg initial source.[a]

		MK90	MK90	MK90	MK90	MK90	Skid waste	Skid waste
	Date	09/27/16	09/27/16	10/05/16	10/05/16	10/05/16	10/06/16	10/06/16
Element	**Unit**	**Burn 1**	**Burn 2,3**	**Burn 1**	**Burn 2**	**Burn 3**	**Burn 1**	**Burn 1**
Na	mg/kg initial source	8.58E+02	9.24E+02	1.06E+03	1.05E+03	6.66E+02	2.77E+01	4.32E+01
Na Unc.	mg/kg initial source	1.16E+02	1.37E+02	1.62E+02	1.68E+02	1.32E+02	1.40E+01	1.61E+01
Mg	mg/kg initial source	1.40E+02	1.66E+02	1.96E+02	1.86E+02	1.25E+02	1.91E+00	2.92E+00
Mg Unc.	mg/kg initial source	1.99E+01	2.56E+01	2.89E+01	3.03E+01	2.45E+01	1.29E+00	1.43E+00
Al	mg/kg initial source	1.54E+00	ND	ND	1.33E+01	7.11E+00	ND	ND
Al Unc.	mg/kg initial source	4.13E+00	5.50E+00	6.43E+00	6.72E+00	5.62E+00	6.11E-01	6.50E-01
Si	mg/kg initial source	1.56E+02	1.22E+02	1.66E+02	1.72E+02	1.39E+02	1.90E+01	2.27E+01
Si Unc.	mg/kg initial source	1.02E+01	9.31E+00	1.18E+01	1.21E+01	9.87E+00	1.33E+00	1.52E+00
P	mg/kg initial source	3.82E+00	2.20E+00	4.06E+00	5.93E+00	5.20E+00	4.30E-01	7.16E-01
P Unc.	mg/kg initial source	1.85E+00	2.30E+00	2.89E+00	2.96E+00	2.39E+00	2.41E-01	2.80E-01
S	mg/kg initial source	ND	ND	ND	ND	ND	ND	ND
S Unc.	mg/kg initial source	1.72E+02	1.49E+02	3.99E+01	1.93E+02	3.06E+01	1.76E+00	2.40E+00
Cl	mg/kg initial source	4.38E+01	6.31E+01	8.86E+00	2.46E+01	7.98E+00	7.08E+01	9.00E+01
Cl Unc.	mg/kg initial source	6.64E+00	9.41E+00	6.73E+00	7.07E+00	5.74E+00	3.70E+00	4.69E+00
K	mg/kg initial source	3.34E+01	2.58E+01	2.00E+01	2.58E+01	2.18E+01	4.30E+01	4.38E+01
K Unc.	mg/kg initial source	2.37E+00	2.70E+00	1.83E+00	2.13E+00	1.75E+00	2.23E+00	2.28E+00
Ca	mg/kg initial source	3.74E+01	2.19E+01	2.82E+01	2.96E+01	2.51E+01	2.39E+00	1.96E+00
Ca Unc.	mg/kg initial source	2.42E+00	2.20E+00	2.13E+00	2.13E+00	1.79E+00	2.21E-01	2.22E-01
Ti	mg/kg initial source	1.89E+00	ND	1.61E+00	9.88E-01	1.82E+00	2.48E-01	1.24E-01
Ti Unc.	mg/kg initial source	4.37E-01	6.97E-01	4.64E-01	4.72E-01	4.02E-01	5.34E-02	5.73E-02
V	mg/kg initial source	ND	1.99E-01	3.25E-01	2.36E-01	ND	3.34E-02	ND
V Unc.	mg/kg initial source	4.37E-01	4.98E-01	3.83E-01	4.72E-01	3.32E-01	3.34E-02	4.10E-02
Cr	mg/kg initial source	1.27E+00	4.98E-01	1.47E+00	1.66E+00	1.20E+00	2.67E-02	4.92E-02
Cr Unc.	mg/kg initial source	3.06E-01	5.97E-01	3.25E-01	3.93E-01	2.82E-01	4.01E-02	4.10E-02
Mn	mg/kg initial source	5.25E-01	ND	ND	1.57E-01	ND	ND	ND
Mn Unc.	mg/kg initial source	5.25E-01	9.96E-01	4.10E-01	5.16E-01	3.55E-01	5.34E-02	7.37E-02
Fe	mg/kg initial source	1.62E+01	1.44E+01	1.53E+01	2.15E+01	1.27E+01	8.79E-01	1.89E-01
Fe Unc.	mg/kg initial source	1.14E+00	1.41E+00	9.80E-01	1.34E+00	8.25E-01	9.43E-02	7.37E-02
Co	mg/kg initial source	ND	ND	ND	ND	ND	ND	ND
Co Unc.	mg/kg initial source	3.94E-01	5.97E-01	3.25E-01	3.93E-01	3.08E-01	3.34E-02	4.10E-02

Element	Unit	MK90 09/27/16 Burn 1	MK90 09/27/16 Burn 2,3	MK90 10/05/16 Burn 1	MK90 10/05/16 Burn 2	MK90 10/05/16 Burn 3	Skid waste 10/06/16 Burn 1	Skid waste 10/06/16 Burn 1
Ni	mg/kg initial source	ND	ND	ND	ND	ND	ND	8.19E-03
Ni Unc.	mg/kg initial source	4.37E-01	6.97E-01	3.56E-01	4.32E-01	3.32E-01	3.34E-02	3.28E-02
Cu	mg/kg initial source	2.99E+03	2.55E+03	3.40E+03	3.48E+03	2.95E+03	2.54E+01	9.44E+00
Cu Unc.	mg/kg initial source	1.50E+02	1.27E+02	1.70E+02	1.74E+02	1.47E+02	1.28E+00	4.85E-01
Zn	mg/kg initial source	ND	ND	ND	ND	ND	3.00E+00	1.22E+01
Zn Unc.	mg/kg initial source	5.25E-01	7.97E-01	5.46E-01	6.34E-01	4.73E-01	1.68E-01	6.26E-01
Ga	mg/kg initial source	9.71E+00	5.30E+00	2.70E+00	3.79E+00	ND	ND	ND
Ga Unc.	mg/kg initial source	2.86E+00	3.30E+00	3.05E+00	3.12E+00	2.55E+00	1.94E-01	2.55E-01
Ge	mg/kg initial source	1.08E+01	6.81E+00	1.29E+01	1.12E+01	1.39E+01	4.70E-01	8.48E-01
Ge Unc.	mg/kg initial source	1.14E+00	1.19E+00	1.28E+00	1.30E+00	1.16E+00	6.68E-02	9.83E-02
As	mg/kg initial source	1.35E+01	2.20E+00	2.09E+01	2.27E+01	2.61E+01	1.01E+00	1.90E+00
As Unc.	mg/kg initial source	6.16E+00	6.81E+00	6.95E+00	7.11E+00	5.95E+00	4.09E-01	5.77E-01
Se	mg/kg initial source	ND	ND	ND	1.26E+00	6.14E-01	ND	ND
Se Unc.	mg/kg initial source	1.10E+00	1.19E+00	1.20E+00	1.22E+00	1.02E+00	6.68E-02	9.01E-02
Br	mg/kg initial source	1.49E+01	1.05E+01	1.69E+01	1.61E+01	1.53E+01	1.19E+00	1.87E+00
Br Unc.	mg/kg initial source	1.06E+00	9.96E-01	1.20E+00	1.18E+00	1.06E+00	8.01E-02	1.24E-01
Rb	mg/kg initial source	7.34E+00	8.40E+00	1.02E+01	9.84E+00	6.28E+00	6.44E-01	9.72E-01
Rb Unc	mg/kg initial source	8.80E-01	8.96E-01	1.01E+00	1.03E+00	8.02E-01	6.01E-02	8.19E-02
Sr	mg/kg initial source	1.54E+00	2.00E+00	ND	9.88E-01	2.17E+00	2.67E-02	ND
Sr Unc.	mg/kg initial source	6.18E-01	7.97E-01	7.36E-01	7.13E-01	5.67E-01	4.01E-02	5.73E-02
Y	mg/kg initial source	1.44E+01	7.41E+00	1.26E+01	9.76E+00	9.31E+00	6.11E-01	9.80E-01
Y Unc.	mg/kg initial source	1.80E+00	1.71E+00	1.94E+00	1.90E+00	1.61E+00	1.01E-01	1.48E-01
Zr	mg/kg initial source	ND	ND	ND	ND	ND	ND	ND
Zr Unc.	mg/kg initial source	7.05E-01	9.96E-01	7.63E-01	8.31E-01	6.61E-01	5.34E-02	6.55E-02
Mo	mg/kg initial source	1.14E+00	6.97E-01	5.42E-02	1.34E+00	1.06E+00	3.34E-02	ND
Mo Unc.	mg/kg initial source	7.05E-01	1.19E+00	7.36E-01	8.31E-01	6.37E-01	6.68E-02	8.19E-02
Pd	mg/kg initial source	2.15E+00	9.96E-02	1.36E-01	ND	1.91E+00	8.76E-02	ND
Pd Unc.	mg/kg initial source	1.36E+00	2.50E+00	1.12E+00	1.34E+00	9.46E-01	1.54E-01	1.98E-01
Ag	mg/kg initial source	1.27E+00	ND	ND	ND	ND	ND	2.06E-01
Ag Unc.	mg/kg initial source	1.32E+00	2.50E+00	1.06E+00	1.34E+00	9.22E-01	1.54E-01	1.89E-01
Cd	mg/kg initial source	1.23E+00	3.10E+00	3.27E+00	1.82E+00	5.43E-01	1.94E-01	ND
Cd Unc.	mg/kg initial source	1.32E+00	2.50E+00	1.12E+00	1.34E+00	9.46E-01	1.48E-01	1.89E-01

Element	Unit	MK90 09/27/16 Burn 1	MK90 09/27/16 Burn 2,3	MK90 10/05/16 Burn 1	MK90 10/05/16 Burn 2	MK90 10/05/16 Burn 3	Skid waste 10/06/16 Burn 1	Skid waste 10/06/16 Burn 1
In	mg/kg initial source	2.37E+00	1.71E+00	2.10E+00	1.97E-01	1.98E+00	ND	1.64E-02
In Unc.	mg/kg initial source	1.36E+00	2.70E+00	1.15E+00	1.46E+00	9.69E-01	1.61E-01	2.06E-01
Sn	mg/kg initial source	ND	7.97E-01	7.71E+00	1.66E+00	2.82E-01	8.01E-02	ND
Sn Unc.	mg/kg initial source	1.58E+00	3.30E+00	1.36E+00	1.66E+00	1.11E+00	2.01E-01	2.47E-01
Sb	mg/kg initial source	ND	ND	3.27E+00	ND	1.37E+00	ND	ND
Sb Unc.	mg/kg initial source	1.67E+00	3.50E+00	1.36E+00	1.74E+00	1.18E+00	2.14E-01	2.63E-01
Ba	mg/kg initial source	5.84E+00	8.96E-01	6.68E+00	6.72E+00	6.19E+00	1.94E-01	2.80E-01
Ba Unc.	mg/kg initial source	1.41E+00	2.30E+00	1.55E+00	1.66E+00	1.32E+00	1.48E-01	1.73E-01
La	mg/kg initial source	3.87E+00	1.31E+00	5.53E+00	6.16E+00	4.37E+00	2.00E-02	1.57E-01
La Unc.	mg/kg initial source	9.68E-01	1.31E+00	1.04E+00	1.15E+00	8.72E-01	9.43E-02	1.16E-01
Hg	mg/kg initial source	ND	ND	ND	ND	ND	ND	ND
Hg Unc.	mg/kg initial source	1.80E+00	2.00E+00	2.04E+00	2.01E+00	1.65E+00	1.21E-01	1.65E-01
Pb	mg/kg initial source	1.00E+04	8.77E+03	1.15E+04	1.11E+04	9.57E+03	5.42E+02	8.16E+02
Pb Unc.	mg/kg initial source	5.02E+02	4.39E+02	5.74E+02	5.55E+02	4.79E+02	2.71E+01	4.08E+01

[a] Yellow box with red text = less than three times the uncertainty level. ND = not detected. Unc. = Uncertainty level

Appendix B: PCDD/PCDF emission factors

Table B-1. PCDD/PCDF total emission factors from skid waste.

Homologue	n[a]	Skid Waste -Type 1 Average ng/kg initial source	Stand. Dev.[b]	RSD[b] %	RPD[c] %
TeCDD Total	0	ND[d]			
PeCDD Total	1	0.14			
HxCDD Total	3	1.25	1.33	107	
HpCDD Total	4	3.71	2.07	56	
OCDD	4	8.49	5.32	63	
TeCDF Total	4	25.51	30.19	118	
PeCDF Total	3	8.51	7.30	86	
HxCDF Total	2	0.85			70
HpCDF Total	2	1.26			64
OCDF	4	0.45	0.17	37	
PCDD Total		13.17	8.66	66	
PCDF Total		33.41	37.48	112	
PCDD/PCDF Total		46.58	41.13	88	

[a] Number of samples with detectable levels. [b] Stand. Dev. = standard deviation, RSD = relative standard deviation calculated when n = 3 or more. [c] RPD = relative percent difference, calculated when n=2. [d] ND = not detected.

Table B-2. PCDD/PCDF TEQ emission factors from skid waste, ND = 0.

Homologue	n[a]	Skid Waste -Type 1 Average ND=0 ng TEQ/kg initial source	Stand. Dev.[b]	RSD[b] %	RPD[c] %
2,3,7,8 - TCDD	0	ND			
1,2,3,7,8 - PeCDD	1	0.208			
1,2,3,4,7,8 - HxCDD	0	ND			
1,2,3,6,7,8 - HxCDD	1	0.037			
1,2,3,7,8,9 - HxCDD	1	0.025			
1,2,3,4,6,7,8 - HpCDD	4	0.025	0.015	60	
1,2,3,4,6,7,8,9 - OCDD	4	0.0025	0.0016	64	
2,3,7,8 - TCDF	4	0.371	0.389	105	
1,2,3,7,8 - PeCDF	2	0.045			31
2,3,4,7,8 - PeCDF	3	0.503	0.285	57	
1,2,3,4,7,8 - HxCDF	2	0.024			64
1,2,3,6,7,8 - HxCDF	1	0.017			
1,2,3,7,8,9 - HxCDF	0	ND			
2,3,4,6,7,8 - HxCDF	0	ND			
1,2,3,4,6,7,8 - HpCDF	0	ND			
1,2,3,4,7,8,9 - HpCDF	0	ND			
1,2,3,4,6,7,8,9 - OCDF	3	0.000145	0.000046	31	
PCDD TEQ Total		0.10	0.15	158	
PCDF TEQ Total		0.79	0.71	90	
PCDD/PCDF TEQ Total		0.88	0.79	90	

[a] Number of samples with detectable levels. [b] Stand. Dev. = standard deviation, RSD = relative standard deviation calculated when n = 3 or more. [c] RPD = relative percent difference, calculated when n=2. [d] ND = not detected.

Table B-3. PCDD/PCDF TEQ emission factors from skid waste, ND = LOD.

Homologue	Skid Waste -Type 1		
	Average	Stand. Dev.[a]	RSD[a]
	ND=LOD[b] ng TEQ/kg initial source		%
2,3,7,8 - TCDD	0.141	0.0591	42
1,2,3,7,8 - PeCDD	0.152	0.0393	26
1,2,3,4,7,8 - HxCDD	0.010	0.00119	12
1,2,3,6,7,8 - HxCDD	0.019	0.0124	65
1,2,3,7,8,9 - HxCDD	0.014	0.00709	49
1,2,3,4,6,7,8 - HpCDD	0.025	0.0152	60
1,2,3,4,6,7,8,9 - OCDD	0.0025	0.00163	64
2,3,7,8 - TCDF	0.371	0.389	105
1,2,3,7,8 - PeCDF	0.025	0.0244	98
2,3,4,7,8 - PeCDF	0.390	0.324	83
1,2,3,4,7,8 - HxCDF	0.017	0.0105	61
1,2,3,6,7,8 - HxCDF	0.013	0.00232	17
1,2,3,7,8,9 - HxCDF	0.014	0.000949	7.0
2,3,4,6,7,8 - HxCDF	0.012	0.000806	6.6
1,2,3,4,6,7,8 - HpCDF	0.0022	0.00132	61
1,2,3,4,7,8,9 - HpCDF	0.0026	0.00158	61
1,2,3,4,6,7,8,9 - OCDF	0.00014	0.000037	26
PCDD TEQ Total	0.36	0.10	27
PCDF TEQ Total	0.85	0.69	81
PCDD/PCDF TEQ Total	1.21	0.69	57

[a] Stand. Dev. = standard deviation, RSD = relative standard deviation. [b] ND = not detected, LOD = limit of detection.

Table B-4. PCDD/PCDF total emission factors from skid waste.

Homologue	n[a]	Skid Waste -Type 1 Average ng/kg waste	Stand. Dev.[b]	RSD[b] %	RPD[c] %
TeCDD Total	0	ND[d]			
PeCDD Total	1	0.28			
HxCDD Total	3	2.51	2.68	107	
HpCDD Total	4	7.45	4.17	56	
OCDD	4	17.06	10.68	63	
TeCDF Total	4	51.25	60.63	118	
PeCDF Total	3	17.10	14.67	86	
HxCDF Total	2	1.71			70
HpCDF Total	2	2.53			64
OCDF	4	0.91	0.34	37	
PCDD Total		26.5	17.4	66	
PCDF Total		67.1	75.3	112	
PCDD/PCDF Total		93.6	82.6	88	

[a] Number of samples with detectable levels. [b] Stand. Dev. = standard deviation, RSD = relative standard deviation calculated when n = 3 or more. [c] RPD = relative percent difference, calculated when n=2. [d] ND = not detected.

Table B-5. PCDD/PCDF TEQ emission factors from skid waste, ND = 0.

Homologue	n[a]	Skid Waste -Type 1 Average ND=0 ng TEQ/kg waste	Stand. Dev.[b]	RSD[b] %	RPD[c] %
2,3,7,8 - TCDD	0	ND			
1,2,3,7,8 - PeCDD	1	0.417			
1,2,3,4,7,8 - HxCDD	0	ND			
1,2,3,6,7,8 - HxCDD	1	0.075			
1,2,3,7,8,9 - HxCDD	1	0.050			
1,2,3,4,6,7,8 - HpCDD	4	0.051	0.030	60	
1,2,3,4,6,7,8,9 - OCDD	4	0.005	0.003	64	
2,3,7,8 - TCDF	4	0.745	0.781	105	
1,2,3,7,8 - PeCDF	2	0.091			31
2,3,4,7,8 - PeCDF	3	1.011	0.572	57	
1,2,3,4,7,8 - HxCDF	2	0.049			64
1,2,3,6,7,8 - HxCDF	1	0.033			
1,2,3,7,8,9 - HxCDF	0	ND			
2,3,4,6,7,8 - HxCDF	0	ND			
1,2,3,4,6,7,8 - HpCDF	0	ND			
1,2,3,4,7,8,9 - HpCDF	0	ND			
1,2,3,4,6,7,8,9 - OCDF	3	0.000291	0.000091	31	
PCDD TEQ Total		0.19	0.30	158	
PCDF TEQ Total		1.58	1.43	90	
PCDD/PCDF TEQ Total		1.77	1.59	90	

[a] Number of samples with detectable levels. [b] Stand. Dev. = standard deviation, RSD = relative standard deviation calculated when n = 3 or more. [c] RPD = relative percent difference, calculated when n=2. [d] ND = not detected.

Table B-6. PCDD/PCDF TEQ emission factors from skid waste, ND = LOD.

Homologue	Skid Waste -Type 1 Average ND=LOD[b] ng TEQ/kg waste	Stand. Dev.[a]	RSD[a] %
2,3,7,8 - TCDD	0.283	0.119	42
1,2,3,7,8 - PeCDD	0.306	0.079	26
1,2,3,4,7,8 - HxCDD	0.020	0.0024	12
1,2,3,6,7,8 - HxCDD	0.038	0.025	65
1,2,3,7,8,9 - HxCDD	0.029	0.014	49
1,2,3,4,6,7,8 - HpCDD	0.051	0.030	60
1,2,3,4,6,7,8,9 - OCDD	0.0051	0.0033	64
2,3,7,8 - TCDF	0.745	0.781	105
1,2,3,7,8 - PeCDF	0.050	0.049	98
2,3,4,7,8 - PeCDF	0.784	0.651	83
1,2,3,4,7,8 - HxCDF	0.034	0.021	61
1,2,3,6,7,8 - HxCDF	0.027	0.0047	17
1,2,3,7,8,9 - HxCDF	0.027	0.0019	7.0
2,3,4,6,7,8 - HxCDF	0.024	0.0016	6.6
1,2,3,4,6,7,8 - HpCDF	0.0043	0.0026	61
1,2,3,4,7,8,9 - HpCDF	0.0052	0.0032	61
1,2,3,4,6,7,8,9 - OCDF	0.00029	0.000075	26
PCDD TEQ Total	0.73	0.20	27
PCDF TEQ Total	1.70	1.38	81
PCDD/PCDF TEQ Total	2.43	1.38	57

[a] Stand. Dev. = standard deviation, RSD = relative standard deviation. [b] ND = not detected, LOD = limit of detection.

Appendix C: Sampling volumes

Date	Fuel	Burn #	PM2.5/Metals	Cr VI	HCl/perchlorate	Nitroaromatics	Nitrocellulose	VOC	PCDD/PCDF
			m^3	m^3	m^3	m^3	m^3	m^3	m^3
9/27/2016	MK90	1	0.0385						
9/27/2016	MK90	2	0.0590			5.217			
9/27/2016	MK90	3							
9/29/2016	MK90	1		0.0780					
9/29/2016	MK90	2					6.946		
9/29/2016	MK90	3		0.0419					
10/3/2016	MK90	1		0.0756		4.510			
10/3/2016	MK90	2		0.0511		2.889			
10/3/2016	MK90	3		0.0401		2.279			
10/5/2016	MK90	1	0.0542						
10/5/2016	MK90	2	0.0403				13.754		
10/5/2016	MK90	3	0.0647						
9/28/2016	SW	1			0.0658				
9/28/2016	SW	2			0.0625				17.519
9/28/2016	SW	3			0.0531				
9/30/2016	SW	1		0.0711				0.00214	
9/30/2016	SW	2		0.0612				0.00109	
10/4/2016	SW	1			0.0643				5.837
10/4/2016	SW	2			0.0640				6.066
10/4/2016	SW	3			0.0459				4.190
10/6/2016	SW	1	0.0687					0.00325	
10/6/2016	SW	1	0.0956						
10/6/2016	SW	2		0.0812				0.00192	
10/4/2016	BS				0.3093				33.548
10/5/2016	BS		0.6312				35.873		
10/6/2016	BS			0.4808		34.638		0.00605	

Date	Fuel	Burn #	PM2.5/Metals	Cr VI	HCl/perchlorate	Nitroaromatics	Nitrocellulose	VOC	PCDD/PCDF
			mg C/m^3	mg C/m^3	mg C/m^3	mg C/m^3	mg C/m^3	mg C/m^3	mg C/m^3
9/27/2016	MK90	1	121						
9/27/2016	MK90	2	35			68			
9/27/2016	MK90	3							
9/29/2016	MK90	1		109					
9/29/2016	MK90	2					137		
9/29/2016	MK90	3		245					
10/3/2016	MK90	1		86		80			
10/3/2016	MK90	2		178		164			
10/3/2016	MK90	3		187		174			
10/5/2016	MK90	1	138						
10/5/2016	MK90	2	128				73		
10/5/2016	MK90	3	134						
9/28/2016	SW	1			136				
9/28/2016	SW	2			247				229
9/28/2016	SW	3			337				
9/30/2016	SW	1		325				325	
9/30/2016	SW	2		237				229	
10/4/2016	SW	1			409				414
10/4/2016	SW	2			301				306
10/4/2016	SW	3			463				465
10/6/2016	SW	1	659					552	
10/6/2016	SW	1	386						
10/6/2016	SW	2		750				753	

Appendix D: Laboratory results

US EPA

PROJECT: READFORD PROPELLANT BURNS, SEPT. – OCT. 2016

CLIENT # U012
REPORT # 16-737

SUBMITTED BY:
CHESTER LabNet
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CHESTER LabNet

12242 SW Garden Place ❖ Tigard, OR 97223-8246 ❖ USA
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Case Narrative

Date: November 8, 2016

General Information

Client:	US EPA
Client Number:	U012
Report Number:	16-737
Sample Description:	37mm Teflon filters

Analysis

Analytes:	Particulate Mass, XRF Metals (Na – Pb)
Analytical Protocols:	Gravimetry, X-Ray Fluorescence
Analytical Notes:	Some of the samples had thicker than usual deposits and did not conform (DNC) to the thin film method. This resulted in high uncertainties for the analytes listed in the comments for each affected sample. Results have **not** been blank corrected.
QA/QC Review:	All of the data have been reviewed by the analysts performing the analyses and the project manager. All of the quality control and sample-specific information in this package is complete and meets or exceeds the minimum requirements for acceptability.
Comments:	If you have any questions or concerns regarding this analysis, please feel free to contact the project manager.
Disclaimer:	This report shall not be reproduced, except in full, without the written approval of the laboratory. The results only represent that of the samples as received into the laboratory.

Paul Duda 11/8/16

Project Manager Date
Paul Duda

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 14-T4414
Client ID: PS-RM-PM2.5-092716-01
Site: Radford Propellant Burns
Sample Date: 9/27/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5
Comments: Na DNC

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	304.	±	10.			
XRF						
Na	15.70	±	2.115	5.165	±	0.7160
Mg	2.569	±	0.3634	0.8450	±	0.1227
* Al	0.0281	±	0.0756	0.0093	±	0.0249
Si	2.858	±	0.1857	0.9402	±	0.0685
* P	0.0699	±	0.0338	0.0230	±	0.0111
* S	0.0000	±	3.155	0.0000	±	1.038
Cl	0.8008	±	0.1214	0.2634	±	0.0409
K	0.6110	±	0.0434	0.2010	±	0.0157
Ca	0.6834	±	0.0442	0.2248	±	0.0163
Ti	0.0346	±	0.0080	0.0114	±	0.0027
* V	0.0000	±	0.0080	0.0000	±	0.0026
Cr	0.0233	±	0.0056	0.0077	±	0.0019
* Mn	0.0096	±	0.0096	0.0032	±	0.0032
Fe	0.2959	±	0.0209	0.0973	±	0.0076
* Co	0.0000	±	0.0072	0.0000	±	0.0024
* Ni	0.0000	±	0.0080	0.0000	±	0.0026
Cu	54.71	±	2.737	18.00	±	1.077
* Zn	0.0000	±	0.0096	0.0000	±	0.0032
Ga	0.1777	±	0.0523	0.0584	±	0.0173
Ge	0.1970	±	0.0209	0.0648	±	0.0072
* As	0.2476	±	0.1126	0.0815	±	0.0371
* Se	0.0000	±	0.0201	0.0000	±	0.0066
Br	0.2734	±	0.0193	0.0899	±	0.0070
Rb	0.1343	±	0.0161	0.0442	±	0.0055
* Sr	0.0281	±	0.0113	0.0093	±	0.0037
Y	0.2629	±	0.0330	0.0865	±	0.0112
* Zr	0.0000	±	0.0129	0.0000	±	0.0042
* Mo	0.0209	±	0.0129	0.0069	±	0.0042
* Pd	0.0394	±	0.0249	0.0130	±	0.0082
* Ag	0.0233	±	0.0241	0.0077	±	0.0079
* Cd	0.0225	±	0.0241	0.0074	±	0.0079
* In	0.0434	±	0.0249	0.0143	±	0.0082
* Sn	0.0000	±	0.0289	0.0000	±	0.0095
* Sb	0.0000	±	0.0306	0.0000	±	0.0100
Ba	0.1069	±	0.0257	0.0352	±	0.0085
La	0.0708	±	0.0177	0.0233	±	0.0059
* Hg	0.0000	±	0.0330	0.0000	±	0.0108
Pb	183.4	±	9.174	60.33	±	3.612

* - XRF Concentration is less than three times the uncertainty

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 14-T4417
Client ID: PS-RM-PM2.5-092716-02
Site: Radford Propellant Burns
Sample Date: 9/27/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	107.	±	10.			
XRF						
Na	7.421	±	1.101	6.935	±	1.216
Mg	1.335	±	0.2058	1.248	±	0.2250
* Al	0.0000	±	0.0442	0.0000	±	0.0413
Si	0.9793	±	0.0748	0.9152	±	0.1104
* P	0.0177	±	0.0185	0.0165	±	0.0174
* S	0.0000	±	1.200	0.0000	±	1.122
Cl	0.5073	±	0.0756	0.4741	±	0.0834
K	0.2074	±	0.0217	0.1939	±	0.0272
Ca	0.1761	±	0.0177	0.1646	±	0.0226
* Ti	0.0000	±	0.0056	0.0000	±	0.0053
* V	0.0016	±	0.0040	0.0015	±	0.0038
* Cr	0.0040	±	0.0048	0.0038	±	0.0045
* Mn	0.0000	±	0.0080	0.0000	±	0.0075
Fe	0.1158	±	0.0113	0.1082	±	0.0146
* Co	0.0000	±	0.0048	0.0000	±	0.0045
* Ni	0.0000	±	0.0056	0.0000	±	0.0053
Cu	20.45	±	1.023	19.11	±	2.026
* Zn	0.0000	±	0.0064	0.0000	±	0.0060
* Ga	0.0426	±	0.0265	0.0398	±	0.0251
Ge	0.0547	±	0.0096	0.0511	±	0.0102
* As	0.0177	±	0.0547	0.0165	±	0.0511
* Se	0.0000	±	0.0096	0.0000	±	0.0090
Br	0.0844	±	0.0080	0.0789	±	0.0105
Rb	0.0675	±	0.0072	0.0631	±	0.0090
* Sr	0.0161	±	0.0064	0.0150	±	0.0062
Y	0.0595	±	0.0137	0.0556	±	0.0138
* Zr	0.0000	±	0.0080	0.0000	±	0.0075
* Mo	0.0056	±	0.0096	0.0053	±	0.0090
* Pd	0.0008	±	0.0201	0.0008	±	0.0188
* Ag	0.0000	±	0.0201	0.0000	±	0.0188
* Cd	0.0249	±	0.0201	0.0233	±	0.0189
* In	0.0137	±	0.0217	0.0128	±	0.0203
* Sn	0.0064	±	0.0265	0.0060	±	0.0248
* Sb	0.0000	±	0.0281	0.0000	±	0.0263
* Ba	0.0072	±	0.0185	0.0068	±	0.0173
* La	0.0105	±	0.0105	0.0098	±	0.0098
* Hg	0.0000	±	0.0161	0.0000	±	0.0150
Pb	70.48	±	3.527	65.87	±	6.983

* - XRF Concentration is less than three times the uncertainty

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 14-T4420
Client ID: PS-MIC90-PM2.5-100516-01
Site: Radford Propellant Burns
Sample Date: 10/ 5/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5
Comments: Na Mg Ca DNC

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	468.	±	10.			
XRF						
Na	31.34	±	4.773	6.697	±	1.030
Mg	5.776	±	0.8514	1.234	±	0.1838
* Al	0.0000	±	0.1897	0.0000	±	0.0405
Si	4.908	±	0.3473	1.049	±	0.0775
* P	0.1198	±	0.0852	0.0256	±	0.0182
* S	0.0000	±	1.176	0.0000	±	0.2513
* Cl	0.2613	±	0.1986	0.0558	±	0.0425
K	0.5901	±	0.0539	0.1261	±	0.0118
Ca	0.8321	±	0.0627	0.1778	±	0.0139
Ti	0.0474	±	0.0137	0.0101	±	0.0029
* V	0.0096	±	0.0113	0.0021	±	0.0024
Cr	0.0434	±	0.0096	0.0093	±	0.0021
* Mn	0.0000	±	0.0121	0.0000	±	0.0026
Fe	0.4502	±	0.0289	0.0962	±	0.0065
* Co	0.0000	±	0.0096	0.0000	±	0.0021
* Ni	0.0000	±	0.0105	0.0000	±	0.0022
Cu	100.3	±	5.017	21.44	±	1.166
* Zn	0.0000	±	0.0161	0.0000	±	0.0034
* Ga	0.0796	±	0.0900	0.0170	±	0.0192
Ge	0.3811	±	0.0378	0.0814	±	0.0083
As	0.6175	±	0.2050	0.1319	±	0.0439
* Se	0.0000	±	0.0354	0.0000	±	0.0076
Br	0.4985	±	0.0354	0.1065	±	0.0079
Rb	0.2999	±	0.0297	0.0641	±	0.0065
* Sr	0.0000	±	0.0217	0.0000	±	0.0046
Y	0.3723	±	0.0571	0.0795	±	0.0123
* Zr	0.0000	±	0.0225	0.0000	±	0.0048
* Mo	0.0016	±	0.0217	0.0003	±	0.0046
* Pd	0.0040	±	0.0330	0.0009	±	0.0070
* Ag	0.0000	±	0.0314	0.0000	±	0.0067
* Cd	0.0965	±	0.0330	0.0206	±	0.0071
* In	0.0619	±	0.0338	0.0132	±	0.0072
Sn	0.2275	±	0.0402	0.0486	±	0.0087
* Sb	0.0965	±	0.0402	0.0206	±	0.0086
Ba	0.1970	±	0.0458	0.0421	±	0.0098
La	0.1632	±	0.0306	0.0349	±	0.0066
* Hg	0.0000	±	0.0603	0.0000	±	0.0129
Pb	338.2	±	16.92	72.26	±	3.930

* - XRF Concentration is less than three times the uncertainty

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 14-T4421
Client ID: PS-MIC90-PM2.5-100516-02
Site: Radford Propellant Burns
Sample Date: 10/ 5/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5
Comments: Na DNC

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	358.	±	10.			
XRF						
Na	21.27	±	3.427	5.940	±	0.9717
Mg	3.785	±	0.6159	1.057	±	0.1745
* Al	0.2709	±	0.1367	0.0757	±	0.0382
Si	3.509	±	0.2468	0.9803	±	0.0742
* P	0.1206	±	0.0603	0.0337	±	0.0169
* S	0.0000	±	3.920	0.0000	±	1.095
Cl	0.5001	±	0.1439	0.1397	±	0.0404
K	0.5242	±	0.0434	0.1464	±	0.0128
Ca	0.6014	±	0.0434	0.1680	±	0.0130
* Ti	0.0201	±	0.0096	0.0056	±	0.0027
* V	0.0048	±	0.0096	0.0013	±	0.0027
Cr	0.0338	±	0.0080	0.0094	±	0.0023
* Mn	0.0032	±	0.0105	0.0009	±	0.0029
Fe	0.4374	±	0.0273	0.1222	±	0.0084
* Co	0.0000	±	0.0080	0.0000	±	0.0022
* Ni	0.0000	±	0.0088	0.0000	±	0.0025
Cu	70.90	±	3.546	19.80	±	1.135
* Zn	0.0000	±	0.0129	0.0000	±	0.0036
* Ga	0.0772	±	0.0635	0.0216	±	0.0178
Ge	0.2275	±	0.0265	0.0636	±	0.0076
As	0.4615	±	0.1447	0.1289	±	0.0406
* Se	0.0257	±	0.0249	0.0072	±	0.0070
Br	0.3272	±	0.0241	0.0914	±	0.0072
Rb	0.2002	±	0.0209	0.0559	±	0.0060
* Sr	0.0201	±	0.0145	0.0056	±	0.0040
Y	0.1986	±	0.0386	0.0555	±	0.0109
* Zr	0.0000	±	0.0169	0.0000	±	0.0047
* Mo	0.0273	±	0.0169	0.0076	±	0.0047
* Pd	0.0000	±	0.0273	0.0000	±	0.0076
* Ag	0.0000	±	0.0273	0.0000	±	0.0076
* Cd	0.0370	±	0.0273	0.0103	±	0.0076
* In	0.0040	±	0.0297	0.0011	±	0.0083
* Sn	0.0338	±	0.0338	0.0094	±	0.0094
* Sb	0.0000	±	0.0354	0.0000	±	0.0099
Ba	0.1367	±	0.0338	0.0382	±	0.0095
La	0.1254	±	0.0233	0.0350	±	0.0066
* Hg	0.0000	±	0.0410	0.0000	±	0.0115
Pb	225.8	±	11.30	63.06	±	3.614

* - XRF Concentration is less than three times the uncertainty

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 14-T4419
Client ID: PS-MIC90-PM2.5-100516-03
Site: Radford Propellant Burns
Sample Date: 10/ 5/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5
Comments: Na Mg Ca DNC

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	493.	±	10.			
XRF						
Na	22.69	±	4.485	4.602	±	0.9145
Mg	4.271	±	0.8346	0.8663	±	0.1702
* Al	0.2420	±	0.1914	0.0491	±	0.0388
Si	4.746	±	0.3361	0.9627	±	0.0709
* P	0.1769	±	0.0812	0.0359	±	0.0165
* S	0.0000	±	1.041	0.0000	±	0.2112
* Cl	0.2718	±	0.1954	0.0551	±	0.0396
K	0.7405	±	0.0595	0.1502	±	0.0124
Ca	0.8547	±	0.0611	0.1734	±	0.0129
Ti	0.0619	±	0.0137	0.0126	±	0.0028
* V	0.0000	±	0.0113	0.0000	±	0.0023
Cr	0.0410	±	0.0096	0.0083	±	0.0020
* Mn	0.0000	±	0.0121	0.0000	±	0.0024
Fe	0.4334	±	0.0281	0.0879	±	0.0060
* Co	0.0000	±	0.0105	0.0000	±	0.0021
* Ni	0.0000	±	0.0113	0.0000	±	0.0023
Cu	100.3	±	5.014	20.34	±	1.097
* Zn	0.0000	±	0.0161	0.0000	±	0.0033
* Ga	0.0000	±	0.0868	0.0000	±	0.0176
Ge	0.4719	±	0.0394	0.0957	±	0.0082
As	0.8876	±	0.2026	0.1800	±	0.0413
* Se	0.0209	±	0.0346	0.0042	±	0.0070
Br	0.5210	±	0.0362	0.1057	±	0.0076
Rb	0.2139	±	0.0273	0.0434	±	0.0056
Sr	0.0740	±	0.0193	0.0150	±	0.0039
Y	0.3168	±	0.0547	0.0643	±	0.0112
* Zr	0.0000	±	0.0225	0.0000	±	0.0046
* Mo	0.0362	±	0.0217	0.0073	±	0.0044
* Pd	0.0651	±	0.0322	0.0132	±	0.0065
* Ag	0.0000	±	0.0314	0.0000	±	0.0064
* Cd	0.0185	±	0.0322	0.0038	±	0.0065
* In	0.0675	±	0.0330	0.0137	±	0.0067
* Sn	0.0096	±	0.0378	0.0020	±	0.0077
* Sb	0.0466	±	0.0402	0.0095	±	0.0082
Ba	0.2106	±	0.0450	0.0427	±	0.0092
La	0.1487	±	0.0297	0.0302	±	0.0061
* Hg	0.0000	±	0.0563	0.0000	±	0.0114
Pb	325.9	±	16.31	66.11	±	3.569

* - XRF Concentration is less than three times the uncertainty

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 14-T4418
Client ID: BS-PM2.5-100516
Site: Radford Propellant Burns
Sample Date: 10/ 5/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	10.	±	10.			
XRF						
* Na	0.7485	±	0.4004	7.485	±	8.489
* Mg	0.1005	±	0.0836	1.005	±	1.307
* Al	0.0000	±	0.0201	0.0000	±	0.2010
* Si	0.0000	±	0.0161	0.0000	±	0.1608
* P	0.0000	±	0.0072	0.0000	±	0.0724
S	0.1584	±	0.0113	1.584	±	1.588
* Cl	0.0000	±	0.0161	0.0000	±	0.1608
* K	0.0000	±	0.0096	0.0000	±	0.0965
* Ca	0.0080	±	0.0080	0.0804	±	0.1137
* Ti	0.0000	±	0.0040	0.0000	±	0.0402
* V	0.0064	±	0.0032	0.0643	±	0.0719
* Cr	0.0072	±	0.0048	0.0724	±	0.0870
* Mn	0.0000	±	0.0056	0.0000	±	0.0563
* Fe	0.0056	±	0.0056	0.0563	±	0.0796
* Co	0.0000	±	0.0032	0.0000	±	0.0322
* Ni	0.0008	±	0.0032	0.0080	±	0.0331
Cu	0.0185	±	0.0040	0.1849	±	0.1892
Zn	0.0129	±	0.0040	0.1286	±	0.1348
* Ga	0.0088	±	0.0153	0.0884	±	0.1765
* Ge	0.0000	±	0.0040	0.0000	±	0.0402
* As	0.0032	±	0.0032	0.0322	±	0.0455
Se	0.0121	±	0.0032	0.1206	±	0.1248
* Br	0.0016	±	0.0024	0.0161	±	0.0290
* Rb	0.0000	±	0.0032	0.0000	±	0.0322
* Sr	0.0000	±	0.0032	0.0000	±	0.0322
* Y	0.0080	±	0.0040	0.0804	±	0.0899
* Zr	0.0000	±	0.0056	0.0000	±	0.0563
* Mo	0.0056	±	0.0080	0.0563	±	0.0981
* Pd	0.0000	±	0.0161	0.0000	±	0.1608
* Ag	0.0000	±	0.0161	0.0000	±	0.1608
* Cd	0.0000	±	0.0161	0.0000	±	0.1608
* In	0.0000	±	0.0177	0.0000	±	0.1769
* Sn	0.0056	±	0.0225	0.0563	±	0.2320
* Sb	0.0000	±	0.0257	0.0000	±	0.2573
* Ba	0.0000	±	0.0145	0.0000	±	0.1447
* La	0.0233	±	0.0080	0.2332	±	0.2466
* Hg	0.0000	±	0.0080	0.0000	±	0.0804
* Pb	0.0072	±	0.0072	0.0724	±	0.1023

* - XRF Concentration is less than three times the uncertainty

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 15-T3152
Client ID: PS-SW-PM2.5-100616-01
Site: Radford Propellant Burns
Sample Date: 10/ 6/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	263.	±	10.			
XRF						
* Na	3.319	±	1.674	1.262	±	0.6383
* Mg	0.2291	±	0.1544	0.0871	±	0.0588
* Al	0.0000	±	0.0732	0.0000	±	0.0278
Si	2.281	±	0.1592	0.8673	±	0.0689
* P	0.0515	±	0.0289	0.0196	±	0.0110
* S	0.0000	±	0.2106	0.0000	±	0.0801
Cl	8.482	±	0.4430	3.225	±	0.2084
K	5.153	±	0.2669	1.959	±	0.1259
Ca	0.2862	±	0.0265	0.1088	±	0.0109
Ti	0.0297	±	0.0064	0.0113	±	0.0025
* V	0.0040	±	0.0040	0.0015	±	0.0015
* Cr	0.0032	±	0.0048	0.0012	±	0.0018
* Mn	0.0000	±	0.0064	0.0000	±	0.0024
Fe	0.1053	±	0.0113	0.0400	±	0.0045
* Co	0.0000	±	0.0040	0.0000	±	0.0015
* Ni	0.0000	±	0.0040	0.0000	±	0.0015
Cu	3.044	±	0.1536	1.157	±	0.0731
Zn	0.3594	±	0.0201	0.1366	±	0.0092
* Ga	0.0000	±	0.0233	0.0000	±	0.0089
Ge	0.0563	±	0.0080	0.0214	±	0.0032
* As	0.1206	±	0.0490	0.0459	±	0.0187
* Se	0.0000	±	0.0080	0.0000	±	0.0031
Br	0.1423	±	0.0096	0.0541	±	0.0042
Rb	0.0772	±	0.0072	0.0293	±	0.0030
* Sr	0.0032	±	0.0048	0.0012	±	0.0018
Y	0.0732	±	0.0121	0.0278	±	0.0047
* Zr	0.0000	±	0.0064	0.0000	±	0.0024
* Mo	0.0040	±	0.0080	0.0015	±	0.0031
* Pd	0.0105	±	0.0185	0.0040	±	0.0070
* Ag	0.0000	±	0.0185	0.0000	±	0.0070
* Cd	0.0233	±	0.0177	0.0089	±	0.0067
* In	0.0000	±	0.0193	0.0000	±	0.0073
* Sn	0.0096	±	0.0241	0.0037	±	0.0092
* Sb	0.0000	±	0.0257	0.0000	±	0.0098
* Ba	0.0233	±	0.0177	0.0089	±	0.0067
* La	0.0024	±	0.0113	0.0009	±	0.0043
* Hg	0.0000	±	0.0145	0.0000	±	0.0055
Pb	64.97	±	3.251	24.70	±	1.553

* - XRF Concentration is less than three times the uncertainty

Client: U012 - US EPA
Report Number: 16-737

Lab ID: 15-T3151
Client ID: PS-SW-PM2.5-100616-02
Site: Radford Propellant Burns
Sample Date: 10/ 6/16
Filter Lot #: T22506
Deposit Area: 8.04 cm²
Size Fraction: PM2.5

Analyte	µg/filter			percent		
Gravimetry						
Net Mass	237.	±	10.			
XRF						
* Na	4.223	±	1.570	1.782	±	0.6668
* Mg	0.2854	±	0.1399	0.1204	±	0.0592
* Al	0.0000	±	0.0635	0.0000	±	0.0268
Si	2.216	±	0.1487	0.9349	±	0.0741
* P	0.0699	±	0.0273	0.0295	±	0.0116
* S	0.0000	±	0.2340	0.0000	±	0.0987
Cl	8.788	±	0.4583	3.708	±	0.2487
K	4.281	±	0.2227	1.806	±	0.1210
Ca	0.1914	±	0.0217	0.0807	±	0.0098
* Ti	0.0121	±	0.0056	0.0051	±	0.0024
* V	0.0000	±	0.0040	0.0000	±	0.0017
* Cr	0.0048	±	0.0040	0.0020	±	0.0017
* Mn	0.0000	±	0.0072	0.0000	±	0.0031
* Fe	0.0185	±	0.0072	0.0078	±	0.0031
* Co	0.0000	±	0.0040	0.0000	±	0.0017
* Ni	0.0008	±	0.0032	0.0003	±	0.0014
Cu	0.9222	±	0.0474	0.3891	±	0.0259
Zn	1.188	±	0.0611	0.5014	±	0.0334
* Ga	0.0000	±	0.0249	0.0000	±	0.0105
Ge	0.0828	±	0.0096	0.0349	±	0.0043
As	0.1857	±	0.0563	0.0784	±	0.0240
* Se	0.0000	±	0.0088	0.0000	±	0.0037
Br	0.1825	±	0.0121	0.0770	±	0.0060
Rb	0.0949	±	0.0080	0.0400	±	0.0038
* Sr	0.0000	±	0.0056	0.0000	±	0.0024
Y	0.0957	±	0.0145	0.0404	±	0.0063
* Zr	0.0000	±	0.0064	0.0000	±	0.0027
* Mo	0.0000	±	0.0080	0.0000	±	0.0034
* Pd	0.0000	±	0.0193	0.0000	±	0.0081
* Ag	0.0201	±	0.0185	0.0085	±	0.0078
* Cd	0.0000	±	0.0185	0.0000	±	0.0078
* In	0.0016	±	0.0201	0.0007	±	0.0085
* Sn	0.0000	±	0.0241	0.0000	±	0.0102
* Sb	0.0000	±	0.0257	0.0000	±	0.0109
* Ba	0.0273	±	0.0169	0.0115	±	0.0071
* La	0.0153	±	0.0113	0.0064	±	0.0048
* Hg	0.0000	±	0.0161	0.0000	±	0.0068
Pb	79.64	±	3.985	33.61	±	2.200

* - XRF Concentration is less than three times the uncertainty

CHESTER LabNet

XRF-772 **XRF Analytical Quality Assurance Report**

Client: US EPA
Report: 16-737
Analysis Period: November 3, 2016
Number of Samples: 8

1. Precision Data

Micromatter Multi-elemental Quality Control Standard: QS285

QC Standard Results

Analyte	n	Counts per Second			c.v.	%E
		Calib.	Meas.	S.D.		
Si(0)	1	981.41	954.90	na	na	-2.70
Ti(1)	1	567.81	580.34	na	na	2.21
Fe(1)	1	1242.11	1254.72	na	na	1.02
Se(3)	1	403.25	425.35	na	na	5.48
Pb(3)	1	463.80	485.84	na	na	4.75
Cd(4)	1	149.01	153.36	na	na	2.92

2. Accuracy Data

NIST Standard Reference Materials: SRM 1832, SRM 1833, SRM 2783

Analyte/ SRM	n	Certified Value(µg/cm²)	Measured Value (µg/cm²)			% Rec.
			High	Low	Average	
Al 1832	4	14.6 +/- .97	14.50	14.19	14.33 +/- 0.11	98.1
Si 1832	4	34.0 +/- 1.1	37.70	36.22	36.85 +/- 0.57	108.4
Si 1833	4	31.5 +/- 2.1	32.36	31.90	32.12 +/- 0.21	102.0
S 2708	4	2.46 +/- .25	2.28	2.25	2.26 +/- 0.01	91.9
K 2783	4	.530 +/- .052	0.54	0.53	0.53 +/- 0.01	100.9
Ca 2783	4	1.33 +/- 0.17	1.35	1.33	1.34 +/- 0.01	101.1
Ti 1833	4	12.1 +/- 1.79	12.62	12.33	12.52 +/- 0.12	103.5
V 1832	4	4.70 +/- .49	4.55	4.41	4.47 +/- 0.05	95.2
Mn 1832	4	4.54 +/- .49	4.86	4.74	4.82 +/- 0.04	106.1
Fe 1833	4	13.6 +/- .45	13.36	13.27	13.33 +/- 0.04	98.0
Cu 1832	4	2.43 +/- .16	2.65	2.62	2.64 +/- 0.01	108.6
Zn 2783	4	.180 +/- .013	0.19	0.19	0.19 +/- 0.00	104.2
Pb 1833	4	16.1 +/- .75	16.39	16.11	16.25 +/- 0.10	100.9

NIST: National Institute of Standards and Technology
% Rec: Percent Recovery = (Experimental/Given) x 100
n: Number of Observations
S.D.: Standard Deviation
c.v.: Coefficient of Variation = (S.D./Measured) x 100
% E: Percent Error = [(Measured-Calibrated)/Calibrated] x 100

XRF-772 REPLICATE REPORT

2.16

Original ID: 14-T4420

Replicate ID: RT4420

Filter Lot:

Deposit Mass: 468 µg

Deposit Area: 8.0 cm^2

Particle Size: F

Element	Original ug/cm2			Replicate ug/cm2			Difference ug/cm2				RPD		
Na	3.8983	+-	0.5936	3.6059	+-	0.4725	0.2924	+-	0.7587	+	7.8	+-	20.2
Mg	0.7184	+-	0.1059	0.6251	+-	0.0811	0.0933	+-	0.1334	+	13.9	+-	19.9
Al	0.0000	+-	0.0236	0.0000	+-	0.0163	0.0000	+-	0.0287				
Si	0.6105	+-	0.0432	0.5795	+-	0.0378	0.0310	+-	0.0574	+	5.2	+-	9.6
P	0.0149	+-	0.0106	0.0241	+-	0.0071	-0.0092	+-	0.0128				
S	0.0000	+-	0.1463	0.0000	+-	0.1413	0.0000	+-	0.2034				
Cl	0.0325	+-	0.0247	0.1833	+-	0.0273	-0.1508	+-	0.0368				
K	0.0734	+-	0.0067	0.0747	+-	0.0067	-0.0013	+-	0.0095	+	-1.8	+-	12.8
Ca	0.1035	+-	0.0078	0.1224	+-	0.0084	-0.0189	+-	0.0115	0	-16.7	+-	10.2
Ti	0.0059	+-	0.0017	0.0021	+-	0.0032	0.0038	+-	0.0036	0	94.7	+-	89.4
V	0.0012	+-	0.0014	0.0000	+-	0.0015	0.0012	+-	0.0021				
Cr	0.0054	+-	0.0012	0.0049	+-	0.0012	0.0006	+-	0.0018	+	11.3	+-	34.3
Mn	0.0000	+-	0.0015	0.0000	+-	0.0015	0.0000	+-	0.0022				
Fe	0.0560	+-	0.0036	0.0535	+-	0.0035	0.0025	+-	0.0050	+	4.6	+-	9.1
Co	0.0000	+-	0.0012	0.0000	+-	0.0013	0.0000	+-	0.0018				
Ni	0.0000	+-	0.0013	0.0000	+-	0.0013	0.0000	+-	0.0019				
Cu	12.4758	+-	0.6240	12.5553	+-	0.6280	-0.0795	+-	0.8853	+	-0.6	+-	7.1
Zn	0.0000	+-	0.0020	0.0000	+-	0.0020	0.0000	+-	0.0028				
Ga	0.0099	+-	0.0112	0.0009	+-	0.0112	0.0090	+-	0.0158				
Ge	0.0474	+-	0.0047	0.0419	+-	0.0046	0.0055	+-	0.0066	+	12.2	+-	14.8
As	0.0768	+-	0.0255	0.1245	+-	0.0263	-0.0477	+-	0.0366	0	-47.4	+-	36.4
Se	0.0000	+-	0.0044	0.0000	+-	0.0045	0.0000	+-	0.0063				
Br	0.0620	+-	0.0044	0.0651	+-	0.0045	-0.0031	+-	0.0063	+	-4.9	+-	10.0
Rb	0.0373	+-	0.0037	0.0442	+-	0.0038	-0.0069	+-	0.0053	0	-17.0	+-	13.0
Sr	0.0000	+-	0.0027	0.0000	+-	0.0027	0.0000	+-	0.0038				
Y	0.0463	+-	0.0071	0.0604	+-	0.0074	-0.0141	+-	0.0103	0	-26.5	+-	19.3
Zr	0.0000	+-	0.0028	0.0000	+-	0.0028	0.0000	+-	0.0040				
Mo	0.0002	+-	0.0027	0.0041	+-	0.0027	-0.0038	+-	0.0038				
Pd	0.0005	+-	0.0041	0.0061	+-	0.0041	-0.0056	+-	0.0058				
Ag	0.0000	+-	0.0039	0.0085	+-	0.0040	-0.0085	+-	0.0056				
Cd	0.0120	+-	0.0041	0.0054	+-	0.0040	0.0066	+-	0.0058				
In	0.0077	+-	0.0042	0.0000	+-	0.0042	0.0077	+-	0.0059				
Sn	0.0283	+-	0.0050	0.0213	+-	0.0048	0.0070	+-	0.0069	0	28.2	+-	27.6
Sb	0.0120	+-	0.0050	0.0000	+-	0.0051	0.0120	+-	0.0071				
Ba	0.0245	+-	0.0057	0.0351	+-	0.0060	-0.0105	+-	0.0082	0	-35.4	+-	27.7
La	0.0203	+-	0.0038	0.0184	+-	0.0037	0.0019	+-	0.0053	+	9.8	+-	27.5
Hg	0.0000	+-	0.0075	0.0000	+-	0.0073	0.0000	+-	0.0105				
Pb	42.0626	+-	2.1045	42.3808	+-	2.1204	-0.3182	+-	2.9874	+	-0.8	+-	7.1

RPD: Relative Percent Difference (X1-X2)/[(X1+X2)/2]*100. RPD is calculated when original value is greater than three times its uncertainty.

Project: Radford Propellant burns Sep-Oct 2016

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

PM2.5

16-737

SAMPLER:

	SAMPLE ID	DATE	TIME	MATRIX	PM	Filter #	Requested Analyses 1	2	3	4	5	6	7	8	9	10	Remarks
1	PS-RM-PM2.5-092716-01	092716	MK 90	Burn#1	PM2.5	14-T4414	X	X									imp #1
2	PS-RM-PM2.5-092716-02	092716	MK90	Burn# 2.3	PM2.5	14-T4417	X	X									imp# 4
3	PS-MK90-PM2.5-100516-01	100516	MK90	Burn#1	PM2.5	14-T4420	X	X									imp 1
4	PS-MK90-PM2.5-100516-02	100516	MK90	Burn#2	PM2.5	14-T4421	X	X									4
5	PS-MK90-PM2.5-100516-03	100516	MK90	Burn#3	PM2.5	14-T4419	X	X									7
6	BS-PM2.5-100516	100516		Ambient	PM2.5	14-T4418	X	X									6
7	PS-SW-PM2.5-100616-01	100616	SW	Burn#1	PM2.5	15-T3152	X	X									
8	PS-SW-PM2.5-100616-02	100616	SW	Burn#1	PM2.5	15-T3151	X	X									

	Requested Analyses
1	Weight
2	XRF
3	
4	
5	
6	
7	

Special Instructions/Comments:

☐ **Special QA/QC Instructions**

Laboratory Information and Receipt

Lab Name:

Shipping Tracking #

Specify Turnaround Requirements:

☐ Cooler packed with ice

☐ Cooler custody seal intact

Sample Receipt:

Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
John Bell	10/11/16	10:05	Lisa Ball 10/25/16 10:45				
Relinquished by:	**DATE**	**TIME**	**Received by:**	**Relinquished by:**	**DATE**	**TIME**	**Received by:**

RAW DATA

Available upon request

US EPA

PROJECT: RADFORD
SEP-OCT 2016

CLIENT # U012
REPORT # 16-746

SUBMITTED BY:
CHESTER LabNet
12242 S.W. GARDEN PLACE
TIGARD, OR 97223
(503)624-2183/FAX (503)624-2653
www.ChesterLab.Net

CHESTER LabNet

12242 SW Garden Place ❖ Tigard, OR 97223-8246 ❖ USA
Telephone 503-624-2183 ❖ Fax 503-624-2653 ❖ www.chesterlab.net

Case Narrative

Date: November 2, 2016

General Information

Client:	US EPA
Client Number:	U012
Report Number:	16-746
Sample Description:	37mm impregnated cellulose filters
Sample Numbers:	16-C758 – 16-C768

Analysis

Analytes:	Hexavalent Chromium
Analytical Protocols:	Modified CARB SOP MLD039
Analytical Notes:	No problems were encountered during the analyses. All samples were analyzed within the 90 day holding time.
QA/QC Review:	All of the data have been reviewed by the analysts performing the analyses and the project manager. All of the quality control and sample-specific information in this package is complete and meets or exceeds the minimum requirements for acceptability.
Comments:	If you have any questions or concerns regarding this analysis, please feel free to contact the project manager.
Disclaimer:	This report shall not be reproduced, except in full, without the written approval of the laboratory. The results only represent that of the samples as received into the laboratory.

Paul Duda 11/2/16

Project Manager Date
Paul Duda

Client: U012 - US EPA
Report Number: 16-746

Lab ID: 16-C758
Client ID: PS-MK90-CrVI-092916-01
Site: Radford
Sample Date: 9/29/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	19.68	0.750

Lab ID: 16-C759
Client ID: PS-MK90-CrVI-092916-02
Site: Radford
Sample Date: 9/29/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	12.60	0.750

Lab ID: 16-C760
Client ID: PS-SW-CrVI-093016-01
Site: Radford
Sample Date: 9/30/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	< MDL	0.750

Lab ID: 16-C761
Client ID: PS-SW-CrVI-093016-02
Site: Radford
Sample Date: 9/30/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	< MDL	0.750

Lab ID: 16-C762
Client ID: PS-MK90-CrVI-100316-01
Site: Radford
Sample Date: 10/ 3/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	9.585	0.750

Client: U012 - US EPA
Report Number: 16-746

Lab ID: 16-C763
Client ID: PS-MK90-CrVI-100316-02
Site: Radford
Sample Date: 10/ 3/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	16.28	0.750

Lab ID: 16-C764
Client ID: PS-MK90-CrVI-100316-03
Site: Radford
Sample Date: 10/ 3/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	7.125	0.750

Lab ID: 16-C765
Client ID: PS-SW-CrVI-100616
Site: Radford
Sample Date: 10/ 6/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	0.855	0.750

Lab ID: 16-C766
Client ID: BS-CrVI-100616
Site: Radford
Sample Date: 10/ 6/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	< MDL	0.750

Lab ID: 16-C767
Client ID: TS-CrVI-101116-01
Site: Radford
Sample Date: 10/11/16
Deposit Area: 8.04 cm²

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	< MDL	0.750

Client: U012 - US EPA
Report Number: 16-746

Lab ID: 16-C768
Client ID: BF-CrVI-101116-02
Site: Radford
Sample Date: 10/11/16
Deposit Area: 8.04 cm^2

Analyte	ng/filter Conc.	MDL
IC		
Cr VI	< MDL	0.750

QA/QC Report

Client Name: US EPA
Project Number: U012
Analytical Technique: IC-PCR
Sample Description: 37mm Impregnated Cellulose
Report Number: 16-746

==========

Blank Data

Analyte	Sample ID	Measured Conc. µg/L	MDL Conc. µg/L
Cr VI	ICB	< MDL	0.050
Cr VI	Prep_Blk	< MDL	0.050
Cr VI	*Meth_Blk* *	*< MDL*	*0.750*
Cr VI	CCB	< MDL	0.050
Cr VI	CCB	< MDL	0.050

*: Method Blank concentration in µg/filter

Calibration QC

Analyte	Sample ID	Standard Conc. µg/L	Measured Conc. µg/L	Percent Recovery
Cr VI	ICV	1.00	1.00	99.7
Cr VI	CCV	1.00	1.02	101.8
Cr VI	CCV	1.00	1.01	100.9

Replicate Data

Analyte	Sample ID	Sample Conc. µg/L	Replicate Conc. µg/L	RPD
Cr VI	16-C758	1.31	1.26	4.44

RPD = {(sample-replicate)/[(sample+replicate)/2]}x100
N/C: RPD is not calculated when sample or replicate is below detection limit
#: per EPA CLP protocol, control limits do not apply if sample and/or replicate concentration is less than 5x the detection limit

Laboratory Control Sample/Matrix Post Spike Analysis

Analyte	Sample ID	Sample Conc. µg/L	Spike Conc. µg/L	Spike Amount µg/L	Percent Recovery
Cr VI	LCS	< 0.05	1.00	1.00	100.
Cr VI	LCS	< 0.05	1.01	1.00	101.
Cr VI	16-C759	0.840	2.79	2.00	97.6

*: per EPA CLP protocol, control limits do not apply if spike concentration is less than 25% of the sample concentration

LCS Duplicate Data

Analyte	Sample ID	Original Conc. µg/L	Replicate Conc. µg/L	RPD
Cr VI	LCS Dup	1.00	1.01	0.20

RPD = {(sample-replicate)/[(sample+replicate)/2]}x100

QA/QC Limits
Continuing Calibration: ± 10% *LCS: ± 20%*
Replicates: ± 20% RPD *Post Spikes: ± 25%*

Project: Radford
Sep-Oct 2016

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Cr VI

16-746

SAMPLER:

Requested Analyses

	SAMPLE ID	DATE	TIME	MATRIX	~~PM~~	Filter #	1	2	3	4	5	6	7	8	9	10	Remarks
1	PS-MK90-CrVI-092916-01	092916		MK-90 Burn 1-2		1	X										16-C758
2	PS-MK90-CrVI-092916-02	092916		MK-90 Burn 3		2	X										16-C759
3	PS-SW-CrVI-093016-01	093016		SW Burn 1		3	X										16-C760
4	PS-SW-CrVI-093016-02	093016		SW Burn 2		4	X										16-C761
5	PS-MK90-CrVI-100316-01	100316		MK90 Burn#1		5	X										16-C762
6	PS-MK90-CrVI-100316-02	100316		MK90 Burn#2		6	X										16-C763
7	PS-MK90-CrVI-100316-03	100316		MK90 Burn#3		7	X										16-C764
8	PS-SW-CrVI-100616	100616		SW Burn#2		8	X										16-C765
9	BS-CrVI-100616	100616		Ambient		9	X										16-C766
10	TS-CrVI-101116-01	101116		Trip blank		10, 11	X										16-C767
11	BFS-CrVI 101116 02			blank filter													16-C768

Report #16-746

Requested Analyses	
1	Cr VI
2	
3	
4	
5	
6	
7	

Special Instructions/Comments:

#11 is a blank filter

☐ **Special QA/QC Instructions**

Laboratory Information and Receipt

Lab Name: [illegible]

Shipping Tracking #

Specify Turnaround Requirements:

☐ Cooler packed with ice

☐ Cooler custody seal intact

Sample Receipt:

Condition/Cooler Temp: 2.6 °C

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
[illegible]	10/11/16	10:05	[illegible] 10/27/16 9:15				
Relinquished by:	**DATE**	**TIME**	**Received by:**	**Relinquished by:**	**DATE**	**TIME**	**Received by:**

RAW DATA

Available upon request

November 30, 2016 Service Request No:R1611762

Dennis Tabor
US Environmental Protection Agency (E-343-03)
Office of Research and Development
National Risk Management Research
Laboratory
109 T.W. Alexander Drive
Research Triangle Park, NC 27711

Laboratory Results for: US EPA RTP, NC

Dear Dennis,

Enclosed are the results of the sample(s) submitted to our laboratory October 28, 2016
For your reference, these analyses have been assigned our service request number **R1611762.**

All analyses were performed according to our laboratory's quality assurance program. The test results meet requirements of the NELAP standards except as noted in the case narrative report. All results are intended to be considered in their entirety, and ALS Environmental is not responsible for use of less than the complete report. Results apply only to the items submitted to the laboratory for analysis and individual items (samples) analyzed, as listed in the report. The measurement uncertainty of the results included in this report is within that expected when using the prescribed method(s) for analysis of these samples, and represented by Laboratory Control Sample control limits. Any events, such as QC failures, which may add to the uncertainty are explained in the report narrative.

Please contact me if you have any questions. My extension is 7478. You may also contact me via email at Ellen.Smith@alsglobal.com.

Respectfully submitted,

ALS Group USA, Corp. dba ALS Environmental

Ellen Smith
Project Manager

ADDRESS 1565 Jefferson Road, Building 300, Suite 360, Rochester, NY 14623
PHONE +1 585 288 5380 | FAX +1 585 288 8475
ALS Group USA, Corp.
dba ALS Environmental

Narrative Documents

ALS Environmental—Rochester Laboratory
1565 Jefferson Road, Building 300, Suite 360, Rochester, NY 14623
Phone (585) 288-5380 Fax (585) 288-8475
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1565 Jefferson Rd, Building 300, Rochester, NY 14623 | 585-288-5380 | www.alsglobal.com

Client: US Environmental Protection Agency (EPA)
Project: US EPA RTP, NC
Sample Matrix: Filter

Service Request: R1611762
Date Received: 10/28/16

CASE NARRATIVE

All analyses were performed consistent with the quality assurance program of ALS Environmental. This report contains analytical results for samples designated for Tier II data deliverables, including results of QC samples analyzed from this delivery group. Analytical procedures performed by the lab are validated in accordance with NELAC standards. Any parameters that are not included in the lab's NELAC accreditation are identified on a "Non-Certified Analytes" report in the Miscellaneous Forms Section of this report. Individual analytical results requiring further explanation are flagged with qualifiers and/or discussed below. The flags are explained in the Report Qualifiers and Definitions page in the Miscellaneous Forms section of this report.

Sample Receipt

Fourteen filter samples were received for analysis at ALS Environmental on 10/28/2016. Any discrepancies noted upon initial sample inspection are noted on the cooler receipt and preservation form included in this data package. The samples were received in good condition and consistent with the accompanying chain of custody form. Samples are refrigerated at ≤6°C upon receipt at the lab except for aqueous samples designated for metals analyses, which are stored at room temperature.

Semi-Volatile Organic Analyses:

No significant anomalies were noted with this analysis.

General Chemistry Analyses:

No significant anomalies were noted with this analysis.

Sample Receiving Notes:

Method 6850, One or more samples were received past the recommended holding time which is 28 days. Analysis was completed 2 days out of hold time and the customer was notified when the discrepancy was found. The analysis was performed as soon as possible after receipt by the laboratory. The data is flagged to indicate the holding time violation.

Approved by _____ Date 11/30/2016

SAMPLE DETECTION SUMMARY

CLIENT ID: PS-SW-HCl-092816-01 2-Bottom	Lab ID: R1611762-002					
Analyte	**Results**	**Flag**	**MDL**	**PQL**	**Units**	**Method**
Chloride	11.4		5.2	6.0	ug/Filter	300.0

CLIENT ID: PS-SW-HCl-092816-02 2-Bottom	Lab ID: R1611762-004					
Analyte	**Results**	**Flag**	**MDL**	**PQL**	**Units**	**Method**
Chloride	11.0		5.2	6.0	ug/Filter	300.0

CLIENT ID: PS-SW-HCl-100416-01 2-Bottom	Lab ID: R1611762-008					
Analyte	**Results**	**Flag**	**MDL**	**PQL**	**Units**	**Method**
Chloride	9.4		5.2	6.0	ug/Filter	300.0

Sample Receipt Information

ALS Environmental—Rochester Laboratory
1565 Jefferson Road, Building 300, Suite 360, Rochester, NY 14623
Phone (585) 288-5380 Fax (585) 288-8475
www.alsglobal.com

Client: US Environmental Protection Agency (EPA) **Service Request:**R1611762
Project: US EPA RTP, NC

SAMPLE CROSS-REFERENCE

SAMPLE #	CLIENT SAMPLE ID	DATE	TIME
R1611762-001	PS-SW-HCl-092816-01 1-Topp	9/28/2016	
R1611762-002	PS-SW-HCl-092816-01 2-Bottom	9/28/2016	
R1611762-003	PS-SW-HCl-092816-02 1-Topp	9/28/2016	
R1611762-004	PS-SW-HCl-092816-02 2-Bottom	9/28/2016	
R1611762-005	PS-SW-HCl-092816-03 1-Topp	9/28/2016	
R1611762-006	PS-SW-HCl-092816-03 2-Bottom	9/28/2016	
R1611762-007	PS-SW-HCl-100416-01 1-Topp	10/4/2016	
R1611762-008	PS-SW-HCl-100416-01 2-Bottom	10/4/2016	
R1611762-009	PS-SW-HCl-100416-02 1-Topp	10/4/2016	
R1611762-010	PS-SW-HCl-100416-02 2-Bottom	10/4/2016	
R1611762-011	PS-SW-HCl-100416-03 1-Topp	10/4/2016	
R1611762-012	PS-SW-HCl-100416-03 2-Bottom	10/4/2016	
R1611762-013	BS-HCl-100416 1-Topp	10/4/2016	
R1611762-014	BS-HCl-100416 2-Bottom	10/4/2016	

Lab Work Order #

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

SAMPLERS:

Requested Analyses

SAMPLE ID	DATE	TIME	MATRIX	Burn #	Filter #	1	2	3	4	5	6	7	8	9	10	Remarks
PS-SW-HCl-092816-01	9/28/2016		Skid waste	1	Cassette 1											
					1-Topp	x	x									
					2-Bottom			x								
PS-SW-HCl-092816-02	9/28/2016		Skid waste	2	Cassette 2											
					1-Topp	x	x									
					2-Bottom			x								
PS-SW-HCl-092816-03	9/28/2016		Skid waste	3	Cassette 3											
					1-Topp	x	x									
					2-Bottom			x								
PS-SW-HCl-100416-01	10/4/2016		Skid waste	1	Cassette 4											
					1-Topp	x	x									
					2-Bottom			x								
PS-SW-HCl-100416-01	10/4/2016		Skid waste	2	Cassette 5											
					1-Topp	x	x									
					2-Bottom			x								

Requested Analyses	
1	Perchlorate
2	Chlorate
3	Chloride
4	
5	
6	
7	

Special Instructions/Comments:

☐ **Special QA/QC Instructions**

Laboratory Information and Receipt

Lab Name:

Shipping Tracking #

Specify Turnaround Requirements:

☐ Cooler packed with ice

☐ Cooler custody seal intact

Sample Receipt:

Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
[signature]	10/11/2016	13:00	[signature] 10-28 0930				
Relinquished by:	**DATE**	**TIME**	**Received by:**	**Relinquished by:**			

R1611762 5
US Environmental Protection Agency (E-343-03)
US EPA RTP, NC

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Lab Work Order #

SAMPLERS:

SAMPLE ID	DATE	TIME	MATRIX	Burn #	Filter #	1	2	3	4	5	6	7	8	9	10	Remarks
						Requested Analyses										
PS-SW-HCl-100416-01	10/4/2016		Skid waste	3	Cassette 6											
					1-Topp	X	X									
					2-Bottom			X								
BS-HCl-100416	10/4/2016		Ambient	Ambient	Cassette 8											
					1-Topp	X	X									
					2-Bottom			X								

Requested Analyses	
1	Perchlorate
2	Chlorate
3	Chloride
4	
5	
6	
7	

Special Instructions/Comments:

☐ **Special QA/QC Instructions**

Laboratory Information and Receipt

Lab Name:

Shipping Tracking #

Specify Turnaround Requirements:

☐ Cooler packed with ice

☐ Cooler custody seal intact

Sample Receipt:

Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
			10-28 0930				
Relinquished by:	DATE	TIME	Received by:	Relinquished by:			

R1611762 5

US Environmental Protection Agency (E-343-03)
US EPA RTP, NC

R1611762 5
US Environmental Protection Agency (E-343-03)
US EPA RTP, NC

Cooler Receipt and Preservation Check Form

Project/Client US EPA Folder Number_____.

Cooler received on 10-28 by: T.S **COURIER:** ALS UPS FEDEX VELOCITY CLIENT

1	Were **Custody seals** on outside of cooler?	Y N	5a	**Perchlorate** samples have required headspace?	Y N NA
2	**Custody papers** properly completed (ink, signed)?	Y N	5b	Did VOA vials, Alk,or Sulfide have sig* **bubbles**?	Y N NA
3	Did all bottles arrive in good **condition** (unbroken)?	Y N	6	Where did the bottles originate?	ALS/ROC CLIENT
4	Circle: **Wet Ice Dry Ice Gel packs** present?	Y N	7	Soil VOA received as: Bulk Encore 5035set	NA

8. Temperature Readings Date: 10-25-16 Time: 0440 ID: IR#7 IR#8 From: Temp Blank Sample Bottle

Observed Temp (°C)	7.4						
Correction Factor (°C)	0						
Corrected Temp (°C)	7.4						
Within 0-6°C?	Y N	Y N	Y N	Y N	Y N	Y N	Y N
If <0°C, were samples frozen?	Y N	Y N	Y N	Y N	Y N	Y N	Y N

If out of Temperature, note packing/ice condition: _____Ice melted Poorly Packed Same Day Rule

&Client Approval to Run Samples:_____ Standing Approval Client aware at drop-off Client notified by: _____

All samples held in storage location: R002 by T.S on 10-25-16 at 0440
5035 samples placed in storage location: _____ by _____ on _____ at _____

Cooler Breakdown: Date : 11/7/16 Time: 1100 by: [illegible]

1. Were all bottle labels complete (*i.e.* analysis, preservation, etc.)? YES NO
2. Did all bottle labels and tags agree with custody papers? YES NO
3. Were correct containers used for the tests indicated? YES NO
4. Were 5035 vials acceptable (no extra labels, not leaking)? YES NO N/A
5. Air Samples: Cassettes / Tubes Intact Canisters Pressurized Tedlar® Bags Inflated N/A

Explain any discrepancies:

pH	Reagent	Yes	No	Lot Received	Exp	Sample ID	Vol. Added	Lot Added	Final pH
≥12	NaOH								
≤2	HNO_3								
≤2	H_2SO_4								
<4	$NaHSO_4$								
Residual Chlorine (-)	For CN Phenol and 522			If +, contact PM to add $Na_2S_2O_3$ (CN), ascorbic (phenol).					
	$Na_2S_2O_3$	-	-						
	ZnAcetate	-	-						
	HCl	**	**						

**Not to be tested before analysis – pH tested and recorded by VOAs on a separate worksheet

Yes=All samples OK

No=Samples were preserved at The lab as listed

PM OK to Adjust: _____

Bottle lot numbers: Client

Other Comments:

CLRES	BULK
DO	FLDT
HPROD	HGFB
HTR	LL3541
PH	SUB
SO3	MARRS
ALS	REV

PC Secondary Review: [illegible]

*significant air bubbles: VOA > 5-6 mm : WC >1 in. diameter

Miscellaneous Forms

ALS Environmental—Rochester Laboratory
1565 Jefferson Road, Building 300, Suite 360, Rochester, NY 14623
Phone (585) 288-5380 Fax (585) 288-8475
www.alsglobal.com

REPORT QUALIFIERS AND DEFINITIONS

U Analyte was analyzed for but not detected. The sample quantitation limit has been corrected for dilution and for percent moisture, unless otherwise noted in the case narrative.

J Estimated value due to either being a Tentatively Identified Compound (TIC) or that the concentration is between the MRL and the MDL. Concentrations are not verified within the linear range of the calibration. For DoD: concentration >40% difference between two GC columns (pesticides/Arclors).

B Analyte was also detected in the associated method blank at a concentration that may have contributed to the sample result.

E Inorganics- Concentration is estimated due to the serial dilution was outside control limits.

E Organics- Concentration has exceeded the calibration range for that specific analysis.

D Concentration is a result of a dilution, typically a secondary analysis of the sample due to exceeding the calibration range or that a surrogate has been diluted out of the sample and cannot be assessed.

* Indicates that a quality control parameter has exceeded laboratory limits. Under the ñNotesò column of the Form I, this qualifier denotes analysis was performed out of Holding Time.

H Analysis was performed out of hold time for tests that have an ñimmediateò hold time criteria.

Spike was diluted out.

+ Correlation coefficient for MSA is <0.995.

N Inorganics- Matrix spike recovery was outside laboratory limits.

N Organics- Presumptive evidence of a compound (reported as a TIC) based on the MS library search.

S Concentration has been determined using Method of Standard Additions (MSA).

W Post-Digestion Spike recovery is outside control limits and the sample absorbance is <50% of the spike absorbance.

P Concentration >40% (25% for CLP) difference between the two GC columns.

C Confirmed by GC/MS

Q DoD reports: indicates a pesticide/Aroclor is not confirmed (Ó100% Difference between two GC columns).

X See Case Narrative for discussion.

MRL Method Reporting Limit. Also known as:
LOQ Limit of Quantitation (LOQ)
The lowest concentration at which the method analyte may be reliably quantified under the method conditions.

MDL Method Detection Limit. A statistical value derived from a study designed to provide the lowest concentration that will be detected 99% of the time. Values between the MDL and MRL are estimated (see J qualifier).

LOD Limit of Detection. A value at or above the MDL which has been verified to be detectable.

ND Non-Detect. Analyte was not detected at the concentration listed. Same as U qualifier.

Rochester Lab ID # for State Certifications[1]

Connecticut ID # PH0556	Maine ID #NY0032	New Hampshire ID # 294100 A/B
Delaware Accredited	Nebraska Accredited	
DoD ELAP #65817	New Jersey ID # NY004	Pennsylvania ID# 68-786
Florida ID # E87674	New York ID # 10145	Rhode Island ID # 158
Illinois ID #200047	North Carolina #676	Virginia #460167

[1] Analyses were performed according to our laboratoryôs NELAP-approved quality assurance program and any applicable state or agency requirements. The test results meet requirements of the current NELAP/TNI standards or state or agency requirements, where applicable, except as noted in the case narrative. Since not all analyte/method/matrix combinations are offered for state/NELAC accreditation, this report may contain results which are not accredited. For a specific list of accredited analytes, contact the laboratory or go to http://www.alsglobal.com/en/Our-Services/Life-Sciences/Environmental/Downloads/North-America-Downloads

Acronyms

ASTM	American Society for Testing and Materials
A2LA	American Association for Laboratory Accreditation
CARB	California Air Resources Board
CAS Number	Chemical Abstract Service registry Number
CFC	Chlorofluorocarbon
CFU	Colony-Forming Unit
DEC	Department of Environmental Conservation
DEQ	Department of Environmental Quality
DHS	Department of Health Services
DOE	Department of Ecology
DOH	Department of Health
EPA	U. S. Environmental Protection Agency
ELAP	Environmental Laboratory Accreditation Program
GC	Gas Chromatography
GC/MS	Gas Chromatography/Mass Spectrometry
LUFT	Leaking Underground Fuel Tank
M	Modified
MCL	Maximum Contaminant Level is the highest permissible concentration of a substance allowed in drinking water as established by the USEPA.
MDL	Method Detection Limit
MPN	Most Probable Number
MRL	Method Reporting Limit
NA	Not Applicable
NC	Not Calculated
NCASI	National Council of the Paper Industry for Air and Stream Improvement
ND	Not Detected
NIOSH	National Institute for Occupational Safety and Health
PQL	Practical Quantitation Limit
RCRA	Resource Conservation and Recovery Act
SIM	Selected Ion Monitoring
TPH	Total Petroleum Hydrocarbons
tr	Trace level is the concentration of an analyte that is less than the PQL but greater than or equal to the MDL.

Client: US Environmental Protection Agency (EPA) **Service Request:** R1611762
Project: US EPA RTP, NC

Non-Certified Analytes

Certifying Agency: New York Department of Health

Method	Matrix	Analyte
300.0	Filter	Chloride
6850	Filter	Chlorate
6850	Filter	Perchlorate

Client: US Environmental Protection Agency (EPA) **Service Request:** R1611762
Project: US EPA RTP, NC

Sample Name: PS-SW-HCl-092816-01 1-Topp **Date Collected:** 09/28/16
Lab Code: R1611762-001 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
6850	MPEDRO	MPEDRO

Sample Name: PS-SW-HCl-092816-01 2-Bottom **Date Collected:** 09/28/16
Lab Code: R1611762-002 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
300.0	CWOODS	CWOODS

Sample Name: PS-SW-HCl-092816-02 1-Topp **Date Collected:** 09/28/16
Lab Code: R1611762-003 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
6850	MPEDRO	MPEDRO

Sample Name: PS-SW-HCl-092816-02 2-Bottom **Date Collected:** 09/28/16
Lab Code: R1611762-004 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
300.0	CWOODS	CWOODS

Sample Name: PS-SW-HCl-092816-03 1-Topp **Date Collected:** 09/28/16
Lab Code: R1611762-005 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
6850	MPEDRO	MPEDRO

Client: US Environmental Protection Agency (EPA) **Service Request:** R1611762
Project: US EPA RTP, NC

Sample Name: PS-SW-HCl-092816-03 2-Bottom **Date Collected:** 09/28/16
Lab Code: R1611762-006 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
300.0	CWOODS	CWOODS

Sample Name: PS-SW-HCl-100416-01 1-Topp **Date Collected:** 10/4/16
Lab Code: R1611762-007 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
6850	MPEDRO	MPEDRO

Sample Name: PS-SW-HCl-100416-01 2-Bottom **Date Collected:** 10/4/16
Lab Code: R1611762-008 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
300.0	CWOODS	CWOODS

Sample Name: PS-SW-HCl-100416-02 1-Topp **Date Collected:** 10/4/16
Lab Code: R1611762-009 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
6850	MPEDRO	MPEDRO

Sample Name: PS-SW-HCl-100416-02 2-Bottom **Date Collected:** 10/4/16
Lab Code: R1611762-010 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
300.0	CWOODS	CWOODS

Client: US Environmental Protection Agency (EPA) **Service Request:** R1611762
Project: US EPA RTP, NC

Sample Name: PS-SW-HCl-100416-03 1-Topp **Date Collected:** 10/4/16
Lab Code: R1611762-011 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
6850	MPEDRO	MPEDRO

Sample Name: PS-SW-HCl-100416-03 2-Bottom **Date Collected:** 10/4/16
Lab Code: R1611762-012 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
300.0	CWOODS	CWOODS

Sample Name: BS-HCl-100416 1-Topp **Date Collected:** 10/4/16
Lab Code: R1611762-013 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
6850	MPEDRO	MPEDRO

Sample Name: BS-HCl-100416 2-Bottom **Date Collected:** 10/4/16
Lab Code: R1611762-014 **Date Received:** 10/28/16
Sample Matrix: Filter

Analysis Method	Extracted/Digested By	Analyzed By
300.0	CWOODS	CWOODS

INORGANIC PREPARATION METHODS

The preparation methods associated with this report are found in these tables unless discussed in the case narrative.

Water/Liquid Matrix

Analytical Method	Preparation Method
200.7	200.2
200.8	200.2
6010C	3005A/3010A
6020A	ILM05.3
9014 Cyanide Reactivity	SW846 Ch7, 7.3.4.2
9034 Sulfide Reactivity	SW846 Ch7, 7.3.4.2
9034 Sulfide Acid Soluble	9030B
9056A Bomb (Halogens)	5050A
9066 Manual Distillation	9065
SM 4500-CN-E Residual Cyanide	SM 4500-CN-G
SM 4500-CN-E WAD Cyanide	SM 4500-CN-I

Solid/Soil/Non-Aqueous Matrix

Analytical Method	Preparation Method
6010C	3050B
6020A	3050B
6010C TCLP (1311) extract	3005A/3010A
6010 SPLP (1312) extract	3005A/3010A
7196A	3060A
7199	3060A
9056A Halogens/Halides	5050
300.0 Anions/ 350.1/ 353.2/ SM 2320B/ SM 5210B/ 9056A Anions	DI extraction

For analytical methods not listed, the preparation method is the same as the analytical method reference.

Sample Results

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Semivolatile Organic Compounds by GC

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ALS Group USA, Corp.
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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	09/28/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-092816-01 1-Topp	**Units:**	ug/Filter
Lab Code:	R1611762-001	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 10:57	11/8/16	*
Perchlorate	0.0040 U	0.0040	1	11/09/16 10:57	11/8/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	09/28/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-092816-02 1-Topp	**Units:**	ug/Filter
Lab Code:	R1611762-003	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 11:12	11/8/16	*
Perchlorate	0.0040 U	0.0040	1	11/09/16 11:12	11/8/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	09/28/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-092816-03 1-Topp	**Units:**	ug/Filter
Lab Code:	R1611762-005	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 11:26	11/8/16	*
Perchlorate	0.0040 U	0.0040	1	11/09/16 11:26	11/8/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-100416-01 1-Topp	**Units:**	ug/Filter
Lab Code:	R1611762-007	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 11:41	11/8/16	*
Perchlorate	0.0040 U	0.0040	1	11/09/16 11:41	11/8/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-100416-02 1-Topp	**Units:**	ug/Filter
Lab Code:	R1611762-009	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 16:59	11/8/16	*
Perchlorate	0.0040 U	0.0040	1	11/09/16 16:59	11/8/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-100416-03 1-Topp	**Units:**	ug/Filter
Lab Code:	R1611762-011	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 12:41	11/8/16	*
Perchlorate	0.0040 U	0.0040	1	11/09/16 12:41	11/8/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	BS-HCl-100416 1-Topp	**Units:**	ug/Filter
Lab Code:	R1611762-013	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 12:55	11/8/16	*
Perchlorate	0.0040 U	0.0040	1	11/09/16 12:55	11/8/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	09/28/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-092816-01 2-Bottom	**Basis:**	As Received
Lab Code:	R1611762-002		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	**11.4**	ug/Filter	6.0	1	11/21/16 19:44	11/21/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	09/28/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-092816-02 2-Bottom	**Basis:**	As Received
Lab Code:	R1611762-004		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	**11.0**	ug/Filter	6.0	1	11/21/16 19:57	11/21/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	09/28/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-092816-03 2-Bottom	**Basis:**	As Received
Lab Code:	R1611762-006		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	6.0 U	ug/Filter	6.0	1	11/21/16 20:10	11/21/16	*

ALS Group USA, Corp.
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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-100416-01 2-Bottom	**Basis:**	As Received
Lab Code:	R1611762-008		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	**9.4**	ug/Filter	6.0	1	11/21/16 20:49	11/21/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-100416-02 2-Bottom	**Basis:**	As Received
Lab Code:	R1611762-010		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	6.0 U	ug/Filter	6.0	1	11/21/16 21:02	11/21/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	PS-SW-HCl-100416-03 2-Bottom	**Basis:**	As Received
Lab Code:	R1611762-012		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	6.0 U	ug/Filter	6.0	1	11/21/16 21:15	11/21/16	*

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	10/04/16
Sample Matrix:	Filter	**Date Received:**	10/28/16 09:30
Sample Name:	BS-HCl-100416 2-Bottom	**Basis:**	As Received
Lab Code:	R1611762-014		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	6.0 U	ug/Filter	6.0	1	11/21/16 21:28	11/21/16	*

QC Summary Forms

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	NA
Sample Matrix:	Filter	**Date Received:**	NA
Sample Name:	Method Blank	**Units:**	ug/Filter
Lab Code:	RQ1613608-01	**Basis:**	As Received

Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Analysis Method: 6850
Prep Method: Method

Analyte Name	Result	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chlorate	0.0040 U	0.0040	1	11/09/16 09:44	11/8/16	
Perchlorate	0.0040 U	0.0040	1	11/09/16 09:44	11/8/16	

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QA/QC Report

Client: US Environmental Protection Agency (EPA)
Project: US EPA RTP, NC
Sample Matrix: Filter

Service Request: R1611762
Date Analyzed: 11/09/16

Duplicate Lab Control Sample Summary
Perchlorates in Water, Soils, Solid Wastes Using High Performance LC/Electrospray/Mass Spectrometry

Units:ug/Filter
Basis: As Received

		Lab Control Sample			Duplicate Lab Control Sample					
		RQ1613608-02			RQ1613608-03					
Analyte Name	**Analytical Method**	**Result**	**Spike Amount**	**% Rec**	**Result**	**Spike Amount**	**% Rec**	**% Rec Limits**	**RPD**	**RPD Limit**
Chlorate	6850	0.00460	0.00400	115	0.00440	0.00400	110	80-120	4	15
Perchlorate	6850	0.00400	0.00400	100	0.00380 J	0.00400	95	80-120	5	15

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Analytical Report

Client:	US Environmental Protection Agency (EPA)	**Service Request:**	R1611762
Project:	US EPA RTP, NC	**Date Collected:**	NA
Sample Matrix:	Filter	**Date Received:**	NA
Sample Name:	Method Blank	**Basis:**	As Received
Lab Code:	R1611762-MB		

Inorganic Parameters

Analyte Name	Analysis Method	Result	Units	MRL	Dil.	Date Analyzed	Date Extracted	Q
Chloride	300.0	6.0 U	ug/Filter	6.0	1	11/21/16 14:15	11/21/16	

ALS Group USA, Corp.
dba ALS Environmental

QA/QC Report

Client: US Environmental Protection Agency (EPA)
Project: US EPA RTP, NC
Sample Matrix: Filter

Service Request: R1611762
Date Analyzed: 11/21/16

Duplicate Lab Control Sample Summary
General Chemistry Parameters

Units:ug/Filter
Basis: As Received

			Lab Control Sample		Duplicate Lab Control Sample					
			R1611762-LCS		R1611762-DLCS					
Analyte Name	**Analytical Method**	**Result**	**Spike Amount**	**% Rec**	**Result**	**Spike Amount**	**% Rec**	**% Rec Limits**	**RPD**	**RPD Limit**
Chloride	300.0	42.9	40.0	107	43.0	40.0	108	90-110	<1	30

Radford Skid Waste Burn Project September-October 2016

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted.
The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.

The Samples were delivered to the lab on October 11th and extracted in Late November and early December.
Due to an instrument failure and delayed repairs the samples were not analyzed until early April.

The samples had presampling surrogates spiked onto the first PUF and had good recoveries with the exception of one set. The most likely reason for the low spike recovery is a bad spike of the PUF. This project used a new very thin PUF and it is likely that during the spiking of the PUF the syringe needle went through the PUF and spiked the wall of the petri dish instead of the PUF. This would cause the recoveries to be about half of the other samples and it was.
The pre-extraction standard recoveries were good with the exception of the HpCDF which was always low and sometimes below the criteria, and the PeCDD which was high and sometimes above the criteria. The filter samples had large areas of the chromatograms that had depressed lock mass signal. In these areas all signals would be depressed and that could explain the low recoveries of the HpCDF. The HpCDF is at the edge of one of these depressed lockmass areas. The elevated PeCDD levels are not understood.

In the breakthrough testing there was virtually no transfer of the Pre-Sampling Spike to the second PUF which would indicate that anything that absorbed on the first PUF would not transfer on to the second PUF during the sampling conditions (temperature and flow). Also very little of the compounds found on the Filter were detected on the front PUF, this indicates but does not prove the PCDD/Fs are most likely particle bound under the sampling conditions and do not vaporize to transfer to the front PUF.

The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	9/28/2016
Sample Name:	PS-SW-PCDDF-092816-01	Date Extracted:	12/5/2016
Lab Sample ID:	161201 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161201 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	109.9	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	112.3	P	13C12-2,3,4,7,8-PCDF	0.0
13C12-1,2,3,7,8 PCDF	52.7	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	178.2	F	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	76.4	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	88.4	P		
13C12-1,2,3,4,6,7,8 HpCDF	22.9	F		
13C12-1,2,3,4,6,7,8 HpCDD	93.5	P		
13C12-1,2,3,4,6,7,8,9 OCDD	86.6	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00196	ND	1	0.000000	0.001960	0.00196
1,2,3,7,8 - PeCDD	Co-elution	0.00300		1	0.003000	0.003000	0.00154
1,2,3,4,7,8 - HxCDD		0.00158	ND	0.1	0.000000	0.000158	0.00158
1,2,3,6,7,8 - HxCDD		0.00540		0.1	0.000540	0.000540	0.00204
1,2,3,7,8,9 - HxCDD		0.00360		0.1	0.000360	0.000360	0.00174
1,2,3,4,6,7,8 - HpCDD		0.06520		0.01	0.000652	0.000652	0.00170
1,2,3,4,6,7,8,9 - OCDD		0.23080		0.0003	0.000069	0.000069	0.00242
2,3,7,8 - TCDF		0.05780		0.1	0.005780	0.005780	0.00504
1,2,3,7,8 - PeCDF		0.01840		0.03	0.000552	0.000552	0.00178
2,3,4,7,8 - PeCDF		0.03660		0.3	0.010980	0.010980	0.00172
1,2,3,4,7,8 - HxCDF		0.00240		0.1	0.000240	0.000240	0.00146
1,2,3,6,7,8 - HxCDF		0.00240		0.1	0.000240	0.000240	0.00170
1,2,3,7,8,9 - HxCDF	Co-elution	0.00190	ND	0.1	0.000000	0.000190	0.00190
2,3,4,6,7,8 - HxCDF	Co-elution	0.00170	ND	0.1	0.000000	0.000170	0.00170
1,2,3,4,6,7,8 - HpCDF		0.00166	ND	0.01	0.000000	0.000017	0.00166
1,2,3,4,7,8,9 - HpCDF		0.00200	ND	0.01	0.000000	0.000020	0.00200
1,2,3,4,6,7,8,9 - OCDF		0.00540		0.0003	0.000002	0.000002	0.00260
				Total TEQ ng TEQ/train	**ND=0 0.022415**	**ND=LOD 0.024929**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	9/28/2016
Sample Name:	PS-SW-PCDDF-092816-01	Date Extracted:	12/5/2016
Lab Sample ID:	161201 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161201 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	109.9	P	37Cl4-2,3,7,8-TeCDD	0	0
13C12-2,3,7,8 TeCDD	112.3	P	13C12-2,3,4,7,8-PCDF	0	0
13C12-1,2,3,7,8 PCDF	52.7	P	13C12-1,2,3,4,7,8-HxCDF	0	0
13C12-1,2,3,7,8 PCDD	178.2	F	13C12-1,2,3,4,7,8-HxCDD	0.0	0
13C12-1,2,3,6,7,8 HxCDF	76.4	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0	0
13C12-1,2,3,6,7,8 HxCDD	88.4	P			
13C12-1,2,3,4,6,7,8 HpCDF	22.9	F			
13C12-1,2,3,4,6,7,8 HpCDD	93.5	P			
13C12-1,2,3,4,6,7,8,9 OCDD	86.6	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	0.354
PeCDD Total	0.002	PeCDF Total	0.134
HxCDD Total	0.040	HxCDF Total	0.008
HpCDD Total	0.092	HpCDF Total	0.024
OCDD	0.230	OCDF	0.006

ND = not detected (S/N <2.5)

NS= not spiked

EMPC=Est. Max. Possible Concentration

Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	9/28/2016
Sample Name:	PS-SW-PCDDF-092816-01	Date Extracted:	11/30/2016
Lab Sample ID:	161202 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161202 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	92.3	P	37Cl4-2,3,7,8-TeCDD	106.0	P
13C12-2,3,7,8 TeCDD	85.9	P	13C12-2,3,4,7,8-PCDF	95.9	P
13C12-1,2,3,7,8 PCDF	89.9	P	13C12-1,2,3,4,7,8-HxCDF	73.0	P
13C12-1,2,3,7,8 PCDD	89.1	P	13C12-1,2,3,4,7,8-HxCDD	79.6	P
13C12-1,2,3,6,7,8 HxCDF	92.0	P	13C12-1,2,3,4,7,8,9-HpCDF	101.8	P
13C12-1,2,3,6,7,8 HxCDD	83.7	P			
13C12-1,2,3,4,6,7,8 HpCDF	75.2	P			
13C12-1,2,3,4,6,7,8 HpCDD	80.8	P			
13C12-1,2,3,4,6,7,8,9 OCDD	74.0	P			

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00074	ND	1	0.000000	0.000740	0.00074
1,2,3,7,8 - PeCDD	Co-elution	0.00082	ND	1	0.000000	0.000820	0.00082
1,2,3,4,7,8 - HxCDD		0.00070	ND	0.1	0.000000	0.000070	0.00070
1,2,3,6,7,8 - HxCDD		0.00090	ND	0.1	0.000000	0.000090	0.00090
1,2,3,7,8,9 - HxCDD		0.00076	ND	0.1	0.000000	0.000076	0.00076
1,2,3,4,6,7,8 - HpCDD		0.00260		0.01	0.000026	0.000026	0.00134
1,2,3,4,6,7,8,9 - OCDD		0.00440	EMPC	0.0003	0.000001	0.000001	0.00180
2,3,7,8 - TCDF		0.00092	ND	0.1	0.000000	0.000092	0.00092
1,2,3,7,8 - PeCDF		0.00086	ND	0.03	0.000000	0.000026	0.00086
2,3,4,7,8 - PeCDF		0.00084	ND	0.3	0.000000	0.000252	0.00084
1,2,3,4,7,8 - HxCDF		0.00058	ND	0.1	0.000000	0.000058	0.00058
1,2,3,6,7,8 - HxCDF		0.00066	ND	0.1	0.000000	0.000066	0.00066
1,2,3,7,8,9 - HxCDF	Co-elution	0.00074	ND	0.1	0.000000	0.000074	0.00074
2,3,4,6,7,8 - HxCDF	Co-elution	0.00068	ND	0.1	0.000000	0.000068	0.00068
1,2,3,4,6,7,8 - HpCDF		0.00100	ND	0.01	0.000000	0.000010	0.00100
1,2,3,4,7,8,9 - HpCDF		0.00120	ND	0.01	0.000000	0.000012	0.00120
1,2,3,4,6,7,8,9 - OCDF		0.00192	ND	0.0003	0.000000	0.000001	0.00192
				Total TEQ ng TEQ/train	**ND=0 0.000027**	**ND=LOD 0.002482**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	9/28/2016
Sample Name:	PS-SW-PCDDF-092816-01	Date Extracted:	11/30/2016
Lab Sample ID:	161202 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161202 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	92.3	P	37Cl4-2,3,7,8-TeCDD	106	P
13C12-2,3,7,8 TeCDD	85.9	P	13C12-2,3,4,7,8-PCDF	95.9	P
13C12-1,2,3,7,8 PCDF	89.9	P	13C12-1,2,3,4,7,8-HxCDF	73	P
13C12-1,2,3,7,8 PCDD	89.1	P	13C12-1,2,3,4,7,8-HxCDD	79.6	P
13C12-1,2,3,6,7,8 HxCDF	92.0	P	13C12-1,2,3,4,7,8,9-HpCDF	101.8	P
13C12-1,2,3,6,7,8 HxCDD	83.7	P			
13C12-1,2,3,4,6,7,8 HpCDF	75.2	P			
13C12-1,2,3,4,6,7,8 HpCDD	80.8	P			
13C12-1,2,3,4,6,7,8,9 OCDD	74.0	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	0.002	HpCDF Total	ND
OCDD	0.004	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	9/28/2016
Sample Name:	PS-SW-PCDDF-092816-01	Date Extracted:	11/30/2016
Lab Sample ID:	161203 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161203 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	74.9	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	67.3	P	13C12-2,3,4,7,8-PCDF	0.0
13C12-1,2,3,7,8 PCDF	75.4	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	77.0	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	64.6	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	70.8	P		
13C12-1,2,3,4,6,7,8 HpCDF	65.5	P		
13C12-1,2,3,4,6,7,8 HpCDD	65.4	P		
13C12-1,2,3,4,6,7,8,9 OCDD	48.8	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00072	ND	1	0.000000	0.000720	0.00072
1,2,3,7,8 - PeCDD	Co-elution	0.00070	ND	1	0.000000	0.000700	0.00070
1,2,3,4,7,8 - HxCDD		0.00058	ND	0.1	0.000000	0.000058	0.00058
1,2,3,6,7,8 - HxCDD		0.00074	ND	0.1	0.000000	0.000074	0.00074
1,2,3,7,8,9 - HxCDD		0.00064	ND	0.1	0.000000	0.000064	0.00064
1,2,3,4,6,7,8 - HpCDD		0.00080	ND	0.01	0.000000	0.000008	0.00080
1,2,3,4,6,7,8,9 - OCDD		0.00246	ND	0.0003	0.000000	0.000001	0.00246
2,3,7,8 - TCDF		0.00082	ND	0.1	0.000000	0.000082	0.00082
1,2,3,7,8 - PeCDF		0.00080	ND	0.03	0.000000	0.000024	0.00080
2,3,4,7,8 - PeCDF		0.00078	ND	0.3	0.000000	0.000234	0.00078
1,2,3,4,7,8 - HxCDF		0.00050	ND	0.1	0.000000	0.000050	0.00050
1,2,3,6,7,8 - HxCDF		0.00058	ND	0.1	0.000000	0.000058	0.00058
1,2,3,7,8,9 - HxCDF	Co-elution	0.00066	ND	0.1	0.000000	0.000066	0.00066
2,3,4,6,7,8 - HxCDF	Co-elution	0.00058	ND	0.1	0.000000	0.000058	0.00058
1,2,3,4,6,7,8 - HpCDF		0.00072	ND	0.01	0.000000	0.000007	0.00072
1,2,3,4,7,8,9 - HpCDF		0.00086	ND	0.01	0.000000	0.000009	0.00086
1,2,3,4,6,7,8,9 - OCDF		0.00282	ND	0.0003	0.000000	0.000001	0.00282
				Total TEQ ng TEQ/train	**ND=0 ND**	**ND=LOD 0.002213**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	9/28/2016
Sample Name:	PS-SW-PCDDF-092816-01	Date Extracted:	11/30/2016
Lab Sample ID:	161203 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161203 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	74.9	P	37Cl4-2,3,7,8-TeCDD	0
13C12-2,3,7,8 TeCDD	67.3	P	13C12-2,3,4,7,8-PCDF	0
13C12-1,2,3,7,8 PCDF	75.4	P	13C12-1,2,3,4,7,8-HxCDF	0
13C12-1,2,3,7,8 PCDD	77.0	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	64.6	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	70.8	P		
13C12-1,2,3,4,6,7,8 HpCDF	65.5	P		
13C12-1,2,3,4,6,7,8 HpCDD	65.4	P		
13C12-1,2,3,4,6,7,8,9 OCDD	48.8	P		

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	ND
OCDD	ND	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-01	Date Extracted:	12/5/2016
Lab Sample ID:	161204 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161204 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	77.4	P	37Cl4-2,3,7,8-TeCDD	1.0
13C12-2,3,7,8 TeCDD	77.8	P	13C12-2,3,4,7,8-PCDF	0.0
13C12-1,2,3,7,8 PCDF	99.1	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	107.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	69.7	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	76.2	P		
13C12-1,2,3,4,6,7,8 HpCDF	21.5	F		
13C12-1,2,3,4,6,7,8 HpCDD	72.5	P		
13C12-1,2,3,4,6,7,8,9 OCDD	48.6	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00080	ND	1	0.000000	0.000800	0.00080
1,2,3,7,8 - PeCDD	Co-elution	0.00102	ND	1	0.000000	0.001020	0.00102
1,2,3,4,7,8 - HxCDD		0.00074	ND	0.1	0.000000	0.000074	0.00074
1,2,3,6,7,8 - HxCDD		0.00096	ND	0.1	0.000000	0.000096	0.00096
1,2,3,7,8,9 - HxCDD		0.00082	ND	0.1	0.000000	0.000082	0.00082
1,2,3,4,6,7,8 - HpCDD		0.02180		0.01	0.000218	0.000218	0.00154
1,2,3,4,6,7,8,9 - OCDD		0.06820		0.0003	0.000020	0.000020	0.00406
2,3,7,8 - TCDF		0.07920		0.1	0.007920	0.007920	0.00106
1,2,3,7,8 - PeCDF		0.01520		0.03	0.000456	0.000456	0.00102
2,3,4,7,8 - PeCDF		0.01600		0.3	0.004800	0.004800	0.00098
1,2,3,4,7,8 - HxCDF		0.00280		0.1	0.000280	0.000280	0.00100
1,2,3,6,7,8 - HxCDF		0.00116	ND	0.1	0.000000	0.000116	0.00116
1,2,3,7,8,9 - HxCDF	Co-elution	0.00130	ND	0.1	0.000000	0.000130	0.00130
2,3,4,6,7,8 - HxCDF	Co-elution	0.00116	ND	0.1	0.000000	0.000116	0.00116
1,2,3,4,6,7,8 - HpCDF		0.00340	ND	0.01	0.000000	0.000034	0.00340
1,2,3,4,7,8,9 - HpCDF		0.00408	ND	0.01	0.000000	0.000041	0.00408
1,2,3,4,6,7,8,9 - OCDF		0.00410	ND	0.0003	0.000000	0.000001	0.00410
				Total TEQ ng TEQ/train	**ND=0 0.013694**	**ND=LOD 0.016204**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-01	Date Extracted:	12/5/2016
Lab Sample ID:	161204 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161204 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	77.4	P	37Cl4-2,3,7,8-TeCDD	1	0
13C12-2,3,7,8 TeCDD	77.8	P	13C12-2,3,4,7,8-PCDF	0	0
13C12-1,2,3,7,8 PCDF	99.1	P	13C12-1,2,3,4,7,8-HxCDF	0	0
13C12-1,2,3,7,8 PCDD	107.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0	0
13C12-1,2,3,6,7,8 HxCDF	69.7	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0	0
13C12-1,2,3,6,7,8 HxCDD	76.2	P			
13C12-1,2,3,4,6,7,8 HpCDF	21.5	F			
13C12-1,2,3,4,6,7,8 HpCDD	72.5	P			
13C12-1,2,3,4,6,7,8,9 OCDD	48.6	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	0.596
PeCDD Total	ND	PeCDF Total	0.134
HxCDD Total	0.006	HxCDF Total	0.010
HpCDD Total	0.034	HpCDF Total	ND
OCDD	0.068	OCDF	ND

ND = not detected (S/N <2.5)

NS= not spiked

EMPC=Est. Max. Possible Concentration

Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-01	Date Extracted:	12/5/2016
Lab Sample ID:	161205 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161205 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	91.4	P	37Cl4-2,3,7,8-TeCDD	59.1	F
13C12-2,3,7,8 TeCDD	84.0	P	13C12-2,3,4,7,8-PCDF	59.7	F
13C12-1,2,3,7,8 PCDF	90.4	P	13C12-1,2,3,4,7,8-HxCDF	44.4	F
13C12-1,2,3,7,8 PCDD	92.5	P	13C12-1,2,3,4,7,8-HxCDD	47.5	F
13C12-1,2,3,6,7,8 HxCDF	81.2	P	13C12-1,2,3,4,7,8,9-HpCDF	57.0	F
13C12-1,2,3,6,7,8 HxCDD	77.2	P			
13C12-1,2,3,4,6,7,8 HpCDF	66.8	P			
13C12-1,2,3,4,6,7,8 HpCDD	68.8	P			
13C12-1,2,3,4,6,7,8,9 OCDD	64.3	P			

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00052	ND	1	0.000000	0.000520	0.00052
1,2,3,7,8 - PeCDD	Co-elution	0.00046	ND	1	0.000000	0.000460	0.00046
1,2,3,4,7,8 - HxCDD		0.00048	ND	0.1	0.000000	0.000048	0.00048
1,2,3,6,7,8 - HxCDD		0.00062	ND	0.1	0.000000	0.000062	0.00062
1,2,3,7,8,9 - HxCDD		0.00054	ND	0.1	0.000000	0.000054	0.00054
1,2,3,4,6,7,8 - HpCDD		0.00074	ND	0.01	0.000000	0.000007	0.00074
1,2,3,4,6,7,8,9 - OCDD		0.00128	ND	0.0003	0.000000	0.000000	0.00128
2,3,7,8 - TCDF		0.00062	ND	0.1	0.000000	0.000062	0.00062
1,2,3,7,8 - PeCDF		0.00052	ND	0.03	0.000000	0.000016	0.00052
2,3,4,7,8 - PeCDF		0.00050	ND	0.3	0.000000	0.000150	0.00050
1,2,3,4,7,8 - HxCDF		0.00050	ND	0.1	0.000000	0.000050	0.00050
1,2,3,6,7,8 - HxCDF		0.00058	ND	0.1	0.000000	0.000058	0.00058
1,2,3,7,8,9 - HxCDF	Co-elution	0.00066	ND	0.1	0.000000	0.000066	0.00066
2,3,4,6,7,8 - HxCDF	Co-elution	0.00058	ND	0.1	0.000000	0.000058	0.00058
1,2,3,4,6,7,8 - HpCDF		0.00070	ND	0.01	0.000000	0.000007	0.00070
1,2,3,4,7,8,9 - HpCDF		0.00084	ND	0.01	0.000000	0.000008	0.00084
1,2,3,4,6,7,8,9 - OCDF		0.00200	EMPC	0.0003	0.000001	0.000001	0.00152
				Total TEQ ng TEQ/train	**ND=0 0.000001**	**ND=LOD 0.001627**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-01	Date Extracted:	12/5/2016
Lab Sample ID:	161205 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161205 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	91.4	P	37Cl4-2,3,7,8-TeCDD	59.1	F
13C12-2,3,7,8 TeCDD	84	P	13C12-2,3,4,7,8-PCDF	59.7	F
13C12-1,2,3,7,8 PCDF	90.4	P	13C12-1,2,3,4,7,8-HxCDF	44.4	F
13C12-1,2,3,7,8 PCDD	92.5	P	13C12-1,2,3,4,7,8-HxCDD	47.5	F
13C12-1,2,3,6,7,8 HxCDF	81.2	P	13C12-1,2,3,4,7,8,9-HpCDF	57.0	F
13C12-1,2,3,6,7,8 HxCDD	77.2	P			
13C12-1,2,3,4,6,7,8 HpCDF	66.8	P			
13C12-1,2,3,4,6,7,8 HpCDD	68.8	P			
13C12-1,2,3,4,6,7,8,9 OCDD	64.3	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	ND
OCDD	ND	OCDF	0.002

ND = not detected (S/N <2.5)

NS= not spiked

EMPC=Est. Max. Possible Concentration

Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-01	Date Extracted:	12/6/2016
Lab Sample ID:	161206 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161206 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	94.5	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	78.7	P	13C12-2,3,4,7,8-PCDF	0.4
13C12-1,2,3,7,8 PCDF	94.0	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	95.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	73.3	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	81.4	P		
13C12-1,2,3,4,6,7,8 HpCDF	69.2	P		
13C12-1,2,3,4,6,7,8 HpCDD	72.1	P		
13C12-1,2,3,4,6,7,8,9 OCDD	62.5	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00086	ND	1	0.000000	0.000860	0.00086
1,2,3,7,8 - PeCDD	Co-elution	0.00098	ND	1	0.000000	0.000980	0.00098
1,2,3,4,7,8 - HxCDD		0.00090	ND	0.1	0.000000	0.000090	0.00090
1,2,3,6,7,8 - HxCDD		0.00116	ND	0.1	0.000000	0.000116	0.00116
1,2,3,7,8,9 - HxCDD		0.00098	ND	0.1	0.000000	0.000098	0.00098
1,2,3,4,6,7,8 - HpCDD		0.00176	ND	0.01	0.000000	0.000018	0.00176
1,2,3,4,6,7,8,9 - OCDD		0.00266	ND	0.0003	0.000000	0.000001	0.00266
2,3,7,8 - TCDF		0.00092	ND	0.1	0.000000	0.000092	0.00092
1,2,3,7,8 - PeCDF		0.00096	ND	0.03	0.000000	0.000029	0.00096
2,3,4,7,8 - PeCDF		0.00094	ND	0.3	0.000000	0.000282	0.00094
1,2,3,4,7,8 - HxCDF		0.00094	ND	0.1	0.000000	0.000094	0.00094
1,2,3,6,7,8 - HxCDF		0.00110	ND	0.1	0.000000	0.000110	0.00110
1,2,3,7,8,9 - HxCDF	Co-elution	0.00122	ND	0.1	0.000000	0.000122	0.00122
2,3,4,6,7,8 - HxCDF	Co-elution	0.00110	ND	0.1	0.000000	0.000110	0.00110
1,2,3,4,6,7,8 - HpCDF		0.00164	ND	0.01	0.000000	0.000016	0.00164
1,2,3,4,7,8,9 - HpCDF		0.00198	ND	0.01	0.000000	0.000020	0.00198
1,2,3,4,6,7,8,9 - OCDF		0.00294	ND	0.0003	0.000000	0.000001	0.00294
				Total TEQ ng TEQ/train	**ND=0 ND**	**ND=LOD 0.003038**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-01	Date Extracted:	12/6/2016
Lab Sample ID:	161206 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161206 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	94.5	P	37Cl4-2,3,7,8-TeCDD	0
13C12-2,3,7,8 TeCDD	78.7	P	13C12-2,3,4,7,8-PCDF	0.4
13C12-1,2,3,7,8 PCDF	94	P	13C12-1,2,3,4,7,8-HxCDF	0
13C12-1,2,3,7,8 PCDD	95.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	73.3	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	81.4	P		
13C12-1,2,3,4,6,7,8 HpCDF	69.2	P		
13C12-1,2,3,4,6,7,8 HpCDD	72.1	P		
13C12-1,2,3,4,6,7,8,9 OCDD	62.5	P		

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	ND
OCDD	ND	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-02	Date Extracted:	12/6/2016
Lab Sample ID:	161207 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161207 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	75.6	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	91.0	P	13C12-2,3,4,7,8-PCDF	0.0
13C12-1,2,3,7,8 PCDF	73.4	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	125.5	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	58.9	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	65.3	P		
13C12-1,2,3,4,6,7,8 HpCDF	16.6	F		
13C12-1,2,3,4,6,7,8 HpCDD	70.0	P		
13C12-1,2,3,4,6,7,8,9 OCDD	62.0	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00074	ND	1	0.000000	0.000740	0.00074
1,2,3,7,8 - PeCDD	Co-elution	0.00090	ND	1	0.000000	0.000900	0.00090
1,2,3,4,7,8 - HxCDD		0.00074	ND	0.1	0.000000	0.000074	0.00074
1,2,3,6,7,8 - HxCDD		0.00096	ND	0.1	0.000000	0.000096	0.00096
1,2,3,7,8,9 - HxCDD		0.00082	ND	0.1	0.000000	0.000082	0.00082
1,2,3,4,6,7,8 - HpCDD		0.01000		0.01	0.000100	0.000100	0.00078
1,2,3,4,6,7,8,9 - OCDD		0.03120		0.0003	0.000009	0.000009	0.00166
2,3,7,8 - TCDF		0.00560		0.1	0.000560	0.000560	0.00146
1,2,3,7,8 - PeCDF		0.00120	ND	0.03	0.000000	0.000036	0.00120
2,3,4,7,8 - PeCDF		0.00116	ND	0.3	0.000000	0.000348	0.00116
1,2,3,4,7,8 - HxCDF		0.00066	ND	0.1	0.000000	0.000066	0.00066
1,2,3,6,7,8 - HxCDF		0.00078	ND	0.1	0.000000	0.000078	0.00078
1,2,3,7,8,9 - HxCDF	Co-elution	0.00086	ND	0.1	0.000000	0.000086	0.00086
2,3,4,6,7,8 - HxCDF	Co-elution	0.00078	ND	0.1	0.000000	0.000078	0.00078
1,2,3,4,6,7,8 - HpCDF		0.00164	ND	0.01	0.000000	0.000016	0.00164
1,2,3,4,7,8,9 - HpCDF		0.00196	ND	0.01	0.000000	0.000020	0.00196
1,2,3,4,6,7,8,9 - OCDF		0.00280	EMPC	0.0003	0.000001	0.000001	0.00182
				Total TEQ ng TEQ/train	**ND=0 0.000670**	**ND=LOD 0.003290**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-02	Date Extracted:	12/6/2016
Lab Sample ID:	161207 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161207 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	75.6	P	37Cl4-2,3,7,8-TeCDD	0	0
13C12-2,3,7,8 TeCDD	91	P	13C12-2,3,4,7,8-PCDF	0	0
13C12-1,2,3,7,8 PCDF	73.4	P	13C12-1,2,3,4,7,8-HxCDF	0	0
13C12-1,2,3,7,8 PCDD	125.5	P	13C12-1,2,3,4,7,8-HxCDD	0.0	0
13C12-1,2,3,6,7,8 HxCDF	58.9	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0	0
13C12-1,2,3,6,7,8 HxCDD	65.3	P			
13C12-1,2,3,4,6,7,8 HpCDF	16.6	F			
13C12-1,2,3,4,6,7,8 HpCDD	70.0	P			
13C12-1,2,3,4,6,7,8,9 OCDD	62.0	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	0.024
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	0.016	HpCDF Total	ND
OCDD	0.032	OCDF	0.004

ND = not detected (S/N <2.5)

NS= not spiked

EMPC=Est. Max. Possible Concentration

Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-02	Date Extracted:	12/6/2016
Lab Sample ID:	161208 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161208 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	82.3	P	37Cl4-2,3,7,8-TeCDD	111.1	P
13C12-2,3,7,8 TeCDD	73.0	P	13C12-2,3,4,7,8-PCDF	104.4	P
13C12-1,2,3,7,8 PCDF	84.6	P	13C12-1,2,3,4,7,8-HxCDF	75.8	P
13C12-1,2,3,7,8 PCDD	86.5	P	13C12-1,2,3,4,7,8-HxCDD	85.5	P
13C12-1,2,3,6,7,8 HxCDF	76.3	P	13C12-1,2,3,4,7,8,9-HpCDF	102.8	P
13C12-1,2,3,6,7,8 HxCDD	68.5	P			
13C12-1,2,3,4,6,7,8 HpCDF	60.9	P			
13C12-1,2,3,4,6,7,8 HpCDD	65.4	P			
13C12-1,2,3,4,6,7,8,9 OCDD	56.4	P			

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00056	ND	1	0.000000	0.000560	0.00056
1,2,3,7,8 - PeCDD	Co-elution	0.00060	ND	1	0.000000	0.000600	0.00060
1,2,3,4,7,8 - HxCDD		0.00050	ND	0.1	0.000000	0.000050	0.00050
1,2,3,6,7,8 - HxCDD		0.00066	ND	0.1	0.000000	0.000066	0.00066
1,2,3,7,8,9 - HxCDD		0.00056	ND	0.1	0.000000	0.000056	0.00056
1,2,3,4,6,7,8 - HpCDD		0.00160		0.01	0.000016	0.000016	0.00114
1,2,3,4,6,7,8,9 - OCDD		0.00260	EMPC	0.0003	0.000001	0.000001	0.00184
2,3,7,8 - TCDF		0.00070	ND	0.1	0.000000	0.000070	0.00070
1,2,3,7,8 - PeCDF		0.00064	ND	0.03	0.000000	0.000019	0.00064
2,3,4,7,8 - PeCDF		0.00062	ND	0.3	0.000000	0.000186	0.00062
1,2,3,4,7,8 - HxCDF		0.00042	ND	0.1	0.000000	0.000042	0.00042
1,2,3,6,7,8 - HxCDF		0.00050	ND	0.1	0.000000	0.000050	0.00050
1,2,3,7,8,9 - HxCDF	Co-elution	0.00056	ND	0.1	0.000000	0.000056	0.00056
2,3,4,6,7,8 - HxCDF	Co-elution	0.00050	ND	0.1	0.000000	0.000050	0.00050
1,2,3,4,6,7,8 - HpCDF		0.00084	ND	0.01	0.000000	0.000008	0.00084
1,2,3,4,7,8,9 - HpCDF		0.00102	ND	0.01	0.000000	0.000010	0.00102
1,2,3,4,6,7,8,9 - OCDF		0.00212	ND	0.0003	0.000000	0.000001	0.00212
				Total TEQ ng TEQ/train	**ND=0 0.000017**	**ND=LOD 0.001841**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-02	Date Extracted:	12/6/2016
Lab Sample ID:	161208 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161208 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	82.3	P	37Cl4-2,3,7,8-TeCDD	111.1	P
13C12-2,3,7,8 TeCDD	73	P	13C12-2,3,4,7,8-PCDF	104.4	P
13C12-1,2,3,7,8 PCDF	84.6	P	13C12-1,2,3,4,7,8-HxCDF	75.8	P
13C12-1,2,3,7,8 PCDD	86.5	P	13C12-1,2,3,4,7,8-HxCDD	85.5	P
13C12-1,2,3,6,7,8 HxCDF	76.3	P	13C12-1,2,3,4,7,8,9-HpCDF	102.8	P
13C12-1,2,3,6,7,8 HxCDD	68.5	P			
13C12-1,2,3,4,6,7,8 HpCDF	60.9	P			
13C12-1,2,3,4,6,7,8 HpCDD	65.4	P			
13C12-1,2,3,4,6,7,8,9 OCDD	56.4	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	0.002	HpCDF Total	ND
OCDD	0.002	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-02	Date Extracted:	12/6/2016
Lab Sample ID:	161209 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161209 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	95.4	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	80.6	P	13C12-2,3,4,7,8-PCDF	0.3
13C12-1,2,3,7,8 PCDF	99.0	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	99.5	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	76.3	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	83.9	P		
13C12-1,2,3,4,6,7,8 HpCDF	70.2	P		
13C12-1,2,3,4,6,7,8 HpCDD	76.1	P		
13C12-1,2,3,4,6,7,8,9 OCDD	63.0	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00066	ND	1	0.000000	0.000660	0.00066
1,2,3,7,8 - PeCDD	Co-elution	0.00068	ND	1	0.000000	0.000680	0.00068
1,2,3,4,7,8 - HxCDD		0.00068	ND	0.1	0.000000	0.000068	0.00068
1,2,3,6,7,8 - HxCDD		0.00088	ND	0.1	0.000000	0.000088	0.00088
1,2,3,7,8,9 - HxCDD		0.00076	ND	0.1	0.000000	0.000076	0.00076
1,2,3,4,6,7,8 - HpCDD		0.00134	ND	0.01	0.000000	0.000013	0.00134
1,2,3,4,6,7,8,9 - OCDD		0.00212	ND	0.0003	0.000000	0.000001	0.00212
2,3,7,8 - TCDF		0.00066	ND	0.1	0.000000	0.000066	0.00066
1,2,3,7,8 - PeCDF		0.00068	ND	0.03	0.000000	0.000020	0.00068
2,3,4,7,8 - PeCDF		0.00066	ND	0.3	0.000000	0.000198	0.00066
1,2,3,4,7,8 - HxCDF		0.00066	ND	0.1	0.000000	0.000066	0.00066
1,2,3,6,7,8 - HxCDF		0.00078	ND	0.1	0.000000	0.000078	0.00078
1,2,3,7,8,9 - HxCDF	Co-elution	0.00086	ND	0.1	0.000000	0.000086	0.00086
2,3,4,6,7,8 - HxCDF	Co-elution	0.00078	ND	0.1	0.000000	0.000078	0.00078
1,2,3,4,6,7,8 - HpCDF		0.00116	ND	0.01	0.000000	0.000012	0.00116
1,2,3,4,7,8,9 - HpCDF		0.00138	ND	0.01	0.000000	0.000014	0.00138
1,2,3,4,6,7,8,9 - OCDF		0.00228	ND	0.0003	0.000000	0.000001	0.00228
				Total TEQ ng TEQ/train	**ND=0**	**ND=LOD**	
					ND	**0.002205**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-02	Date Extracted:	12/6/2016
Lab Sample ID:	161209 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161209 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	95.4	P	37Cl4-2,3,7,8-TeCDD	0
13C12-2,3,7,8 TeCDD	80.6	P	13C12-2,3,4,7,8-PCDF	0.3
13C12-1,2,3,7,8 PCDF	99	P	13C12-1,2,3,4,7,8-HxCDF	0
13C12-1,2,3,7,8 PCDD	99.5	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	76.3	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	83.9	P		
13C12-1,2,3,4,6,7,8 HpCDF	70.2	P		
13C12-1,2,3,4,6,7,8 HpCDD	76.1	P		
13C12-1,2,3,4,6,7,8,9 OCDD	63.0	P		

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	ND
OCDD	ND	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-03	Date Extracted:	12/6/2016
Lab Sample ID:	161210 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161210 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	107.3	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	98.7	P	13C12-2,3,4,7,8-PCDF	0.0
13C12-1,2,3,7,8 PCDF	59.4	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	155.4	F	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	61.8	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	71.1	P		
13C12-1,2,3,4,6,7,8 HpCDF	32.0	P		
13C12-1,2,3,4,6,7,8 HpCDD	75.1	P		
13C12-1,2,3,4,6,7,8,9 OCDD	62.4	P		

Isomer.	ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD	0.00158	ND	1	0.000000	0.001580	0.00158
1,2,3,7,8 - PeCDD Co-elution	0.00104	ND	1	0.000000	0.001040	0.00104
1,2,3,4,7,8 - HxCDD	0.00072	ND	0.1	0.000000	0.000072	0.00072
1,2,3,6,7,8 - HxCDD	0.00092	ND	0.1	0.000000	0.000092	0.00092
1,2,3,7,8,9 - HxCDD	0.00078	ND	0.1	0.000000	0.000078	0.00078
1,2,3,4,6,7,8 - HpCDD	0.01020		0.01	0.000102	0.000102	0.00076
1,2,3,4,6,7,8,9 - OCDD	0.03500		0.0003	0.000011	0.000011	0.00136
2,3,7,8 - TCDF	0.00620		0.1	0.000620	0.000620	0.00210
1,2,3,7,8 - PeCDF	0.00074	ND	0.03	0.000000	0.000022	0.00074
2,3,4,7,8 - PeCDF	0.00460	EMPC	0.3	0.001380	0.001380	0.00072
1,2,3,4,7,8 - HxCDF	0.00070	ND	0.1	0.000000	0.000070	0.00070
1,2,3,6,7,8 - HxCDF	0.00082	ND	0.1	0.000000	0.000082	0.00082
1,2,3,7,8,9 - HxCDF Co-elution	0.00092	ND	0.1	0.000000	0.000092	0.00092
2,3,4,6,7,8 - HxCDF Co-elution	0.00082	ND	0.1	0.000000	0.000082	0.00082
1,2,3,4,6,7,8 - HpCDF	0.00080	ND	0.01	0.000000	0.000008	0.00080
1,2,3,4,7,8,9 - HpCDF	0.00096	ND	0.01	0.000000	0.000010	0.00096
1,2,3,4,6,7,8,9 - OCDF	0.00460		0.0003	0.000001	0.000001	0.00160
			Total TEQ ng TEQ/train	**ND=0 0.002114**	**ND=LOD 0.005342**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-03	Date Extracted:	12/6/2016
Lab Sample ID:	161210 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161210 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	107.3	P	37Cl4-2,3,7,8-TeCDD	0	0
13C12-2,3,7,8 TeCDD	98.7	P	13C12-2,3,4,7,8-PCDF	0	0
13C12-1,2,3,7,8 PCDF	59.4	P	13C12-1,2,3,4,7,8-HxCDF	0	0
13C12-1,2,3,7,8 PCDD	155.4	F	13C12-1,2,3,4,7,8-HxCDD	0.0	0
13C12-1,2,3,6,7,8 HxCDF	61.8	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0	0
13C12-1,2,3,6,7,8 HxCDD	71.1	P			
13C12-1,2,3,4,6,7,8 HpCDF	32.0	P			
13C12-1,2,3,4,6,7,8 HpCDD	75.1	P			
13C12-1,2,3,4,6,7,8,9 OCDD	62.4	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	0.038
PeCDD Total	ND	PeCDF Total	0.006
HxCDD Total	0.002	HxCDF Total	ND
HpCDD Total	0.012	HpCDF Total	0.006
OCDD	0.034	OCDF	0.004

ND = not detected (S/N <2.5)

NS= not spiked

EMPC=Est. Max. Possible Concentration

Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-03	Date Extracted:	12/7/2016
Lab Sample ID:	161211 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161211 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	77.3	P	37Cl4-2,3,7,8-TeCDD	103.9	P
13C12-2,3,7,8 TeCDD	68.8	P	13C12-2,3,4,7,8-PCDF	98.7	P
13C12-1,2,3,7,8 PCDF	81.1	P	13C12-1,2,3,4,7,8-HxCDF	72.3	P
13C12-1,2,3,7,8 PCDD	85.2	P	13C12-1,2,3,4,7,8-HxCDD	83.1	P
13C12-1,2,3,6,7,8 HxCDF	69.8	P	13C12-1,2,3,4,7,8,9-HpCDF	99.7	P
13C12-1,2,3,6,7,8 HxCDD	62.8	P			
13C12-1,2,3,4,6,7,8 HpCDF	55.3	P			
13C12-1,2,3,4,6,7,8 HpCDD	63.8	P			
13C12-1,2,3,4,6,7,8,9 OCDD	51.0	P			

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00100	ND	1	0.000000	0.001000	0.00100
1,2,3,7,8 - PeCDD	Co-elution	0.00078	ND	1	0.000000	0.000780	0.00078
1,2,3,4,7,8 - HxCDD		0.00094	ND	0.1	0.000000	0.000094	0.00094
1,2,3,6,7,8 - HxCDD		0.00122	ND	0.1	0.000000	0.000122	0.00122
1,2,3,7,8,9 - HxCDD		0.00104	ND	0.1	0.000000	0.000104	0.00104
1,2,3,4,6,7,8 - HpCDD		0.00176	ND	0.01	0.000000	0.000018	0.00176
1,2,3,4,6,7,8,9 - OCDD		0.00318	ND	0.0003	0.000000	0.000001	0.00318
2,3,7,8 - TCDF		0.00150	ND	0.1	0.000000	0.000150	0.00150
1,2,3,7,8 - PeCDF		0.00094	ND	0.03	0.000000	0.000028	0.00094
2,3,4,7,8 - PeCDF		0.00090	ND	0.3	0.000000	0.000270	0.00090
1,2,3,4,7,8 - HxCDF		0.00088	ND	0.1	0.000000	0.000088	0.00088
1,2,3,6,7,8 - HxCDF		0.00104	ND	0.1	0.000000	0.000104	0.00104
1,2,3,7,8,9 - HxCDF	Co-elution	0.00116	ND	0.1	0.000000	0.000116	0.00116
2,3,4,6,7,8 - HxCDF	Co-elution	0.00104	ND	0.1	0.000000	0.000104	0.00104
1,2,3,4,6,7,8 - HpCDF		0.00142	ND	0.01	0.000000	0.000014	0.00142
1,2,3,4,7,8,9 - HpCDF		0.00170	ND	0.01	0.000000	0.000017	0.00170
1,2,3,4,6,7,8,9 - OCDF		0.00334	ND	0.0003	0.000000	0.000001	0.00334
				Total TEQ ng TEQ/train	**ND=0 ND**	**ND=LOD 0.003011**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-03	Date Extracted:	12/7/2016
Lab Sample ID:	161211 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161211 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	77.3	P	37Cl4-2,3,7,8-TeCDD	103.9	P
13C12-2,3,7,8 TeCDD	68.8	P	13C12-2,3,4,7,8-PCDF	98.7	P
13C12-1,2,3,7,8 PCDF	81.1	P	13C12-1,2,3,4,7,8-HxCDF	72.3	P
13C12-1,2,3,7,8 PCDD	85.2	P	13C12-1,2,3,4,7,8-HxCDD	83.1	P
13C12-1,2,3,6,7,8 HxCDF	69.8	P	13C12-1,2,3,4,7,8,9-HpCDF	99.7	P
13C12-1,2,3,6,7,8 HxCDD	62.8	P			
13C12-1,2,3,4,6,7,8 HpCDF	55.3	P			
13C12-1,2,3,4,6,7,8 HpCDD	63.8	P			
13C12-1,2,3,4,6,7,8,9 OCDD	51.0	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	ND
OCDD	ND	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-03	Date Extracted:	12/7/2016
Lab Sample ID:	161212 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161212 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	107.3	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	85.8	P	13C12-2,3,4,7,8-PCDF	0.2
13C12-1,2,3,7,8 PCDF	111.7	P	13C12-1,2,3,4,7,8-HxCDF	0.2
13C12-1,2,3,7,8 PCDD	116.3	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	78.2	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	84.4	P		
13C12-1,2,3,4,6,7,8 HpCDF	72.1	P		
13C12-1,2,3,4,6,7,8 HpCDD	75.8	P		
13C12-1,2,3,4,6,7,8,9 OCDD	63.8	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00040	ND	1	0.000000	0.000400	0.00040
1,2,3,7,8 - PeCDD	Co-elution	0.00038	ND	1	0.000000	0.000380	0.00038
1,2,3,4,7,8 - HxCDD		0.00036	ND	0.1	0.000000	0.000036	0.00036
1,2,3,6,7,8 - HxCDD		0.00046	ND	0.1	0.000000	0.000046	0.00046
1,2,3,7,8,9 - HxCDD		0.00040	ND	0.1	0.000000	0.000040	0.00040
1,2,3,4,6,7,8 - HpCDD		0.00112	ND	0.01	0.000000	0.000011	0.00112
1,2,3,4,6,7,8,9 - OCDD		0.00236	ND	0.0003	0.000000	0.000001	0.00236
2,3,7,8 - TCDF		0.00046	ND	0.1	0.000000	0.000046	0.00046
1,2,3,7,8 - PeCDF		0.00044	ND	0.03	0.000000	0.000013	0.00044
2,3,4,7,8 - PeCDF		0.00042	ND	0.3	0.000000	0.000126	0.00042
1,2,3,4,7,8 - HxCDF		0.00036	ND	0.1	0.000000	0.000036	0.00036
1,2,3,6,7,8 - HxCDF		0.00042	ND	0.1	0.000000	0.000042	0.00042
1,2,3,7,8,9 - HxCDF	Co-elution	0.00046	ND	0.1	0.000000	0.000046	0.00046
2,3,4,6,7,8 - HxCDF	Co-elution	0.00042	ND	0.1	0.000000	0.000042	0.00042
1,2,3,4,6,7,8 - HpCDF		0.00092	ND	0.01	0.000000	0.000009	0.00092
1,2,3,4,7,8,9 - HpCDF		0.00110	ND	0.01	0.000000	0.000011	0.00110
1,2,3,4,6,7,8,9 - OCDF		0.00258	ND	0.0003	0.000000	0.000001	0.00258
				Total TEQ ng TEQ/train	**ND=0 ND**	**ND=LOD 0.001286**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	PS-SW-PCDDF-100416-03	Date Extracted:	12/7/2016
Lab Sample ID:	161212 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161212 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	107.3	P	37Cl4-2,3,7,8-TeCDD	0
13C12-2,3,7,8 TeCDD	85.8	P	13C12-2,3,4,7,8-PCDF	0.2
13C12-1,2,3,7,8 PCDF	111.7	P	13C12-1,2,3,4,7,8-HxCDF	0.2
13C12-1,2,3,7,8 PCDD	116.3	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	78.2	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	84.4	P		
13C12-1,2,3,4,6,7,8 HpCDF	72.1	P		
13C12-1,2,3,4,6,7,8 HpCDD	75.8	P		
13C12-1,2,3,4,6,7,8,9 OCDD	63.8	P		

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	ND
OCDD	ND	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	BS-Ambient-PCDDF-100416	Date Extracted:	12/7/2016
Lab Sample ID:	161213 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161213 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	103.9	P	37Cl4-2,3,7,8-TeCDD	0.0
13C12-2,3,7,8 TeCDD	84.8	P	13C12-2,3,4,7,8-PCDF	0.0
13C12-1,2,3,7,8 PCDF	105.1	P	13C12-1,2,3,4,7,8-HxCDF	0.1
13C12-1,2,3,7,8 PCDD	114.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	83.1	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0
13C12-1,2,3,6,7,8 HxCDD	97.2	P		
13C12-1,2,3,4,6,7,8 HpCDF	81.0	P		
13C12-1,2,3,4,6,7,8 HpCDD	87.4	P		
13C12-1,2,3,4,6,7,8,9 OCDD	70.1	P		

Isomer.	ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD	0.00024	ND	1	0.000000	0.000240	0.00024
1,2,3,7,8 - PeCDD Co-elution	0.00034	ND	1	0.000000	0.000340	0.00034
1,2,3,4,7,8 - HxCDD	0.00028	ND	0.1	0.000000	0.000028	0.00028
1,2,3,6,7,8 - HxCDD	0.00036	ND	0.1	0.000000	0.000036	0.00036
1,2,3,7,8,9 - HxCDD	0.00030	ND	0.1	0.000000	0.000030	0.00030
1,2,3,4,6,7,8 - HpCDD	0.00036	ND	0.01	0.000000	0.000004	0.00036
1,2,3,4,6,7,8,9 - OCDD	0.00280		0.0003	0.000001	0.000001	0.00046
2,3,7,8 - TCDF	0.00024	ND	0.1	0.000000	0.000024	0.00024
1,2,3,7,8 - PeCDF	0.00042	ND	0.03	0.000000	0.000013	0.00042
2,3,4,7,8 - PeCDF	0.00042	ND	0.3	0.000000	0.000126	0.00042
1,2,3,4,7,8 - HxCDF	0.00026	ND	0.1	0.000000	0.000026	0.00026
1,2,3,6,7,8 - HxCDF	0.00030	ND	0.1	0.000000	0.000030	0.00030
1,2,3,7,8,9 - HxCDF Co-elution	0.00032	ND	0.1	0.000000	0.000032	0.00032
2,3,4,6,7,8 - HxCDF Co-elution	0.00030	ND	0.1	0.000000	0.000030	0.00030
1,2,3,4,6,7,8 - HpCDF	0.00052	ND	0.01	0.000000	0.000005	0.00052
1,2,3,4,7,8,9 - HpCDF	0.00062	ND	0.01	0.000000	0.000006	0.00062
1,2,3,4,6,7,8,9 - OCDF	0.00066	ND	0.0003	0.000000	0.000000	0.00066
			Total TEQ ng TEQ/train	**ND=0 0.000001**	**ND=LOD 0.000971**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	BS-Ambient-PCDDF-100416	Date Extracted:	12/7/2016
Lab Sample ID:	161213 Filters	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161213 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	103.9	P	37Cl4-2,3,7,8-TeCDD	0	0
13C12-2,3,7,8 TeCDD	84.8	P	13C12-2,3,4,7,8-PCDF	0	0
13C12-1,2,3,7,8 PCDF	105.1	P	13C12-1,2,3,4,7,8-HxCDF	0.1	0
13C12-1,2,3,7,8 PCDD	114.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0	0
13C12-1,2,3,6,7,8 HxCDF	83.1	P	13C12-1,2,3,4,7,8,9-HpCDF	0.0	0
13C12-1,2,3,6,7,8 HxCDD	97.2	P			
13C12-1,2,3,4,6,7,8 HpCDF	81.0	P			
13C12-1,2,3,4,6,7,8 HpCDD	87.4	P			
13C12-1,2,3,4,6,7,8,9 OCDD	70.1	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	ND
OCDD	0.002	OCDF	ND

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	BS-BLANK-PCDDF-100416	Date Extracted:	12/7/2016
Lab Sample ID:	161214 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161214 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	108.2	P	37Cl4-2,3,7,8-TeCDD	107.7	P
13C12-2,3,7,8 TeCDD	92.0	P	13C12-2,3,4,7,8-PCDF	96.9	P
13C12-1,2,3,7,8 PCDF	110.2	P	13C12-1,2,3,4,7,8-HxCDF	59.6	F
13C12-1,2,3,7,8 PCDD	112.5	P	13C12-1,2,3,4,7,8-HxCDD	76.6	P
13C12-1,2,3,6,7,8 HxCDF	108.4	P	13C12-1,2,3,4,7,8,9-HpCDF	85.6	P
13C12-1,2,3,6,7,8 HxCDD	89.3	P			
13C12-1,2,3,4,6,7,8 HpCDF	73.5	P			
13C12-1,2,3,4,6,7,8 HpCDD	82.5	P			
13C12-1,2,3,4,6,7,8,9 OCDD	54.9	P			

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00024	ND	1	0.000000	0.000240	0.00024
1,2,3,7,8 - PeCDD	Co-elution	0.00038	ND	1	0.000000	0.000380	0.00038
1,2,3,4,7,8 - HxCDD		0.00026	ND	0.1	0.000000	0.000026	0.00026
1,2,3,6,7,8 - HxCDD		0.00034	ND	0.1	0.000000	0.000034	0.00034
1,2,3,7,8,9 - HxCDD		0.00030	ND	0.1	0.000000	0.000030	0.00030
1,2,3,4,6,7,8 - HpCDD		0.00140		0.01	0.000014	0.000014	0.00036
1,2,3,4,6,7,8,9 - OCDD		0.00280		0.0003	0.000001	0.000001	0.00046
2,3,7,8 - TCDF		0.00040		0.1	0.000040	0.000040	0.00026
1,2,3,7,8 - PeCDF		0.00042	ND	0.03	0.000000	0.000013	0.00042
2,3,4,7,8 - PeCDF		0.00040	ND	0.3	0.000000	0.000120	0.00040
1,2,3,4,7,8 - HxCDF		0.00018	ND	0.1	0.000000	0.000018	0.00018
1,2,3,6,7,8 - HxCDF		0.00022	ND	0.1	0.000000	0.000022	0.00022
1,2,3,7,8,9 - HxCDF	Co-elution	0.00024	ND	0.1	0.000000	0.000024	0.00024
2,3,4,6,7,8 - HxCDF	Co-elution	0.00022	ND	0.1	0.000000	0.000022	0.00022
1,2,3,4,6,7,8 - HpCDF		0.00200		0.01	0.000020	0.000020	0.00040
1,2,3,4,7,8,9 - HpCDF		0.00048	ND	0.01	0.000000	0.000005	0.00048
1,2,3,4,6,7,8,9 - OCDF		0.00660		0.0003	0.000002	0.000002	0.00070
				Total TEQ ng TEQ/train	**ND=0 0.000077**	**ND=LOD 0.001010**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	BS-BLANK-PCDDF-100416	Date Extracted:	12/7/2016
Lab Sample ID:	161214 Front PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161214 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery	
13C12-2,3,7,8 TeCDF	108.2	P	37Cl4-2,3,7,8-TeCDD	107.7	P
13C12-2,3,7,8 TeCDD	92	P	13C12-2,3,4,7,8-PCDF	96.9	P
13C12-1,2,3,7,8 PCDF	110.2	P	13C12-1,2,3,4,7,8-HxCDF	59.6	F
13C12-1,2,3,7,8 PCDD	112.5	P	13C12-1,2,3,4,7,8-HxCDD	76.6	P
13C12-1,2,3,6,7,8 HxCDF	108.4	P	13C12-1,2,3,4,7,8,9-HpCDF	85.6	P
13C12-1,2,3,6,7,8 HxCDD	89.3	P			
13C12-1,2,3,4,6,7,8 HpCDF	73.5	P			
13C12-1,2,3,4,6,7,8 HpCDD	82.5	P			
13C12-1,2,3,4,6,7,8,9 OCDD	54.9	P			

Isomer.	ng/Sample		ng/Sample
TeCDD Total	ND	TeCDF Total	0.002
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	0.002	HpCDF Total	0.002
OCDD	0.002	OCDF	0.006

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis TEQ Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	BS-Ambient-PCDDF-100416	Date Extracted:	12/7/2016
Lab Sample ID:	161215 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161215 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin HRGC/HRMS	Analyst:	Dennis Tabor

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next.
The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	95.3	P	37Cl4-2,3,7,8-TeCDD	0.3
13C12-2,3,7,8 TeCDD	75.2	P	13C12-2,3,4,7,8-PCDF	0.4
13C12-1,2,3,7,8 PCDF	97.8	P	13C12-1,2,3,4,7,8-HxCDF	0.0
13C12-1,2,3,7,8 PCDD	101.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	73.7	P	13C12-1,2,3,4,7,8,9-HpCDF	0.3
13C12-1,2,3,6,7,8 HxCDD	82.2	P		
13C12-1,2,3,4,6,7,8 HpCDF	71.4	P		
13C12-1,2,3,4,6,7,8 HpCDD	78.3	P		
13C12-1,2,3,4,6,7,8,9 OCDD	58.3	P		

Isomer.		ng/Sample		2005 WHO TEF (Mammals/Humans) Toxicity Equiv. Factor	TEQ ng/Sample ND=0	TEQ ng/Sample ND=LOD	Instrument Stated Limit of Detection ng/train
2,3,7,8 - TCDD		0.00030	ND	1	0.000000	0.000300	0.00030
1,2,3,7,8 - PeCDD	Co-elution	0.00036	ND	1	0.000000	0.000360	0.00036
1,2,3,4,7,8 - HxCDD		0.00028	ND	0.1	0.000000	0.000028	0.00028
1,2,3,6,7,8 - HxCDD		0.00038	ND	0.1	0.000000	0.000038	0.00038
1,2,3,7,8,9 - HxCDD		0.00032	ND	0.1	0.000000	0.000032	0.00032
1,2,3,4,6,7,8 - HpCDD		0.00044	ND	0.01	0.000000	0.000004	0.00044
1,2,3,4,6,7,8,9 - OCDD		0.00140		0.0003	0.000000	0.000000	0.00044
2,3,7,8 - TCDF		0.00030	ND	0.1	0.000000	0.000030	0.00030
1,2,3,7,8 - PeCDF		0.00046	ND	0.03	0.000000	0.000014	0.00046
2,3,4,7,8 - PeCDF		0.00044	ND	0.3	0.000000	0.000132	0.00044
1,2,3,4,7,8 - HxCDF		0.00032	ND	0.1	0.000000	0.000032	0.00032
1,2,3,6,7,8 - HxCDF		0.00038	ND	0.1	0.000000	0.000038	0.00038
1,2,3,7,8,9 - HxCDF	Co-elution	0.00042	ND	0.1	0.000000	0.000042	0.00042
2,3,4,6,7,8 - HxCDF	Co-elution	0.00038	ND	0.1	0.000000	0.000038	0.00038
1,2,3,4,6,7,8 - HpCDF		0.00120	EMPC	0.01	0.000012	0.000012	0.00046
1,2,3,4,7,8,9 - HpCDF		0.00054	ND	0.01	0.000000	0.000005	0.00054
1,2,3,4,6,7,8,9 - OCDF		0.00340		0.0003	0.000001	0.000001	0.00082
				Total TEQ ng TEQ/train	**ND=0 0.000013**	**ND=LOD 0.001107**	

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

APPCD Organic Support Laboratory
High Resolution Dioxin Analysis Totals Report

Project:	Radford Skid Waster Burns	Date Sampled:	10/4/2016
Sample Name:	BS-Ambient-PCDDF-100416	Date Extracted:	12/7/2016
Lab Sample ID:	161215 Back PUFs	Date Acquired:	04/11/2017
MS Data file:	H 170411 Radford 161215 Sample ID:	Dilution factor:	1
		Operator:	Dennis Tabor
Method:	Total Congener Dioxin	Analyst:	Dennis Tabor
	HRGC/HRMS		

Sample Description/Narrative:

The Radford Project samples comprised two samplers each with a filter followed by 2 PUF Sorbents. The Filters were combined and extracted. The Front PUFs were combined and the Back PUFs were combined. This was to determine breakthrough from each stage to the next. The upper end of the calibration range was 0.4 ng/sample. The lower end of the calibration range was 0.005 ng/sample.

Pre Extraction Surrogates	% Recovery		Pre-Sampling Surrogates	% Recovery
13C12-2,3,7,8 TeCDF	95.3	P	37Cl4-2,3,7,8-TeCDD	0.3
13C12-2,3,7,8 TeCDD	75.2	P	13C12-2,3,4,7,8-PCDF	0.4
13C12-1,2,3,7,8 PCDF	97.8	P	13C12-1,2,3,4,7,8-HxCDF	0
13C12-1,2,3,7,8 PCDD	101.7	P	13C12-1,2,3,4,7,8-HxCDD	0.0
13C12-1,2,3,6,7,8 HxCDF	73.7	P	13C12-1,2,3,4,7,8,9-HpCDF	0.3
13C12-1,2,3,6,7,8 HxCDD	82.2	P		
13C12-1,2,3,4,6,7,8 HpCDF	71.4	P		
13C12-1,2,3,4,6,7,8 HpCDD	78.3	P		
13C12-1,2,3,4,6,7,8,9 OCDD	58.3	P		

Isomer.	ng/Sample		ng/Sample
TeCDD Total	0.004	TeCDF Total	ND
PeCDD Total	ND	PeCDF Total	ND
HxCDD Total	ND	HxCDF Total	ND
HpCDD Total	ND	HpCDF Total	0.002
OCDD	0.002	OCDF	0.004

ND = not detected (S/N <2.5)
NS= not spiked
EMPC=Est. Max. Possible Concentration
Because this data is to be incorporated into further calculations it has not been reduced to the appropiate number of significant figures. For later reporting these data should be considered to have 2 significant figures.

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LABORATORY REPORT

October 28, 2016

Dennis Tabor
US Environmental Protection Agency (E-343-03)
Office of Research and Development
National Risk Management Research Laboratory
109 T.W. Alexander Drive
Research Traingle Park, NC 27711

Dear Dennis:

Enclosed are the results of the samples submitted to our laboratory on October 12, 2016. For your reference, these analyses have been assigned our service request number P1604824.

All analyses were performed according to our laboratory's NELAP and DoD-ELAP-approved quality assurance program. The test results meet requirements of the current NELAP and DoD-ELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP and DoD-ELAP-accredited analytes, refer to the certifications section at www.alsglobal.com. Results are intended to be considered in their entirety and apply only to the samples analyzed and reported herein.

If you have any questions, please call me at (805) 526-7161.

Respectfully submitted,

ALS | Environmental

By Sue Anderson at 10:37 am, Oct 28, 2016

Sue Anderson
Project Manager

2655 Park Center Dr., Suite A
Simi Valley, CA 93065
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www.alsglobal.com

Client: US Environmental Protection Agency (E-343-03) Service Request No: P1604824
Project:

CASE NARRATIVE

The samples were received intact under chain of custody on October 12, 2016 and were stored in accordance with the analytical method requirements. Please refer to the sample acceptance check form for additional information. The results reported herein are applicable only to the condition of the samples at the time of sample receipt.

Volatile Organic Compound Analysis

The samples were analyzed for volatile organic compounds in accordance with the methodology outlined in EPA Method TO-17. This procedure is described in laboratory SOP VOA-TO17. The analyses were performed by thermal desorption/gas chromatography/mass spectrometry. This analysis is included on the laboratory's NELAP and DoD-ELAP scope of accreditation, however it is not part of the AIHA-LAP, LLC accreditation.

The spike recovery of multiple analytes for the Laboratory Control Sample (LCS) and Duplicate Laboratory Control Sample (DLCS) analyzed on October 13, 2016 were outside the laboratory generated control criteria. The recovery errors equate to a potential high bias. However, the spike recovery of the analytes in question were within the method criteria; therefore, the data quality has not been significantly affected. No corrective action was taken.

The toluene result is estimated for sample PS-SW-VOC-100616-01 (P1604824-003) because the concentration exceeded the instrument calibration range by 140%. Insufficient sample remained for additional analysis.

The results of analyses are given in the attached laboratory report. All results are intended to be considered in their entirety, and ALS Environmental (ALS) is not responsible for utilization of less than the complete report.

Use of ALS Environmental (ALS)'s Name. Client shall not use ALS's name or trademark in any marketing or reporting materials, press releases or in any other manner ("Materials") whatsoever and shall not attribute to ALS any test result, tolerance or specification derived from ALS's data ("Attribution") without ALS's prior written consent, which may be withheld by ALS for any reason in its sole discretion. To request ALS's consent, Client shall provide copies of the proposed Materials or Attribution and describe in writing Client's proposed use of such Materials or Attribution. If ALS has not provided written approval of the Materials or Attribution within ten (10) days of receipt from Client, Client's request to use ALS's name or trademark in any Materials or Attribution shall be deemed denied. ALS may, in its discretion, reasonably charge Client for its time in reviewing Materials or Attribution requests. Client acknowledges and agrees that the unauthorized use of ALS's name or trademark may cause ALS to incur irreparable harm for which the recovery of money damages will be inadequate. Accordingly, Client acknowledges and agrees that a violation shall justify preliminary injunctive relief. For questions contact the laboratory.

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ALS Environmental – Simi Valley

CERTIFICATIONS, ACCREDITATIONS, AND REGISTRATIONS

Agency	Web Site	Number
AIHA-LAP, LLC	http://www.aihaaccreditedlabs.org	101661
Arizona DHS	http://www.azdhs.gov/lab/license/env.htm	AZ0694
PJLA (DoD ELAP)	http://www.pjlabs.com/search-accredited-labs	65818 (Testing)
Florida DOH (NELAP)	http://www.doh.state.fl.us/lab/EnvLabCert/WaterCert.htm	E871020
Maine DHHS	http://www.maine.gov/dhhs/mecdc/environmental-health/water/dwp-services/labcert/labcert.htm	2014025
Minnesota DOH (NELAP)	http://www.health.state.mn.us/accreditation	977273
New Jersey DEP (NELAP)	http://www.nj.gov/dep/oqa/	CA009
New York DOH (NELAP)	http://www.wadsworth.org/labcert/elap/elap.html	11221
Oregon PHD (NELAP)	http://public.health.oregon.gov/LaboratoryServices/EnvironmentalLaboratoryAccreditation/Pages/index.aspx	4068-003
Pennsylvania DEP	http://www.depweb.state.pa.us/labs	68-03307 (Registration)
Texas CEQ (NELAP)	http://www.tceq.texas.gov/field/qa/env_lab_accreditation.html	T104704413-16-7
Utah DOH (NELAP)	http://www.health.utah.gov/lab/labimp/certification/index.html	CA016272016-6
Washington DOE	http://www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html	C946

Analyses were performed according to our laboratory's NELAP and DoD-ELAP approved quality assurance program. A complete listing of specific NELAP and DoD-ELAP certified analytes can be found in the certifications section at www.alsglobal.com, or at the accreditation body's website.

Each of the certifications listed above have an explicit Scope of Accreditation that applies to specific matrices/methods/analytes; therefore, please contact the laboratory for information corresponding to a particular certification.

ALS ENVIRONMENTAL

DETAIL SUMMARY REPORT

Client: US Environmental Protection Agency (E-343-03) Service Request: P1604824

Date Received: 10/12/2016
Time Received: 10:05

Client Sample ID	Lab Code	Matrix	Date Collected	Time Collected	TO-17 - VOC Sorbent
PS-SW-VOC-093016-01	P1604824-001	Air	9/30/2016	00:00	X
PS-SW-VOC-093016-02	P1604824-002	Air	9/30/2016	00:00	X
PS-SW-VOC-100616-01	P1604824-003	Air	10/6/2016	00:00	X
PS-SW-VOC-100616-02	P1604824-004	Air	10/6/2016	00:00	X
BS-VOC-100616	P1604824-005	Air	10/6/2016	00:00	X
TS-VOC-101116	P1604824-006	Air	10/11/2016	00:00	X

ALS Environmental

Chain of Custody Record & Analytical Service Request

2655 Park Center Drive, Suite A
Simi Valley, California 93065
Phone: +1 805 526 7161 Fax: +1 805 526 7270

Requested Turnaround Time in Business Days (Surcharges) Please Circle:
1 Day (100%) 2 Day (75%) 3 Day (50%) 4 Day (35%) 5 Day (25%) 10 Day (Standard)

ALS Project No. P1604824

Company Name & Address (Reporting Information): US EPA, 4930 Old Page Road, Durham NC 27703

Project Name:

ALS Contact:

Project Number:

Project Manager: Dennis Tabor

P.O. # / Billing Information:

Phone: 919-541-2686

Fax:

Email Address for Result Reporting: tabor.dennis@epa.gov

Sampler (Print & Sign): Johanna Arell

Client Sample ID	Laboratory ID #	Tube ID	Date Collected	Sampling Pump Flow (mL/min)	Sampling Start Time	Sampling End Time	Sample Volume	Analysis Method/Analytes: TO-17		Comments e.g. Actual Preservative or specific instructions
PS-SW-VOC-093016-01	1	Mi176407	093016	250				X		
PS-SW-VOC-093016-02	2	Mi176404	093016	150			2.5 L	X		
PS-SW-VOC-100616-01	3	Mi176403	100616	0.2			2.1 L	X		
PS-SW-VOC-100616-02	4	Mi181524	100616	0.2			2.0 L	X		
BS-VOC-100616	5	Mi180767	100616	0.2			5.8 L	X		
TS-VOC-101116	6	Mi172447						X		Trip blank

Report Tier Levels - please select
Tier I - (Results/Default if not specified) _____
Tier II (Results + QC) _____
Tier III (Data Validation Package) 10% Surcharge _____
Tier IV (client specified) _____
EDD required Yes / No
Type: _____

Project Requirements (MRLs, QAPP): 3 gal

Relinquished by: (Signature)	Date	Time	Received by: (Signature)	Time
Johanna Arell	10/11/16	9:40	10/12/16	1085

Cooler / Blank Temperature _____ °C

ALS Environmental
Sample Acceptance Check Form

Client: US Environmental Protection Agency (E-343-03) Work order: P1604824

Project:

Sample(s) received on: 10/12/16 Date opened: 10/12/16 by: KKELPE

Note: This form is used for all samples received by ALS. The use of this form for custody seals is strictly meant to indicate presence/absence and not as an indication of compliance or nonconformity. Thermal preservation and pH will only be evaluated either at the request of the client and/or as required by the method/SOP.

		Yes	No	N/A
1	Were **sample containers** properly marked with client sample ID?	☒	☐	☐
2	Did **sample containers** arrive in good condition?	☒	☐	☐
3	Were **chain-of-custody** papers used and filled out?	☒	☐	☐
4	Did **sample container labels** and/or tags agree with custody papers?	☒	☐	☐
5	Was **sample volume** received adequate for analysis?	☒	☐	☐
6	Are samples within specified holding times?	☒	☐	☐
7	Was proper **temperature** (thermal preservation) of cooler at receipt adhered to?	☒	☐	☐
	Cooler Temperature: 3° C Blank Temperature: ° C **Gel Packs**			
8	Were **custody seals** on outside of cooler/Box/Container?	☐	☒	☐
	Location of seal(s)? Sealing Lid?	☐	☐	☒
	Were signature and date included?	☐	☐	☒
	Were seals intact?	☐	☐	☒
9	Do containers have appropriate **preservation**, according to method/SOP or Client specified information?	☐	☐	☒
	Is there a client indication that the submitted samples are **pH** preserved?	☐	☐	☒
	Were **VOA vials** checked for presence/absence of air bubbles?	☐	☐	☒
	Does the client/method/SOP require that the analyst check the sample pH and if necessary alter it?	☐	☐	☒
10	**Tubes:** Are the tubes capped and intact?	☒	☐	☐
11	**Badges:** Are the badges properly capped and intact?	☐	☐	☒
	Are dual bed badges separated and individually capped and intact?	☐	☐	☒

Lab Sample ID	Container Description	Required pH *	Received pH	Adjusted pH	VOA Headspace (Presence/Absence)	Receipt / Preservation Comments
P1604824-001.01	Tube, TD					
P1604824-002.01	Tube, TD					
P1604824-003.01	Tube, TD					
P1604824-004.01	Tube, TD					
P1604824-005.01	Tube, TD					
P1604824-006.01	Tube, TD					

Explain any discrepancies: (include lab sample ID numbers):

Collection times were not listed on the chain of custody or the sample bags.

RSK - MEEPP, HCL (pH<2); RSK - CO2, (pH 5-8); Sulfur (pH>4)

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **PS-SW-VOC-093016-01**

ALS Project ID: P1604824
ALS Sample ID: P1604824-001

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 9/30/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	**8.8**	1.0	0.12	NA	NA	NA	
74-87-3	Chloromethane	**3.8**	1.0	0.27	NA	NA	NA	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	**0.26**	1.0	0.16	NA	NA	NA	**J**
75-01-4	Vinyl Chloride	ND	1.0	0.14	NA	NA	NA	
106-99-0	1,3-Butadiene	**15**	1.1	0.28	NA	NA	NA	
75-00-3	Chloroethane	**2.4**	1.0	0.20	NA	NA	NA	
64-17-5	Ethanol	**13**	5.2	0.73	NA	NA	NA	
75-05-8	Acetonitrile	**31**	2.1	0.23	NA	NA	NA	
67-64-1	Acetone	**38**	5.3	1.9	NA	NA	NA	
75-69-4	Trichlorofluoromethane	**3.4**	1.0	0.079	NA	NA	NA	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	2.1	0.52	NA	NA	NA	
75-35-4	1,1-Dichloroethene	ND	1.1	0.17	NA	NA	NA	
75-09-2	Methylene Chloride	**2.9**	1.1	0.13	NA	NA	NA	
76-13-1	Trichlorotrifluoroethane	**1.8**	1.0	0.14	NA	NA	NA	
75-15-0	Carbon Disulfide	ND	5.3	0.80	NA	NA	NA	
156-60-5	trans-1,2-Dichloroethene	ND	1.1	0.12	NA	NA	NA	
75-34-3	1,1-Dichloroethane	ND	1.0	0.059	NA	NA	NA	
1634-04-4	Methyl tert-Butyl Ether	ND	1.1	0.070	NA	NA	NA	
78-93-3	2-Butanone (MEK)	**7.6**	1.0	0.20	NA	NA	NA	
156-59-2	cis-1,2-Dichloroethene	ND	1.1	0.093	NA	NA	NA	
110-54-3	n-Hexane	**1.6**	1.1	0.12	NA	NA	NA	
67-66-3	Chloroform	**0.14**	1.1	0.11	NA	NA	NA	**J**
109-99-9	Tetrahydrofuran (THF)	**0.54**	1.1	0.25	NA	NA	NA	**J**
107-06-2	1,2-Dichloroethane	ND	1.1	0.15	NA	NA	NA	
71-55-6	1,1,1-Trichloroethane	ND	1.1	0.12	NA	NA	NA	
71-43-2	Benzene	**170**	2.1	0.94	NA	NA	NA	
56-23-5	Carbon Tetrachloride	**1.7**	1.1	0.098	NA	NA	NA	
110-82-7	Cyclohexane	ND	2.1	0.18	NA	NA	NA	
78-87-5	1,2-Dichloropropane	ND	1.1	0.20	NA	NA	NA	
75-27-4	Bromodichloromethane	ND	1.1	0.095	NA	NA	NA	
79-01-6	Trichloroethene	ND	1.1	0.13	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **PS-SW-VOC-093016-01**

ALS Project ID: P1604824
ALS Sample ID: P1604824-001

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 9/30/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
123-91-1	1,4-Dioxane	ND	1.1	0.20	NA	NA	NA	
540-84-1	2,2,4-Trimethylpentane (Isooctane)	**0.54**	1.1	0.13	NA	NA	NA	**J**
142-82-5	n-Heptane	**4.0**	1.1	0.14	NA	NA	NA	
10061-01-5	cis-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
108-10-1	4-Methyl-2-pentanone	**0.77**	2.1	0.16	NA	NA	NA	**J**
10061-02-6	trans-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
79-00-5	1,1,2-Trichloroethane	ND	1.1	0.20	NA	NA	NA	
108-88-3	Toluene	**57**	1.1	0.47	NA	NA	NA	
591-78-6	2-Hexanone	ND	1.1	0.23	NA	NA	NA	
124-48-1	Dibromochloromethane	ND	1.1	0.068	NA	NA	NA	
106-93-4	1,2-Dibromoethane	ND	1.1	0.098	NA	NA	NA	
111-65-9	n-Octane	**11**	1.1	0.21	NA	NA	NA	
127-18-4	Tetrachloroethene	ND	1.1	0.12	NA	NA	NA	
108-90-7	Chlorobenzene	ND	1.1	0.084	NA	NA	NA	
100-41-4	Ethylbenzene	**13**	1.1	0.11	NA	NA	NA	
179601-23-1	m,p-Xylenes	**28**	2.1	0.17	NA	NA	NA	
75-25-2	Bromoform	ND	1.1	0.14	NA	NA	NA	
100-42-5	Styrene	**28**	1.1	0.078	NA	NA	NA	
95-47-6	o-Xylene	**12**	1.1	0.071	NA	NA	NA	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.1	0.14	NA	NA	NA	
98-82-8	Cumene	**2.7**	1.1	0.28	NA	NA	NA	
108-67-8	1,3,5-Trimethylbenzene	**6.4**	1.0	0.27	NA	NA	NA	
95-63-6	1,2,4-Trimethylbenzene	**23**	1.1	0.14	NA	NA	NA	
541-73-1	1,3-Dichlorobenzene	ND	1.1	0.15	NA	NA	NA	
106-46-7	1,4-Dichlorobenzene	ND	1.1	0.14	NA	NA	NA	
95-50-1	1,2-Dichlorobenzene	ND	1.1	0.17	NA	NA	NA	
96-12-8	1,2-Dibromo-3-chloropropane	ND	1.1	0.21	NA	NA	NA	
120-82-1	1,2,4-Trichlorobenzene	ND	1.0	0.41	NA	NA	NA	
91-20-3	Naphthalene	**80**	1.1	0.37	NA	NA	NA	
87-68-3	Hexachlorobutadiene	ND	1.1	0.30	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **PS-SW-VOC-093016-02**

ALS Project ID: P1604824
ALS Sample ID: P1604824-002

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 9/30/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	**5.1**	1.0	0.12	NA	NA	NA	
74-87-3	Chloromethane	**3.6**	1.0	0.27	NA	NA	NA	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	**0.18**	1.0	0.16	NA	NA	NA	**J**
75-01-4	Vinyl Chloride	ND	1.0	0.14	NA	NA	NA	
106-99-0	1,3-Butadiene	**4.6**	1.1	0.28	NA	NA	NA	
75-00-3	Chloroethane	**0.44**	1.0	0.20	NA	NA	NA	**J**
64-17-5	Ethanol	**3.2**	5.2	0.73	NA	NA	NA	**J**
75-05-8	Acetonitrile	**11**	2.1	0.23	NA	NA	NA	
67-64-1	Acetone	**18**	5.3	1.9	NA	NA	NA	
75-69-4	Trichlorofluoromethane	**1.4**	1.0	0.079	NA	NA	NA	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	2.1	0.52	NA	NA	NA	
75-35-4	1,1-Dichloroethene	ND	1.1	0.17	NA	NA	NA	
75-09-2	Methylene Chloride	**3.2**	1.1	0.13	NA	NA	NA	
76-13-1	Trichlorotrifluoroethane	**1.1**	1.0	0.14	NA	NA	NA	
75-15-0	Carbon Disulfide	ND	5.3	0.80	NA	NA	NA	
156-60-5	trans-1,2-Dichloroethene	ND	1.1	0.12	NA	NA	NA	
75-34-3	1,1-Dichloroethane	ND	1.0	0.059	NA	NA	NA	
1634-04-4	Methyl tert-Butyl Ether	ND	1.1	0.070	NA	NA	NA	
78-93-3	2-Butanone (MEK)	**4.1**	1.0	0.20	NA	NA	NA	
156-59-2	cis-1,2-Dichloroethene	ND	1.1	0.093	NA	NA	NA	
110-54-3	n-Hexane	**0.86**	1.1	0.12	NA	NA	NA	**J**
67-66-3	Chloroform	ND	1.1	0.11	NA	NA	NA	
109-99-9	Tetrahydrofuran (THF)	ND	1.1	0.25	NA	NA	NA	
107-06-2	1,2-Dichloroethane	ND	1.1	0.15	NA	NA	NA	
71-55-6	1,1,1-Trichloroethane	ND	1.1	0.12	NA	NA	NA	
71-43-2	Benzene	**120**	2.1	0.94	NA	NA	NA	
56-23-5	Carbon Tetrachloride	**1.1**	1.1	0.098	NA	NA	NA	
110-82-7	Cyclohexane	ND	2.1	0.18	NA	NA	NA	
78-87-5	1,2-Dichloropropane	ND	1.1	0.20	NA	NA	NA	
75-27-4	Bromodichloromethane	ND	1.1	0.095	NA	NA	NA	
79-01-6	Trichloroethene	ND	1.1	0.13	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **PS-SW-VOC-093016-02**

ALS Project ID: P1604824
ALS Sample ID: P1604824-002

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 9/30/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
123-91-1	1,4-Dioxane	ND	1.1	0.20	NA	NA	NA	
540-84-1	2,2,4-Trimethylpentane (Isooctane)	**0.29**	1.1	0.13	NA	NA	NA	**J**
142-82-5	n-Heptane	**1.3**	1.1	0.14	NA	NA	NA	
10061-01-5	cis-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
108-10-1	4-Methyl-2-pentanone	**0.91**	2.1	0.16	NA	NA	NA	**J**
10061-02-6	trans-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
79-00-5	1,1,2-Trichloroethane	**0.23**	1.1	0.20	NA	NA	NA	**J**
108-88-3	Toluene	**47**	1.1	0.47	NA	NA	NA	
591-78-6	2-Hexanone	**1.4**	1.1	0.23	NA	NA	NA	
124-48-1	Dibromochloromethane	ND	1.1	0.068	NA	NA	NA	
106-93-4	1,2-Dibromoethane	ND	1.1	0.098	NA	NA	NA	
111-65-9	n-Octane	**3.8**	1.1	0.21	NA	NA	NA	
127-18-4	Tetrachloroethene	ND	1.1	0.12	NA	NA	NA	
108-90-7	Chlorobenzene	ND	1.1	0.084	NA	NA	NA	
100-41-4	Ethylbenzene	**7.3**	1.1	0.11	NA	NA	NA	
179601-23-1	m,p-Xylenes	**14**	2.1	0.17	NA	NA	NA	
75-25-2	Bromoform	ND	1.1	0.14	NA	NA	NA	
100-42-5	Styrene	**20**	1.1	0.078	NA	NA	NA	
95-47-6	o-Xylene	**5.6**	1.1	0.071	NA	NA	NA	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.1	0.14	NA	NA	NA	
98-82-8	Cumene	**1.4**	1.1	0.28	NA	NA	NA	
108-67-8	1,3,5-Trimethylbenzene	**2.2**	1.0	0.27	NA	NA	NA	
95-63-6	1,2,4-Trimethylbenzene	**8.8**	1.1	0.14	NA	NA	NA	
541-73-1	1,3-Dichlorobenzene	ND	1.1	0.15	NA	NA	NA	
106-46-7	1,4-Dichlorobenzene	ND	1.1	0.14	NA	NA	NA	
95-50-1	1,2-Dichlorobenzene	ND	1.1	0.17	NA	NA	NA	
96-12-8	1,2-Dibromo-3-chloropropane	ND	1.1	0.21	NA	NA	NA	
120-82-1	1,2,4-Trichlorobenzene	ND	1.0	0.41	NA	NA	NA	
91-20-3	Naphthalene	**55**	1.1	0.37	NA	NA	NA	
87-68-3	Hexachlorobutadiene	ND	1.1	0.30	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **PS-SW-VOC-100616-01**

ALS Project ID: P1604824
ALS Sample ID: P1604824-003

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/6/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	**9.2**	1.0	0.12	NA	NA	NA	
74-87-3	Chloromethane	**8.1**	1.0	0.27	NA	NA	NA	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	**0.42**	1.0	0.16	NA	NA	NA	**J**
75-01-4	Vinyl Chloride	ND	1.0	0.14	NA	NA	NA	
106-99-0	1,3-Butadiene	**21**	1.1	0.28	NA	NA	NA	
75-00-3	Chloroethane	**1.2**	1.0	0.20	NA	NA	NA	
64-17-5	Ethanol	**23**	5.2	0.73	NA	NA	NA	
75-05-8	Acetonitrile	**26**	2.1	0.23	NA	NA	NA	
67-64-1	Acetone	**100**	5.3	1.9	NA	NA	NA	
75-69-4	Trichlorofluoromethane	**3.8**	1.0	0.079	NA	NA	NA	
67-63-0	2-Propanol (Isopropyl Alcohol)	**5.9**	2.1	0.52	NA	NA	NA	
75-35-4	1,1-Dichloroethene	ND	1.1	0.17	NA	NA	NA	
75-09-2	Methylene Chloride	**720**	1.1	0.13	NA	NA	NA	
76-13-1	Trichlorotrifluoroethane	**2.0**	1.0	0.14	NA	NA	NA	
75-15-0	Carbon Disulfide	**1.6**	5.3	0.80	NA	NA	NA	**J, B**
156-60-5	trans-1,2-Dichloroethene	ND	1.1	0.12	NA	NA	NA	
75-34-3	1,1-Dichloroethane	ND	1.0	0.059	NA	NA	NA	
1634-04-4	Methyl tert-Butyl Ether	ND	1.1	0.070	NA	NA	NA	
78-93-3	2-Butanone (MEK)	**7.9**	1.0	0.20	NA	NA	NA	
156-59-2	cis-1,2-Dichloroethene	ND	1.1	0.093	NA	NA	NA	
110-54-3	n-Hexane	**91**	1.1	0.12	NA	NA	NA	
67-66-3	Chloroform	**0.68**	1.1	0.11	NA	NA	NA	
109-99-9	Tetrahydrofuran (THF)	**1.1**	1.1	0.25	NA	NA	NA	
107-06-2	1,2-Dichloroethane	**0.15**	1.1	0.15	NA	NA	NA	**J**
71-55-6	1,1,1-Trichloroethane	ND	1.1	0.12	NA	NA	NA	
71-43-2	Benzene	**240**	2.1	0.94	NA	NA	NA	
56-23-5	Carbon Tetrachloride	**2.4**	1.1	0.098	NA	NA	NA	
110-82-7	Cyclohexane	**13**	2.1	0.18	NA	NA	NA	
78-87-5	1,2-Dichloropropane	**2.0**	1.1	0.20	NA	NA	NA	
75-27-4	Bromodichloromethane	ND	1.1	0.095	NA	NA	NA	
79-01-6	Trichloroethene	**0.42**	1.1	0.13	NA	NA	NA	**J**

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.
B = Analyte detected in both the sample and associated method blank.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **PS-SW-VOC-100616-01**

ALS Project ID: P1604824
ALS Sample ID: P1604824-003

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/6/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
123-91-1	1,4-Dioxane	**1.4**	1.1	0.20	NA	NA	NA	
540-84-1	2,2,4-Trimethylpentane (Isooctane)	**3.1**	1.1	0.13	NA	NA	NA	
142-82-5	n-Heptane	**7.6**	1.1	0.14	NA	NA	NA	
10061-01-5	cis-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
108-10-1	4-Methyl-2-pentanone	**1.8**	2.1	0.16	NA	NA	NA	
10061-02-6	trans-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
79-00-5	1,1,2-Trichloroethane	ND	1.1	0.20	NA	NA	NA	
108-88-3	Toluene	**1,400**	1.1	0.47	NA	NA	NA	**E**
591-78-6	2-Hexanone	ND	1.1	0.23	NA	NA	NA	
124-48-1	Dibromochloromethane	ND	1.1	0.068	NA	NA	NA	
106-93-4	1,2-Dibromoethane	ND	1.1	0.098	NA	NA	NA	
111-65-9	n-Octane	**30**	1.1	0.21	NA	NA	NA	
127-18-4	Tetrachloroethene	**1.9**	1.1	0.12	NA	NA	NA	
108-90-7	Chlorobenzene	**2.6**	1.1	0.084	NA	NA	NA	
100-41-4	Ethylbenzene	**22**	1.1	0.11	NA	NA	NA	
179601-23-1	m,p-Xylenes	**44**	2.1	0.17	NA	NA	NA	
75-25-2	Bromoform	ND	1.1	0.14	NA	NA	NA	
100-42-5	Styrene	**42**	1.1	0.078	NA	NA	NA	
95-47-6	o-Xylene	**13**	1.1	0.071	NA	NA	NA	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.1	0.14	NA	NA	NA	
98-82-8	Cumene	**2.4**	1.1	0.28	NA	NA	NA	
108-67-8	1,3,5-Trimethylbenzene	**4.4**	1.0	0.27	NA	NA	NA	
95-63-6	1,2,4-Trimethylbenzene	**18**	1.1	0.14	NA	NA	NA	
541-73-1	1,3-Dichlorobenzene	**0.17**	1.1	0.15	NA	NA	NA	**J**
106-46-7	1,4-Dichlorobenzene	**0.35**	1.1	0.14	NA	NA	NA	**J**
95-50-1	1,2-Dichlorobenzene	ND	1.1	0.17	NA	NA	NA	
96-12-8	1,2-Dibromo-3-chloropropane	ND	1.1	0.21	NA	NA	NA	
120-82-1	1,2,4-Trichlorobenzene	ND	1.0	0.41	NA	NA	NA	
91-20-3	Naphthalene	**120**	1.1	0.37	NA	NA	NA	
87-68-3	Hexachlorobutadiene	ND	1.1	0.30	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.
E = Estimated; concentration exceeded calibration range.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**
Client Sample ID: **PS-SW-VOC-100616-02**

ALS Project ID: P1604824
ALS Sample ID: P1604824-004

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/6/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	**4.3**	1.0	0.12	NA	NA	NA	
74-87-3	Chloromethane	**2.0**	1.0	0.27	NA	NA	NA	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	ND	1.0	0.16	NA	NA	NA	
75-01-4	Vinyl Chloride	ND	1.0	0.14	NA	NA	NA	
106-99-0	1,3-Butadiene	**20**	1.1	0.28	NA	NA	NA	
75-00-3	Chloroethane	ND	1.0	0.20	NA	NA	NA	
64-17-5	Ethanol	**3.1**	5.2	0.73	NA	NA	NA	**J**
75-05-8	Acetonitrile	**23**	2.1	0.23	NA	NA	NA	
67-64-1	Acetone	**37**	5.3	1.9	NA	NA	NA	
75-69-4	Trichlorofluoromethane	**1.3**	1.0	0.079	NA	NA	NA	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	2.1	0.52	NA	NA	NA	
75-35-4	1,1-Dichloroethene	ND	1.1	0.17	NA	NA	NA	
75-09-2	Methylene Chloride	**4.8**	1.1	0.13	NA	NA	NA	
76-13-1	Trichlorotrifluoroethane	**1.2**	1.0	0.14	NA	NA	NA	
75-15-0	Carbon Disulfide	ND	5.3	0.80	NA	NA	NA	
156-60-5	trans-1,2-Dichloroethene	ND	1.1	0.12	NA	NA	NA	
75-34-3	1,1-Dichloroethane	ND	1.0	0.059	NA	NA	NA	
1634-04-4	Methyl tert-Butyl Ether	ND	1.1	0.070	NA	NA	NA	
78-93-3	2-Butanone (MEK)	**8.5**	1.0	0.20	NA	NA	NA	
156-59-2	cis-1,2-Dichloroethene	ND	1.1	0.093	NA	NA	NA	
110-54-3	n-Hexane	**1.3**	1.1	0.12	NA	NA	NA	
67-66-3	Chloroform	**0.19**	1.1	0.11	NA	NA	NA	**J**
109-99-9	Tetrahydrofuran (THF)	**0.63**	1.1	0.25	NA	NA	NA	**J**
107-06-2	1,2-Dichloroethane	ND	1.1	0.15	NA	NA	NA	
71-55-6	1,1,1-Trichloroethane	ND	1.1	0.12	NA	NA	NA	
71-43-2	Benzene	**260**	2.1	0.94	NA	NA	NA	
56-23-5	Carbon Tetrachloride	**1.0**	1.1	0.098	NA	NA	NA	**J**
110-82-7	Cyclohexane	ND	2.1	0.18	NA	NA	NA	
78-87-5	1,2-Dichloropropane	ND	1.1	0.20	NA	NA	NA	
75-27-4	Bromodichloromethane	ND	1.1	0.095	NA	NA	NA	
79-01-6	Trichloroethene	ND	1.1	0.13	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **PS-SW-VOC-100616-02**

ALS Project ID: P1604824
ALS Sample ID: P1604824-004

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/6/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
123-91-1	1,4-Dioxane	**0.54**	1.1	0.20	NA	NA	NA	**J**
540-84-1	2,2,4-Trimethylpentane (Isooctane)	**0.47**	1.1	0.13	NA	NA	NA	**J**
142-82-5	n-Heptane	**2.8**	1.1	0.14	NA	NA	NA	
10061-01-5	cis-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
108-10-1	4-Methyl-2-pentanone	**0.42**	2.1	0.16	NA	NA	NA	**J**
10061-02-6	trans-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
79-00-5	1,1,2-Trichloroethane	ND	1.1	0.20	NA	NA	NA	
108-88-3	Toluene	**85**	1.1	0.47	NA	NA	NA	
591-78-6	2-Hexanone	ND	1.1	0.23	NA	NA	NA	
124-48-1	Dibromochloromethane	ND	1.1	0.068	NA	NA	NA	
106-93-4	1,2-Dibromoethane	ND	1.1	0.098	NA	NA	NA	
111-65-9	n-Octane	**8.2**	1.1	0.21	NA	NA	NA	
127-18-4	Tetrachloroethene	**0.14**	1.1	0.12	NA	NA	NA	**J**
108-90-7	Chlorobenzene	ND	1.1	0.084	NA	NA	NA	
100-41-4	Ethylbenzene	**15**	1.1	0.11	NA	NA	NA	
179601-23-1	m,p-Xylenes	**29**	2.1	0.17	NA	NA	NA	
75-25-2	Bromoform	ND	1.1	0.14	NA	NA	NA	
100-42-5	Styrene	**37**	1.1	0.078	NA	NA	NA	
95-47-6	o-Xylene	**12**	1.1	0.071	NA	NA	NA	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.1	0.14	NA	NA	NA	
98-82-8	Cumene	**2.4**	1.1	0.28	NA	NA	NA	
108-67-8	1,3,5-Trimethylbenzene	**5.5**	1.0	0.27	NA	NA	NA	
95-63-6	1,2,4-Trimethylbenzene	**20**	1.1	0.14	NA	NA	NA	
541-73-1	1,3-Dichlorobenzene	ND	1.1	0.15	NA	NA	NA	
106-46-7	1,4-Dichlorobenzene	ND	1.1	0.14	NA	NA	NA	
95-50-1	1,2-Dichlorobenzene	ND	1.1	0.17	NA	NA	NA	
96-12-8	1,2-Dibromo-3-chloropropane	ND	1.1	0.21	NA	NA	NA	
120-82-1	1,2,4-Trichlorobenzene	ND	1.0	0.41	NA	NA	NA	
91-20-3	Naphthalene	**120**	1.1	0.37	NA	NA	NA	
87-68-3	Hexachlorobutadiene	ND	1.1	0.30	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**
Client Sample ID: **BS-VOC-100616**

ALS Project ID: P1604824
ALS Sample ID: P1604824-005

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/6/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	**14**	1.0	0.12	NA	NA	NA	
74-87-3	Chloromethane	**0.31**	1.0	0.27	NA	NA	NA	**J**
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	**0.63**	1.0	0.16	NA	NA	NA	**J**
75-01-4	Vinyl Chloride	ND	1.0	0.14	NA	NA	NA	
106-99-0	1,3-Butadiene	ND	1.1	0.28	NA	NA	NA	
75-00-3	Chloroethane	ND	1.0	0.20	NA	NA	NA	
64-17-5	Ethanol	**1.8**	5.2	0.73	NA	NA	NA	**J**
75-05-8	Acetonitrile	**0.64**	2.1	0.23	NA	NA	NA	**J**
67-64-1	Acetone	**5.4**	5.3	1.9	NA	NA	NA	
75-69-4	Trichlorofluoromethane	**3.0**	1.0	0.079	NA	NA	NA	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	2.1	0.52	NA	NA	NA	
75-35-4	1,1-Dichloroethene	ND	1.1	0.17	NA	NA	NA	
75-09-2	Methylene Chloride	**2.1**	1.1	0.13	NA	NA	NA	
76-13-1	Trichlorotrifluoroethane	**3.2**	1.0	0.14	NA	NA	NA	
75-15-0	Carbon Disulfide	ND	5.3	0.80	NA	NA	NA	
156-60-5	trans-1,2-Dichloroethene	ND	1.1	0.12	NA	NA	NA	
75-34-3	1,1-Dichloroethane	ND	1.0	0.059	NA	NA	NA	
1634-04-4	Methyl tert-Butyl Ether	ND	1.1	0.070	NA	NA	NA	
78-93-3	2-Butanone (MEK)	**2.0**	1.0	0.20	NA	NA	NA	
156-59-2	cis-1,2-Dichloroethene	ND	1.1	0.093	NA	NA	NA	
110-54-3	n-Hexane	**1.7**	1.1	0.12	NA	NA	NA	
67-66-3	Chloroform	**0.15**	1.1	0.11	NA	NA	NA	**J**
109-99-9	Tetrahydrofuran (THF)	ND	1.1	0.25	NA	NA	NA	
107-06-2	1,2-Dichloroethane	ND	1.1	0.15	NA	NA	NA	
71-55-6	1,1,1-Trichloroethane	ND	1.1	0.12	NA	NA	NA	
71-43-2	Benzene	**1.7**	2.1	0.94	NA	NA	NA	**J**
56-23-5	Carbon Tetrachloride	**3.0**	1.1	0.098	NA	NA	NA	
110-82-7	Cyclohexane	ND	2.1	0.18	NA	NA	NA	
78-87-5	1,2-Dichloropropane	ND	1.1	0.20	NA	NA	NA	
75-27-4	Bromodichloromethane	**0.13**	1.1	0.095	NA	NA	NA	**J**
79-01-6	Trichloroethene	ND	1.1	0.13	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **BS-VOC-100616**

ALS Project ID: P1604824
ALS Sample ID: P1604824-005

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/6/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
123-91-1	1,4-Dioxane	ND	1.1	0.20	NA	NA	NA	
540-84-1	2,2,4-Trimethylpentane (Isooctane)	**0.91**	1.1	0.13	NA	NA	NA	**J**
142-82-5	n-Heptane	**0.85**	1.1	0.14	NA	NA	NA	**J**
10061-01-5	cis-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
108-10-1	4-Methyl-2-pentanone	**0.65**	2.1	0.16	NA	NA	NA	**J**
10061-02-6	trans-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
79-00-5	1,1,2-Trichloroethane	ND	1.1	0.20	NA	NA	NA	
108-88-3	Toluene	**13**	1.1	0.47	NA	NA	NA	
591-78-6	2-Hexanone	**0.35**	1.1	0.23	NA	NA	NA	**J**
124-48-1	Dibromochloromethane	ND	1.1	0.068	NA	NA	NA	
106-93-4	1,2-Dibromoethane	ND	1.1	0.098	NA	NA	NA	
111-65-9	n-Octane	**0.79**	1.1	0.21	NA	NA	NA	**J**
127-18-4	Tetrachloroethene	**0.27**	1.1	0.12	NA	NA	NA	**J**
108-90-7	Chlorobenzene	**0.10**	1.1	0.084	NA	NA	NA	**J**
100-41-4	Ethylbenzene	**0.70**	1.1	0.11	NA	NA	NA	**J**
179601-23-1	m,p-Xylenes	**2.2**	2.1	0.17	NA	NA	NA	
75-25-2	Bromoform	**0.15**	1.1	0.14	NA	NA	NA	**J**
100-42-5	Styrene	**0.25**	1.1	0.078	NA	NA	NA	**J**
95-47-6	o-Xylene	**0.86**	1.1	0.071	NA	NA	NA	**J**
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.1	0.14	NA	NA	NA	
98-82-8	Cumene	ND	1.1	0.28	NA	NA	NA	
108-67-8	1,3,5-Trimethylbenzene	ND	1.0	0.27	NA	NA	NA	
95-63-6	1,2,4-Trimethylbenzene	**0.93**	1.1	0.14	NA	NA	NA	**J**
541-73-1	1,3-Dichlorobenzene	ND	1.1	0.15	NA	NA	NA	
106-46-7	1,4-Dichlorobenzene	**0.17**	1.1	0.14	NA	NA	NA	**J**
95-50-1	1,2-Dichlorobenzene	ND	1.1	0.17	NA	NA	NA	
96-12-8	1,2-Dibromo-3-chloropropane	ND	1.1	0.21	NA	NA	NA	
120-82-1	1,2,4-Trichlorobenzene	ND	1.0	0.41	NA	NA	NA	
91-20-3	Naphthalene	**2.1**	1.1	0.37	NA	NA	NA	
87-68-3	Hexachlorobutadiene	ND	1.1	0.30	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **TS-VOC-101116**

ALS Project ID: P1604824
ALS Sample ID: P1604824-006

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/11/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	ND	1.0	0.12	NA	NA	NA	
74-87-3	Chloromethane	ND	1.0	0.27	NA	NA	NA	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	ND	1.0	0.16	NA	NA	NA	
75-01-4	Vinyl Chloride	ND	1.0	0.14	NA	NA	NA	
106-99-0	1,3-Butadiene	ND	1.1	0.28	NA	NA	NA	
75-00-3	Chloroethane	ND	1.0	0.20	NA	NA	NA	
64-17-5	Ethanol	**1.6**	5.2	0.73	NA	NA	NA	**J**
75-05-8	Acetonitrile	**0.49**	2.1	0.23	NA	NA	NA	**J**
67-64-1	Acetone	**2.8**	5.3	1.9	NA	NA	NA	**J**
75-69-4	Trichlorofluoromethane	ND	1.0	0.079	NA	NA	NA	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	2.1	0.52	NA	NA	NA	
75-35-4	1,1-Dichloroethene	ND	1.1	0.17	NA	NA	NA	
75-09-2	Methylene Chloride	ND	1.1	0.13	NA	NA	NA	
76-13-1	Trichlorotrifluoroethane	ND	1.0	0.14	NA	NA	NA	
75-15-0	Carbon Disulfide	ND	5.3	0.80	NA	NA	NA	
156-60-5	trans-1,2-Dichloroethene	ND	1.1	0.12	NA	NA	NA	
75-34-3	1,1-Dichloroethane	ND	1.0	0.059	NA	NA	NA	
1634-04-4	Methyl tert-Butyl Ether	ND	1.1	0.070	NA	NA	NA	
78-93-3	2-Butanone (MEK)	ND	1.0	0.20	NA	NA	NA	
156-59-2	cis-1,2-Dichloroethene	ND	1.1	0.093	NA	NA	NA	
110-54-3	n-Hexane	ND	1.1	0.12	NA	NA	NA	
67-66-3	Chloroform	ND	1.1	0.11	NA	NA	NA	
109-99-9	Tetrahydrofuran (THF)	ND	1.1	0.25	NA	NA	NA	
107-06-2	1,2-Dichloroethane	ND	1.1	0.15	NA	NA	NA	
71-55-6	1,1,1-Trichloroethane	ND	1.1	0.12	NA	NA	NA	
71-43-2	Benzene	ND	2.1	0.94	NA	NA	NA	
56-23-5	Carbon Tetrachloride	ND	1.1	0.098	NA	NA	NA	
110-82-7	Cyclohexane	ND	2.1	0.18	NA	NA	NA	
78-87-5	1,2-Dichloropropane	ND	1.1	0.20	NA	NA	NA	
75-27-4	Bromodichloromethane	ND	1.1	0.095	NA	NA	NA	
79-01-6	Trichloroethene	ND	1.1	0.13	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **TS-VOC-101116**

ALS Project ID: P1604824
ALS Sample ID: P1604824-006

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: 10/11/16
Date Received: 10/12/16
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
123-91-1	1,4-Dioxane	ND	1.1	0.20	NA	NA	NA	
540-84-1	2,2,4-Trimethylpentane (Isooctane)	ND	1.1	0.13	NA	NA	NA	
142-82-5	n-Heptane	ND	1.1	0.14	NA	NA	NA	
10061-01-5	cis-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
108-10-1	4-Methyl-2-pentanone	ND	2.1	0.16	NA	NA	NA	
10061-02-6	trans-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
79-00-5	1,1,2-Trichloroethane	ND	1.1	0.20	NA	NA	NA	
108-88-3	Toluene	ND	1.1	0.47	NA	NA	NA	
591-78-6	2-Hexanone	ND	1.1	0.23	NA	NA	NA	
124-48-1	Dibromochloromethane	ND	1.1	0.068	NA	NA	NA	
106-93-4	1,2-Dibromoethane	ND	1.1	0.098	NA	NA	NA	
111-65-9	n-Octane	ND	1.1	0.21	NA	NA	NA	
127-18-4	Tetrachloroethene	ND	1.1	0.12	NA	NA	NA	
108-90-7	Chlorobenzene	ND	1.1	0.084	NA	NA	NA	
100-41-4	Ethylbenzene	ND	1.1	0.11	NA	NA	NA	
179601-23-1	m,p-Xylenes	ND	2.1	0.17	NA	NA	NA	
75-25-2	Bromoform	ND	1.1	0.14	NA	NA	NA	
100-42-5	Styrene	ND	1.1	0.078	NA	NA	NA	
95-47-6	o-Xylene	ND	1.1	0.071	NA	NA	NA	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.1	0.14	NA	NA	NA	
98-82-8	Cumene	ND	1.1	0.28	NA	NA	NA	
108-67-8	1,3,5-Trimethylbenzene	ND	1.0	0.27	NA	NA	NA	
95-63-6	1,2,4-Trimethylbenzene	ND	1.1	0.14	NA	NA	NA	
541-73-1	1,3-Dichlorobenzene	ND	1.1	0.15	NA	NA	NA	
106-46-7	1,4-Dichlorobenzene	ND	1.1	0.14	NA	NA	NA	
95-50-1	1,2-Dichlorobenzene	ND	1.1	0.17	NA	NA	NA	
96-12-8	1,2-Dibromo-3-chloropropane	ND	1.1	0.21	NA	NA	NA	
120-82-1	1,2,4-Trichlorobenzene	ND	1.0	0.41	NA	NA	NA	
91-20-3	Naphthalene	ND	1.1	0.37	NA	NA	NA	
87-68-3	Hexachlorobutadiene	ND	1.1	0.30	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **Method Blank**

ALS Project ID: P1604824
ALS Sample ID: P161013-MB

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	ND	1.0	0.12	NA	NA	NA	
74-87-3	Chloromethane	ND	1.0	0.27	NA	NA	NA	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	ND	1.0	0.16	NA	NA	NA	
75-01-4	Vinyl Chloride	ND	1.0	0.14	NA	NA	NA	
106-99-0	1,3-Butadiene	ND	1.1	0.28	NA	NA	NA	
75-00-3	Chloroethane	ND	1.0	0.20	NA	NA	NA	
64-17-5	Ethanol	ND	5.2	0.73	NA	NA	NA	
75-05-8	Acetonitrile	ND	2.1	0.23	NA	NA	NA	
67-64-1	Acetone	ND	5.3	1.9	NA	NA	NA	
75-69-4	Trichlorofluoromethane	ND	1.0	0.079	NA	NA	NA	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	2.1	0.52	NA	NA	NA	
75-35-4	1,1-Dichloroethene	ND	1.1	0.17	NA	NA	NA	
75-09-2	Methylene Chloride	ND	1.1	0.13	NA	NA	NA	
76-13-1	Trichlorotrifluoroethane	ND	1.0	0.14	NA	NA	NA	
75-15-0	Carbon Disulfide	**0.92**	5.3	0.80	NA	NA	NA	**J**
156-60-5	trans-1,2-Dichloroethene	ND	1.1	0.12	NA	NA	NA	
75-34-3	1,1-Dichloroethane	ND	1.0	0.059	NA	NA	NA	
1634-04-4	Methyl tert-Butyl Ether	ND	1.1	0.070	NA	NA	NA	
78-93-3	2-Butanone (MEK)	ND	1.0	0.20	NA	NA	NA	
156-59-2	cis-1,2-Dichloroethene	ND	1.1	0.093	NA	NA	NA	
110-54-3	n-Hexane	ND	1.1	0.12	NA	NA	NA	
67-66-3	Chloroform	ND	1.1	0.11	NA	NA	NA	
109-99-9	Tetrahydrofuran (THF)	ND	1.1	0.25	NA	NA	NA	
107-06-2	1,2-Dichloroethane	ND	1.1	0.15	NA	NA	NA	
71-55-6	1,1,1-Trichloroethane	ND	1.1	0.12	NA	NA	NA	
71-43-2	Benzene	ND	2.1	0.94	NA	NA	NA	
56-23-5	Carbon Tetrachloride	ND	1.1	0.098	NA	NA	NA	
110-82-7	Cyclohexane	ND	2.1	0.18	NA	NA	NA	
78-87-5	1,2-Dichloropropane	ND	1.1	0.20	NA	NA	NA	
75-27-4	Bromodichloromethane	ND	1.1	0.095	NA	NA	NA	
79-01-6	Trichloroethene	ND	1.1	0.13	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.
J = The result is an estimated concentration that is less than the MRL but greater than or equal to the MDL.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Client: **US Environmental Protection Agency (E-343-03)**

Client Sample ID: **Method Blank**

ALS Project ID: P1604824
ALS Sample ID: P161013-MB

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Result ng/Tube	MRL ng/Tube	MDL ng/Tube	Result µg/m³	MRL µg/m³	MDL µg/m³	Data Qualifier
123-91-1	1,4-Dioxane	ND	1.1	0.20	NA	NA	NA	
540-84-1	2,2,4-Trimethylpentane (Isooctane)	ND	1.1	0.13	NA	NA	NA	
142-82-5	n-Heptane	ND	1.1	0.14	NA	NA	NA	
10061-01-5	cis-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
108-10-1	4-Methyl-2-pentanone	ND	2.1	0.16	NA	NA	NA	
10061-02-6	trans-1,3-Dichloropropene	ND	1.1	0.11	NA	NA	NA	
79-00-5	1,1,2-Trichloroethane	ND	1.1	0.20	NA	NA	NA	
108-88-3	Toluene	ND	1.1	0.47	NA	NA	NA	
591-78-6	2-Hexanone	ND	1.1	0.23	NA	NA	NA	
124-48-1	Dibromochloromethane	ND	1.1	0.068	NA	NA	NA	
106-93-4	1,2-Dibromoethane	ND	1.1	0.098	NA	NA	NA	
111-65-9	n-Octane	ND	1.1	0.21	NA	NA	NA	
127-18-4	Tetrachloroethene	ND	1.1	0.12	NA	NA	NA	
108-90-7	Chlorobenzene	ND	1.1	0.084	NA	NA	NA	
100-41-4	Ethylbenzene	ND	1.1	0.11	NA	NA	NA	
179601-23-1	m,p-Xylenes	ND	2.1	0.17	NA	NA	NA	
75-25-2	Bromoform	ND	1.1	0.14	NA	NA	NA	
100-42-5	Styrene	ND	1.1	0.078	NA	NA	NA	
95-47-6	o-Xylene	ND	1.1	0.071	NA	NA	NA	
79-34-5	1,1,2,2-Tetrachloroethane	ND	1.1	0.14	NA	NA	NA	
98-82-8	Cumene	ND	1.1	0.28	NA	NA	NA	
108-67-8	1,3,5-Trimethylbenzene	ND	1.0	0.27	NA	NA	NA	
95-63-6	1,2,4-Trimethylbenzene	ND	1.1	0.14	NA	NA	NA	
541-73-1	1,3-Dichlorobenzene	ND	1.1	0.15	NA	NA	NA	
106-46-7	1,4-Dichlorobenzene	ND	1.1	0.14	NA	NA	NA	
95-50-1	1,2-Dichlorobenzene	ND	1.1	0.17	NA	NA	NA	
96-12-8	1,2-Dibromo-3-chloropropane	ND	1.1	0.21	NA	NA	NA	
120-82-1	1,2,4-Trichlorobenzene	ND	1.0	0.41	NA	NA	NA	
91-20-3	Naphthalene	ND	1.1	0.37	NA	NA	NA	
87-68-3	Hexachlorobutadiene	ND	1.1	0.30	NA	NA	NA	

ND = Compound was analyzed for, but not detected above the laboratory detection limit.
MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

SURROGATE SPIKE RECOVERY RESULTS

Client: **US Environmental Protection Agency (E-343-03)**

ALS Project ID: P1604824

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube(s)
Test Notes:

Date(s) Collected: 9/30 - 10/11/16
Date(s) Received: 10/12/16
Date(s) Analyzed: 10/13/16

Client Sample ID	ALS Sample ID	1,2-Dichloroethane-d4 % Recovered	Acceptance Limits	Toluene-d8 % Recovered	Acceptance Limits	Bromofluorobenzene % Recovered	Acceptance Limits	Data Qualifier
Method Blank	P161013-MB	**90**	70-140	**100**	70-140	**101**	70-140	
Lab Control Sample	P161013-LCS	**99**	70-140	**99**	70-140	**106**	70-140	
Duplicate Lab Control Sample	P161013-DLCS	**104**	70-140	**98**	70-140	**107**	70-140	
PS-SW-VOC-093016-01	P1604824-001	**95**	70-140	**100**	70-140	**104**	70-140	
PS-SW-VOC-093016-02	P1604824-002	**87**	70-140	**100**	70-140	**102**	70-140	
PS-SW-VOC-100616-01	P1604824-003	**85**	70-140	**99**	70-140	**103**	70-140	
PS-SW-VOC-100616-02	P1604824-004	**86**	70-140	**98**	70-140	**104**	70-140	
BS-VOC-100616	P1604824-005	**86**	70-140	**99**	70-140	**102**	70-140	
TS-VOC-101116	P1604824-006	**91**	70-140	**99**	70-140	**103**	70-140	

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE / DUPLICATE LABORATORY CONTROL SAMPLE SUMMARY

Client: **US Environmental Protection Agency (E-343-03)**
Client Sample ID: **Duplicate Lab Control Sample**

ALS Project ID: P1604824
ALS Sample ID: P161013-DLCS

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Spike Amount LCS / DLCS ng	Result LCS ng	Result DLCS ng	% Recovery LCS	% Recovery DLCS	ALS Acceptance Limits	RPD	RPD Limit	Data Qualifier
75-71-8	Dichlorodifluoromethane (CFC 12)	52.5	52.3	56.6	**100**	**108**	73-120	8	25	
74-87-3	Chloromethane	52.5	53.6	58.2	**102**	**111**	69-120	8	25	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	52.8	53.5	57.2	**101**	**108**	79-112	7	25	
75-01-4	Vinyl Chloride	52.5	54.5	57.9	**104**	**110**	75-119	6	25	
106-99-0	1,3-Butadiene	52.5	61.5	58.9	**117**	**112**	77-118	4	25	
75-00-3	Chloroethane	52.5	55.8	58.3	**106**	**111**	75-120	5	25	
64-17-5	Ethanol	265	278	282	**105**	**106**	72-120	0.9	25	
75-05-8	Acetonitrile	53.3	53.8	56.2	**101**	**105**	66-115	4	25	
67-64-1	Acetone	266	277	277	**104**	**104**	70-110	0	25	
75-69-4	Trichlorofluoromethane	52.6	53.1	56.1	**101**	**107**	70-103	6	25	**L**
67-63-0	2-Propanol (Isopropyl Alcohol)	106	116	117	**109**	**110**	75-123	0.9	25	
75-35-4	1,1-Dichloroethene	53.2	54.9	58.2	**103**	**109**	79-111	6	25	
75-09-2	Methylene Chloride	53.1	53.1	57.4	**100**	**108**	75-106	8	25	**L**
76-13-1	Trichlorotrifluoroethane	52.9	54.1	57.3	**102**	**108**	65-127	6	25	
75-15-0	Carbon Disulfide	53.4	52.6	54.3	**99**	**102**	53-100	3	25	**L**
156-60-5	trans-1,2-Dichloroethene	53.4	56.7	60.5	**106**	**113**	78-119	6	25	
75-34-3	1,1-Dichloroethane	53.1	55.3	57.9	**104**	**109**	76-118	5	25	
1634-04-4	Methyl tert-Butyl Ether	53.2	58.9	62.7	**111**	**118**	81-120	6	25	
78-93-3	2-Butanone (MEK)	53.1	67.0	71.1	**126**	**134**	88-138	6	25	
156-59-2	cis-1,2-Dichloroethene	53.0	56.5	59.6	**107**	**112**	78-119	5	25	
110-54-3	n-Hexane	53.2	54.8	58.2	**103**	**109**	75-114	6	25	
67-66-3	Chloroform	53.0	56.0	56.9	**106**	**107**	73-115	0.9	25	
109-99-9	Tetrahydrofuran (THF)	53.2	60.3	60.3	**113**	**113**	80-119	0	25	
107-06-2	1,2-Dichloroethane	53.0	56.1	59.1	**106**	**112**	71-131	6	25	
71-55-6	1,1,1-Trichloroethane	53.0	57.7	56.9	**109**	**107**	79-116	2	25	
71-43-2	Benzene	53.1	47.7	47.8	**90**	**90**	68-99	0	25	
56-23-5	Carbon Tetrachloride	53.2	58.5	57.7	**110**	**108**	78-114	2	25	
110-82-7	Cyclohexane	106	110	110	**104**	**104**	77-113	0	25	
78-87-5	1,2-Dichloropropane	53.1	56.9	56.6	**107**	**107**	78-114	0	25	
75-27-4	Bromodichloromethane	53.4	62.1	61.7	**116**	**116**	85-121	0	25	
79-01-6	Trichloroethene	53.1	54.5	56.1	**103**	**106**	78-102	3	25	**L**

L = Laboratory control sample recovery outside the specified limits, results may be biased high.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE / DUPLICATE LABORATORY CONTROL SAMPLE SUMMARY

Client: **US Environmental Protection Agency (E-343-03)**
Client Sample ID: **Duplicate Lab Control Sample**

ALS Project ID: P1604824
ALS Sample ID: P161013-DLCS

Test Code: EPA TO-17
Instrument ID: Markes ATD/Agilent 5975Cinert/7890A/MS18
Analyst: Rui Malinowski
Sampling Media: TD Carbo 300 Sorbent Tube
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 10/13/16
Volume(s) Analyzed: NA Liter(s)

CAS #	Compound	Spike Amount LCS / DLCS ng	Result LCS ng	Result DLCS ng	% Recovery LCS	% Recovery DLCS	ALS Acceptance Limits	RPD	RPD Limit	Data Qualifier
123-91-1	1,4-Dioxane	53.2	58.3	57.9	**110**	**109**	85-117	0.9	25	
540-84-1	2,2,4-Trimethylpentane (Isooctane)	53.1	54.7	54.5	**103**	**103**	74-110	0	25	
142-82-5	n-Heptane	53.2	56.4	57.5	**106**	**108**	82-109	2	25	
10061-01-5	cis-1,3-Dichloropropene	52.6	61.7	59.1	**117**	**112**	86-117	4	25	
108-10-1	4-Methyl-2-pentanone	53.2	60.9	60.4	**114**	**114**	85-114	0	25	
10061-02-6	trans-1,3-Dichloropropene	53.4	63.1	61.2	**118**	**115**	83-123	3	25	
79-00-5	1,1,2-Trichloroethane	53.1	58.1	57.1	**109**	**108**	84-107	0.9	25	**L**
108-88-3	Toluene	52.9	55.1	55.2	**104**	**104**	78-102	0	25	**L**
591-78-6	2-Hexanone	53.2	59.6	58.1	**112**	**109**	82-121	3	25	
124-48-1	Dibromochloromethane	53.2	58.2	57.1	**109**	**107**	84-110	2	25	
106-93-4	1,2-Dibromoethane	52.9	60.3	59.9	**114**	**113**	85-111	0.9	25	**L**
111-65-9	n-Octane	53.0	52.5	53.5	**99**	**101**	75-118	2	25	
127-18-4	Tetrachloroethene	53.2	54.0	55.5	**102**	**104**	81-109	2	25	
108-90-7	Chlorobenzene	53.0	53.8	54.7	**102**	**103**	82-108	1	25	
100-41-4	Ethylbenzene	52.9	54.1	55.5	**102**	**105**	81-112	3	25	
179601-23-1	m,p-Xylenes	106	109	111	**103**	**105**	83-111	2	25	
75-25-2	Bromoform	53.1	55.0	55.1	**104**	**104**	73-103	0	25	**L**
100-42-5	Styrene	53.0	57.3	58.1	**108**	**110**	85-113	2	25	
95-47-6	o-Xylene	52.9	54.1	55.7	**102**	**105**	82-112	3	25	
79-34-5	1,1,2,2-Tetrachloroethane	53.0	58.0	58.0	**109**	**109**	79-115	0	25	
98-82-8	Cumene	53.1	54.0	55.4	**102**	**104**	81-110	2	25	
108-67-8	1,3,5-Trimethylbenzene	53.1	54.3	55.6	**102**	**105**	81-111	3	25	
95-63-6	1,2,4-Trimethylbenzene	53.1	55.4	56.4	**104**	**106**	80-111	2	25	
541-73-1	1,3-Dichlorobenzene	53.0	55.3	57.6	**104**	**109**	73-112	5	25	
106-46-7	1,4-Dichlorobenzene	53.3	53.8	55.9	**101**	**105**	75-119	4	25	
95-50-1	1,2-Dichlorobenzene	53.1	54.9	56.5	**103**	**106**	74-112	3	25	
96-12-8	1,2-Dibromo-3-chloropropane	53.0	64.7	63.1	**122**	**119**	63-135	2	25	
120-82-1	1,2,4-Trichlorobenzene	53.0	58.0	60.6	**109**	**114**	53-127	4	25	
91-20-3	Naphthalene	53.4	61.0	62.9	**114**	**118**	52-130	3	25	
87-68-3	Hexachlorobutadiene	53.2	54.0	55.1	**102**	**104**	58-113	2	25	

L = Laboratory control sample recovery outside the specified limits, results may be biased high.

Response Factor Report GCMS18

Method Path : I:\MS18\METHODS\
Method File : F18101216.M
Title : EPA TO-17 per SOP VOA-TO17 (CASS TO-17/GC-MS)
Last Update : Thu Oct 20 09:15:10 2016
Response Via : Initial Calibration

RM 10/20/16

Calibration Files
1.0 =10121602.D 2.0 =10121603.D 5.0 =10121604.D 10 =10121605.D 50 =10121606.D 100 =10121607.D 500 =10121608.D
1000=10121609.D

		Compound	1.0	2.0	5.0	10	50	100	500	1000	Avg	%RSD
1)	IR	Bromochloromethane...	----------ISTD----------									
2)	T	Propene	1.367	1.362	1.126	1.117	0.876	0.935	0.856	0.876	1.064	20.02
3)	T	Dichlorodifluo...	1.543	1.610	1.758	1.792	1.502	1.576	1.435	1.380	1.575	9.16
4)	T	Chloromethane	1.268	1.364	1.338	1.394	1.159	1.239	1.132	1.087	1.247	9.13
5)	T	Freon 114	0.983	0.993	1.017	1.000	0.864	0.907	0.789	0.738	0.911	11.59
6)	T	Vinyl Chloride	1.236	1.219	1.375	1.445	1.205	1.260	1.195	1.163	1.262	7.73
7)	T	1,3-Butadiene	1.077	0.855	1.055	1.109	1.042	0.945	0.944	0.836	0.983	10.47
8)	T	Bromomethane	0.973	0.832	0.634	0.618	0.635	0.640	0.612	0.541	0.686	20.76
9)	T	Chloroethane	0.625	0.646	0.677	0.684	0.619	0.644	0.611	0.585	0.636	5.28
10)	T	Ethanol	0.664	0.653	0.632	0.712	0.621	0.641	0.621	0.600	0.643	5.35
11)	T	Acetonitrile	1.734	1.786	1.779	1.923	1.619	1.692	1.600	1.547	1.710	7.12
12)	T	Acrolein	0.521	0.649	0.595	0.577	0.492	0.494	0.451	0.432	0.526	14.19
13)	T	Acetone	0.816	0.771	0.661	0.679	0.584	0.557	0.494	0.458	0.627	20.26
14)	T	Trichlorofluor...	1.717	1.601	1.696	1.737	1.439	1.473	1.346	1.213	1.528	12.52
15)	T	Isopropanol	2.164	2.268	2.442	2.519	2.210	2.173	1.991	1.856	2.203	9.84
16)	T	Acrylonitrile	0.752	0.733	1.120	1.300	1.069	1.124	1.051	1.019	1.021	18.76
17)	T	1,1-Dichloroet...	0.865	0.893	0.899	0.936	0.783	0.806	0.791	0.775	0.844	7.38
18)	T	tert-Butanol	2.289	2.299	2.476	2.693	2.351	2.302	1.337	1.115	2.108	26.75
19)	T	Methylene Chlo...	0.883	0.901	0.942	0.964	0.757	0.800	0.741	0.724	0.839	11.32
20)	T	Allyl Chloride	1.339	1.444	1.340	1.342	1.267	1.192	1.165	1.010	1.262	10.77
21)	T	Trichlorotrifl...	0.978	0.914	0.856	0.914	0.740	0.776	0.708	0.648	0.817	14.20
22)	T	Carbon Disulfide		3.949	3.786	3.666	3.013	3.070	2.864	2.674	3.289	15.25
23)	T	trans-1,2-Dich...	1.205	1.252	1.350	1.480	1.253	1.275	1.203	1.122	1.267	8.53
24)	T	1,1-Dichloroet...	1.577	1.699	1.764	1.795	1.539	1.563	1.478	1.377	1.599	9.01
25)	T	Methyl tert-Bu...	2.729	2.923	2.997	3.130	2.593	2.758	2.253	1.697	2.635	17.63
26)	T	2-Butanone	0.425	0.492	0.528	0.641	0.578	0.609	0.370		0.520	18.95
27)	T	cis-1,2-Dichlo...	1.145	1.283	1.320	1.376	1.161	1.206	1.137	1.069	1.212	8.65
28)	T	n-Hexane	1.580	1.757	1.772	1.899	1.558	1.618	1.519	1.450	1.644	9.19
29)	T	Chloroform	1.657	1.605	1.627	1.671	1.404	1.324	1.344	1.272	1.488	11.25
30)	S	1,2-Dichloroet...	1.669	1.772	1.765	1.822	1.745	1.770	1.566	1.290	1.675	10.42
31)	T	Tetrahydrofuran	0.527	0.574	0.661	0.669	0.538	0.513	0.477	0.462	0.552	14.05
32)	T	Ethyl tert-But...	1.087	1.125	1.157	1.226	1.046	1.096	1.057	0.995	1.099	6.49
33)	T	1,2-Dichloroet...	1.135	1.247	1.304	1.352	1.134	1.141	0.990	0.847	1.144	14.45
34)	IR	1,4-Difluorobenzen...	----------ISTD----------									
35)	T	1,1,1-Trichlor...	0.318	0.319	0.331	0.337	0.288	0.290	0.260	0.238	0.298	11.87
36)	T	1-Butanol			0.158	0.201	0.209	0.208	0.214	0.209	0.200	10.53
37)	T	Benzene	1.412	1.159	0.949	0.890	0.723	0.731	0.721	0.736	0.915	27.65
38)	T	Carbon Tetrach...	0.280	0.259	0.300	0.304	0.264	0.263	0.217	0.159	0.256	18.69
39)	T	Cyclohexane	0.355	0.333	0.334	0.336	0.288	0.290	0.286	0.285	0.313	9.16
40)	T	tert-Amyl Meth...	0.628	0.589	0.612	0.616	0.538	0.543	0.554	0.571	0.581	6.02
41)	T	1,2-Dichloropr...	0.219	0.206	0.221	0.233	0.199	0.200	0.199	0.192	0.209	6.74
42)	T	Bromodichlorom...	0.271	0.258	0.273	0.284	0.257	0.257	0.204	0.151	0.245	18.21

Method Path : I:\MS18\METHODS\
Method File : F18101216.M
Title : EPA TO-17 per SOP VOA-TO17 (CASS TO-17/GC-MS)

43)	T	Trichloroethene	0.237	0.235	0.243	0.258	0.208	0.215	0.213	0.219	0.229	7.75
44)	T	1,4-Dioxane	0.148	0.152	0.169	0.173	0.152	0.153	0.153	0.159	0.157	5.73
45)	T	Isooctane	0.898	0.860	0.906	0.930	0.792	0.798	0.812	0.833	0.854	6.21
46)	T	n-Heptane	0.211	0.222	0.241	0.251	0.214	0.220	0.216	0.221	0.224	6.28
47)	T	cis-1,3-Dichlo...	0.262	0.312	0.309	0.320	0.312	0.313	0.315	0.254	0.300	8.64
48)	T	4-Methyl-2-pen...	0.163	0.150	0.183	0.200	0.190	0.193	0.201	0.206	0.186	10.64
49)	T	trans-1,3-Dich...	0.198	0.228	0.262	0.282	0.276	0.284	0.302	0.276	0.263	12.98
50)	T	1,1,2-Trichlor...	0.177	0.179	0.190	0.212	0.185	0.185	0.192	0.197	0.190	5.93
51)	S	Toluene-d8 (SS2)	1.196	1.209	1.219	1.239	1.260	1.238	1.296	1.283	1.242	2.84
52)	T	Toluene	0.847	0.885	0.872	0.895	0.777	0.781	0.806	0.815	0.835	5.57
53)	T	2-Hexanone		0.392	0.441	0.498	0.484	0.485	0.514	0.536	0.479	10.06
54)	T	Dibromochlorom...	0.198	0.217	0.226	0.238	0.217	0.222	0.235	0.212	0.221	5.81
55)	T	1,2-Dibromoethane	0.174	0.175	0.198	0.210	0.199	0.203	0.215	0.213	0.198	8.03
56)	IR	Chlorobenzene-d5 (...	----------ISTD----------									
57)		n-Octane	0.287	0.233	0.244	0.233	0.197	0.200	0.192	0.193	0.223	14.95
58)	T	Tetrachloroethene	0.306	0.276	0.291	0.293	0.244	0.248	0.241	0.248	0.269	9.75
59)	T	Chlorobenzene	0.710	0.630	0.658	0.649	0.535	0.545	0.534	0.557	0.602	11.22
60)	T	Ethylbenzene	1.144	1.115	1.141	1.143	0.944	0.967	0.947	0.959	1.045	9.36
61)	T	m- & p-Xylene	0.875	0.842	0.862	0.858	0.721	0.738	0.722	0.733	0.794	8.91
62)	T	Bromoform	0.196	0.201	0.207	0.218	0.195	0.207	0.211	0.221	0.207	4.63
63)	T	Styrene	0.578	0.569	0.605	0.641	0.559	0.583	0.584	0.619	0.592	4.62
64)	T	o-Xylene	0.854	0.876	0.889	0.888	0.742	0.759	0.731	0.739	0.810	8.98
65)	T	n-Nonane	0.619	0.577	0.577	0.592	0.496	0.502	0.478	0.471	0.539	10.79
66)	T	1,1,2,2-Tetrac...	0.350	0.345	0.377	0.373	0.345	0.349	0.349	0.353	0.355	3.49
67)	S	Bromofluoroben...	0.428	0.421	0.436	0.445	0.467	0.458	0.464	0.454	0.446	3.80
68)	T	Cumene	1.123	1.096	1.106	1.147	0.955	0.974	0.941	0.933	1.034	8.84
69)	T	alpha-Pinene	0.575	0.503	0.574	0.566	0.440	0.454	0.435	0.453	0.500	12.55
70)	T	n-Propylbenzene	1.318	1.241	1.318	1.370	1.152	1.183	1.149	1.055	1.223	8.75
71)	T	3-Ethyltoluene	1.072	1.027	1.107	1.114	0.938	0.961	0.970	0.968	1.020	6.88
72)	T	4-Ethyltoluene	1.089	0.969	1.011	1.094	0.935	0.956	0.914	0.924	0.986	7.23
73)	T	1,3,5-Trimethy...	0.923	0.854	0.927	0.955	0.788	0.810	0.783	0.792	0.854	8.33
74)	T	alpha-Methylst...	0.341	0.363	0.436	0.450	0.418	0.435	0.441	0.466	0.419	10.45
75)	T	2-Ethyltoluene	1.072	0.979	1.050	1.094	0.918	0.935	0.900	0.901	0.981	8.16
76)	T	1,2,4-Trimethy...	0.884	0.848	0.899	0.942	0.808	0.819	0.805	0.826	0.854	5.80
77)	T	n-Decane	0.546	0.509	0.554	0.561	0.495	0.500	0.487	0.494	0.518	5.85
78)	T	1,3-Dichlorobe...	0.499	0.467	0.517	0.540	0.455	0.468	0.462	0.485	0.487	6.17
79)	T	1,4-Dichlorobe...	0.544	0.517	0.578	0.571	0.459	0.474	0.468	0.497	0.514	9.12
80)	T	sec-Butylbenzene	1.260	1.131	1.249	1.241	1.068	1.094	1.040	0.962	1.131	9.74
81)	T	p-Isopropyltol...	1.108	1.035	1.126	1.176	1.010	1.043	1.018	0.952	1.059	6.88
82)	T	1,2,3-Trimethy...	0.864	0.843	0.929	0.954	0.816	0.833	0.813	0.819	0.859	6.28
83)	T	1,2-Dichlorobe...	0.481	0.484	0.515	0.526	0.442	0.452	0.446	0.469	0.477	6.50
84)	T	d-Limonene	0.310	0.322	0.360	0.384	0.344	0.359	0.353	0.358	0.349	6.69
85)	T	1,2-Dibromo-3-...	0.142	0.128	0.135	0.148	0.158	0.169	0.170	0.175	0.153	11.42
86)	T	n-Undecane	0.601	0.550	0.537	0.569	0.525	0.540	0.532	0.532	0.548	4.63
87)	T	1,2,4-Trichlor...	0.084	0.090	0.117	0.120	0.107	0.112	0.112	0.120	0.108	12.51
88)	T	Naphthalene	1.010	0.903	1.074	1.180	1.025	1.066	1.059	0.969	1.036	7.87
89)	T	n-Dodecane	0.639	0.455	0.488	0.529	0.534	0.557	0.561	0.569	0.542	10.23
90)	T	Hexachloro-1,3...	0.257	0.226	0.251	0.259	0.224	0.232	0.226	0.233	0.238	6.15
91)	T	Cyclohexanone	0.320	0.261	0.280	0.283	0.291	0.290	0.283	0.297	0.288	5.83
92)	T	tert-Butylbenzene	0.952	0.856	0.923	0.919	0.781	0.801	0.756	0.747	0.842	9.69
93)	T	n-Butylbenzene	0.957	0.833	0.976	1.012	0.884	0.907	0.888	0.863	0.915	6.69

Evaluate Continuing Calibration Report

RM 10/20/16

Data Path : I:\MS18\DATA\2016 10\13\
Data File : 10131601.D
Acq On : 13 Oct 2016 11:19
Operator : RM
Sample : CCV F18 101316 S29-10051601
Misc : C300/C300 LIST/TO17 LIST 1042001
ALS Vial : 1 Sample Multiplier: 1

Quant Time: Oct 20 10:27:18 2016
Quant Method : I:\MS18\METHODS\F18101216.M
Quant Title : EPA TO-17 per SOP VOA-TO17 (CASS TO-17/GC-MS)
QLast Update : Thu Oct 20 09:15:10 2016
Response via : Initial Calibration

Min. RRF : 0.000 Min. Rel. Area : 50% Max. R.T. Dev 0.33min
Max. RRF Dev : 30% Max. Rel. Area : 200%

		Compound	AvgRF	CCRF	%Dev	Area%	Dev(min)
1	IR	Bromochloromethane (IS1)	1.000	1.000	0.0	109	0.00
2	T	Propene	1.064	0.933	12.3	116	0.00
3	T	Dichlorodifluoromethane	1.575	1.548	1.7	113	0.00
4	T	Chloromethane	1.247	1.250	-0.2	118	0.00
5	T	Freon 114	0.911	0.919	-0.9	116	0.00
6	T	Vinyl Chloride	1.262	1.274	-1.0	116	0.00
7	T	1,3-Butadiene	0.983	1.122	-14.1	118	0.00
8	T	Bromomethane	0.686	0.712	-3.8	123	0.00
9	T	Chloroethane	0.636	0.668	-5.0	118	0.00
10	T	Ethanol	0.643	0.672	-4.5	118	0.00
11	T	Acetonitrile	1.710	1.731	-1.2	117	0.00
12	T	Acrolein	0.526	0.545	-3.6	121	0.00
13	T	Acetone	0.627	0.632	-0.8	118	0.00
14	T	Trichlorofluoromethane	1.528	1.488	2.6	113	0.00
15	T	Isopropanol	2.203	2.371	-7.6	117	0.00
16	T	Acrylonitrile	1.021	1.175	-15.1	120	0.00
17	T	1,1-Dichloroethene	0.844	0.851	-0.8	119	0.00
18	T	tert-Butanol	2.108	2.516	-19.4	117	0.00
19	T	Methylene Chloride	0.839	0.820	2.3	118	0.00
20	T	Allyl Chloride	1.262	1.403	-11.2	121	0.00
21	T	Trichlorotrifluoroethane	0.817	0.794	2.8	117	0.00
22	T	Carbon Disulfide	3.289	3.262	0.8	118	0.00
23	T	trans-1,2-Dichloroethene	1.267	1.315	-3.8	115	0.00
24	T	1,1-Dichloroethane	1.599	1.625	-1.6	115	0.00
25	T	Methyl tert-Butyl Ether	2.635	2.788	-5.8	118	0.00
26	T	2-Butanone	0.520	0.634	-21.9	120	0.00
27	T	cis-1,2-Dichloroethene	1.212	1.240	-2.3	117	0.00
28	T	n-Hexane	1.644	1.639	0.3	115	0.00
29	T	Chloroform	1.488	1.502	-0.9	117	0.00
30	S	1,2-Dichloroethane-d4(SS1)	1.675	1.654	1.3	104	0.00
31	T	Tetrahydrofuran	0.552	0.603	-9.2	123	0.00
32	T	Ethyl tert-Butyl Ether	1.099	1.118	-1.7	117	0.00
33	T	1,2-Dichloroethane	1.144	1.154	-0.9	111	0.00
34	IR	1,4-Difluorobenzene (IS2)	1.000	1.000	0.0	109	0.00
35	T	1,1,1-Trichloroethane	0.298	0.304	-2.0	115	0.00
36	T	1-Butanol	0.200	0.217	-8.5	114	0.00
37	T	Benzene	0.915	0.782	14.5	118	0.00
38	T	Carbon Tetrachloride	0.256	0.279	-9.0	116	0.00
39	T	Cyclohexane	0.313	0.311	0.6	118	0.00
40	T	tert-Amyl Methyl Ether	0.581	0.575	1.0	117	0.00
41	T	1,2-Dichloropropane	0.209	0.211	-1.0	116	0.00
42	T	Bromodichloromethane	0.245	0.266	-8.6	113	0.00
43	T	Trichloroethene	0.229	0.223	2.6	117	0.00
44	T	1,4-Dioxane	0.157	0.167	-6.4	120	0.00
45	T	Isooctane	0.854	0.837	2.0	116	0.00
46	T	n-Heptane	0.224	0.228	-1.8	117	0.00
47	T	cis-1,3-Dichloropropene	0.300	0.333	-11.0	117	0.00
48	T	4-Methyl-2-pentanone	0.186	0.204	-9.7	117	0.00
49	T	trans-1,3-Dichloropropene	0.263	0.307	-16.7	122	0.00
50	T	1,1,2-Trichloroethane	0.190	0.198	-4.2	117	0.00
51	S	Toluene-d8 (SS2)	1.242	1.228	1.1	107	0.00
52	T	Toluene	0.835	0.821	1.7	116	0.00
53	T	2-Hexanone	0.479	0.508	-6.1	115	0.00

Evaluate Continuing Calibration Report

Data Path : I:\MS18\DATA\2016 10\13\
Data File : 10131601.D
Acq On : 13 Oct 2016 11:19
Operator : RM
Sample : CCV F18 101316 S29-10051601
Misc : C300/C300 LIST/TO17 LIST 1042001
ALS Vial : 1 Sample Multiplier: 1

Quant Time: Oct 20 10:27:18 2016
Quant Method : I:\MS18\METHODS\F18101216.M
Quant Title : EPA TO-17 per SOP VOA-TO17 (CASS TO-17/GC-MS)
QLast Update : Thu Oct 20 09:15:10 2016
Response via : Initial Calibration

Min. RRF : 0.000 Min. Rel. Area : 50% Max. R.T. Dev 0.33min
Max. RRF Dev : 30% Max. Rel. Area : 200%

		Compound	AvgRF	CCRF	%Dev	Area%	Dev(min)
54	T	Dibromochloromethane	0.221	0.232	-5.0	117	0.00
55	T	1,2-Dibromoethane	0.198	0.215	-8.6	118	0.00
56	IR	Chlorobenzene-d5 (IS3)	1.000	1.000	0.0	104	0.00
57		n-Octane	0.223	0.220	1.3	116	0.00
58	T	Tetrachloroethene	0.269	0.270	-0.4	116	0.00
59	T	Chlorobenzene	0.602	0.597	0.8	116	0.00
60	T	Ethylbenzene	1.045	1.046	-0.1	115	0.00
61	T	m- & p-Xylene	0.794	0.794	0.0	115	0.01
62	T	Bromoform	0.207	0.221	-6.8	118	0.00
63	T	Styrene	0.592	0.629	-6.3	118	0.00
64	T	o-Xylene	0.810	0.819	-1.1	115	0.00
65	T	n-Nonane	0.539	0.537	0.4	113	0.00
66	T	1,1,2,2-Tetrachloroethane	0.355	0.395	-11.3	119	0.00
67	S	Bromofluorobenzene (SS3)	0.446	0.448	-0.4	100	0.00
68	T	Cumene	1.034	1.049	-1.5	115	0.00
69	T	alpha-Pinene	0.500	0.489	2.2	116	0.00
70	T	n-Propylbenzene	1.223	1.263	-3.3	114	0.00
71	T	3-Ethyltoluene	1.020	1.056	-3.5	117	0.00
72	T	4-Ethyltoluene	0.986	1.013	-2.7	113	0.00
73	T	1,3,5-Trimethylbenzene	0.854	0.869	-1.8	115	0.00
74	T	alpha-Methylstyrene	0.419	0.460	-9.8	115	0.00
75	T	2-Ethyltoluene	0.981	1.013	-3.3	115	0.00
76	T	1,2,4-Trimethylbenzene	0.854	0.880	-3.0	113	0.00
77	T	n-Decane	0.518	0.538	-3.9	113	0.00
78	T	1,3-Dichlorobenzene	0.487	0.501	-2.9	115	0.00
79	T	1,4-Dichlorobenzene	0.514	0.523	-1.8	119	0.00
80	T	sec-Butylbenzene	1.131	1.160	-2.6	113	0.00
81	T	p-Isopropyltoluene	1.059	1.106	-4.4	114	0.01
82	T	1,2,3-Trimethylbenzene	0.859	0.880	-2.4	113	0.00
83	T	1,2-Dichlorobenzene	0.477	0.488	-2.3	115	0.00
84	T	d-Limonene	0.349	0.378	-8.3	115	0.00
85	T	1,2-Dibromo-3-Chloropropane	0.153	0.180	-17.6	119	0.01
86	T	n-Undecane	0.548	0.571	-4.2	114	0.00
87	T	1,2,4-Trichlorobenzene	0.108	0.122	-13.0	119	0.00
88	T	Naphthalene	1.036	1.189	-14.8	121	0.00
89	T	n-Dodecane	0.542	0.585	-7.9	114	0.00
90	T	Hexachloro-1,3-butadiene	0.238	0.245	-2.9	114	0.01
91	T	Cyclohexanone	0.288	0.336	-16.7	120	0.00
92	T	tert-Butylbenzene	0.842	0.859	-2.0	115	0.00
93	T	n-Butylbenzene	0.915	0.968	-5.8	114	0.01

(#) = Out of Range SPCC's out = 0 CCC's out = 0

908 North Temperance Ave. ∇ Clovis, CA 93611 ∇ Phone 559-275-2175 ∇ Fax 559-275-4422

NELAP Certification number: CA00046 (HW)
State Certification Number: CA1312 (WW & DW)

November 21, 2016

Environmental Protection Agency
4930 Old Page Road
Durham, North Carolina 27703

Attn: Dennis Tabor

Subject: Report of Data: Case 81316

Results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Dear Mr. Tabor:

Three miscellaneous samples for the "Radford Sept-Oct 2016" project were received October 28, 2016, at room temperature. Written results are being provided on this November 21, 2016, for the requested analysis. All holding times were met.

For the nitrocellulose analysis, the samples were extracted according to APPL SOP ANANC and analyzed according to EPA method 353.2-Mod and APPL SOP ANANC for Nitrocellulose.

No unusual problems or complications were encountered with this sample set.

If you have any questions or require further information, please contact us at your convenience. Thank you for choosing APPL, Inc.

I certify that this data package is in compliance with the terms and conditions of the contract, both technically and for completeness, for other than the conditions detailed above. These test results meet all requirements of NELAC. Release of the hard copy has been authorized by the Laboratory Manager or her designee, as verified by the following signature.

Paula McCartney

Paula McCartney, Laboratory Director
APPL, Inc.

PM/rp
Enclosure
cc: File

Number of pages in this report: ____

Wetlab Results

ARF: 81316

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Environmental Protection Agency
4930 Old Page Road
Durham, NC 27703

Attn: Dennis Tabor

Method	Analyte	Result	PQL	Units	Prep Date	Analysis Date
APPL ID: AZ45036 -Client Sample ID: PS-MK90-NC-092916-01			-Sample Collection Date: 09/29/16		Project: Radford Sept-Oct 2016	
EPA 353.2M	NITROCELLULOSE	Not detected	200	ug/sample	11/11/16	11/11/16
APPL ID: AZ45037 -Client Sample ID: PS-MK90-NC-100516			-Sample Collection Date: 10/05/16		Project: Radford Sept-Oct 2016	
EPA 353.2M	NITROCELLULOSE	Not detected	200	ug/sample	11/11/16	11/11/16
APPL ID: AZ45038 -Client Sample ID: BS-NC-100516			-Sample Collection Date: 10/05/16		Project: Radford Sept-Oct 2016	
EPA 353.2M	NITROCELLULOSE	Not detected	200	ug/sample	11/11/16	11/11/16

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APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Method	Analyte	Result	PQL	Units	Prep Date	Anal Date	QC Group
EPA 353.2M	NITROCELLULOSE	Not detected	200	ug/sample	11/11/16	11/11/16	#353NC-161101A-AZ45036

AMENDED PAGE

Printed: 11/23/16 11:31:27 AM

Laboratory Control Spike Recovery

WETLAB

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Method	Compound Name	Spike Level ug/sample	SPK Result ug/sample	SPK % Recovery	Recovery Limits	Extract Date	Analysis Date	QC Group
EPA 353.2	NITROCELLULOSE	1000	1080	108	40-120	11/11/16	11/11/16	#353NC-161101A-AZ45036

AMENDED PAGE

Comments: _____

Printed: 11/23/16 11:31:12 AM
APPL Standard LCS

Project: Radford
Sep-Oct 2016

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Nitro Cellulose

8/31/16

22.2°

SAMPLER:

	SAMPLE ID	DATE	~~TIME~~ Born	MATRIX	PUF/ FILTER	Requested Analyses 1	2	3	4	5	6	7	8	9	10	Remarks
1	PS-MK90-NC-092916-01	092916	1-3	MK90		X										2 Filters, 0.70g C sampled
2	PS-MK90-NC-100516	100516	1-3	MK90		X										
3	BS-NC-100516	100516		Ambient		X										

	Requested Analyses
1	Nitro Cellulose
2	
3	
4	
5	
6	
7	

Special Instructions/Comments:

☐ Special QA/QC Instructions

Laboratory Information and Receipt

Lab Name:

Shipping Tracking #

Specify Turnaround Requirements:

☐ Cooler packed with ice

☐ Cooler custody seal intact

Sample Receipt:

Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
[signature]	10/11/16	13:45	[signature] 10:10 10/28/16				
Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:

908 North Temperance Ave. ∇ Clovis, CA 93611 ∇ Phone 559-275-2175 ∇ Fax 559-275-4422

NELAP Certification number: CA00046 (HW)
State Certification Number: CA1312 (WW & DW)

November 9, 2016

Environmental Protection Agency
4930 Old Page Road
Durham, North Carolina 27703

Attn: Dennis Tabor

Subject: Report of Data: Case 81317

Results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Dear Mr. Tabor:

Five miscellaneous samples for the "Radford Sept-Oct 2016" project were received October 28, 2016, at room temperature. Written results are being provided on this November 9, 2016, for the requested analysis. All holding times were met.

For the EPA 8330B analysis, the samples were extracted according to the method.

No unusual problem or complication was encountered with this sample set.

If you have any questions or require further information, please contact us at your convenience. Thank you for choosing APPL, Inc.

I certify that this data package is in compliance with the terms and conditions of the contract, both technically and for completeness, for other than the conditions detailed above. These test results meet all requirements of NELAC. Release of the hard copy has been authorized by the Laboratory Manager or her designee, as verified by the following signature.

Paula McCartney

Paula McCartney, Laboratory Director
APPL, Inc.

PM/rp
Enclosure
cc: File

Number of pages in this report: ____

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor

Project: Radford Sept-Oct 2016

ARF: 81317

Sample ID: PS-MK90-NA-092716-01

APPL ID AZ45039

Sample Collection Date: 09/27/16

QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	102	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000012
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

Printed: 11/09/16 2:25:55 PM
Form 1 - APPL Standard GC - No MC

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor

Project: Radford Sept-Oct 2016

ARF: 81317

Sample ID: PS-MK90-NG-100316-01

APPL ID AZ45040

Sample Collection Date: 10/03/16

QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	104	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000013
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

Printed: 11/09/16 2:25:56 PM
Form 1 - APPL Standard GC - No MC

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor

Project: Radford Sept-Oct 2016

ARF: 81317

Sample ID: PS-MK90-NG-100316-02

APPL ID AZ45041

Sample Collection Date: 10/03/16

QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	99.9	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000014
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

Printed: 11/09/16 2:25:56 PM
Form 1 - APPL Standard GC - No MC

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor

Project: Radford Sept-Oct 2016

ARF: 81317

Sample ID: PS-MK90-NG-100316-03

APPL ID AZ45042

Sample Collection Date: 10/03/16

QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	103	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000015
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

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Form 1 - APPL Standard GC - No MC

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor

Project: Radford Sept-Oct 2016

ARF: 81317

Sample ID: BS-NA-100616

APPL ID AZ45043

Sample Collection Date: 10/06/16

QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	100	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000016
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

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Form 1 - APPL Standard GC - No MC

Method Blank

EPA 8330B EXPLOSIVES

APPL Inc.
908 North Temperance Avenu
Clovis, CA 93611

Blank Name/QCG: **161101S-45039 - 213396**
Batch ID: #8330M-161101A

Sample Type	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
BLANK	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
BLANK	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	SURROGATE: 1,2-DINITROBENZENE (S)	101	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000011
Instrument: Waldorf
Sequence: 161103
Initials: MP

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Laboratory Control Spike Recovery
EPA 8330B EXPLOSIVES

APPL ID: **161101S-45039 LCS - 213396**
Batch ID: #8330M-161101A

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Compound Name	Spike Level ug/sample	SPK Result ug/sample	SPK % Recovery	Recovery Limits
1,3,5-TRINITROBENZENE	20.0	19.9	99.5	75-125
1,3-DINITROBENZENE	20.0	19.5	97.5	80-125
2,4,6-TRINITROTOLUENE	20.0	20.0	100	55-140
2,4-DINITROTOLUENE	20.0	19.9	99.5	80-125
2-AMINO-4,6-DINITROTOLUENE	20.0	20.0	100	80-125
3,5-DNA	20.0	19.2	96.0	70-130
4-AMINO-2,6-DINITROTOLUENE	20.0	20.0	100	80-125
HMX	20.0	19.1	95.5	75-125
RDX	20.0	19.5	97.5	70-135
TETRYL	20.0	20.0	100	10-150
SURROGATE: 1,2-DINITROBENZENE (S	20.0	19.3	96.5	70-130

Primary	SPK
Quant Method :	W160916.M
Extraction Date :	11/01/16
Analysis Date :	11/03/16
Instrument :	Waldorf
Run :	1103_000005
Initials :	MP

Comments:

Printed: 11/09/16 2:25:50 PM
APPL Standard LCS

Project: Radford
Sep-Oct 2016

8/3/17 Page 1 of 1

22.2°

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Nitro Aromatics

SAMPLER:

Requested Analyses

	SAMPLE ID	DATE	~~TIME~~ Run	MATRIX	~~PUF/~~ FILTER	1	2	3	4	5	6	7	8	9	10	Remarks
1	PS-MK90-NA-092716-01	092716	1-3	MK90		X	X									2 Filters, 0.3 g C
2	PS-MK90-NG-100316-01	100316	1	MK90		X	X									2 Filters 0.24 g C
3	PS-MK90-NG-100316-02	100316	2	MK90		X	X									2 Filters 0.37 g C
4	PS-MK90-NG-100316-03	100316	3	MK90		X	X									2 Filters 0.25 g C
5	BS-NA-100616	100616		Ambient		X	X									2 Filters, 1 L

	Requested Analyses
1	Nitro Aromatics
2	Nitramines
3	
4	
5	
6	
7	

Special Instructions/Comments: Compounds

HMX, RDX, 1,3,5-Trinitrobenzene, 1,3-Dinitrobenzene, Tetryl, TNT, 4-Amino-2,6 dinitrotoluene, 2-Amino-4,6 dinitrotoluene, 2,4-dinitrotoluene, 3,5-dinitrotoluene PETN

☐ Special QA/QC Instructions

Laboratory Information and Receipt

Lab Name:
Shipping Tracking #
Specify Turnaround Requirements:
☐ Cooler packed with ice
☐ Cooler custody seal intact
Sample Receipt:
Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
[signature]	10/11/16	13:17					
Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor

Project: Radford Sept-Oct 2016

ARF: 81317

Sample ID: PS-MK90-NA-092716-01

APPL ID AZ45039

Sample Collection Date: 09/27/16

QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROGLYCERIN	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	102	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000012
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

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EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor
Project: Radford Sept-Oct 2016
Sample ID: PS-MK90-NG-100316-01
Sample Collection Date: 10/03/16

ARF: 81317
APPL ID AZ45040
QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROGLYCERIN	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	104	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000013
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

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Form 1 - APPL Standard GC - No MC

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor
Project: Radford Sept-Oct 2016
Sample ID: PS-MK90-NG-100316-02
Sample Collection Date: 10/03/16

ARF: 81317
APPL ID AZ45041
QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROGLYCERIN	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	99.9	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000014
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

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Form 1 - APPL Standard GC - No MC

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor
Project: Radford Sept-Oct 2016
Sample ID: PS-MK90-NG-100316-03
Sample Collection Date: 10/03/16

ARF: 81317
APPL ID AZ45042
QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROGLYCERIN	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	103	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000015
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

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Form 1 - APPL Standard GC - No MC

EPA 8330B EXPLOSIVES

Environmental Protection Agenci
4930 Old Page Road
Durham, NC 27703

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Attn: Dennis Tabor
Project: Radford Sept-Oct 2016
Sample ID: BS-NA-100616
Sample Collection Date: 10/06/16

ARF: 81317
APPL ID AZ45043
QCG: #8330M-161101A-213396

Method	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
EPA 8330B	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	2-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	3-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	4-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	NITROGLYCERIN	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
EPA 8330B	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
EPA 8330B	SURROGATE: 1,2-DINITROBENZENE (S)	100	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000016
Instrument: Waldorf
Sequence: 161103
Dilution Factor: 1
Initials: MP

Printed: 05/17/17 11:01:10 AM
Form 1 - APPL Standard GC - No MC

Method Blank

EPA 8330B EXPLOSIVES

APPL Inc.
908 North Temperance Avenu
Clovis, CA 93611

Blank Name/QCG: **161101S-45039 - 213396**
Batch ID: #8330M-161101A

Sample Type	Analyte	Result	PQL	Units	Extraction Date	Analysis Date
BLANK	1,3,5-TRINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	1,3-DINITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2,4,6-TRINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2,4-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2-AMINO-4,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	2-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	3,5-DNA	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	3-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	4-AMINO-2,6-DINITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	4-NITROTOLUENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	HMX	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	NITROBENZENE	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	NITROGLYCERIN	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	PETN	Not detected	5.0	ug/sample	11/01/16	11/02/16
BLANK	RDX	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	TETRYL	Not detected	2.0	ug/sample	11/01/16	11/02/16
BLANK	SURROGATE: 1,2-DINITROBENZENE (S)	101	70-130	%	11/01/16	11/02/16

Quant Method: W160916.M
Run #: 1102_000011
Instrument: Waldorf
Sequence: 161103
Initials: MP

Printed: 05/17/17 11:01:07 AM

Laboratory Control Spike Recovery
EPA 8330B EXPLOSIVES

APPL ID: **161101S-45039 LCS - 213396**
Batch ID: #8330M-161101A

APPL Inc.
908 North Temperance Avenue
Clovis, CA 93611

Compound Name	Spike Level ug/sample	SPK Result ug/sample	SPK % Recovery	Recovery Limits
1,3,5-TRINITROBENZENE	20.0	19.9	99.5	75-125
1,3-DINITROBENZENE	20.0	19.5	97.5	80-125
2,4,6-TRINITROTOLUENE	20.0	20.0	100	55-140
2,4-DINITROTOLUENE	20.0	19.9	99.5	80-125
2,6-DINITROTOLUENE	20.0	19.9	99.5	80-120
2-AMINO-4,6-DINITROTOLUENE	20.0	20.0	100	80-125
2-NITROTOLUENE	20.0	19.8	99.0	80-125
3,5-DNA	20.0	19.2	96.0	70-130
3-NITROTOLUENE	20.0	19.8	99.0	75-120
4-AMINO-2,6-DINITROTOLUENE	20.0	20.0	100	80-125
4-NITROTOLUENE	20.0	20.0	100	75-125
HMX	20.0	19.1	95.5	75-125
NITROBENZENE	20.0	19.3	96.5	75-125
NITROGLYCERIN	20.0	20.0	100	68-131
PETN	20.0	18.3	91.5	69-132
RDX	20.0	19.5	97.5	70-135
TETRYL	20.0	20.0	100	10-150
SURROGATE: 1,2-DINITROBENZENE (S	20.0	19.3	96.5	70-130

Comments:

Primary	SPK
Quant Method :	W160916.M
Extraction Date :	11/01/16
Analysis Date :	11/03/16
Instrument :	Waldorf
Run :	1103_000005
Initials :	MP

Printed: 05/17/17 11:01:03 AM
APPL Standard LCS

Appendix E: Quality Assurance Project Plan

Approval Page

QA Project Plan Title:	**Emission Sampling at Radford Army Ammunition Plant**
NRMRL QA Tracking ID:	QLOG No. A-21434-QP10, QTRAK No. 15030, QA Category III (B)
If Intramural or Extramural, EPA NRMRL Project Approvals	
Name: Technical Lead Person (TLP) Brian Gullett	Signature/Date: Brian Gullett Digitally signed by Brian Gullett DN: cn=Brian Gullett, o=U.S. EPA, ou=ORD/NRMRL, email=gullett.brian@epa.gov, c=US Date: 2016.09.21 14:50:25 -04'00'
Name: TLP's Supervisor Gary Foley	Signature/Date: GARY FOLEY Digitally signed by GARY FOLEY DN: c=US, o=U.S. Government, ou=USEPA, ou=Staff, cn=GARY FOLEY, dnQualifier=0000004109 Date: 2016.09.21 15:41:18 -04'00'
Name: QA Manager Libby Nessley	Signature/Date: LAURA NESSLEY Digitally signed by LAURA NESSLEY DN: c=US, o=U.S. Government, ou=USEPA, ou=Staff, cn=LAURA NESSLEY, dnQualifier=0000035926 Date: 2016.09.21 15:52:46 -04'00'
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Name: Other EPA	Signature/Date:
If Extramural, Contractor Approvals	
Name: Contractor Manager/Lead	Signature/Date:
Name: Contractor QA:	Signature/Date:
Name: Other Contractors: Johanna Aurell, UDRI	Signature/Date: Johanna Aurell 09/21/2016
Name: Other Contractors: NASA Ames Research Center	Signature/Date: Matt Fladeland Digitally signed by Matt Fladeland DN: cn=Matt Fladeland, o, ou, email=matthew.fladeland@nasa.gov, c=US Date: 2016.09.21 11:54:15 -07'00'

NRMRL QUALITY ASSURANCE PROJECT PLAN

Office of Research and Development

National Risk Management Research Laboratory

Air Pollution Prevention and Control Division

Characterization of Air Emissions from Open Burning at Radford Army Ammunition Plant

EPA NRMRL Technical Lead Person: Brian Gullett, Ph.D.

Measurements Project, QA Category B

QA Tracking: G-A-21434-QP10

Extramural Research

Revision Number: 3

Date: September 13, 2016

Approval Page

QA Project Plan Title:	**Emission Sampling at Radford Army Ammunition Plant**
NRMRL QA Tracking ID:	QLOG No. A-21434-QP10, QTRAK No. 15030, QA Category III (B)

If Intramural or Extramural, EPA NRMRL Project Approvals	
Name: Technical Lead Person (TLP) Brian Gullett	Signature/Date:
Name: TLP's Supervisor Gary Foley	Signature/Date:
Name: QA Manager Libby Nessley	Signature/Date:
Name: Other EPA	Signature/Date:
Name: Other EPA	Signature/Date:

If Extramural, Contractor Approvals	
Name: Contractor Manager/Lead	Signature/Date:
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List of Acronyms

AA	Graphite Furnace atomic absorption
AED	Automated external defibrillator
AGL	Above ground level
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CoC	Chain of Custody
DAQ	Data acquisition
DAS	Data acquisition system
DOD	U.S. Department of Defense
DQI	Data Quality Indicator
EF	Emission Factor
EMS	Emergency Medical Services
EPA	U. S. Environmental Protection Agency
ESTCP	Environmental Security and Technology Certification Program
FID	Flame ionization detector
GC	Gas chromatography
HAZWOPER	Hazardous Waste Operations and Emergency Response
HCl	Hydrogen chloride
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HPLC	High-Performance Liquid Chromatography
IC	Ion chromatography
ICP	Inductively coupled plasma
LC	Liquid chromatography
LRGC	Low resolution gas chromatography
LRMS	Low resolution mass spectrometer
MK-90	MK-90 rocket motors
NASA	National Aeronautics and Space Administration
NC	Nitrocellulose
NDIR	Non-dispersive infrared
NG	Nitroglycerine
NIST	National Institute for Standards and Technology
NO	Nitrogen oxide

NO2	Nitrogen dioxide
NRE	New river energetics
OB	Open burning
OD	Open detonation
OD	Outer diameter
ORD	Office of Research and Development
PI	Principal Investigator
$PM_{2.5}$	Particulate matter equal to and less than 2.5 µm
QA	Quality Assurance
QAPP	Quality assurance project plan
RDX	Research Department Formula X, 1,3,5-Trinitroperhydro-1,3,5-triazine
RFAAP	Radford Army Ammunition Plant
RPD	Relative percent difference
SD	Secure digtial card
SIM	Selective ion monitoring
SVOC	Semivolatile organic compounds
UAV	Unmanned aerial vehicle
UDRI	University of Dayton Research Institute
USB	Universal serial bus
VOCs	Volatile organic compounds
XRF	x-ray fluorescence spectrometry

1 Project Description and Objectives

1.1 Introduction

The Radford Army Ammunition Plant (RFAAP) conducts on-site disposal of a variety of hazardous energetic wastes via open burn pans located at the facility's open burning ground (OBG). Data on potential combustion emissions and emission factors are available only from small laboratory and pilot scale simulations and their relevance to the RFAAP's scenario has been questioned. To resolve this issue, the RFAAP has asked the U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD) to perform direct sampling and quantification of the RFAAP's OBG emissions. ORD has considerable experience sampling emissions from open burning and open detonation (OB/OD) of military ordnance and static firing of rocket motors (for example, see Aurell et al. [1]). Since 2010, ORD has worked with the Department of Defense's (DoD's) Joint Munitions Command (and their predecessor, the Defense Ammunition Center), the Army Corps of Engineers, and the Defence Research and Development Canada -Valcartier to sample OB/OD emissions at three sites in the US and Canada. ORD has developed a suite of technologies for sampling an array of OB/OD emission constituents from both aerial and ground-based sampling platforms. These sampling methods have been developed over the last five years and include novel methods employing small sensors and samplers, necessitated by the challenge of sampling within a plume located several hundred feet in the open air.

1.2 Objective

The objective of this work is to characterize and quantify emissions from open burning of dry propellant burns (MK-90 rocket motors) and so-called "skid burns", which is a combination of process wastes from onsite production operations. This skid waste is generally a combination of energetic material, soil, gravel, and other foreign object debris (FOD). Skid burns are what the facility refers to as "assisted burns," where the materials are placed on wooden skids, and nested with dunnage and diesel fuel to promote burning. Quantification of the emissions includes determination of emission factors relating the amount of compound emitted to the amount present in the original material.

2 Organization and responsibilities

2.1 Mechanism and Personnel

This work will be conducted by ORD, National Aeronautics and Space Administration (NASA), and the University of Dayton Research Institute (UDRI). The latter two entities are engaged by an Interagency Agreement between the US Army and NASA and a contract between UDRI and BAE, Inc., the on-site contractors operating RFAAP for the U.S. Army. Dr. Brian Gullett (U.S. Environmental Protection Agency, EPA) will oversee the project effort and coordinate amongst RFAAP, NASA, and UDRI. He is responsible for the overall conduct and output of the project. William Mitchell (EPA) is the chief electronics engineer and will be responsible for the

functioning of the sampling system, called the “Kolibri”. Dr. Johanna Aurell (UDRI) is the chief operator of the sampling system, and is responsible for field sampling instruments and is the Field Sampling Lead. Drs. Ved Chirayath and Ron Instrella will supply and operate two aerial platforms for the sampling instruments.

Dr. Gullett is responsible for EPA personnel and contractors and for UDRI and NASA team coordination (through BAE, Inc. - Mr. Jay Stewart and the U.S. Army -Mr. R. Brad Jennings, respectfully). Mr. Steward will coordinate between the sampling team and the RFAAP personnel. Dr. Gullett is responsible for EPA personnel logistics, the project quality assurance project plan (QAPP), the conduct of the project in the field, and the analysis and dissemination of the results to RFAAP. Mr. Dennis Tabor (EPA chemist) will coordinate sample transferral to outside testing laboratories for energetics analysis (ALS Kelso), gravimetrics, ultimate/proximate analyses, and XRF for elements (Chester LabNet), volatile organics (ALS Simi Valley) as well as ensuring that the team follows the appropriate protocol for sample containment, storage, and shipment. Mr. Tabor will review external laboratory reports as well as conduct analyses for PCDD/PCDF. Dr. Johanna Aurell (UDRI), as Sampling Lead, will conduct equipment checks prior to shipment including pump flows and gas calibration checks. She will be the lead sample and data custodian and will be responsible for downloading, storing, and reducing the instrumental data for analysis. Mr. Bill Mitchell (EPA) is responsible for the electronic components, including the Kolibri computer and transmission/receiving systems. Drs. Ved Chirayath and Ron Instrella (NASA) are responsible for flight operations of the NASA unmanned aerial vehicle (UAV). Ms. Libby Nessley is the EPA QA manager and will review this QAPP as well as any products derived herein.

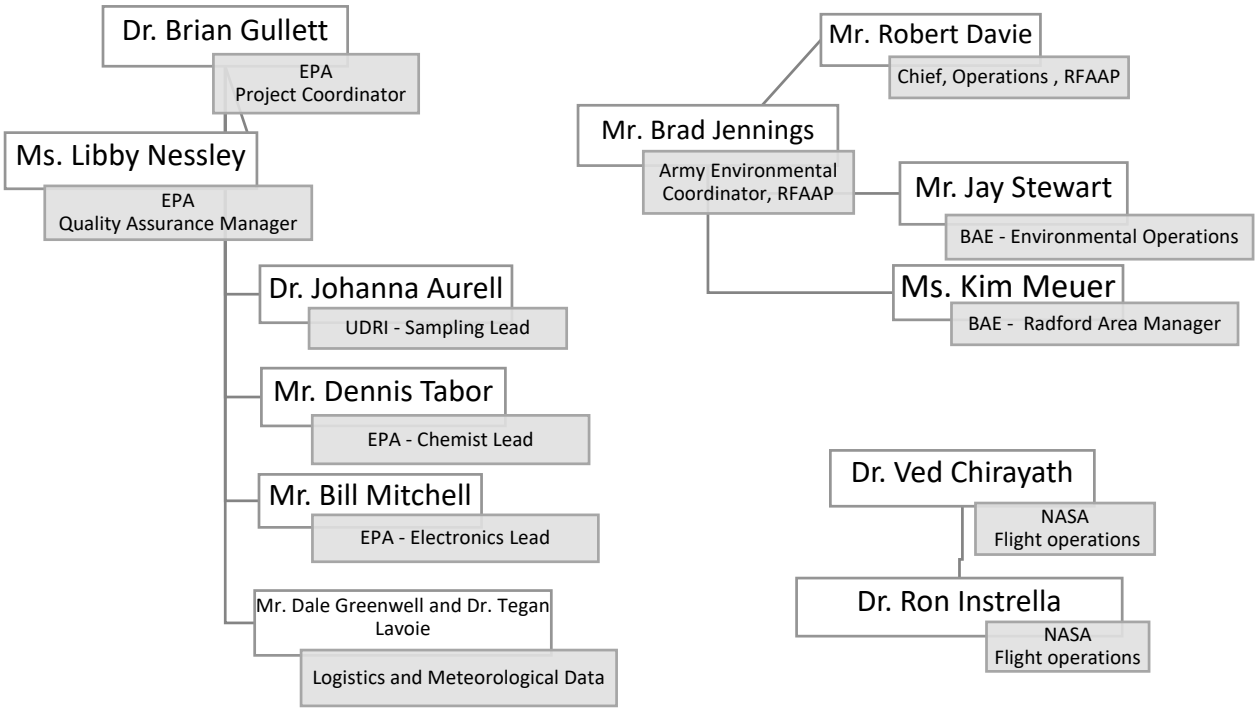

Figure 2-1. Organization Chart.

Table 2-1. Site and Project Personnel

Name	Organization	Responsibility	Contact Information
Dr. Brian Gullett	EPA/ORD	Project Coordinator, EPA Air Sampling Team	919-541-1534 ofc, 919-699-3074 cell, gullett.brian@epa.gov
Ms. Libby Nessley	EPA/ORD	EPA QA manager	919-541-4381, nessley.libby@epa.gov
Dr. Johanna Aurell	UDRI	Lead Field Sampler	919-541-5355, aurell.johanna@epa.gov
Mr. Dennis Tabor	EPA/ORD	Chemist, sample transmittal methods, analyses	919-541-2686, tabor.dennis@epa.gov
Mr. Bill Mitchell	EPA/ORD	Electronics operations	919-541-2515, mitchell.bill@epa.gov
Mr. Dale Greenwell	EPA/ORD	In-field support	919-541-2828 Greenwell.dale@epa.gov
Dr. Tegan Lavoie	ORISE	Meteorological data	919-541-5110, Lavoie.tegan@epa.gov
Dr. Ved Chirayath	NASA, Ames	UAV flight operations	949-413-8928, ved.chirayath@nasa.gov

Dr. Matt Fladeland	NASA, Ames	NASA Division Director	650-604-3325, matthew.fladeland@nasa.gov
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Mr. David Satterfield	NASA, Ames	Range Safety Officer	209-366-4421 cell, david.r.satterfield@nasa.gov
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Mr. R. Brad Jennings	U.S. Army	Radford Army Ammunition Plant	540-731-5781, ross.b.jennings.civ@mail.mil
Mr. Jay Stewart	BAE, Inc.	Radford On-site Environmental Operations	540-639-7785 ofc, 540-200-9536 cell jay.stewart@baesystems.com
Ms. Kim Meuer	BAE, Inc.	Radford Area Manager	540-395-4927 kim.meuer@baesystems.com

2.2 On-Site Personnel

EPA team personnel on site include, Drs. Gullett and Aurell, and Mr. Mitchell. Mr. Greenwell and Dr. Lavoie will be on-site from Monday, September 19 to Wednesday, September 21. All personnel will have completed the EPA field safety training. Dr. Gullett is CPR/AED certified. Both Drs. Gullett and Aurell are HAZWOPER certified. NASA personnel on site includes Drs. Chirayath and Instrella and one Range Safety Officer (TBD).

2.3 Schedule

Tests will be conducted over a two-week period. A typical emission sampling day of the two different kinds of waste/fuel is shown in Table 2-3. The first day (September 19) will be used to set-up and prepare (e.g., calibrate instruments) sampling equipment. Test flights for calibrating weight will be conducted day 1 (September 19), weather permitting. The two waste/fuel types will be alternated as per RFAAP's procedural requirements. An ambient background sample for each of the target compounds will be performed upwind of any work area during non-burning periods.

Table 2-2. Schedule.

Date – Option 1	Activity
July 20, 2016	QAPP Draft submitted for approval
September 7, 2016	QAPP revision 1 approved
September 14, 2016	QAPP revision 2 submitted
September 19, 2016	On-site arrival (0700), badge-in, brief, equipment set up, procedural walk through, communication checks, and test UAV flights
September 19, 2016	Sampling commences if possible
September 24-25, 2016	Weekend Off
September 26, 2016	Sampling resumes
September 30, 2016	Sampling concludes, AM
September 30, 2016	RFAAP departure, PM
December 30, 2016	Sample analysis complete
May 1, 2017	Draft final report submitted to RFAAP

Table 2-3. Typical Emission Sampling Day.

Estimated Time	Typical dry propellant day	Typical skid waste day
1-2 h	Load five pans on three pads*	Load three pans on three pads*
	Prepare sampling equipment – calibration, attach sampling media	Prepare sampling equipment – calibration, attach sampling media
1 h	Sample emissions from two simultaneous pans, first pad	Sample emissions from first pad.
1 h	Change out sampling equipment if needed	Change out sampling equipment if needed
1 h	Sample emissions from two simultaneous pans, second pad	Sample emissions from second pad.
1 h	Change out sampling equipment if needed	Change out sampling equipment if needed
1 h	Sample emissions from the fifth pan on the third pad.	Sample emissions from third pad.
1-2 h	Take care of samples, conduct post-drift test on monitors. Clean out pans and prepare for next day	Take care of samples, conduct post-drift test on monitors. Clean out pans and prepare for next day

*With RFAAP willingness and DEQ permission, it would be desirable to consider spreading out the same daily propellant/waste mass into more pans, allowing for more burns and greater likelihood of sampling effectiveness.

3 Method

ORD will conduct aerial sampling of emissions from both dry propellant burns and Skid burns. Ten total days on site is estimated to allow for collection of four sets of samples from each type of burn including background samples. Since the MK-90 composition is constant and that of the

Skid waste is variable (depending on where and when the waste is gathered at RFAAP), emission sampling for the latter will provide only a source-representative range of emission quantification. The RFAAP will provide ORD with composition (carbon, energetics, metals) and mass data on the disposal material and any ignition-assist fuel to enable calculation of emission factors from their sampling data.

Figure 3-1. Pan Burns of MK-90 Rockets.

Plumes from these high intensity fires rise vertically into the atmosphere where they are dispersed. Successful capture of samples depends on the ability to intercept the plume. This work will accomplish the interception of the plume by use of UAV multicopters which will carry our sampling equipment aloft into the plumes and in the wind direction into the plume. UAV use will be precluded during adverse weather conditions.

3.1 Site Location

The sampling site is located at the Radford Army Ammunition Plant (RFAAP) in the mountains of southwest Virginia, approximately five miles northeast of the city of Radford, Virginia. RFAAP lies along the New River in the relatively narrow northeastern corner of the valley. Approximate GPS coordinates are 37.1925 N, 80.5233 W. Figure 3-2 shows an overview of the RFAAP burn pan site.

Figure 3-2. Overhead View of RFAAP Burn Pan Site.

3.2 Fuel

As described previously, burns of two fuel sources will be sampled: dry propellant burns, and skid burns. For this test program, the dry propellant burns will be conducted with MK-90 motors. The MK-90 motors are bagged and placed in a 20 gallon tub without the lid, each tub weighing approximately 180 pounds, allowing knowledge of how many pounds of waste is spread out on the pans. The waste materials for skid burns are kept in 20 gallon tubs and worked up as 47 pounds net weight per tub, also allowing for knowledge of how many pounds of waste is spread out on the pounds. MK-90 pans may be loaded with a total of 3,400 lbs of waste while skid waste burns are more typically between 500 lbs and 1100 lbs. The PI will record in the laboratory notebook the date, pan #, pan content, and ignition time for each burn in coordination with RFAAP.

RFAAP will determine the composition of the all of the wastes loaded onto each type of burn and provide these data to EPA/ORD. Of particular interest is the carbon and elemental concentrations. The MK-90 rocket motors are primarily comprised of nitrocellulose and nitroglycerin grains (Table 3-1). The energetic composition of the skid waste may vary depending upon the energetics found in the pit waste or other materials included in the skid burn. Regardless, the mass components of the energetics, as well as target elements/metals (Table 3-2), chlorine, and perchlorate will be determined via sampling and analysis of the wastes selected for each burn. Therefore, the energetics present will be largely known for each pan burn. RFAAP will also determine the carbon concentration based on their internal stoichiometric data or measurements. In the case of the Skid waste which varies considerably in composition, RFAAP will come up with a best estimate of the composition, particularly the carbon content and uncertainty, and provide it to EPA/ORD.

Table 3-1. Fuel composition and approximate carbon fractions.

Fuel	Composition	Fc
MK-90		0.30
Skid waste	Varies	Varies

3.3 Target Compounds

The target compounds for sampling and the number of samples were determined in consultation with RFAAP. RFAAP is interested in compounds related to environmental risk assessments. The minimum number of compounds is determined based on RFAAP's determination of importance, anticipated variability of values, UAV payload allowances, and the budget/time allowed.

The two primary energetics in the MK90 burn are nitrocellulose (NC) and nitroglycerine (NG). The NC concentration determination is actually a measure of nitrate and nitrite after the sample has been reacted. Care will be taken to consider potential interferences from other nitro compounds. In addition, potential products of incomplete combustion will be a focus, such as nitroaromatics, that can captured on a filter without sorbent backup. Note that the NC and NG/nitroaromatic samples are distinct and analyzed separately.

Additional target analytes include nonvolatile metals and compounds (see Table 3-3), particularly Al, Ba, Pb and Cr, as well as Cl species such as perchlorate and chloride, and carbon compounds including CO and CO_2. The metals and compounds will be analyzed via a 2.5 micrometer mass median diameter particulate matter collection on a Teflon filter. Calculation of carbon species content is necessary to ratio the mass of co-collected pollutant with the carbon, enabling determination of an emission factor for the whole burn. Targeted emission constituents and their sampling methods are listed in
Table 3-2.

Table 3-2. Emission Targets.

Analyte	Instrument/Method	Frequency	Minimal # of Samples for Each Source
CO_2	NDIR[a]	Continuous	Continuous
CO	Electrochemical cell	Continuous	Continuous
$PM_{2.5}$[b]	Impactor/Teflon filter/ gravimetric	Batch	4
NC	Glass filter, calorimetric	Batch	1
NG and nitroaromatics	Glass filter, HPLC[c]	Batch	1
Elements see Table 3-3	Filter, XRF[d]	Batch	4
Cr (VI)	Filters, NIOSH[e] 7605-7300/LC[f]	Batch	2[j]/4[k]
Perchlorate (skid only)	MCE[g] filter/LC/MS[h]	Batch	2
Chloride (skid only)	MCE filter/IC[i]	Batch	2
HCl (skid only)	Na_2CO_3 filter/IC	Batch	2
VOCs see Table 3-4	Carbotrap 300	Batch	1[j]/2[k]
PCDD/PCDF (skid only)	Glass fiber	Batch	1

[a]Non-dispersive infrared. [b]Fine particles in the ambient air with particles less than or equal to 2.5 µm in diameter. [c]High performance liquid chromatography. [d]X-ray fluorescence. [e]National Institute for Occupational Safety and Health. [f]Liquid chromatography. [g]Mixed cellulose ester. [h]Liquid chromatography/mass spectrometry. [i]Ion chromatography. [j] Skid waste. [k] Dry propellant.

Table 3-3. Metals and compounds included in XRF-analyses.

Compound		**Compound**		**Compound**		**Compound**	
Na	Sodium	V	Vanadium	As	Arsenic	Cd	Cadmium[b]
Mg	Magnesium	Cr	Chrome[b]	Se	Selenium[b]	In	Indium
Al	Aluminum	Mn	Manganese[b]	Br	Bromine	Sn	Tin
Si	Silica	Fe	Iron	Rb	Rubidium	Sb	Antimony[b]
P	Phosphorus	Co	Cobalt[b]	Sr	Strontium	Ba	Barium
S	Sulfur	Ni	Nickel[b]	Y	Yttrium	La	Lanthanum
Cl	Chlorine	Cu	Copper	Zr	Zirconium	Hg	Mercury[a,b]
K	Potassium	Zn	Zink	Mo	Molybdenum	Pb	Lead[b]
Ca	Calcium	Ga	Gallium	Pd	Palladium		
Ti	Titanium	Ge	Germanium	Ag	Silver		

[a] Oxidized mercury. [b] On U.S. EPA's list of hazardous air pollutants [2].

Table 3-4. VOCs to be analyzed from Carbotrap 300.

VOCs		
1,1,1-Trichloroethane*	2-Hexanone	Ethanol
1,1,2,2-Tetrachloroethane*	2-Propanol (Isopropyl Alcohol)	Ethylbenzene*
1,1,2-Trichloroethane*	4-Methyl-2-pentanone	Hexachlorobutadiene*
1,1-Dichloroethane	Acetone	m,p-Xylenes*
1,1-Dichloroethene	Acetonitrile*	Methyl tert-Butyl Ether
1,2,4-Trichlorobenzene*	Benzene*	Methylene Chloride*
1,2,4-Trimethylbenzene	Bromodichloromethane	Naphthalene*
1,2-Dibromo-3-chloropropane	Bromoform*	n-Heptane
1,2-Dibromoethane	Carbon Disulfide*	n-Hexane
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	Carbon Tetrachloride*	n-Octane
1,2-Dichlorobenzene	Chlorobenzene*	o-Xylene*
1,2-Dichloroethane	Chloroethane	Styrene*
1,2-Dichloropropane	Chloroform*	Tetrachloroethene
1,3,5-Trimethylbenzene	Chloromethane*	Tetrahydrofuran (THF)
1,3-Butadiene*	cis-1,2-Dichloroethene	Toluene*
1,3-Dichlorobenzene	cis-1,3-Dichloropropene*	trans-1,2-Dichloroethene
1,4-Dichlorobenzene	Cumene*	trans-1,3-Dichloropropene
1,4-Dioxane	Cyclohexane	Trichloroethene
2,2,4-Trimethylpentane (Isooctane)	Dibromochloromethane	Trichlorofluoromethane
2-Butanone (MEK)*	Dichlorodifluoromethane (CFC 12)	Trichlorotrifluoroethane
		Vinyl Chloride*

* On U.S. EPA's list of hazardous air pollutants [2].

Efforts will be made to gather the minimum number of samples as indicated in Table 3-2 of each batch emission constituent to provide for statistical confidence. As time, site logistics, weather, and sampling dictate, additional samples will be taken. While the goal is to gather samples that sufficiently exceed analyte detection limits, the desired sampling volume to achieve this goal cannot be known a priori, as this would require knowledge of the emission factor itself and the sampling efficiency. ORD's best engineering judgment based on similar past sampling, along with a cumulative carbon counter to reflect the plume concentration observed by the sampler, will be used to estimate the necessary and sufficient sampling time/volume. The limiting constituents will likely be the trace polychlorinated dibenzodioxin/dibenzofuran (PCDD/PCDF) and NC and NG, all requiring a longer sampling time/volume than the other target compounds.

Figure 3-3. Open burns of propellant at Tooele Army Depot. Aerostat/Flyer sampling of emissions.

3.4 Sampling

Air sampling will be accomplished while NASA maneuvers their ground-controlled UAV, specifically a six-motor multicopter (hexacopter), into the plume with the EPA/ORD sampling system called the "Kolibri", Figure 3-4 (see Zhou et al., "A small, lightweight multipollutant sensor system for ground-mobile and aerial emission sampling from open area sources," EPA/ORD, in press, 2016 for further details). There are two configurations of the Kolibri (Figure 3-4) primarily relating to the different sizes of the pumps needed for specific analytes. There are duplicate models of both Kolibris for redundancy, #1/#2 for the smaller unit and #3/#4 for the larger unit. Because of payload limitations on the UAV, it is not possible to sample all of the target analytes with all of the pumps on a single platform. In addition, one pump has to be used for multiple analytes and these can only be sampled separately. Hence, the full suite of analytes can only be collected with both Kolibris and with variations in each one. In addition, some samples, such as the PCDDs/PCDFs and energetics, are trace and will require composite samples comprised of emission sampling from plumes of multiple burns. Of course, the amount of sample required to exceed method detection limits cannot be determined a priori so the Principal Investigator (PI) will have to rely on data from previous sampling efforts to form a best engineering judgment of required sampling time. This judgment, in addition to data from sampling success in the field (the number of plumes entered by the sampling craft, the residence time in the plume, and the average CO_2 concentration -- as a surrogate for analyte concentration), will be used to assess the frequency at which sample media can be refreshed.

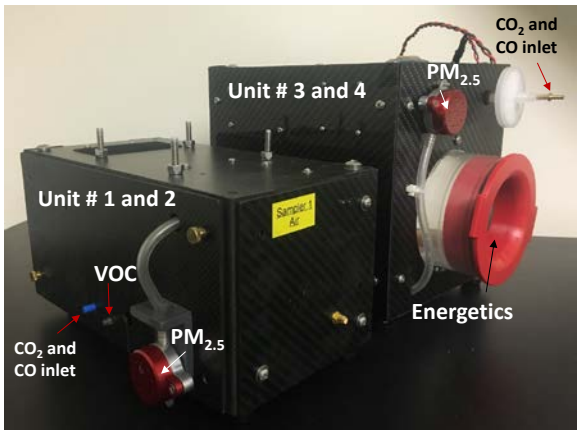

Figure 3-4. Kolibri instrumentation. The $PM_{2.5}$ impactor sampler can be switched out for Cr VI or HCl sampling cassettes.

Different configurations of the Kolibri will be used as the sampling pumps have different flow capacity and can only be used for specific analytes/methods (Table 3-5). For example, the PCDD/PCDF, NC, and NG samples all require separate sampling media and the large pump on Kolibri unit #3/4. Because each of these samples has to be collected separately with composite samples, the number of repeat samples is limited. During collection of the composite PCDD/PCDF, NC, and NG samples, more than sample of the other analytes may be gathered, depending on the sampling efficiency. All Kolibri units have CO_2 and CO sensors.

Table 3-5. Prospective Sampling Schedule with Different Kolibri configurations.

Day	Kolibri Units	Waste	All Burn Pans Sampled For:	First Half of Burn Pans/Second Half of Burn Pans*	VOC Samples:
2	3/4	Skid	NC	$PM_{2.5}$/Elements	Not applicable to Unit 3/4
				$PM_{2.5}$/Elements	
3	3/4	Dry propellant	NC	$PM_{2.5}$/Elements	Not applicable to Unit 3/4
				$PM_{2.5}$/Elements	
4	1/2	Skid	Not applicable	Chrome VI	VOC
				Chrome VI	
5	3/4	Dry propellant	NG, nitroaromatics	Chrome VI	Not applicable to Unit 3/4
				Chrome VI	
6	3/4	Skid	NG, nitroaromatics	HCl, perchlorate	Not applicable to Unit 3/4
				HCl, perchlorate	
7	1/2	Dry propellant	Not applicable	Chrome VI	VOC
				Chrome VI	
8	3/4	Skid	PCDD/PCDF	$PM_{2.5}$/Elements	Not applicable to Unit 3/4
				$PM_{2.5}$/Elements	
9	1/2	Dry propellant	Not applicable	$PM_{2.5}$/Elements	VOC
				PM2.5/Elements	

*Requires media change out for second sample. All units have CO_2 and CO sensors.

The PM sample will be used for dual purposes – gravimetry for $PM_{2.5}$ mass followed by x-ray fluorescence spectrometry (XRF) for Elements. Separate energetics samples for NC and NG will be analyzed due to their separate and distinctive analytical methods.

3.5 Flight Operations

Aerial sampling will be conducted by a UAV (see Figure 3-5 for an example) operated by a DoD contractor (NASA) at a height of less than 400 feet, will not extend beyond the boundaries of the RFAAP, and will be in visual contact with ground observers at all times. These parameters will be strictly adhered to as the site (Figure 3-2) is physically constrained by the river on one side, a tree-covered ridge on the parallel side, and a utility pole line down the center. Observers in radio communication at both ends of the pan line and in the midpoint of the ridge will allow for visual observation of the plume and coordinating the optimal position of the sampler.

Observation of previous plume burns suggests a burn time of approximately 30 seconds, suggesting that the UAV will need to be airborne downwind prior to pan ignition and the samplers must be "on" in order to maximize plume capture. Because the effect of the burn turbulence upon the UAV is unknown, the UAV flight will start at a conservative distance during initial tests. Observers with communication radios, stationed at RFAAP-approved locations, and the Lead Field Sampler (Aurell), will coordinate the positioning of the UAV through the EPA Project Coordinator (Gullett) to the UAV operator (Chirayath) to ensure the most effective positioning within the plume.

Figure 3-5. Univ. Alaska - Fairbanks hexacopter with ORD sensor/sampler payload. Detonation plume sampling at Joint Base Elmendorf-Richardson, February 2015.

3.6 Sample Identification

Each sample data sheet and sample fraction will be given an identifying code number that will designate the run number (Table 3-6). The codes and code sequence will be explained to the field team and laboratory personnel to prevent sample mislabeling. Proper application of the code will simplify sample tracking throughout the collection, handling, analysis, and reporting processes.

The Flyer data sets and all derivative data sets will be retained by Dr. Gullett. All primary and secondary data will be retained in duplicate by Dr. Brian Gullett who will create a file folder in the L drive, Public, GullettResearchUpdates labeled "raw data" to preserve all of the raw data files collected and separately store any copies and/or derivative files in a "data analysis" folder.

The matrix, start and stop time, flyer name, data logging file name, sample ID, filter ID, PM filter, HCl filter, perchlorate filter and Carbotrap 300 number for each burn will be recorded on a Sampling Record form (Figure 3-6). For each collected target compound sample a Sample Chain of Custody (CoC) (Figure 3-7) sheet will be generated. The CoC forms will be initiated and maintained by Dr. Aurell and in duplicate by Mr. Dennis Tabor, Chemist.

Table 3-6. Sample Nomenclature.

AA-CC-DD-MMDDYY-EE-FF		
	Sample Code	**Code definition**
AA	TB	Test condition (TB = Trip blank, PL = Plume Sample, BS = Background Field Sample)
CC	PM	Sampling Media (PM2.5 = Particulate Matter Filter, Energetics, HCl, PCh – perchlorate, NC/NG, VOC, Cr – Chrome VI, PCDD/PCDF)
DD	RAAP/MK90/01	Test burn number, place and matrix (RAAP = Radford Army Ammunition Plant, MK90, SW = Skid waste)
MMDDYY	071510	Date Field, month/day/year
EE	U04	Kolibri used (Unit 01-04)
FF	01	Sample Number (01, 02, 03, etc.)

SAMPLING RECORD

Project name:
Project location:

Matrix: Start time:

Date: Stop time:

☐ CO_2	☐ SVOC Sorbent pack	☐ Black Carbon - Aeth.
☐ CO	☐ $PM_{2.5}$ Quartz filter	☐ PM_{10}
☐	☐ 6 L Summa Canister	☐ $PM_{2.5}$ Teflon filter
☐ GPS, MTiG	☐	☐ Continuous PM

CO_2 trigger concentration (ppm):

Ambient temperature (°C):

Ambient pressure:

SVOC Sorbent pack

Sample ID:

Venturi #:

$PM_{2.5}$ Teflon filter

Sample ID:
Lab filter ID:
Impactor #:

6 L Summa Canister

Sample ID:
CAS Lab #:
Filter pore size:

$PM_{2.5}$ Quartz filter

Sample ID:
Lab filter ID:
Impactor #:

PM_{10}

Sample ID:
Lab filter ID:
Impactor #:

Black Carbon - Aeth.

Sample ID:
Start:
Stop:

Sample ID:
Filter #1:
Filter #2:
Filter #3:

Continuous PM

Data file name:

LabView Data file names:

Comments:

Figure 3-6. Sampling Record Form.

Project: Page of

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

SAMPLER:

Requested Analyses

	SAMPLE ID	DATE	TIME	MATRIX	PM	Filter #	1	2	3	4	5	6	7	8	9	10	Remarks

Requested Analyses	
1	
2	
3	
4	
5	
6	
7	

Special Instructions/Comments:

☐ Special QA/QC Instructions

Laboratory Information and Receipt

Lab Name:
Shipping Tracking #
Specify Turnaround Requirements:

☐ Cooler packed with ice
☐ Cooler custody seal intact

Sample Receipt:
Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:

Figure 3-7. Chain of Custody Form.

4 Measurement and Quality Assurance Procedures

4.1 CO_2 Measurements

The carbon balance method for determining emission factors requires a comparison of the amount of carbon sampled in the gas stream versus that in the original fuel. The majority of the carbon is present as CO_2. The system CO_2 sensor (DX62210/DX6220 OEM Model, RMT Ltd, Moscow, Russia) measures CO_2 concentration by means of infrared absorption (NDIR). Sensor output voltage is linear from 200 to 2000 ppm. The DX62210/DX6220 will be calibrated in the EPA Metrology Laboratory prior to departure at 0 to 2000 ppm with ± 2 ppm error using EPA Method 3A [3]. A particulate filter precedes the optical lens. The DX62210/DX6220 will be calibrated for CO_2 on a daily basis in accordance with EPA Method 3A[3]. The DX62210/DX6220 CO_2 concentration will be recorded on the Teensy a USB-based microcontroller board using an Arduino-generated data program. CO_2 background samples will be taken daily prior to sampling.

CO_2 from AirGas (ca. 4500 ppm) will be used for calibration. All gas cylinders used for calibration are certified by the suppliers that they are traceable to National Institute of Standards and Technology (NIST) standards. A precision dilution calibrator Serinus Cal 2000 (American ECOTECH L.C., Warren, RI, USA) will be used to dilute the high-level span gases for acquiring the mid-point concentrations for the e2V EC4-500-CO calibration curves. The Serinus Cal will be evaluated in the field as specified in U.S. EPA Method 205 – Verification of Gas Dilution Systems for Field Instrument Calibrations [4].

Table 4-1. CO_2 Quality Information.

Target Compound	Measurement/ Analytical Method	Sampling Rate	QA/QC Check Procedure	QA/QC Check Frequency	Acceptance Criteria/DQIs	Reference Standard	Corrective Action	Preservation/ Storage
Carbon dioxide	NDIR CEM DX6210 or DX6220 [3]	Every second	3 point zero & calibration drift test	1 per sample, daily in field	±5% of span	Certified CO_2 calibration gases	Re-calibrate monitor	L: drive storage

4.2 CO Measurements

The CO sensor (e2V EC4-500-CO) is an electrochemical gas sensor (SGX Sensortech Ltd, High Wycombe, Buckinghamshire United Kingdom) which measures CO concentration by means of an electrochemical cell through CO oxidation and changing impedance. The E2v CO sensor has a CO detection range of 1-500 ppm with resolution of 1 ppm and sensitivity of 55-85 nA/ppm. The temperature and relative humidity (RH) operating range is -20 to +50 °C and 15 to 90% RH, respectively. The response time is less than 30 seconds. Output is

non-linear from 0 to 500 ppm. A calibration curve has been calculated in the EPA Metrology Laboratory at 0 to 100 ppm with ± 2 ppm error using U.S. EPA Method 3A[3]. The sensor will be calibrated for CO on a daily basis in accordance with U.S. EPA Method 3A[3]. The sensor has a weight of approximately 5 g. The storage life of the CO sensor is six months. The e2V CO concentration will be recorded on the Teensy a USB-based microcontroller board using an Arduino-generated data program. CO background samples will be taken daily prior to sampling.

CO from AirGas (ca. 100 ppm) will be used for calibration. All gas cylinders used for calibration are certified by the suppliers that they are traceable to NIST standards. A precision dilution calibrator Serinus Cal 2000 (American ECOTECH L.C., Warren, RI, USA) will be used to dilute the high-level span gases for acquiring the mid-point concentrations for the e2V EC4-500-CO calibration curves. The Serinus Cal will be evaluated in the field as specified in U.S. EPA Method 205 – Verification of Gas Dilution Systems for Field Instrument Calibrations [4].

Table 4-2. CO Quality Information.

Target Compound	Sampling/ Measurement/ Analytical Method	Sampling Rate	QA/QC Check Frequency	QA/QC Check Procedure	Acceptance Criteria/DQIs	Reference Standard	Corrective Action	Storage
Carbon monoxide	CEM/E2v EC4-500-CO Electrochemical cell[3]	Every second	1 per sample, daily in field	3 point zero & calibration drift test	±5% of span	Certified CO calibration gases	Re-calibrate monitor	L: drive storage

4.3 Volatile Organic Compounds

VOCs will be sampled using Carbotrap 300 stainless steel TD Tube (Supelco Inc., Bellefonte, PA, USA) via a constant micro air pump (3A120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) in accordance with U.S. EPA Method TO-17 [5]. The VOCs captured on the Carbopack 300 are stated in Table 3-4 . The Carbotrap 300 tubes are analyzed by ALS Simi Valley for VOCs by thermal desorption GC/MS according to U.S. EPA Method TO-17 [5]. A total of less than 6L of gas, sampled at 150 mL/min, will be sampled. An ambient background sample will be taken as well as a trip blank.

The constant flow pump will be calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Peterburg, FL, USA). The constant pump is turned off and on based on the CO_2 concentration trigger set point using the KolibriDAQ program a labview generated program on the remote computer. The trigger function is turned off when the pump can no longer maintain the set flow, which is indicated on the KolibriDAQ interface.

Table 4-3.VOC Measurements via Carbotrap 300 Quality Information.

Target Compound	Measurement/ Analytical Method	Sampling Rate	Reference Standard	QA/QC Check Procedure	Acceptance Criteria/ DQIs	Corrective Action	Sample Handling/ Preservation	Hold Time	Laboratory
Volatile organic compounds (VOCs)	Carbotrap 300/U.S. EPA[5], GC/LRMS	0.15 L/min	Blank carbotrap sample	Sample leak check, blank samples, background sample, pre-run blanks and standards	±10% of 6L of gas sampled	compare blank with samples	Store in cooler	30 d	ALS – Simi Valley

4.4 Energetics

Energetics are sampled using two 15 cm glass fiber filters (Fisher Scientific) with a nominal rate of 600 L/min. Energetics are sampled using a low voltage MINIjammer brushless blower (AMTEK, USA). The blower is triggered by the CO_2 concentration set points using the KolibriDAQ program. The flow rate is measured by a 0-622 Pa Model 265 pressure differential transducer (Setra, USA) across a Herschel Standard Venturi tube (EPA in-house made). The Venturi tube is specially designed to meet the desired sampling rate for the target compound. The Venturi tube is mounted on the outlet of the MINIjammer blower (AMTEK, USA). The voltage equivalent to this pressure differential is recorded on the onboard Teensy USB microcontroller board, which is calibrated with a Roots meter (Model 5M, Dresser Measurement, USA) in the U.S. EPA metrology laboratory before sampling effort. A K-type temperature thermistor (Adafruit, New York, NY USA) is measuring the air temperature exiting the venturi as well as the ambient temperature these thermistors are calibrated in the U.S. EPA metrology laboratory before sampling effort. The Kolibri has battery capacity for about twenty minutes of energetics sampling.

In accordance with previous experience, all of the energetics are believed to be captured on the glass microfiber filter thimble prior to the blower. The filters will be removed, folded into aluminum foil, bagged, and tagged prior to transferring to the analytical laboratories. The outside laboratory analytical methods are U.S. EPA Method 8330b [6] for Nitroglycerin and possible degradation products and the nitrocellulose by U.S EPA Method 353.2 [7] which is a nitrate-nitrite colorimetric method. The filters would may need to be cut to perform the methods but will not be subsampled. The deposition pattern on the thimble has not been demonstrated to be uniform so the whole sample will need to go to an analysis, which may increase detection limits because of the increased amount of solvent needed. Background samples for ambient energetics will be taken for analysis.

Table 4-4. Energetic Sampling.

Target Compound	Sampling/Measurement/Analytical Method	Sampling Rate	Sample Container/Handling	Preservation/ Storage	Hold Time	Laboratory
Energetics	Glass microfiber filters/Methods 8330b [6] and 353.2 [7]	300 L/min	Store in jar in cool, dark place	refrigerator	60 d	ALS Kelso
Temperature	K-type thermocouple with amplifier	1 Hz	Range: -25 to 400°C	Accuracy: ±2°C	NA	NA

Table 4-5. Quality Assurance for Energetic Sampling.

Measured Parameter	QA/QC Check Procedure	Reference Standard(s)	QA/QC Check Frequency	Acceptance Criteria/ DQIs	Corrective Action
Energetics, venturi	Gas pump flow calibration/Filter cartridge blanks	Roots meter in EPA Met Lab	Before and after field tests	±10%	Re-calibrate gas pump
Temperature	Calibration	EPA Met Lab	Before and after field tests	±10%	Re-calibrate

4.5 PCDD/PCDF

PCDD/PCDF will be sampled as for energetics (see 4.4) with the addition of a polyurethane foam plug (PUF) inside the glass fiber thimble. After sampling the glass filter and PUF will be removed, folded, folded into aluminum foil, bagged, kept cool, and tagged prior to transferring to the analytical laboratories.

PCDD/PCDF samples will be cleaned up and analyzed using an isotope dilution method based on U.S. EPA Method 23 [8]. Concentrations will be determined using high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) with a Hewlett-Packard gas chromatograph 6890 Series coupled to a Micromass Premier mass spectrometer (Waters Corp., Milford, MA, USA) with an RTX-Dioxin 2, 60 m × 0.25 mm × 0.25µm film thickness column (Restek Corp., Bellefonte, PA, USA). For analysis of tetra- through octa-CDDs/Fs, Method 8290 [9] will be followed. The standard used for chlorinated dioxin/furan identification and quantification will be a mixture of standards containing tetra- to octa-PCDD/F native and 13C-labeled congeners designed for modified U.S. EPA Method 23 [8] (ED-2521, EDF-4137A, EDF-4136A, EF-4134, ED-4135, CIL Cambridge Isotope Laboratories Inc., U.S.A.). The PCDD/F calibration solutions will be prepared in house and will contain native PCDD/F congeners at concentration from 1 (ICAL-1)-100 (I-CAL6) ng/mL.

A background sample for ambient PCDD/PCDF will be taken for analysis.

Table 4-6. PCDD/PCDF Quality Information.

Target Compound	Sampling/Measurement/Analytical Method	Sampling Rate	Sample Container/Handling	Preservation/ Storage	Hold Time	Laboratory
PCDD/PCDF	Modified TO-9A[10], PUF/glass microfiber filter, HRGC/HRMS	300 L/min	Store in jar in cool, dark place	refrigerator	60 d	EPA

Table 4-7. DQI Goals for PCDD/PCDF Pre-Extraction Standard Recoveries

Measurement Method	Reference	Data Quality Parameter	Specifications (%)	Completeness (%)
$^{13}C_{12}$-labelled Tetra-Hexa PCDDs/Fs	EPA Method 23 [8]	Recovery	40-130	>90
$^{13}C_{12}$-labelled Hepta –Octa PCDDs/Fs	EPA Method 23 [8]	Recovery	40-130	>90

4.6 Particulate Matter

4.6.1 $PM_{2.5}$

$PM_{2.5}$ will be sampled with SKC impactors (761-203B) using 37 mm tared Teflon filter (Chester LabNet) with a pore size of 2.0 µm via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) of 10 L/min. PM will be measured gravimetrically following the procedures described in 40 CFR Part 50 [11]. Particles larger than 2.5 µm in the $PM_{2.5}$ impactor will be collected on a greased impaction disc mounted on the top of the first filter cassette. The constant flow pump will be calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Petersburg, FL, USA).

The Teflon filters will be obtained from Chester Lab net. The analytical balance used to weigh filters shall be suitable for weighing the type and size of filters and have a readability of ±10 µg. All sample filters used shall be conditioned to 20-23 °C and 30-40 % RH for a minimum of 24 h immediately before both the pre- and post-sampling weighing. Both the pre- and post-sampling weighing should be carried out on the same analytical balance, using an effective technique to neutralize static charges on the filter. The pre-sampling (tare) weighing shall be within 30 days of the sampling period. The post-sampling conditioning and weighing shall be completed within 30 days after the end of the sample period. Sampled filters are returned to the filters' petri-dish and sealed with Teflon tape. The petri-dishes are stored in separate Zip-Lock bags with desiccant. The Zip-lock bags are marked with the sampling information e.g. filter number, petri-dish number, sampling date. Filter samples are shipped to the laboratory separate from bulk samples. Background samples will be taken for analysis.

Table 4-8. $PM_{2.5}$ Filter Sampling Information.

Target Compound	Sampling/Measurement/ Analytical Method	Sampling Rate	Sample Handling	Preservation/ Storage	Hold Time	Laboratory
$PM_{2.5}$	37 mm Teflon Filter/gravimetric/40 CFR Part 50 Appendix J [11]	10 L/min	1 filter in one petri dish/ sample	dessicator	30 d	Chester LabNet

Table 4-9. $PM_{2.5}$ Filter Sampling Quality Information.

Measured Parameter/Method	QA/QC Check Procedure	Reference Standard(s)	QA/QC Check Frequency	Acceptance Criteria/ DQIs	Corrective Action
$PM_{2.5}$ Particulate Concentration/analytical balance	Gas pump flow calibration with Gilibrator, filter blanks, balance calibration	Bubble flow meter, ASTM Class 1 weights	Flow meter prior to and 1x during sampling trip	±5% of 10 L/min, ±30 ug, 90% complete	Re-calibrate gas pump, check for contamination, re-calibrate balance

4.6.2 Metals/Elements

Metal/element species will be determined by x-ray fluorescence spectrometry (XRF) analysis of the Teflon $PM_{2.5}$ filters using EPA Compendium Method I0-3.3 [12]. XRF is non-destructive, so filters can be saved for additional analyses using more expensive inductively coupled plasma (ICP) using EPA Compendium Method Io-3.4 [13] or Graphite Furnace atomic absorption (AA)[14], if necessary. Chester LabNet will evaluate precision with a multi-element quality control standard (QS285) and accuracy using NIST standard reference materials: SRM 1832-3 and 2783.

Chrome VI will be determined using a proprietary method (ChesterLabNet, Tigard, OR) based on an EPA standard procedure https://www3.epa.gov/ttnamti1/files/ambient/airtox/hexchromsop.pdf . This method uses an ion chromatographic method and a post-column derivation. The method is applicable to Cr VI determination when air samples are captured on a bicarbonate-impregnated "acid hardened" cellulose filter (Chester LabNet prepared). Chrome VI will be sampled with a filter cartridge via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) of 10 L/min.

The MDL is 0.05 µg/L in 15 mL of total extract or 75 ng/filter and the Practical Quantitation Limit (PQL) is five times the Method Detection Limit (MDL). The bicarbonate-impregnated cellulose filters will be kept in a cooler before sampling and put into the cooler immediately after sampling. Background, and trip blank samples will be taken for analysis. Chester LabNet is certified by the state of Oregon to do CARB MLD039 for Cr VI.

Table 4-10. Metals Sampling and Quality Information.

Measured Parameter	Measurement/Analytical Method	Sampling Rate	QA/QC Check Procedure	Sample Handling	Storage	Hold Time	Laboratory
Metals	Teflon filter/XRF [12], ICP [13], AA [14]	10 L/min	Blank filter, Flowrate - Gilibrator, before and after sampling	1 filter in one petri dish/ sample	Desiccator	Years	ChesterLab net
Chrome VI	Bicarbonate-impregnated cellulose filter/ Chester method based on Methods 40 CFR 60 Method 306 [15] and SW 846 Method 0061 [16]	10 L/min	Background filter, Trip blank, Blank filter, Flowrate - Gilibrator, before and after sampling	1 filter in one petri dish/ sample, cooler	Freezer	90 d	ChesterLab net

4.6.3 HCl, Perchlorate, Chlorate and Chloride

Methods for sampling HCl are derived primarily from the methods intended for sampling inhalable HCl to relate to exposure risk. A filter method (ISO Method 21438-2) [17], will sample HCl using 1-2 alkali-impregnated filters following a solid perchlorate and chloride filter. HCl gas is expected to pass through the first perchlorate/chloride filter and be adsorbed by a second filter coated with Na_2CO_3 . These coated filters are available in a cartridge from SKC Corporation. Any hydrochloric acid transiently collected on the initial filter is expected to rapidly evaporate and be collected along with the gaseous HCl [18]. This method, including the prefilter followed by a Na_2CO_3-impregnated filter, is consistent with a method from France (INRS) [19], as cited in Howe et al. [18] and became a European standard method 2009 (ISO Method 21438-2) [17]. Perchlorate will be sampled using a modification of the method discussed in Lamm et al. [20]. The method consists of sampling at a flow rate of 2 L/min through a 37 mm mixed cellulose ester (MCE) filter (0.8 µm pore size) enclosed in a closed-face cassette (SKC Corporation) using a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA). The constant flow pump will be calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Petersburg, FL, USA). Perchlorate salts are captured as a solid on the filter, which assumes no perchloric acid formation. Cassette samples will be dissolved/extracted in water, an internal standard added, and then analyzed for perchlorate and chlorate with LCMS and for chloride with ion chromatography as per methods in Table 4-11. Samples will be analyzed at ALS, NY. The detection limit for perchlorate is cited as 0.004 µg/filter by ALS (NY). This filter will be analyzed for HCl by ion chromatography methods specified in U.S. EPA Method 26 [21]. Background samples will be taken for analysis. Laboratory method blanks and control samples will be analyzed.

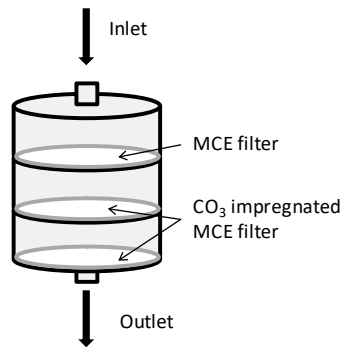

Figure 4-1. Sampling apparatus for HCl, perchlorate, and chlorate.

Table 4-11. Chloride Measurements and Quality Information

Measured Parameter	Measurement/Analytical Method	Sampling Rate	QA/QC Check Procedure	Sample Handling	Storage	Hold Time	Laboratory
Chlorides	alkali-impregnated filter/ ISO Method 21438-2 [17], IC method 300.0	2 L/min	Blank filter, Flowrate - Gilibrator, before and after sampling	Cool dark box	Refrigerator	28 d	ALS NY
Perchlorate Chlorate	Filter/Modifications from Lamm et al. [20]; EPA Method 6850 [24].	2 L/min	Blank filter, Flowrate - Gilibrator, before and after sampling	Cool dark box	Refrigerator	28 d	ALS NY

4.7 Emission factor calculations

The determination of emission factors, mass of pollutant per mass of fuel burned, depends upon foreknowledge of the fuel composition, specifically its carbon concentration. The carbon in the fuel is presumed for calculation purposes to proceed to either CO_2 or CO, with the minor carbon mass in hydrocarbons and PM is ignored. Concurrent emission measurements of pollutant mass per carbon (as CO_2 + CO) can be used to calculate total emissions of the pollutant from the fuel using its carbon concentration.

An estimation of the sampling time required to exceed analyte detection limits can be done using ORD's historical data. Past sampling and analytical data for RDX, as a surrogate for NC and NG, indicated that the minimum amount of carbon sampled (from V453 detonations) as plume CO_2 to exceed RDX detection limits was 0.0053 g. From past OB work an expected carbon sampling concentration is 0.002 g C/L of gas volume sampled. Using these data, the Kolibri sampling rate (300 L/min), and the higher detection limits for NG (20X higher than RDX), we estimate a requirement for 0.11 g carbon to exceed the NG detection limit which will require a cumulative amount of 1.7 min of residence time in one or more plumes. The same calculations for NC (with 125X the detection limit of RDX) suggest a requirement of about 10 minutes cumulative plume residence time.

4.8 Kolibri Data Acquisition System and Data Storage

The Kolibri's data acquisition system (DAS) consist of an onboard Teensy universal serial bus (USB)-based microcontroller board (Teensy 3.1, PJRC, LLC., Sherwood, OR, USA) running an Arduino based data acquisition and control program ("TeensyDAQ"). The main assignment for the TeensyDAQ is power regulation, data logging, and data transmission. The power control circuit on the Teensy board provides a regulated voltage for all the electrical components in the sensor package. Also included in the DAS is a ground based computer which is running "KolibriDAQ" a Labview generated data acquisition and control program, which is used to view live data and run/control the onboard TeensyDAQ via a XBee wireless network (Xbee S1B, Digi International, Inc., Minnetonka, MN, USA) (see Figure 4-2 below). The KolibriDAQ is capable of plotting real time CO_2 and CO data, display sampling time, VOC sampling volume, and performing on the fly calculations to estimate the total amount of gaseous carbon sampled for the energetic sample.

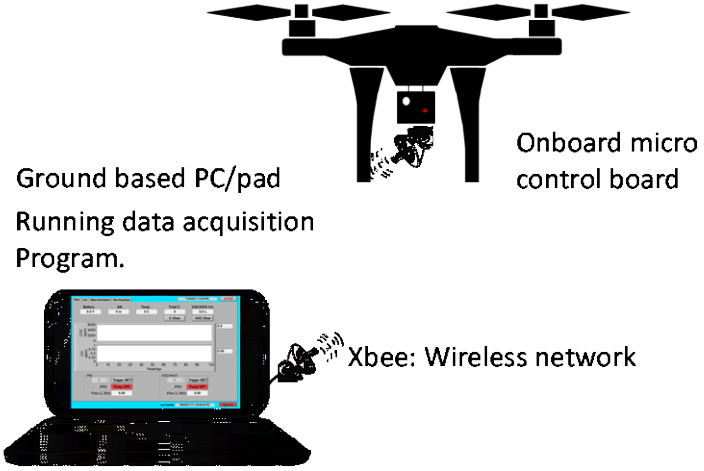

Figure 4-2. Schematic of Data Acquisition System, not to scale.

All raw data will be time stamped, and written to a standard secure digital (SD) card on the onboard TeensyDAQ at a rate of one sample per second (1 Hz). Visual indicators for station-to-station communications and data logging will be checked and downloaded to computers periodically during the test. At the end of each test, the micro SD memory cards will be transferred from the SD cards to external hard drives via a laptop computer with a Universal Serial Bus (USB) port. The SD cards will also be checked for valid data and labeled for physical archive with project name, date, and time. Data will also be uploaded to EPA's managed servers for archive and accessibility. Data files are in tab delimited text files and are thus easily imported into common spreadsheet/database analysis programs (*e.g.* MS Excel and Origin).

Electronic data and pictures will be posted in the folder L:\Lab\NRML_Public\GullettResearchUpdates\ on the EPA network share drive upon return from the field or as they are generated or received.

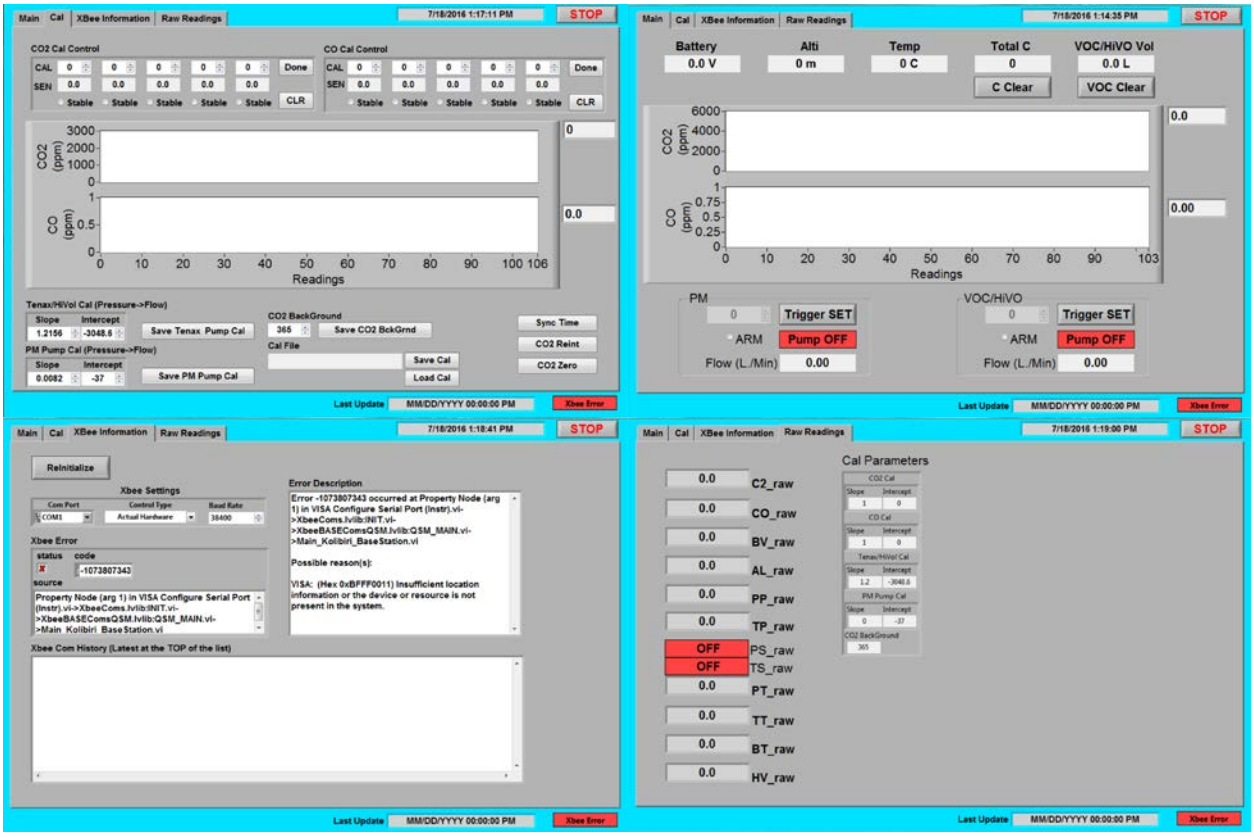

Figure 4-3. KolibriDAQ interface windows: Run, Calibration, Xbee wireless network information, and raw data readings.

5 Data Analysis, Interpretation, and Management

The emission ratio of each species of interest will be calculated from the ratio of pollutant concentrations to background-corrected carbon dioxide and carbon monoxide concentrations. Emissions factors will be calculated using these emissions ratios following the carbon balance method (see, for example, Burling et al.[22]), shown in equation 1.

$$EF_i = f_c \frac{ER_i}{\sum_j \frac{\Delta C_j}{\Delta CO_2 + \Delta CO}} \qquad \text{Eq. 1}$$

where EF_i is the emission factor of species i in terms of gram effluent per kilogram fuel (waste burned), f_c is the fraction of carbon in the fuel, ER_i is the mass emission ratio of species i, ΔCO_2 is the background-corrected mass concentration of CO_2, ΔCO is the background-corrected mass concentration of CO, ΣCj is the background corrected mass concentration of carbon in major carbon emissions species j. The majority of the carbon emissions will be emitted as carbon dioxide.

Replicate test data will be compared by means and standard deviations (or relative percent difference when only two values are known).

Emission factor data can be discussed in comparison to previous emission estimates provided by RFAAP.

6 Assessment and Oversight

This project does not require planned technical systems and performance evaluation audits. However, should deficiencies be identified by any of the key individuals responsible, the EPA PI will discuss the problem and corrective actions to be taken for subsequent sampling or analyses.

7 Reporting

7.1 Deliverables

- An outside laboratory (ALS Global, Kelso, WA, USA; backup: APPL, Clovis, CA, USA) will provide energetics analyses.
- An outside laboratory (ChesterLabNet, OR) will provide gravimetrics, XRF.
- ALS NY is doing chloride, chlorate, and perchlorate analyses.
- An outside laboratory (ALS, Simi Valley, CA USA) will provide VOC analyses.
- Tabor (EPA) will provide PCDD/PCDF mass to Dr. Aurell.
- Dr. Aurell will calculate cumulative CO and CO_2 values relative to sampling times and then determine emission factors.
- EPA (Gullett) will provide a data report/paper.

7.2 Output

The product output of this effort will include a final report/paper to be reviewed by and written by ORD, UDRI, and RFAAP.

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Appendix F: Data Quality Audit

Internal Audit Report

Title:	Characterization of Air Emissions from Open Burning at the Radford Army Ammunition Plant
Audit Type:	Data Quality
EPA PI:	Brian Gullett Air and Energy Management Division (AEMD) Immediate Office of the Director US Environmental Protection Agency
Audit Date:	August 9-11, 2017
Auditors:	Libby Nessley, AEMD QA Manager Immediate Office of the Director US Environmental Protection Agency Research Triangle Park, NC

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1.0 Background/Scope

The Department of the Army commissioned NASA-Ames to fly their unmanned aerial vehicle (UAV), a hexacopter, into the plumes from open burning of propellant and manufacturing discards at the Radford Army Ammunition Plant while carrying a gas a particle sensor system designed and operated by EPA ORD. Over a 2-week period the team sampled 33 plumes, determining emissions factors for particulate matter, metals, chloride, perchlorate, volatile organic compounds, chlorinated dioxins/furans, and nitrogen-based organics.

A summary report titled *Characterization of Air Emissions from Open Burning at the Radford Army Ammunition Plant* was generated by EPA ORD detailing sampling and analytical results. This data quality audit (DQA) focused on traceability of the reported results back to the raw data. Original laboratory reports were reviewed to ensure data was entered correctly in to spreadsheets. Spreadsheet calculations were checked and verified to be accurate. The origin of 100% of the data included in the report was traced back to the original spreadsheet or laboratory report. Associated data and calculations in ancillary spreadsheets and files were reviewed at a rate of approximately 100% for the 09-27-2016 test to check use of spreadsheets for calculation of emission factors. Other test dates were reviewed at a rate or approximately 10%.

2.0 Data QA Review Process

100% of the data in the Radford report was traced back to the original spreadsheet or laboratory report from which it came. The following folders and files were provided by the EPA Principal Investigator for use in the DQA and evaluating spreadsheets and calculation of emission factors:

- Kolibri Unit 2-Balder
  - *Unit 2 09-30-2016.xlsm*
- Kolibri Unit 1-Loke
  - Processed
    - *Unit 4 09-27-2016.xlsm*
    - *Unit 4 09-28-2016.xlsm*
    - *Unit 4 09-29-2016.xlsm*
    - *Unit 4 10-03-2016 ambient.xlsm*
    - *Unit 4 10-04-2016.xlsm*
    - *Unit 4 10-05-2016 ambient.xlsm*
    - *Unit 4 10-05-2016.xlsm*
    - *Unit 4 10-06-2016 ambient.xlsm*
- PM and Metals
  - *16-737.xlsx*
  - *Metals Results Radford.xlsx*
  - *PM Results Radford.xlsx*
  - *PM2.5, XRF metals 16-737.pdf*
- Cr VI
  - *Cr VI Results Radford.xlsx*
  - *CR(VI) 16-746.pdf*
- HCL

- *HCl perchlorate chlorate results Radford.xlsx*
- *HCl, perchlorate R1611762-US EPA RTP, NC.pdf*
- *To162-c6.pdf*

- PCDDF
  - *Summary PCDDF Radford 2016.xlsx*
  - *Radford 2016 Combined PCDDF report.pdf*
- VOC
  - *VOC P1604824.pdf*
  - Processed
    - *VOC 09-30-2016 01.xlsx*
    - *VOC 09-30-2016 02.xlsx*
    - *VOC 10-06-2016 01.xlsx*
    - *VOC 10-06-2016 02.xlsx*
    - *VOC Radford Summary.xlsx*
- Energetics
  - *Energetics EPA Radford 81217.pdf*
  - *Energetics cont DOC051717.pdf*
  - *EPA-Radford 81317.pdf*
  - *Explosives Radford 2016.xlsx*
- COC-all COCs associated with the project

QA review of spreadsheets generated for the Radford report included the following:

- ✓ Could the number reported in the report be located in a spreadsheet or laboratory report?
- ✓ Were the numbers reported calculated correctly?
- ✓ Was information in the spreadsheets easily located and identified?
- ✓ Were calculations shown in the spreadsheets?
- ✓ Were multiple calculations and numbers linked to other spreadsheets easily traced?

Results of the review are reported in Section 3. Specific findings or observations are presented in **bold text** so they can be easily identified.

3.0 Results

Data presented in Section 3-Results and Discussion of the Radford report was traced back to its origin by review of laboratory reports and spreadsheets provided by the EPA ORD Principal Investigator.

3.1 Particulate Data review

Particle data is presented in Section 3.1 (Table 3-1) of the Radford report. Filter results were correctly transferred to the *PM Results Radford.xlsx* spreadsheet for emission factor calculations. Results from spreadsheet calculations were correctly reported. No further observations were noted in the PM data review.

3.2 Elements/Metals Data Review

3.2.1 Metals by XRF

Sixteen metals were identified and emission factors reported in Tables 3-2, 3-3, and 3-4 of the Radford report. There were some minor observations noted for how the spreadsheets were organized but all of the data in the report was supported by the original laboratory report (Chester LabNet Report #16-737) and spreadsheet calculations. One observation was noted in reference to spreadsheet organization of metals data in reference spreadsheet *Metal Results Radford.xlsx*:

1. **When copying/pasting and moving large amounts of data from one area in the spreadsheet to another for performing calculations or presenting data in a different way, make sure column headings are also transferred and any calculations in cells that are not being used are either deleted or clearly marked. The following observations support this:**
    a. **On the Results tab of the spreadsheet columns/cells C82-160 through G82-160, waste fraction for skid waste applied to emission factor calculations shown in cell B82 was also inadvertently applied to MK90 waste. This data was not used in the report, but should be marked or removed from the final spreadsheet.**
    b. **Also on the Results tab columns Y/Z and AB, data for metal emission factors for lb/lb initial source (Table 3-3) was not labeled as such.**

It is recommended that when the spreadsheets are finalized, they be cleaned up, properly labeled, and locked down to "read-only" so no other manipulations can be performed.

3.2.2 Chromium IV

Cr(VI) emission factors were reported in Table 3-5 of the Radford report. Data was correctly transcribed from the laboratory report (Chester LabNet Report #16-746). One observation was noted during the spreadsheet review.

1. **An error was found in the spreadsheet *CrVI Results Radford.xlsx* on the Emission factors tab. Units for emission factors were incorrectly labeled as g/kg in the spreadsheet. The correct units of mg/kg are contained in the report. The spreadsheets were corrected when this error was pointed out.**

3.3 HCL, Chlorate, and Perchlorate Data Review

This data is reported in Table 3-6 of the Radford report. No chlorate or perchlorate compounds were detected in any of the samples collected. HCl results were correctly transferred from the original laboratory report (ALS Environmental, Service Request #R1611762) to the *HCL perchlorate chlorate results Radford.slsx* spreadsheet for calculation of emission factors. Calculations in the spreadsheet were performed correctly. One observation was noted from the spreadsheet review;

1. **On the Emission factors tab, the calculation for the numbers reported in Table 3-6 for % into air from waste could not be located in the spreadsheet.**

3.4 PCDD/PCDF Data Review

Dioxin/furan emission factors are reported in Table 3-7 of the Radford report. Raw data was correctly transferred from the laboratory report (APPCD Organic Support Laboratory, 161201 Filters) to the

Summary PCDDF Radford 2016.xlsx spreadsheet. Emission factor calculations were correctly applied and reported. No other observations were noted for the PCDD/PCDF data.

3.5 VOC Data Review

VOC emission factors are reported in Table 3-8, 3-9, 3-10, and 3-11 of the Radford report. VOC sample concentrations were correctly transferred from the laboratory report (ALS Environmental, Service Request #P1604824) to the *VOC 09-30-2016.xlsx* and *VOC Radford Summary.xlsx* spreadsheets. Two observations were noted in the VOC data review:

1. **For the VOC 09-30-2016.xlsx spreadsheet, the trip blank subtraction for acetone and acetonitrile was performed incorrectly. This was corrected and made a very minor difference in the numbers contained in final emission factor and standard deviation results. This was the only spreadsheet that was done incorrectly.**
2. **The tables in the *VOC Radford Summary.xlsx* spreadsheet, VOC Tables tab should be clearly labeled**

3.6 Energetics

Nitroaromatics/nitrocellulose were analyzed by APPL Labs and accurately summarized in *Explosives Radford 2016.xlsx*. All samples were below the detection limits and emissions factors reported in Table 3-12 were calculated based on the method detection limit.

3.7 Kolibri Unit Spreadsheets-Continuous Emissions Data

Kolibri unit spreadsheets were provided for data review to have the origin of the CO/CO2 data used in emission factor calculations. One observation was noted regarding the Kolibri spreadsheets:

1. **In the Kolibri Unit 4-Loke processed spreadsheets, INPUT and OUTPUT tab, the selection of "summertime" vs. "wintertime" was not consistent across the spreadsheets. This has no ramifications on processed data.**

4.0 Summary

There were no major findings resulting from this DQA. All discrepancies/inconsistencies specified in Section 3 were minor and classified as observations. In general, the spreadsheets used for this project are excellent. Information in cells is referenced and can be traced back to origin. Calculations are adequately documented and units are included.

Final versions of spreadsheets could be improved by removing redundant data and making sure all columns are clearly labeled. It is also important when copying/pasting or dragging down cells to copy to be very careful with cells that contain calculations. These can easily be altered inadvertently and cause erroneous results that are difficult to detect. It would be a good practice once spreadsheets are finalized to delete any redundant information, make sure all data is clearly labeled with associated units and make the final spreadsheets read-only.

Appendix G: Scientific Journal Paper

“Field determination of multipollutant, open are combustion source emission factors with a hexacopter unmanned aerial vehicle”

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journal homepage: www.elsevier.com/locate/atmosenv

Field determination of multipollutant, open area combustion source emission factors with a hexacopter unmanned aerial vehicle☆

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[d] Stinger Ghaffarian Technologies, Inc., Moffett Field, CA 94035, USA

HIGHLIGHTS

- An unmanned hexacopter aircraft was coupled to an emission sampler.
- The system was flown into 84 combustion plumes.
- Gas and particles were sampled to determine emission factors.
- The system measured particulate matter, metals, volatile and semi-volatile organics.
- This system can safely and efficiently sample open area emission sources.

GRAPHICAL ABSTRACT

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ABSTRACT

An emission sensor/sampler system was coupled to a National Aeronautics and Space Administration (NASA) hexacopter unmanned aerial vehicle (UAV) to characterize gases and particles in the plumes emitted from open burning of military ordnance. The UAV/sampler was tested at two field sites with test and sampling flights spanning over 16 h of flight time. The battery-operated UAV was remotely maneuvered into the plumes at distances from the pilot of over 600 m and at altitudes of up to 122 m above ground level. While the flight duration could be affected by sampler payload (3.2–4.6 kg) and meteorological conditions, the 57 sampling flights, ranging from 4 to 12 min, were typically terminated when the plume concentrations of CO_2 were diluted to near ambient levels. Two sensor/sampler systems, termed "Kolibri," were variously configured to measure particulate matter, metals, chloride, perchlorate, volatile organic compounds, chlorinated dioxins/furans, and nitrogen-based organics for determination of emission factors. Gas sensors were selected based on their applicable concentration range, light weight, freedom from interferents, and response/recovery times. Samplers were designed, constructed, and operated based on U.S. Environmental Protection Agency (EPA) methods and quality control criteria. Results show agreement with published emission factors and good reproducibility (e.g., 26% relative standard deviation for $PM_{2.5}$). The UAV/Kolibri represents a significant advance in multipollutant emission characterization capabilities for open area sources, safely and effectively making measurements heretofore deemed too hazardous for personnel or beyond the reach of land-based samplers.

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1. Introduction

Characterizing emissions from open area sources such as fires poses unique challenges to fully quantifying the release of pollutants over a wide area. Short of sampling the whole emission plume, the carbon balance method (Nelson, 1982) is often used for combustion sources. The carbon balance method relies on sampling a subset of the emissions and relating that value back to the original fuel. The method employs co-sampling the target emissions along with carbon species such as CO_2 and CO and, with knowledge of the carbon content in the combustible fuel, allows calculation of an emission factor as mass of pollutant per mass of combusted fuel. These emission factors are used in dispersion models (for example Bjorklund et al., 1998) to predict exposure and environmental deposition as well as in emission inventories to set source priorities.

The challenges of sampling open area combustion sources include representative sampling of a wind-driven, mixing, and convective plume. Proximity to the source may present hazards to personnel and equipment alike. Sampling at a distance raises challenges of securing sufficient sample to exceed detection limits from a diluted plume. Solutions to quantifying these hard to sample sources often include aerial sampling of the plume. Airplanes equipped with gas samplers (Yokelson et al., 2013; Burling et al., 2011) have used the carbon balance method and plume transects (Lavoie et al., 2017) to determine emission factors. Tethered aerostats (helium-filled balloons) equipped with gas/particle samplers have been employed for oil fires at sea (Aurell and Gullett, 2010), prescribed forest fires (Aurell et al., 2015a), and open burning and open detonation of military ordnance (Aurell et al., 2011, 2015b). Both aerial sampling technologies have disadvantages. Airplanes can be expensive and can require long lead times to schedule. The speed of airplanes can limit the transect residence time in narrow plumes, limiting the sample size, resulting in non-detects. Many emission source types preclude the use of low-flying aircraft. Aerostats solve some of these issues but present other difficulties including the presence of obstacles to tethers, the need for a large ground-based crew, safety considerations, logistical issues such as the supply of helium cylinders, and limited freedom of movement.

The confluence of developments in global positioning system (GPS) technology, battery power density, miniaturization of circuitry, small gas sensors, carbon fiber materials, 3D printers to create custom structures, and unmanned aerial system (UAV) technology have erased many of the barriers to aerial emission sampling. Recent advances have demonstrated the use of UAV for atmospheric (Peng et al., 2015), laboratory-generated (Alvarado et al., 2017), and surf zone (Brady et al., 2016) particulate matter (PM) distributions. Volcano measurements of sulfur gas species have been measured by sensor-equipped UAVs (McGonigle et al., 2008; Shinohara, 2013). Multisensor-equipped UAVs have been tested on a stationary diesel engine (Villa et al., 2016) and on a roadway tunnel (Chang et al., 2016).

Applications to field sources involving multiple pollutant types, particularly trace air toxics, and determination of source emission factors, are not yet demonstrated. Preliminary laboratory and field results of a UAV-based emission sampler measuring open area combustion emissions showed emission factors consistent with those from an aerostat-lofted system (Zhou et al., 2016). This current paper extends this work, describing field applications of a more comprehensive UAV-based sensor/sampling system (termed the "Kolibri") for characterizing gas and particle emissions from open area sources. Sensors/samplers included CO, CO_2, and particulate matter ($PM_{2.5}$), and novel measurement of metals, chloride, perchlorate, volatile organic compounds, chlorinated dioxins/furans, and nitrogen-based organics. The system performance is demonstrated at three military open burn campaigns at the Radford (Virginia) and McAlester (Oklahoma) Army Ammunition Plants (RFAAP and MCAAP, respectively) where hazardous, obsolete, and off-specification ordnance is demilitarized. These open area sources are particularly challenging, as the events are short in duration, typically less than 5 s, and the rapid heat release gives rise to a fast-moving, convectively-driven plume. The potential hazards to personnel and equipment require careful consideration. These challenges have been successfully addressed with the use of a highly mobile UAV coupled to an instrumented system with fast-response/recovery sensors and high throughput samplers. The performance of the UAV is characterized by its ability to maneuver into the plume, maintain position, and follow the wind-driven plume. The functioning of the Kolibri system is described in terms of concentration determinations and emission factor reproducibility.

2. Method

The Department of Defense enlisted NASA to fly their UAV into the plumes from open burning of obsolete and hazardous military ordnance while carrying a lightweight battery operated system of gas and particle samplers/sensors (termed the "Kolibri") developed and operated by the U.S. Environmental Protection Agency (EPA) and the University of Dayton Research Institute (UDRI). The systems were used at two test sites in Virginia and Oklahoma, USA.

2.1. Test sites and materials

Both tests sites were U.S. Army ammunition facilities. The Radford Army Ammunition Plant (RFAAP) is located in the rolling hills of southwest Virginia, approximately 5 km northeast of the city of Radford, Virginia (37° 11′ 35.93″ N; 80° 31' 16.35″ W). RFAAP lies along the New River in the relatively narrow northeastern corner of the valley. The RFAAP site consists of eight pairs of burn pans in a 420 m row. Trees and a river parallel the burn pan row, separated by approximately 15 m. On the other side of the pan row, a tree-covered ridge forms the other side boundary, approximately 65 m from the pans. The pans were loaded with off-specification rocket motor propellants and manufacturing process waste ("skid" waste).

The second sampling site is located at the McAlester Army Ammunition Plant (MCAAP). MCAAP is in central Oklahoma, approximately 220 km south of Tulsa (34° 48′ 50″ N; 95° 54′ 28″ W). The site's terrain is fairly level, surrounded by fields, and centrally located between pine forests, with the shortest distance from the pan site to the tree line being 142 m. MCAAP conducts open burning of projectile propellants that are excess, obsolete, or unserviceable.

RFAAP's rocket motor propellants consist primarily of nitrocellulose and nitroglycerin (NG); sampling targeted residual nitrocellulose and other nitroaromatics to evaluate the presence of unburned propellant and its combustion byproducts. The rocket motor propellants were bagged and placed into a 5 m × 2 m pan after which they were remotely ignited using an electric arming and ignition coil. Typically, a total of about 1300 kg of propellant was placed in the three pans which were ignited over the course of an hour. The skid waste contained a variety of waste materials from propellant manufacture totaling between 227 and 736 kg. To assist the skid waste combustion, wood pallets, corrugated cardboard sheets, and diesel fuel were added to each pan. The skid waste pans were similarly ignited remotely but in three single-pan burns per day. Eight days of testing at RFAAP in a two-week period saw 25 UAV/Kolibri plume sampling flights. The total flight time including UAV test flights was 7 h 30 min.

MCAAPs open burning material consisted of projectile propellants (155 mm, M67, and M17). The open burn (OB) grounds consist of five pad locations, each with five pans. The propellant burn is initiated by igniting a detonation cord fuse which serves as a timer. Burns consisted of 360 kg of propellant in each pan. Fourteen days of testing resulted in 32 UAV/Kolibri sampling flights at MCAAP. Including UAV tests flights, a combined flight time of 8 h 55 min was undertaken.

2.2. The unmanned aerial vehicle

NASA's UAV is a DJI Innovations Matrice 600 (M600) hexacopter with 44.5 cm arm length, 32.7 cm center frame diameter, and 55.4 cm height, including landing gear (Fig. 1). The M600 is powered by six 22.2 VDC lithium polymer batteries. The aircraft weight is 9.1 kg, and it has a 15.1 kg maximum acceptable gross take-off weight. The maximum transmission distance is 5 km with a Class G airspace maximum operating altitude of 122 m. An in-field test of transmission capability showed no loss in signal strength at a distance of 1025 m. The height accuracy is ± 0.1 m from a barometrically-corrected global position satellite (GPS) readout. The M600 is equipped with the A3 Flight Controller with ground control station and remote control stick functions, using a Lightbridge 2 link 2.4 GHz telemetry system. The A3 autopilot supplied by DJI displays voltage, GPS signal strength, and telemetry in real time. The A3 uses a multi-rotor stabilization controller for navigation, flight controls, and autopilot with an inertial measurement unit (IMU) and GPS. The M600 can fly preprogrammed flight paths or be manually controlled by the pilot. The pilot can initiate an automatic controlled or manual landing. The unit has a return-to-home function when the batteries reach a preset charge threshold. An array of automatic response actions covers all event contingencies such as loss of Command & Control signal, loss of GPS signal, geofence breach, propeller/motor failure, or low voltage. The M600 has navigational LED lights for night time, line of sight operation. The combined UAV and emission sampling payload, flight procedures, safety review, and operating procedures were certified for aircraft worthiness by NASA Ames' Air Flight Safety Review Board (AFSRB) and Flight Readiness Review Board (FRRB).

2.3. Emission targets and sampling method

The target emission species for both sites and associated sampling and analytical methods are included in Table 1.

2.4. The Kolibri sensor/sampler

The Kolibri system is comprised of lightweight samplers, pumps, sensors, a GPS unit, a microcomputer, and a radio module surrounded by a carbon fiber frame (detailed in Zhou et al., 2016). The samplers and sensors were selected based on weight, power needs, and function, the latter particularly in regard to response time and recovery time, as plume sampling often involves rapid swings from ambient to elevated pollutant concentration levels. Two basic configurations of the Kolibri ("Oden" and "Loke") sample multiple pollutants; weight limitations preclude including all of the current samplers/sensors on a single model and some analytes require the same pump, precluding simultaneous sampling. Oden can be outfitted with any of the sensor/samplers except for the semivolatile sampler which is included on Loke. Both Kolibris require CO_2 and CO sensors so that pollutants can be measured in a ratio to sampled carbon. Then, with knowledge of the fuel's carbon composition, the pollutant per mass of fuel or emission factor, can be determined.

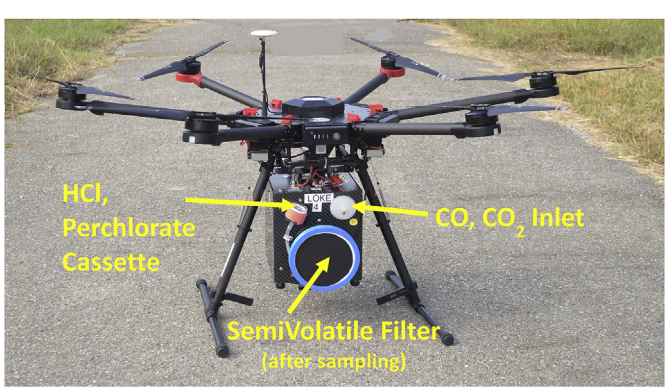


Fig. 1. UAV with attached lightweight instrument sampler, Kolibri – Loke version.

Typical Kolibri configurations for Oden weigh 3.2 kg within a 16.5 cm × 17.8 cm x 31.7 cm volume. Loke contains the larger pump motor for sampling air at a high flowrate (550 L min^{-1}) so its weight is 4.6 kg within a 21.6 cm × 26.0 cm x 45.7 cm volume. Kolibri units were secured to the base of the M600 using custom carbon fiber mounting plates and eight (8) ¼-20 stainless steel machine screws and hex nuts. Non-sampling tests for flight endurance to 20% depth of battery discharge determined flight time limits to be 17 and 25 min for the Oden and Loke Kolibri sampler payloads, respectively.

The Kolibri's data acquisition system (DAS) consists of an onboard Teensy USB-based microcontroller board (Teensy 3.2, PJRC, LLC, Sherwood, OR, USA) running an Arduino-based data acquisition and control program ("TeensyDAQ"). The main assignment for the TeensyDAQ is data logging, and data transmission (1 Hz). The Kolibri main printed circuit board (PCB) consisting of the Teensy microcontroller, connectors, and voltage regulators provides regulated voltages for all the electrical components in the sensor package. Data were stored on board the system using a Teensy universal serial bus (USB)-based microcontroller board (Teensy 3.2, PJRC, LLC, Sherwood, OR, USA) running an Arduino based data acquisition and control program ("TeensyDAQ"). Also included in the DAS is a ground-based computer that is running "KolibriDAQ", a Labview-generated data acquisition and control program, which is used to view live data and run/control the onboard TeensyDAQ via a XBee wireless network (Xbee S1B (2.4 GHz) or S3B (900 MHz), Digi International, Inc., Minnetonka, MN, USA). The XBee wireless network allowed two-way communication for control of samplers (on/off) to minimize sample dilution with ambient air. The Kolibri sampler/sensor system was controlled by a ground operator who received real time CO_2 concentrations (~4 s lag) that further helped position the UAV in the combustion plume. The KolibriDAQ plots real time CO_2 and CO data, displaying sampling time, VOC sampling volume, and performing real time calculations to estimate the total amount of gaseous carbon sampled for the energetic sample. This allows the operator to assess whether sufficient sample volume was collected for each test. Additional details are available from a previous publication (Zhou et al., 2016). During the Radford and the first McAlester campaigns, we discovered that the DJI flight control radio interfered with the Kolibri telemetry radios, causing a reduction in communication range. To address the problem, the Kolibri Digi radios were switched from the 2.4 GHz to 900 MHz bands.

The PM, CO, and CO_2 sensors/sampler (described more fully elsewhere Zhou et al., 2016) consisted of an inertial impactor (SKC, Eighty Four, PA, USA) operating at 10 L min^{-1} with a 37 mm polytetrafluoroethylene (PTFE) filter, an electrochemical sensor (EC-4-500-CO by SGX Sensortech, High Wycombe, Buckinghamshire, UK), and a nondispersive infrared (NDIR) gas analyzer (RMT Ltd.,

Table 1
Emission targets, sampling sites, and sampling frequency.

Analyte	Instrument/Method	Site	Frequency
CO_2	NDIR[a], RMT Ltd. DX6220	BOTH	Continuous
CO	Electrochemical cell, SGX Sensortech EC4-500	BOTH	Continuous
$PM_{2.5}$[b]	Impactor/Teflon filter/ gravimetric	BOTH	Batch
Nitrocellulose	Glass fiber filter, calorimetric	BOTH	Batch
Nitroglycerin and nitroaromatics	Glass fiber filter, HPLC[c]	BOTH	Batch
Elements	Teflon Filter, XRF[d]	BOTH	Batch
Cr(VI)	Filters, NIOSH[e] 7 605-7 300/LC[f]	RFAAP	Batch
Perchlorate	MCE[g] filter/LC/MS[h]	RFAAP	Batch
Chloride	MCE filter/IC[i]	RFAAP	Batch
HCl	Na_2CO_3 filter/IC	RFAAP	Batch
VOCs	Carbotrap 300, Supelco/TD GCMS[j]	BOTH	Batch
PCDDs/PCDFs[k]	Glass fiber filter/HRGC, HRMS[l]	RFAAP	Batch

[a] Non-dispersive infrared.
[b] Fine particles in the ambient air with particles less than or equal to 2.5 μm in diameter.
[c] High performance liquid chromatography.
[d] X-ray fluorescence.
[e] National Institute for Occupational Safety and Health.
[f] Liquid chromatography.
[g] Mixed cellulose ester.
[h] Liquid chromatography/mass spectrometry.
[i] Ion chromatography.
[j] Thermal desorption gas chromatography mass spectrometry (GCMS).
[k] Polychlorinated dibenzo-*p*-dioxin/polychlorinated dibenzofuran.
[l] High resolution gas chromatography/high resolution mass spectrometry.

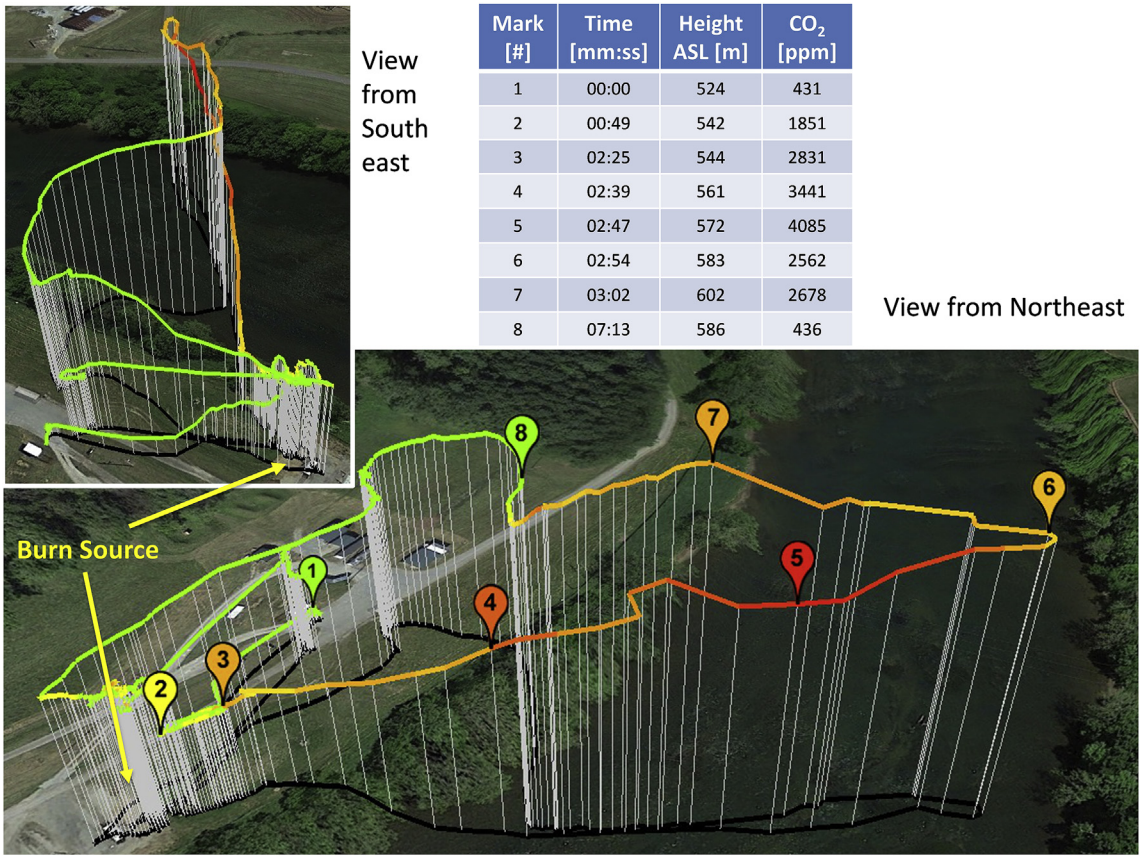
Moscow, Russia), respectively. The system CO_2 sensor (DX62210/DX6220 OEM Model, RMT Ltd., Moscow, Russia) measures CO_2 concentration by means of NDIR. The sensor underwent a daily four-point calibration in accordance with EPA Method 3A (U.S. EPA Method 3A, 1989) using National Institute of Standards and Technology (NIST)-traceable standards and a precision dilution calibrator (Serinus Cal 2000, American ECOTECH L.C., Warren, RI, USA). The CO sensor (e2V EC4-500-CO) is an electrochemical gas sensor (SGX Sensortech Ltd., High Wycombe, Buckinghamshire, United Kingdom) which measures CO oxidation and changing impedance. A calibration curve calculated in the EPA Metrology Laboratory from 0 to 100 ppm resulted in ±2 ppm error using U.S. EPA Method 3A (U.S. EPA Method 3A, 1989). As with the CO_2 sensor, CO was calibrated on a daily basis. Both the CO and CO_2 concentrations were recorded on the Teensy a USB-based microcontroller board using an Arduino-generated data program. $PM_{2.5}$ was sampled with SKC impactors (761-203B) using a 37 mm tared Teflon filter with a pore size of 2.0 μm via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) of 10 L min^{-1}. Gravimetric measurements were made following the procedures described in 40 CFR Part 50 (40 CFR Part 50, 1987). The constant flow pump was calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Petersburg, FL, USA).

A VOC sampler consisted of a Carbotrap 300 stainless steel TD Tube (Supelco Inc., Bellefonte, PA, USA) through which gas was sampled via a constant micro air pump at 160 mL min^{-1} (3A120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) in accordance with U.S. EPA Method TO-17 (U.S. EPA Method TO-17, 1997). The constant flow pump was calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Petersburg, FL, USA) and is turned on and off by the operator or automatically with a user-set CO_2 concentration trigger. The Carbotrap tubes are sampled using thermal desorption coupled to gas chromatography/mass spectrometry methods as per U.S. EPA Method TO-17 (U.S. EPA Method TO-17, 1997).

Plumes were sampled for nitrogen-based energetics through two 15 cm glass fiber filters (Fisher Scientific) with a nominal rate of 500 L min^{-1} powered by a low voltage MINIjammer brushless blower (Amtek Technology Co., Ltd., Arnold, MD, USA). The blower is triggered by the CO_2 concentration set points using the Kolibri's data acquisition program. The flow rate is measured by a ±5″ H2O Model ASDX pressure differential transducer (Honeywell, Wabash, Indiana, USA) across a Herschel Standard Venturi tube (EPA in-house made). The Venturi tube is specially designed to PCDDmeet the desired sampling rate for the target compound. The Venturi tube is mounted on the outlet of the MINIjammer blower Model 119378-52 (Amtek). The voltage equivalent to this pressure differential is recorded on the onboard Teensy USB microcontroller board, which is calibrated with a Roots meter (Model 5M, Dresser Measurement, Santa Ana, CA USA). A K-type temperature thermistor (Adafruit, New York, NY USA) measures the air temperature exiting the Venturi as well as the ambient temperature. Analytical methods include EPA Method 8330b (U.S. EPA Method 8330B, 2006) for nitroglycerin and possible degradation products and EPA Method 353.2 (U.S. EPA Method 353.2, 1993) (a nitrate-nitrite colorimetric method) for nitrocellulose,.

PCDD/PCDF sampling was done by adding a polyurethane foam plug (PUF) inside a glass fiber thimble to the energetic setup. With the pre-filter the sampler flow rate is 450 L min^{-1}. Samples were cleaned up and analyzed using an isotope dilution method based on U.S. EPA Method 23 (U.S. EPA Method 23, 1991). Concentrations were determined using high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) with a Hewlett-Packard gas chromatograph 6 890 Series coupled to a Micromass Premier mass spectrometer (Waters Corp., Milford, MA, USA) with an RTX-Dioxin 2, 60 m × 0.25 mm × 0.25 μm film thickness column (Restek Corp., Bellefonte, PA, USA). For analysis of tetra-through octa-CDDs/Fs, Method 8290a (U.S. EPA Method 8290A, 2007) was followed using the isotope dilution method with standards from Cambridge Isotope Laboratories Inc. (Cambridge, MA, USA.).

Metal/elemental species are analyzed from the PM collected on the filters. X-ray fluorescence spectrometry (XRF) analysis of the Teflon $PM_{2.5}$ filters used EPA Compendium Method IO-3.3 (U.S. EPA Compendium Method IO-3.3, 1999) and inductively coupled



Mark [#]	Time [mm:ss]	Height ASL [m]	CO_2 [ppm]
1	00:00	524	431
2	00:49	542	1851
3	02:25	544	2831
4	02:39	561	3441
5	02:47	572	4085
6	02:54	583	2562
7	03:02	602	2678
8	07:13	586	436

Fig. 2. Two views of a typical UAV/Kolibri flight path at RFAAP while sampling burn emissions. Multicolor flight path indicates CO_2 concentration (plume concentration). Projection downward indicates the ground path as a black line. ASL = Above sea level.

plasma (ICP) using EPA Compendium Method IO-3.4 (U.S. EPA Compendium Method IO-3.4, 1999) were used to identify metals. Specialty analyses for Chrome VI were conducted based on an EPA standard operating procedure (U.S. EPA SOP, 2006). Samples were captured on a bicarbonate-impregnated "acid hardened" cellulose filter through a filter cartridge (Chester LabNet, Tigard, OR, USA) via a constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA) at 9 L min^{-1}.

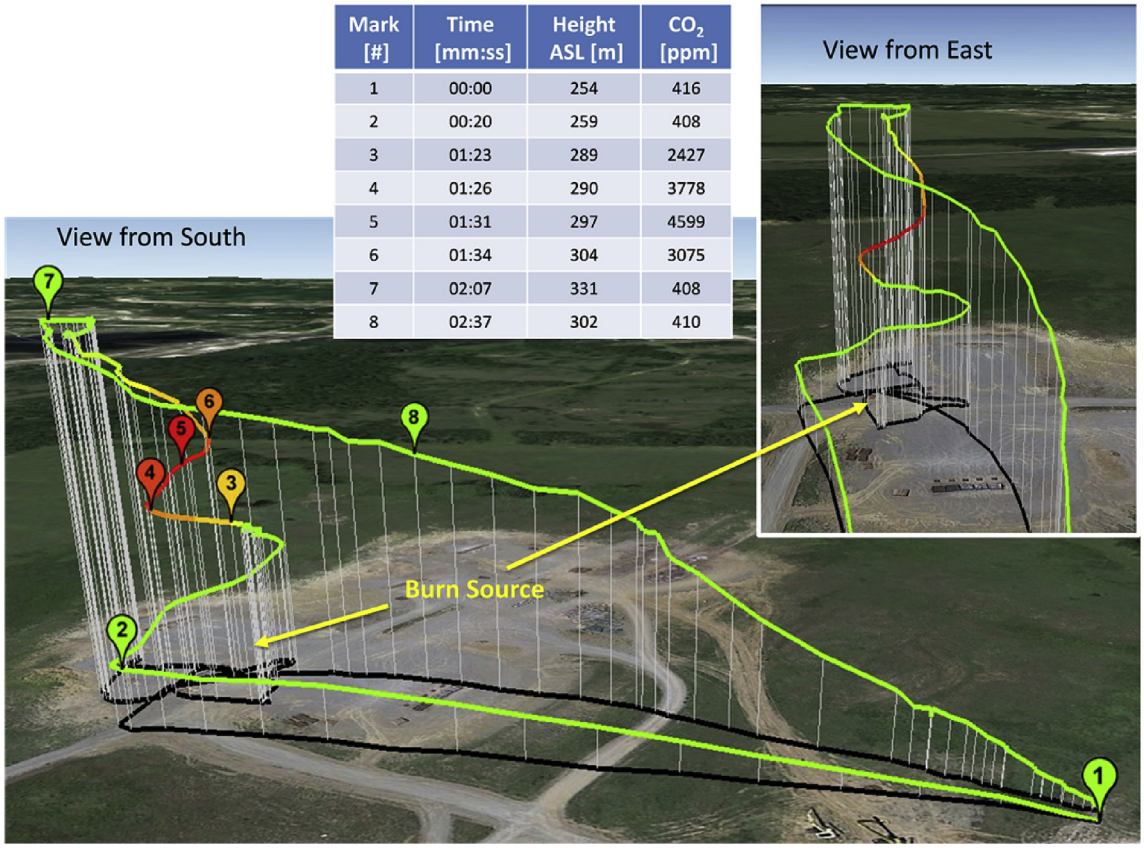
A similar sampling method was used for the collection of HCl, perchlorate, chlorate, and chloride. Methods for sampling HCl are derived primarily from the methods intended for sampling inhalable HCl to relate to exposure risk. A filter "sandwich" cassette used alkali-impregnated filters following a solid perchlorate and chloride filter (International standard ISO 21438-2:2009, 2009). HCl gas is expected to pass through the first perchlorate/chloride filter and be adsorbed by a second filter coated with Na_2CO_3. This second filter was analyzed for HCl by ion chromatographic methods specified in U.S. EPA Method 26. Perchlorate was sampled at 5 L min^{-1} through a 37 mm mixed cellulose ester (MCE) filter (0.8 μm pore size) enclosed in a closed-face cassette (SKC Corporation) using a calibrated, constant micro air pump (C120CNSN, Sensidyne, LP, St. Petersburg, FL, USA). The constant flow pump was calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, St. Petersburg, FL, USA). Perchlorate salts are captured as a solid on the filter, which assumes no perchloric acid formation. Cassette samples were dissolved/extracted in water, an internal standard added, and then analyzed for perchlorate and chlorate with liquid chromatography/mass spectrometry (LC/MS) and for chloride with ion chromatography.

2.5. Plume sampling operations

Air sampling was accomplished by maneuvering the NASA UAV hexacopter into the plume with the EPA/ORD sampling system called the "Kolibri" straddled underneath the central axis. The UAV was launched approximately 1 min prior to the burn ignitions, set to a safe altitude, and hovered over the expected path of the plume. Heights for the UAV throughout the sampling process were 10–122 m; the UAV was made to follow the plume and, if residual smoldering was observed, brought closer to the source to capture any remaining emissions. Typical downwind distances from the UAV to the source were 50–200 m; visual contact with the UAV was maintained at all times. Optimal contact with the plume was achieved by positioning radio-equipped observers in an orthogonal position to each other and by use of a visible camera with live video transmitted to the UAV operator via the DJI Lightbridge system. The pilot was aided by a Google Earth© screen image tracking the UAV position, orthogonally-positioned spotters in radio communication, and feedback from the Kolibri system's CO_2 concentration.

2.6. Emission factor calculations

The determination of emission factors, mass of pollutant per mass of fuel burned, depends upon foreknowledge of the fuel composition, specifically its carbon concentration. The carbon in the fuel is presumed for calculation purposes to proceed to either CO_2 or CO, with the minor carbon mass in hydrocarbons, and PM is ignored. Concurrent emission measurements of pollutant mass per



Mark [#]	Time [mm:ss]	Height ASL [m]	CO_2 [ppm]
1	00:00	254	416
2	00:20	259	408
3	01:23	289	2427
4	01:26	290	3778
5	01:31	297	4599
6	01:34	304	3075
7	02:07	331	408
8	02:37	302	410

Fig. 3. Two views of a typical UAV/Kolibri flight path at MCAAP while sampling burn emissions. Multicolor flight path indicates CO_2 concentration (plume concentration). Projection downward indicates the ground path as a black line. ASL = Above sea level.

carbon (as $CO_2 + CO$) can be used to calculate total emissions of the pollutant from the fuel using its carbon concentration.

3. Results and discussion

Typical UAV/Kolibri flight paths at RFAAP and MCAAP are shown in Figs. 2 and 3, respectively. Each figure illustrates the elevation and flight time. At both sites, the Matrice pilot positioned the UAV at a safe height above and slightly downwind of the burn site prior to ignition. After ignition, the UAV was maneuvered into the plume to maximize sample collection efficiency, successfully sampling every plume. The altitude stability in the turbulent convective plumes created typical altitude variations of 1–3 m due to flow instability (qualitative observation).

For plume sampling of an OB, the mobility and positional flexibility of the UAV/Kolibri system had significant advantages over more static sampling systems, such as the tethered balloon system (the Aerostat/Flyer) documented in Aurell et al. (2011, 2015b). or highly mobile systems such as airplanes running plume transects (Lavoie et al., 2017). The mobility of the UAV/Kolibri system allowed the operator to set up a takeoff zone independent of wind direction and at a safe standoff distance for personnel, saving considerable time in predicting wind direction, positioning samplers downwind of the source, and moving personnel from equipment to safe zones. The UAV/Kolibri also showed considerable x-y-z positional flexibility, allowing the operator to adjust to wind shifts and plume rise, maximizing the sampling period within the concentrated portion of the plume. The ability of the UAV/Kolibri to loiter in the plume increased the plume sampling time considerably over use of fixed wing airplanes that must deal with a few seconds of sampling through the plume before a long, looping return flight.

The performance of the UAV/Kolibri system can be assessed by comparing results with published emission factors and noting the relative standard deviation (precision) of the measurements. While limited data are available to compare the same energetic material and emissions obtained via aerial sampling, some comparisons can be made. One of the critical measures of sampling system performance is the carbon collection efficiency. The carbon collection efficiency measure reflects the ability of the UAV to be in the highest concentration of the combustion plume, measuring carbon as predominantly CO and CO_2. We compared the performance of the UAV/Kolibri system with that of the balloon-lofted instrument package (Aurell et al., 2011) measuring the same propellant type during an open burn. The UAV/Kolibri system for sampling $PM_{2.5}$ doubled the carbon collection rate of the Aerostat/Flyer, collecting 5.2 mg carbon as $CO + CO_2$ per minute for the McAlester tests. Collection rates of 5.1 mg carbon per min were obtained at Radford on the skid waste. These higher carbon collection rates indicate that the sampler is in a more concentrated part of the plume, increasing the sampling effectiveness.

The UAV/Kolibri system performance can also be assessed by comparing previous emission factors determined by the aforementioned Aerostat/Flyer to those determined using the UAV. Comparisons are made using propellants with identical composition: M67 from this work and M1 from Aurell et al. (2011). $PM_{2.5}$ measurements (this work) are compared with PM_{10} measurements in previous work (Aurell et al., 2011) without compromise as previous OB sampling has shown that these measurements are indistinct (Aurell et al., 2015b), meaning that all of the particles are of mass median diameter $PM_{2.5}$ or less. We compared M67 propellant

emission factors for $PM_{2.5}$ at McAlester versus M1 propellant emission factors for PM_{10} at Tooele (Aurell et al., 2011) and versus published airplane-based sampling data (U.S. Army AMMCOM, 1992). The airplane-based plume sampling resulted in a PM_{10} emission factor of 6.9 g PM_{10} kg^{-1} M1 (n = 2, U.S. Army AMMCOM, 1992) while the Aerostat/Flyer had a value of 5.7 g PM_{10} kg^{-1} M1 (n = 1, Aurell et al., 2011). In comparison, the UAV/Kolibri at McAlester resulted in an M67 emission factor of 4.0 g $PM_{2.5}$ kg^{-1} M67 (±1.2 std. dev., n = 9) and 4.8 g PM_{TOT} kg^{-1} M67 (±2.8 std. dev., n = 4), values statistically consistent with the limited previous data. This agreement is reasonable, given uncertainties in comparable burn methods and the limited number of historical samples, but should be further compared with additional measurements. The $PM_{2.5}$ emission factor is similar to that from the UAV also suggesting that the rotor wash does not reduce the particle sampling by the inertial impactor.

Comparisons of the measurements can also be made with lead, Pb. The UAV/Kolibri emission factor is 2.4 g Pb kg^{-1} M67 (±0.8 std. dev., n = 9, $PM_{2.5}$), whereas the Aerostat/Flyer resulted in a value of 4.3 g Pb kg^{-1} M1 (n = 1, PM_{10}, Aurell et al., 2011). The airplane-based data were below detection limit for Pb (U.S. Army AMMCOM, 1992). Given differences in the propellant amounts and the limited number of data points, these values are tentatively comparable, pending additional data.

Measurement precision can also be used to assess the performance of the sampling system. At McAlester, a total of 20 samples for $PM_{2.5}$ resulted in a sample-number-weighted relative standard deviation of 26.2%. Six samples of PM_{TOT} resulted in a 50% RSD. Likewise, lead (Pb) emissions, determined by analysis of the $PM_{2.5}$ filters (n = 17) at McAlester, resulted in emission factors with a sample-number-weighted relative standard deviation of 32.2%. VOC concentrations, sampled by a sorbent/pump system at McAlester, were measured with an average relative standard deviation of 46% whereas an evacuated canister sampler on the Aerostat/Flyer system got 54% (Aurell et al., 2011), indicating good precision for replicates.

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