Assessment of Volatile Organic Compounds from Tubing Used for Soil Vapour Sample Collection

Prepared by:

CARO Analytical Services
120 – 12791 Clarke Place,
Richmond, BC V6V 2H9
www.caro.ca

Brent Mussato, B.Sc., PChem
Stephen Varisco, B.Sc., PChem.
Luba Tsurikova, Dip.Tech.

April 1, 2009

Submitted to:

Science Advisory Board for Contaminated Sites in British Columbia
Department of Chemistry
University of Victoria
PO Box 3064 Stn C
Victoria, BC V8W 3V6

PREFACE

This report was prepared by CARO Analytical Services of Richmond, BC, for the Science Advisory Board for Contaminated Sites in British Columbia (SABCS). It provides research on volatile organic compounds (VOCs) emitted from tubing materials used for collecting soil vapour samples.

This study was conducted as a result of the British Columbia Ministry of Environment Contaminated Site Regulation (BCMOE CSR) Schedule 11 Generic Numeric Vapour Standards (1) that became effective January 1, 2009. This regulation includes risk-based numerical standards for soil vapour VOCs for various land uses. For some regulated VOCs numerical standards are at the lower limit of analytical quantitation.

Anecdotal accounts, limited literature references, and limited experimental data suggest that some tubing materials, in particular those with synthetic organic composition, may contribute detectable VOCs to sample results. These effects cannot be understated, especially when conservative regulatory limits apply.

The research study evaluated VOCs emitted from seven synthetic flexible tubing materials (silicone, PVC, LDPE, Nylon (2 types), Tygon, and Teflon) commonly used for environmental sampling and rigid PVC pipe used to construct in-ground soil vapour probes. Findings are presented for use by practitioners to help guide selection of tubing materials for soil vapour sample collection.

This document was authored by Brent Mussato, B.Sc., PChem, and Stephen Varisco, B.Sc., PChem of CARO Analytical Services in Richmond, BC. The experimental component of this study was conducted by Luba Tsurikova, of CARO Analytical Services. Technical advice and review was provided by Ian Hers, Ph.D. of Golder Associates Ltd. and Mark Hugdahl, B.Sc. of ALS Environmental. We acknowledge the SABCS Board for their support of this study.

TABLE OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

1. INTRODUCTION

Soil vapour investigations are conducted to assess the presence and concentration of sub-surface volatile organic compounds (VOCs). Soil vapour samples are collected from in-ground monitoring probes onto sorbent media or directly into canisters. Analytical test results are compared to regulatory or risk-based standards to determine if potential environmental or health concerns exist.

Soil vapour regulation is relatively new in many North American jurisdictions. This study was conducted as a result of the British Columbia Ministry of Environment Contaminated Site Regulation (BCMOE CSR) Schedule 11 Generic Numeric Vapour Standards that became effective January 1, 2009 (1). This regulation includes risk-based numerical standards for soil vapour VOCs for various land uses. For some regulated VOCs, numerical standards are at the lower limit of analytical quantitation.

Soil vapour samples are typically collected on sorbent media or into canisters, followed by analysis using gas chromatography / mass spectrometry (GC/MS). These techniques are extremely sensitive and contamination from ambient air or sample equipment is a potential concern. Sample train materials (STMs) are used to transfer the sample from the subsurface to the collection device and can include vapour probes, fittings, valves and tubing. Anecdotal accounts, limited literature references, and limited experimental data suggest that some tubing materials, in particular those with synthetic organic composition, may contribute detectable VOCs to sample results. These effects cannot be understated, especially when conservative regulatory limits apply.

A need was identified to formally assess common sample collection tubing materials for measurable VOCs. The study evaluated VOCs emitted from seven synthetic flexible tubing materials commonly used for environmental sampling (silicone, PVC, LDPE, Nylon (2 types), Tygon, and Teflon) and rigid PVC pipe used to construct in-ground soil vapour probes.

The study involved passing ultra-high purity (UHP) nitrogen through tubing materials then onto a thermal desorption (TD) tube designed to adsorb volatile and semi-volatile hydrocarbons. Analysis by GC/MS quantified VOC concentrations emitted from each tubing material. Findings are presented for use by practitioners to help guide selection of tubing materials for soil vapour sample collection.

2. Study Design and Methodology

The following sections describe study design development and methods used. A conservative study design approach was applied to maximize the potential for VOC detection while maintaining practical applications that may exist in the field. This approach influenced decisions on material storage, sample sizes, sampling volumes, experiment temperature and material handling.

2.1 Tubing Materials Studied

Multiple suppliers, grades and manufacturers exist for tubing materials. The study objective was to investigate a reasonable and representative sample of common materials. Samples were obtained from laboratory suppliers, an environmental supply company and from a drilling company. Table 2-1 lists the materials investigated.

Table 2-1 Sample Train Materials

Material Type	Bend Radius (cm)	ID x OD (inch)	Manufacturer/Supplier
Silicone	1.0	0.19 x 0.39	Calflex, Environmental Service Products, Irvine CA
PVC	1.2	0.19 x 0.31	Nalge Nunc Intl. , VWR Canlab, Mississauga ON
Polyethylene (LDPE)	1.2	0.17 x 0.25	Calflex, Environmental Service Products, Irvine CA
Nylon (Extra-Flex)	1.6	0.18 x 0.25	Mazzer Ind., Cole Parmer, Montreal QC
Tygon (R-3603)	2.5	0.19 x 0.25	Saint-Gobain, VWR Canlab, Mississauga ON
Teflon (FEP)	2.5	0.19 x 0.25	Zeus Industrial Prod., Environmental Service Products, Irvine CA
Nylon (Nylaflow T)	3.2	0.19 x 0.25	S&L Plastics, Environmental Service Products, Irvine CA
PVC Pipe	Rigid	1.19 x 1.31	IPEX

Flexible tubing materials included: silicone, PVC, polyethylene (LDPE), Tygon, Teflon and two types of Nylon (Extra-Flex and Nylaflow). Tubing sized at ¼" OD was selected because of its common use for soil vapour collection. Consistent diameters reduced variability related to internal surface areas. Two meter sample lengths provided a reasonable potential maximum length used under field conditions. Three replicates of each material were tested.

Rigid schedule 40 PVC pipe was assessed due to its common use for soil vapour probe construction. Samples were prepared in 1.3m lengths. Observations from previous experimentation conducted by the study team showed that freshly screened and cut PVC pipe samples generated higher VOC levels than PVC pipe samples that had been allowed to sit for a period of time. To simulate potential worst case field conditions related to cutting and equipment abrasion, while maintaining a closed system for the experiment, the inner surface of one PVC pipe sample set was abraded with a barbed rod just prior to beginning the experiment. Three replicates of each material were tested.

Considerable deliberation surrounded storage of the materials prior to testing. The concern was that the laboratory environment might contaminate tubing samples. It was recognized that exposure to potential contaminant sources also exists outside the laboratory environment, including contaminated field equipment, vehicle exhaust, and VOCs in ambient air. It was considered that consistent environmental control would be provided by storing materials and conducting the experiment in a positive pressure and solvent-restricted area in the laboratory. All materials were stored in this environment for a minimum of three days prior to beginning the experiment. Tubing ends were left open to the atmosphere.

2.2 EXPERIMENTAL DESIGN

The experiment involved passing UHP nitrogen (99.999% purity) through tubing materials onto a thermal desorption tube designed to collect volatile and semi-volatile hydrocarbons. A three-position manifold was constructed (Figure 2-1) that was supplied by UHP nitrogen with inline moisture and hydrocarbon traps to ensure dry and clean carrier gas. To ensure system inertness, tubing connections were made directly to fittings (for ¼" OD tubing) or using 1/4" metal tubing connectors (for > ¼" OD tubing). Nitrogen delivery to each manifold port was adjusted to deliver 100 ± 5 mL/min and flow rates were monitored throughout the experimental program. Purity of the carrier gas and manifold system was verified through triplicate blank analysis of TD tubes connected directly to the manifold.

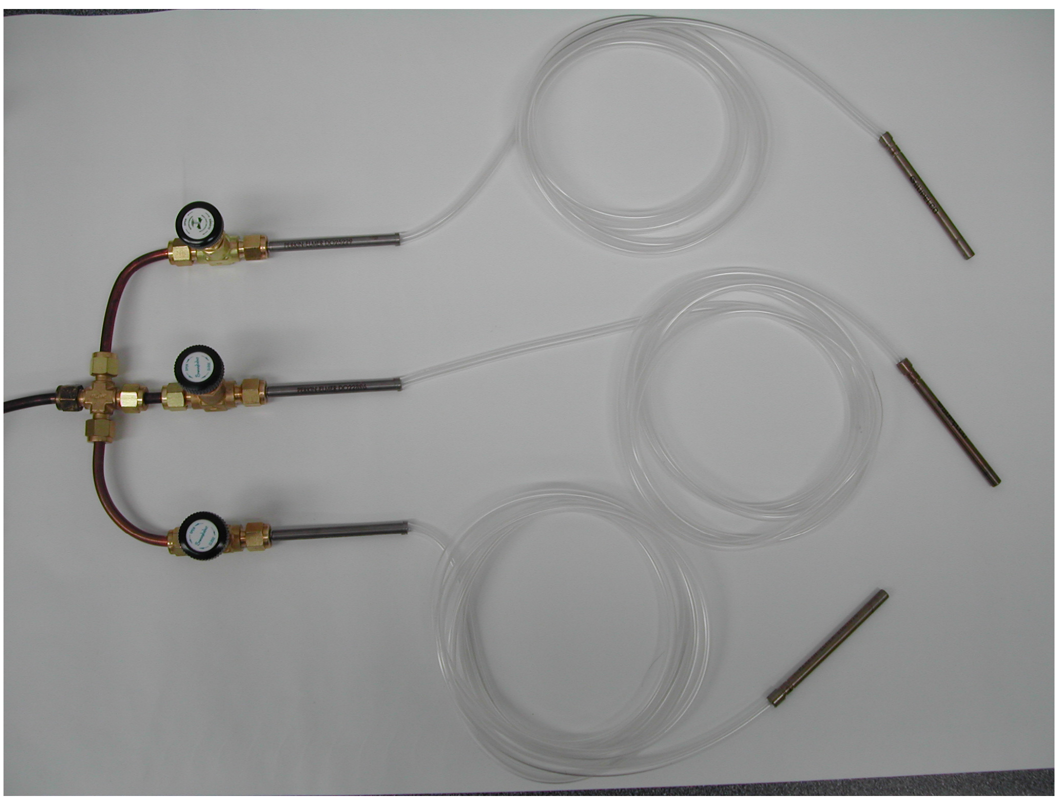

Figure 2-1 Three-Position Manifold System with Tubing and TD Tubes Attached

Carbotrap 300 TD tubes (CT300, Supelco P/N 25050) were selected to collect VOCs emitted from the tubing samples. This is a triple-bed sorbent tube (Carbotrap C, Carbotrap B, and Carbosieve S-III) designed to adsorb volatile and semi-volatile components in the nC4-nC20 range. TD tubes were pre-conditioned for 2 hours at 350℃ and then analyzed by thermal desorption gas chromatography mass spectrometry (TD-GC/MS) to verify cleanliness. TD tubes were capped with Swagelok fittings and stored until ready for use.

It was suspected from earlier experimental observations conducted by the study team that VOC off-gassing from tubing materials increased with temperature. Environmental conditions were maintained at 25℃ during the study to represent conditions on a typical warm summer day.

PVC pipe samples were capped with Teflon tape sealed PVC end caps fitted with ¼" metal tubing connectors. Each tubing and pipe sample was pre-purged with three internal volumes of UHP nitrogen to displace ambient air. Ten litres of UHP nitrogen was passed through each sample tube: 100 mL/min for 100 minutes. This was determined to be a suitable safe sampling volume for the CT300 TD tube for the experimental conditions and for the broad list of target VOCs being investigated. All samples were processed over a period of three days, and TD tubes were tightly capped until instrumental analysis.

2.3 Instrumental Analysis

Analysis of VOCs on the TD tubes was performed using a Perkin Elmer ATD-650 thermal desorption autosampler coupled to an Agilent 6890/5973 GC/MS system using a 60m 100% polydimethysiloxane capillary column. The mass spectrometer was operated in scan mode with a range of 35 to 205 atomic mass units (AMU) to allow identification of non-target compounds, as well as the target list of VOCs (2, 4). Table 2-2 shows the parameters that were analyzed.

A 71 component target VOC list was quantified using a five-point calibration curve. An internal standard (1,4-difluorobenzene) was used to ensure accurate quantification. Analytes were identified on the basis of their retention times and electron impact (EI) fingerprint using three characteristic masses.

Volatile Hydrocarbons (VHv) is an aggregate hydrocarbon parameter, and was obtained by summing the Total Ion Chromatogram (TIC) from the GC/MS analysis between n-hexane (nC6) and n-tridecane (nC13) markers and quantifying against toluene (3).

Qualitative (non-target) assessment of identifiable hydrocarbons was conducted using MS scan mode between 35-205 AMU and comparing the findings to a standard mass spectrometry library.

Table 2-2 List of Analytes Tested

1) Assessment of Target VOCs:		
1,1,1,2-tetrachloroethane	Allyl Chloride	Hexachloroethane
1,1,1-trichloroethane	Benzene	Isopropylbenzene
1,1,2,2-tetrachloroethane	Bromobenzene	m&p-Xylene
1,1,2-trichloroethane	Bromodichloromethane	Methacrylonitrile
1,1-dichloroethane	Bromoform	Methyl acrylate
1,1-dichloroethene	Bromomethane	Methyl cyclohexane
1,2,3-trichloropropane	Butadiene	Methyl Methacrylate
1,2,4-trichlorobenzene	Carbon Disulfide	Methyl tert-butyl ether
1,2,4-trimethylbenzene	Carbon tetrachloride	Naphthalene
1,2-dibromo-3-chloropropane	Chlorobenzene	n-decane
1,2-dibromoethane	Chloroethane	n-hexane
1,2-dichlorobenzene	Chloroform	Nitrobenzene
1,2-dichloroethane	Chloromethane	o-Xylene
1,2-dichloropropane	cis-1,2-dichloroethene	Styrene
1,3,5-trimethylbenzene	cis-1,3-dichloropropene	Tetrachloroethene
1,3-dichlorobenzene	Dibromochloromethane	Tetrahydrofuran
1,3-dichloropropane	Dibromomethane	Toluene
1,4-dichlorobenzene	Dichlorodifluoromethane	trans-1,2-dichloroethene
2-butanone	Dichloromethane	trans-1,3-dichloropropene
2-chlorotoluene	Ethyl acetate	trans-1,4-dichloro-2-butene
4-methyl-2-pentanone	Ethyl Ether	Trichloroethene
Acetaldehyde	Ethyl Methyacrylate	Trichlorofluoromethane
Acetone	Ethylbenzene	Vinyl Chloride
Acrylonitrile	Hexachlorobutadiene	
2) Volatile Hydrocarbons (VHv):		
Summation of TIC from MS analysis between hexane and tridecane markers quantifed vs. toluene.		
3) Qualitative Analysis of Non-Target VOCs:		
Comparison of scan mode between 35-205 AMU to a standard mass spectrometry library. This provides qualitative identification of the detectable compounds not included on the target VOC list.		

3. RESULTS

Complete triplicate data for each tubing material for the 71 VOC target list and VHv is tabulated in the Appendix. Data is reported in µg/m^3 based on the total mass detected divided by the 10 L experimental sample volume. Blank data, averaged results and relative standard deviation data is also provided.

Table 3-1 and Table 3-2 summarize averages of triplicate data where target VOCs and VHv were detected. For reference, the BCMOE CSR Schedule 11 Vapour Standards for residential land use have been provided.

For some tubing materials, the VHv levels were much higher than the sum of the detected target VOCs. The difference in these values provides an estimation of the total concentration of qualitatively identified non-target hydrocarbons tabulated in Table 3-3.

3.1 DATA QUALITY

Blank analysis results for all target VOCs and VHv were less than the reported detection limits. This confirms absence of contaminants and carry-over for the manifold system, TD tubes and instrument system.

Relative standard deviations (RSD) for replicates are tabulated with the data in the Appendix. Overall study precision is a difficult metric to quantitatively describe. Firstly, the sample set is large with 9 material samples and over 30 detected analytes. Secondly, detected analyte levels ranged from 1-100 times the detection limit, with many in the 1-5 times range where higher variability is expected.

Regardless, RSD values were calculated for the entire sample set above the detection limit and on this basis, the mean RSD for detectable analytes was 19% and the median RSD was 11%. Overall, the reasonably low RSD values indicate that good analytical precision was achieved through the design and conduct of the experimental portion of this study. RSD values would be lower if low-level data points within 1-5 times the detection limit were excluded from this calculation.

The scratched PVC pipe had mean and median replicate RSD values of 39% and 38% respectively. This is higher than the average study variability and is likely related more to sample preparation, specifically consistency in scratching the inner surface of the PVC pipe, than analytical variability for the specific parameters. Exclusion of this data would also have reduced the mean and median RSD values for the entire sample set.

Table 3-1 Summary of Detectable VOCs in Flexible Tubing

Analyte (Units =μg/m³)	BCMOE Schedule 11 (RL)[1]	Blank	Flexible Tubing						
			Silicone	PVC	LDPE	ExtraFlex Nylon	Tygon	Teflon	Nylaflow Nylon
1,1,1-trichloroethane	2000	< 0.1	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
1,2,3-trichloropropane	10	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
1,2,4-trimethylbenzene	6	< 0.1	1.5	1.0	4.3	0.4	2.2	< 0.1	< 0.1
1,2-dichloroethane	0.4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
1,3,5-trimethylbenzene	6	< 0.1	0.3	0.2	1.3	< 0.1	0.8	< 0.1	< 0.1
1,3-dichlorobenzene	80	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
1,4-dichlorobenzene	800	< 0.1	0.2	0.1	0.3	< 0.1	1.5	< 0.1	< 0.1
2-butanone	5000	< 0.2	1.2	0.7	< 0.2	< 0.2	2.9	< 0.2	< 0.2
4-methyl-2-pentanone	3000	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	2.2	< 0.1	< 0.1
Acetaldehyde	4.5	< 0.8	38.3	13.3	1.5	2.2	16.0	< 0.8	< 0.8
Acetone	20	< 5	133	12	5	< 5	13	< 5	< 5
Benzene	1.5	< 0.4	1.1	< 0.4	< 0.4	< 0.4	0.5	< 0.4	< 0.4
Carbon Disulfide	700	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Chloroform	1	< 0.1	0.4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Dichloromethane	20	< 4	6	10	< 4	< 4	< 4	< 4	< 4
Ethyl acetate	2000	< 0.3	5.4	< 0.3	< 0.3	< 0.3	1.2	< 0.3	< 0.3
Ethylbenzene	1000	< 0.1	1.4	0.6	1.6	< 0.1	4.3	< 0.1	< 0.1
Hexachloroethane	2.5	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Isopropylbenzene	400	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	4.4	< 0.1	< 0.1
Methyl cyclohexane	3000	< 0.1	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
n-decane	2500	< 2	< 2	< 2	8	< 2	42	< 2	< 2
n-hexane	700	< 2	18	< 2	< 2	< 2	2	< 2	< 2
Styrene	1000	< 0.1	0.3	0.3	0.6	0.1	1.4	< 0.1	< 0.1
Tetrachloroethene	600	< 0.2	0.3	< 0.2	< 0.2	< 0.2	0.6	< 0.2	< 0.2
Tetrahydrofuran	4	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Toluene	5000	< 0.2	13	14	5.7	3.1	20	< 0.2	< 0.2
trans-1,2-Dichloroethene	60	< 0.2	0.8	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Trichloroethene	0.5	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Vinyl Chloride	1	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Xylenes (total)	100	< 0.5	6.9	3.5	11	0.4	20	< 0.5	< 0.5
VHv nC6-nC13	1000	< 100	400	350	1490	< 100	1490	< 100	< 100
Sum of targeted VOCs	na	< 100	230	55	40	6	140	< 100	< 100
Non-target VOC estimate[2]	na	< 100	170	295	1400	< 100	1350	< 100	< 100

[1] BCMOE Schedule 11 Vapour Standards Residential Limit
[2] Non-target VOC estimate = VHv – Sum of targeted VOCs
Shaded cells = standard exceedence

Table 3-2 Summary of Detectable VOCs in Rigid PVC Pipe

Analyte (Units =µg/m^3)	BCMOE Schedule 11 (RL)[1]	Rigid PVC Pipe	
		Unscratched	Scratched
1,1,1-trichloroethane	2000	< 0.1	< 0.1
1,2,3-trichloropropane	10	< 0.1	0.3
1,2,4-trimethylbenzene	6	< 0.1	0.4
1,2-dichloroethane	0.4	< 0.1	0.2
1,3,5-trimethylbenzene	6	< 0.1	0.2
1,3-dichlorobenzene	80	< 0.1	< 0.1
1,4-dichlorobenzene	800	< 0.1	< 0.1
2-butanone	5000	< 0.2	1.6
4-methyl-2-pentanone	3000	< 0.1	< 0.1
Acetaldehyde	4.5	2.1	33
Acetone	20	< 5	25
Benzene	1.5	< 0.4	0.5
Carbon Disulfide	700	< 0.2	2.7
Chloroform	1	< 0.1	0.1
Dichloromethane	20	< 4	< 4
Ethyl acetate	2000	< 0.3	< 0.3
Ethylbenzene	1000	< 0.1	0.3
Hexachloroethane	2.5	< 0.1	< 0.1
Isopropylbenzene	400	< 0.1	1.3
Methyl cyclohexane	3000	< 0.1	< 0.1
n-decane	2500	< 2	< 2
n-hexane	700	< 2	5
Styrene	1000	< 0.1	< 0.1
Tetrachloroethene	600	< 0.2	< 0.2
Tetrahydrofuran	4	< 0.1	< 0.1
Toluene	5000	< 0.2	5.4
trans-1,2-Dichloroethene	60	< 0.2	< 0.2
Trichloroethene	0.5	< 0.1	< 0.1
Vinyl Chloride	1	< 0.4	3.0
Xylenes (total)	100	< 0.5	1.7
VHv nC6-nC13	1000	< 100	360
Sum of targeted VOCs	na	< 100	80
Non-target VOC estimate[2]	na	< 100	280

[1] BCMOE Schedule 11 Vapour Standards Residential Limit
[2] Non-target VOC estimate = VHv – Sum of targeted VOCs
Shaded cells = standard exceedence

Table 3-3 Qualitative VOC Assessment

Tubing Material	Analytes Found
Silicone	Propane, 3-methylpentane, Ethanol, Methylcyclopentane, Cyclohexanone, d-limonene, Acetophenone, Dodecane, Tetradecane, Siloxanes
PVC Tubing	Hexanal, Cyclohexanone, 2-ethyl-1-hexanol, d-limonene, Nonanal, Octanal, Phthalates
Polyethylene (LDPE)	Hundreds of unidentified aliphatic hydrocarbons in the nC10-nC16+ range
Tygon	Hexanal, Cyclohexanone, Dimethyloctanes, Cyclohexanes, Methyl-nonane; Hundreds of other unidentified aliphatic hydrocarbons in the nC10-nC13 range
Nylon (Extra-Flex)	d-limonene, cyclododecane, tetradecane
Nylon (Nylaflow)	None detectable
Teflon	None detectable
PVC Pipe - Unscratched	Thiirane, Hexanal, Nonanal, Acetophenone
PVC Pipe - Scratched	Thiirane, Hexanal, Acetophenone, Nonanal, Octanal, d-limonene, 2-ethyl-1-hexanol, isopropanol, Pentane, Methylcyclopentanes, Octane, 3-heptanone, Heptanal, Octanal, Decanal, Several other aliphatics

4. Discussion

There are various possible approaches to discuss the data. Given that the purpose of this study was to support selection of tubing materials used for soil vapour collection, that end will form the basis of discussion. The data is compared to the BCMOE CSR Schedule 11 Generic Numerical Vapour Standards for residential land use, the most conservative standard in the regulation. In many cases detectable VOCs are well below the numerical standard**.**

For the following discussion those VOCs greater than 20% the numerical standard will be deemed "appreciable". This is an arbitrary but reasonable threshold used to provide perspective on analyte levels that could potentially contribute to a regulatory exceedence. This approach may not be appropriate for other applications or jurisdictions. It is up to the practitioner using the analytical findings to determine the appropriate practical application.

4.1 Tygon and Polyethylene Tubing

Tygon and polyethylene (LDPE) yielded the highest concentrations of detectable target VOCs. Tygon showed "appreciable" levels of 1,2,4-trimethylbenzene, acetaldehyde, acetone, benzene and total xylenes. LDPE showed "appreciable" levels of 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, acetaldehyde and acetone.

Both materials had VHv levels of 1490 µg/m^3 which is 50% greater than the 1000 µg/m^3 Schedule 11 standard shown in Table 3-1. The difference in concentration between VHv and the sum of detected target VOCs (1450 µg/m^3 for LDPE and 1350 µg/m^3 for Tygon) provides an estimate of the collective concentration of the hundreds of non-target VOCs identified in Table 3-3. This is not surprising for LDPE which is produced from ethylene gas under high pressures and temperatures in a reactor containing a liquid hydrocarbon solvent in the presence of metallic catalysts (6).

4.2 Silicone and PVC Tubing

Silicone and PVC tubing both yielded relatively moderate concentrations of detectable target VOCs. Silicone showed "appreciable" levels of 1,2,4-trimethylbenzene, acetaldehyde, acetone, benzene, chloroform, and dichoromethane. PVC showed "appreciable" levels of acetaldehyde, acetone and dichloromethane.

Silicone and PVC tubing had VHv levels of 400 and 350 µg/m^3 respectively. These levels are less than the Schedule 11 standards but could contribute to a regulatory exceedence. As with Tygon and LDPE a large portion of the VHv (170 µg/m^3 for silicone and 295 µg/m^3 for PVC) is attributable to non-target VOCs identified in Table 3-3.

4.3 Nylon Tubing

Two types of nylon tubing were assessed: 1) Extra-Flex and 2) Nylaflow. The Nylaflow Nylon did not yield any detectable target VOCs, VHv or non-target VOCs.

The Extra-Flex Nylon yielded relatively low levels of detectable target VOCs. Only acetaldehyde was considered "appreciable" and VHv was less than the detection limit. Some non-targeted VOCs were detected in the Extra-Flex Nylon (Table 3-3). This product had a powder-like coating and was more flexible than the Nylaflow Nylon. The differences in detected hydrocarbons between these two products, albeit minor, demonstrate the potential variability within a material grouping.

4.4 Teflon Tubing

Teflon tubing did not yield any detectable target VOCs, VHv or non-targeted VOCs.

4.5 PVC Pipe

For the rigid PVC pipe, there was a significant difference in the number and levels of detectable VOCs and VHv between the scratched and unscratched samples. For unscratched PVC, only acetaldehyde was detected and at a level considered “appreciable”.

The scratched PVC pipe yielded 16 detectable target VOCs plus VHv. Acetaldehyde, acetone, benzene, vinyl chloride and VHv were at levels considered “appreciable”. This observation suggests that PVC pipe handling practices can have a significant influence on soil vapour monitoring data. The experiment on scratched PVC was started shortly after the inner surface was scratched. The study did not attempt to determine the period of time necessary for scratched PVC pipe VOC levels to stabilize to non-scratched PVC pipe levels.

4.6 General Discussion

It was observed that the number of compounds detected and concentrations of VOCs and VHv were greater in more flexible materials (those with lower bend radius values from Table 2-1) than in more rigid materials. The question arises whether the detected analytes result from off-gassing of components in the tubing material composition, from VOC contamination adsorbed from the environment, or from a combination of both processes. The following observations provide further insight into these processes:

- Typical laboratory-based solvents (acetone, hexane, dichloromethane, and toluene) were detected in more flexible tubing at concentrations greater than for more rigid tubing. Relatively high concentrations of non-laboratory-based VOCs were also detected in these materials. This suggests that at least some VOCs off-gas from the tubing materials. However, this is not sufficient to rule out the possibility that flexible tubing materials may have higher potential to adsorb and re-entrain environmental VOCs than more rigid materials.

- For all materials, detectible VHv concentrations tended to be much greater than the sum of target VOCs. Qualitative assessment indicated that a broad range of non-target VOCs existed, many of which are not known to be common in a laboratory environment, and some of which are likely precursors and products of synthetic polymer manufacturing. This suggests that the majority of detected VOCs are more likely related to off-gassing.

- Scratched PVC pipe had much higher numbers of detectable compounds and concentrations of VOCs and VHv than the non-scratched PVC pipe. It is possible that the abraded inner surface could have increased the environmental sorption potential. However, it is more likely that this process liberated additional hydrocarbons from the material composition.

- A literature reference (5) also investigated Teflon, Nylaflow, and LDPE tubing for VOCs. While it is difficult to directly compare both studies, a number of similarities exist. For LDPE tubing, many of the same VOCs were detected (such as 1,2,4-trimethylbenzen, 1,4-dichlorobenzene, carbon disulfide, ethylbenzene, styrene, trichloroethylene, toluene and xylenes) and are within the same order of magnitude as those measured in the current study.

The weight of evidence suggests that detected VOCs most likely originate from the tubing material composition. However, there is potential that environmental conditions may also contribute, especially for more flexible materials. Regardless of the source, the outcome will invariably be the same – unwanted contamination. Ideally, more rigid tubing should be used for soil vapour sample collection and it should be stored away from VOC-emitting sources and be capped to protect the inner surfaces. As well, tubing should be discarded after each use to prevent potentially adsorbed VOCs from being released back into the sampling stream.

A number of aspects of the study design involved attempting to maximize detection while maintaining conditions expected in practice. These include:

1. Flexible tubing length of 2 m was selected to represent the potential maximum practical tubing length that might be used in the field. This study did attempt to develop a relationship between tubing length and VOCs concentrations detected. However, it can be reasonably argued that shorter tubing lengths will decrease the area of exposure and reduce the contamination potential.

2. Testing was conducted at 25°C to replicate conditions that might exist on a summer day. This study did not attempt to determine a relationship between tubing temperature and detected VOCs. It can be reasonably argued based on principals of volatility that more VOCs should be emitted from tubing as the temperature increases.

3. The study did not model the time needed for scratched PVC pipe VOC levels to eventually equilibrate to the levels of un-scratched PVC pipe. This could warrant further investigation; however, the range of influencing conditions makes this a challenging study to design and carry out. It is recommended that practitioners utilize the information supplied in Table 3-2 as a qualitative “fingerprint” to confirm the suitably of PVC pipe probe installations for soil vapour collection.

The study limited investigation to eight common material types, and did not examine an exhaustive list of materials, grades, batches, manufacturers or suppliers.

Soil vapour samples tend to include water moisture. This study was conducted using dry nitrogen as a carrier gas and did not evaluate the effect of moisture on VOCs emitted from tubing materials.

It is important that the practitioner using the data presented in this study understands the discussion presented above. The data should not be used to quantitatively adjust soil vapour sample results. The information presented provides guidance as to what possible parameters can exist should tubing contamination be suspected.

5. CONCLUSIONS

Of the flexible tubing materials tested only Nylaflow Nylon and Teflon showed VOC levels below the laboratory's reported detection limit. Other flexible tubing materials yielded detectable VOC levels, which in some cases were considered "appreciable" at levels greater than 20% of the referenced regulatory standards.

Freshly scratched PVC pipe had higher numbers and levels of detected VOCs than unscratched PVC pipe which showed detectable acetaldehyde only. The study did not model the time needed for abraded PVC to eventually equilibrate. Acetaldehyde may not be a contaminant of concern on some sites.

It is at the discretion of the environmental practitioner to use the data presented based on their specific application. By no means should the data generated under the conditions of this study be used to quantitatively correct soil vapour VOC data suspected to have VOC contribution from tubing materials. The data generated from this study provides a qualitative fingerprint of VOCs that may be present if tubing contamination is suspected.

6. REFERENCES

1. Province of British Columbia Regulation of the Minister of Environment, January 1, 2009, Amendment to the Contaminated Sites Regulation, B.C. Reg. 375/96, Schedule 11 Generic Numerical Vapour Standards.

2. Volatile Organic Compounds in Air by Thermal Desorption Tube /GC/MS, Draft, January 19, 2009, British Columbia Ministry of Environment Laboratory Manual.

3. Volatile Hydrocarbons in Air by GC-FID / GC-MS, Draft January 19, 2009, British Columbia Ministry of Environment Laboratory Manual.

4. Method TO-17, Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Active Sampling onto Sorbent Tubes with Subsequent Analysis By Gas Chromatography, from the Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, Center for Environmental Research Information, Office of Research and Development, US EPA, Cincinnati, OH, January 1999.

5. Air Toxics: "Impact of Sampling Media on Soil Gas Measurements": http://www.airtoxics.com/literature/papers/Media_AWMA_Sept06_Final.pdf

6. Plastics New Zealand - http://www.plastics.org.nz/_attachments/docs/ronz-ldpe-fact-sheet.pdf

APPENDIX

Table A-1 Analytical Data – Blank and Silicone Tubing

Analyte	Units	Blank					Silicone Tubing				
		1	2	3	Ave	RSD	1	2	3	Ave	RSD
1,1,1,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,1-trichloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.3	0.3	0.3	0.3	8%
1,1,2,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2-trichloroethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,2,3-trichloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2,4-trichlorobenzene	ug/m3	< 0.5	< 0.5	< 0.5	< 0.5	N/A	1.0	< 0.5	< 0.5	< 0.5	N/A
1,2,4-trimethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	1.5	1.5	1.4	1.5	5%
1,2-dibromo-3-chloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	0.3	< 0.1	< 0.1	N/A
1,2-dibromoethane	ug/m3	< 0.3	< 0.3	< 0.2	< 0.3	N/A	< 0.2	< 0.3	< 0.3	< 0.2	N/A
1,2-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloroethane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,3,5-trimethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.3	0.3	0.3	0.3	9%
1,3-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.1	0.1	< 0.1	0.1	12%
1,3-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,3-dichloropropene (total)	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,4-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.2	0.2	0.1	0.2	11%
2-butanone	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	1.3	1.1	1.2	1.2	5%
2-chlorotoluene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
4-methyl-2-pentanone	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Acetaldehyde	ug/m3	< 0.8	< 0.8	< 0.8	< 0.8	N/A	38.3	37.6	39.2	38.3	2%
Acetone	ug/m3	< 5	< 5.1	< 5	< 4.9	N/A	138.2	136.9	123.0	132.8	6%
Acrylonitrile	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Allyl Chloride	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
Benzene	ug/m3	< 0.4	< 0.4	< 0.4	< 0.4	N/A	1.1	1.1	1.1	1.1	2%
Bromobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromodichloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Bromoform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromomethane	ug/m3	< 1.8	< 1.8	< 1.7	< 1.8	N/A	< 1.7	< 1.8	< 1.8	< 1.7	N/A
Butadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Carbon Disulfide	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Carbon tetrachloride	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.1	< 0.1	< 0.1	< 0.1	N/A
Chlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloroethane	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Chloroform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.5	0.4	0.4	0.4	17%
Chloromethane	ug/m3	< 2.1	< 2.2	< 2	< 2.1	N/A	< 1.9	< 2.1	< 2.1	< 2	N/A
cis-1,2-dichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Dibromochloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dibromomethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dichlorodifluoromethane	ug/m3	< 0.6	< 0.6	< 0.6	< 0.6	N/A	< 0.6	< 0.6	< 0.6	< 0.6	N/A
Dichloromethane	ug/m3	< 4.4	< 4.5	< 4.2	< 4.3	N/A	6.4	6.2	5.2	6.0	10%
Ethyl acetate	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	2.9	11.1	2.4	5.4	91%
Ethyl Ether	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Methyacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Ethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	1.3	1.4	1.3	1.4	2%
Hexachlorobutadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	0.3	< 0.1	< 0.1	N/A
Hexachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	0.6	< 0.1	0.2	N/A
Isopropylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
m&p-Xylene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	5.0	5.4	5.1	5.2	4%
Methacrylonitrile	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
Methyl acrylate	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	0.7	< 0.3	< 0.3	N/A
Methyl cyclohexane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.3	0.2	0.2	0.3	16%
Methyl Methacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl tert-butyl ether	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Naphthalene	ug/m3	< 1	< 1	< 0.9	< 1	N/A	1.2	< 1	< 1	< 0.9	N/A
n-decane	ug/m3	< 2.2	< 2.2	< 2	< 2.1	N/A	< 2	< 2.1	< 2.1	< 2.1	N/A
n-hexane	ug/m3	< 2	< 2	< 1.9	< 2	N/A	17.7	17.8	18.5	18.0	3%
Nitrobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
o-Xylene	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	1.6	1.8	1.7	1.7	6%
Styrene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.3	0.4	0.3	0.3	9%
Tetrachloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	0.3	0.3	0.3	0.3	5%
Tetrahydrofuran	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.2	0.2	0.1	0.2	28%
Toluene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	13.3	13.7	13.2	13.4	2%
trans-1,2-Dichloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	0.9	0.8	0.8	0.8	6%
trans-1,4-dichloro-2-butene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.2	< 0.1	< 0.1	0.1	N/A
Trichlorofluoromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Vinyl Chloride	ug/m3	< 0.4	< 0.4	< 0.3	< 0.4	N/A	< 0.3	< 0.4	< 0.3	< 0.3	N/A
VHv nC6-nC13	ug/m3	< 100	< 101	< 94.3	< 98.4	N/A	359.1	434.7	419.4	403.2	10%
Sample Volume (L)	L	10.0	9.9	10.6	10.2		11.0	10.1	10.3	10.5	

Table A-2 Analytical Data – PVC and LDPE Tubing

Analyte	Units	PVC Tubing 1	2	3	Ave	RSD	Polyethylene (LDPE) Tubing 1	2	3	Ave	RSD
1,1,1,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,1-trichloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2-trichloroethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethene	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,2,3-trichloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2,4-trichlorobenzene	ug/m3	< 0.5	< 0.6	< 0.5	< 0.5	N/A	< 0.5	< 0.5	< 0.5	< 0.5	N/A
1,2,4-trimethylbenzene	ug/m3	1.0	1.1	1.0	1.0	4%	4.3	4.1	4.4	4.3	3%
1,2-dibromo-3-chloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dibromoethane	ug/m3	< 0.3	< 0.3	< 0.2	< 0.3	N/A	< 0.3	< 0.3	< 0.2	< 0.3	N/A
1,2-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloroethane	ug/m3	< 0.1	< 0.2	< 0.1	< 0.1	N/A	< 0.2	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,3,5-trimethylbenzene	ug/m3	0.2	0.2	0.2	0.2	5%	1.3	1.3	1.3	1.3	1%
1,3-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,3-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,3-dichloropropene (total)	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,4-dichlorobenzene	ug/m3	0.1	0.1	0.1	0.1	14%	0.3	0.3	0.4	0.3	10%
2-butanone	ug/m3	0.7	0.8	0.7	0.7	8%	< 0.2	< 0.2	< 0.2	< 0.2	N/A
2-chlorotoluene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
4-methyl-2-pentanone	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Acetaldehyde	ug/m3	13.1	18.1	9.6	13.3	32%	1.2	0.9	2.5	1.5	55%
Acetone	ug/m3	9.0	10.3	15.0	11.7	27%	10.3	< 4.9	< 4.8	5.0	N/A
Acrylonitrile	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Allyl Chloride	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Benzene	ug/m3	< 0.4	< 0.5	< 0.4	< 0.4	N/A	< 0.4	< 0.4	< 0.4	< 0.4	N/A
Bromobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromodichloromethane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Bromoform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromomethane	ug/m3	< 1.8	< 1.9	< 1.6	< 1.8	N/A	< 1.9	< 1.8	< 1.7	< 1.8	N/A
Butadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Carbon Disulfide	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Carbon tetrachloride	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloroethane	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Chloroform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloromethane	ug/m3	< 2.1	< 2.3	< 1.9	< 2.1	N/A	< 2.2	< 2.1	< 2	< 2.1	N/A
cis-1,2-dichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Dibromochloromethane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dibromomethane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dichlorodifluoromethane	ug/m3	< 0.6	< 0.6	< 0.5	< 0.6	N/A	< 0.6	< 0.6	< 0.6	< 0.6	N/A
Dichloromethane	ug/m3	9.6	9.6	9.5	9.6	1%	8.6	< 4.3	< 4.2	< 4.3	N/A
Ethyl acetate	ug/m3	< 0.3	< 0.4	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Ether	ug/m3	< 0.3	< 0.3	< 0.2	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Methyacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Ethylbenzene	ug/m3	0.6	0.6	0.5	0.6	14%	1.6	1.5	1.6	1.6	3%
Hexachlorobutadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Hexachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Isopropylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
m&p-Xylene	ug/m3	2.7	2.8	2.2	2.6	12%	8.4	8.0	7.9	8.1	3%
Methacrylonitrile	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Methyl acrylate	ug/m3	< 0.3	< 0.3	< 0.2	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Methyl cyclohexane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl Methacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl tert-butyl ether	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Naphthalene	ug/m3	< 1	< 1	< 0.9	< 0.9	N/A	< 1	< 1	< 0.9	< 1	N/A
n-decane	ug/m3	< 2.1	< 2.3	< 1.9	< 2.1	N/A	7.6	7.5	8.1	7.7	4%
n-hexane	ug/m3	< 2	< 2.1	< 1.7	< 1.9	N/A	2.9	< 2	< 1.9	< 2	N/A
Nitrobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
o-Xylene	ug/m3	0.9	0.9	0.8	0.9	11%	2.7	2.6	2.7	2.7	2%
Styrene	ug/m3	0.3	0.3	0.3	0.3	2%	0.6	0.5	0.6	0.6	3%
Tetrachloroethene	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Tetrahydrofuran	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Toluene	ug/m3	14.2	15.7	11.8	13.8	14%	6.0	5.1	6.0	5.7	9%
trans-1,2-Dichloroethene	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
trans-1,4-dichloro-2-butene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichlorofluoromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Vinyl Chloride	ug/m3	< 0.4	< 0.4	< 0.3	< 0.3	N/A	< 0.4	< 0.4	< 0.3	< 0.4	N/A
VHv nC6-nC13	ug/m3	379.2	352.1	320.9	349.4	8%	1501.0	1499.0	1481.9	1493.8	1%
Sample Volume (L)	L	10.1	9.4	11.5	10.3		9.8	10.2	10.5	10.2	

Table A-3 Analytical Data – ExtraFlex Nylon and Tygon Tubing

Analyte	Units	ExtraFlex Nylon Tubing					Tygon Tubing				
		1	2	3	Ave	RSD	1	2	3	Ave	RSD
1,1,1,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,1-trichloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2-trichloroethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethene	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,2,3-trichloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2,4-trichlorobenzene	ug/m3	< 0.5	< 0.5	< 0.5	< 0.5	N/A	< 0.5	< 0.5	< 0.5	< 0.5	N/A
1,2,4-trimethylbenzene	ug/m3	0.6	0.5	< 0.1	0.4	23%	1.9	2.0	2.5	2.2	16%
1,2-dibromo-3-chloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dibromoethane	ug/m3	< 0.3	< 0.3	< 0.2	< 0.3	N/A	< 0.2	< 0.3	< 0.2	< 0.2	N/A
1,2-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,3,5-trimethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.7	0.7	0.9	0.8	15%
1,3-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,3-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,3-dichloropropene (total)	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
1,4-dichlorobenzene	ug/m3	0.1	< 0.1	< 0.1	< 0.1	N/A	1.5	1.3	1.6	1.5	13%
2-butanone	ug/m3	< 0.2	0.2	< 0.2	< 0.2	N/A	3.0	2.6	3.2	2.9	10%
2-chlorotoluene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
4-methyl-2-pentanone	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	1.6	2.4	2.7	2.2	24%
Acetaldehyde	ug/m3	2.4	2.4	2.0	2.2	10%	15.8	20.5	11.8	16.0	27%
Acetone	ug/m3	< 4.9	< 4.9	< 4.7	< 4.8	N/A	6.5	11.7	22.2	13.4	59%
Acrylonitrile	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Allyl Chloride	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
Benzene	ug/m3	< 0.4	< 0.4	< 0.4	< 0.4	N/A	0.4	0.5	0.5	0.5	6%
Bromobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromodichloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Bromoform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromomethane	ug/m3	< 1.8	< 1.8	< 1.7	< 1.8	N/A	< 1.7	< 1.8	< 1.7	< 1.7	N/A
Butadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Carbon Disulfide	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Carbon tetrachloride	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloroethane	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Chloroform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloromethane	ug/m3	< 2.1	< 2.1	< 2	< 2.1	N/A	< 2	< 2.1	< 2	< 2	N/A
cis-1,2-dichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Dibromochloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dibromomethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dichlorodifluoromethane	ug/m3	< 0.6	< 0.6	< 0.6	< 0.6	N/A	< 0.6	< 0.6	< 0.6	< 0.6	N/A
Dichloromethane	ug/m3	< 4.3	< 4.3	< 4.1	< 4.3	N/A	< 4.1	< 4.2	< 4.2	< 4.2	N/A
Ethyl acetate	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	1.2	0.6	1.7	1.2	47%
Ethyl Ether	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Methyacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Ethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	3.9	4.0	5.1	4.3	15%
Hexachlorobutadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Hexachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Isopropylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	3.8	4.0	5.4	4.4	19%
m&p-Xylene	ug/m3	0.5	0.4	0.4	0.4	13%	14.8	13.7	17.1	15.2	11%
Methacrylonitrile	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
Methyl acrylate	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Methyl cyclohexane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl Methacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl tert-butyl ether	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Naphthalene	ug/m3	< 1	< 1	< 0.9	< 0.9	N/A	< 0.9	< 0.9	< 0.9	< 0.9	N/A
n-decane	ug/m3	< 2.1	< 2.1	< 2	< 2.1	N/A	40.3	39.9	45.8	42.0	8%
n-hexane	ug/m3	< 2	< 2	< 1.9	< 1.9	N/A	2.4	2.4	2.5	2.4	4%
Nitrobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
o-Xylene	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	4.1	4.8	5.6	4.9	15%
Styrene	ug/m3	0.2	0.1	< 0.1	0.1	26%	1.3	1.3	1.5	1.4	8%
Tetrachloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	0.4	0.6	0.7	0.6	24%
Tetrahydrofuran	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Toluene	ug/m3	3.4	3.0	3.0	3.1	7%	19.8	19.8	21.8	20.5	6%
trans-1,2-Dichloroethene	ug/m3	< 0.2	< 0.2	< 0.1	< 0.2	N/A	< 0.1	< 0.2	< 0.2	< 0.2	N/A
trans-1,4-dichloro-2-butene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichlorofluoromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Vinyl Chloride	ug/m3	< 0.4	< 0.4	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
VHv nC6-nC13	ug/m3	100.0	103.9	< 93.5	< 96.5	N/A	1507.4	1351.9	1597.1	1486.1	8%
Sample Volume (L)	L	10.2	10.2	10.7	10.4		10.8	10.4	10.5	10.6	

Table A-4 Analytical Data – NylaFlow Nylon and Teflon Tubing

Analyte	Units	Nylaflow Nylon Tubing					Teflon Tubing				
		1	2	3	Ave	RSD	1	2	3	Ave	RSD
1,1,1,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,1-trichloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2-trichloroethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethane	ug/m3	< 0.1	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
1,1-dichloroethene	ug/m3	< 0.1	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
1,2,3-trichloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2,4-trichlorobenzene	ug/m3	< 0.5	< 0.5	< 0.5	< 0.5	N/A	< 0.5	< 0.5	< 0.5	< 0.5	N/A
1,2,4-trimethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dibromo-3-chloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dibromoethane	ug/m3	< 0.2	< 0.3	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.3	< 0.2	N/A
1,2-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.2	< 0.1	N/A
1,2-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,3,5-trimethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,3-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,3-dichloropropane	ug/m3	< 0.1	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
1,3-dichloropropene (total)	ug/m3	< 0.1	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
1,4-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
2-butanone	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
2-chlorotoluene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
4-methyl-2-pentanone	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Acetaldehyde	ug/m3	< 0.8	< 0.8	< 0.8	< 0.8	N/A	< 0.8	< 0.7	< 0.8	< 0.8	N/A
Acetone	ug/m3	< 4.9	< 4.9	< 4.8	< 4.8	N/A	< 4.8	< 4.6	< 5.1	< 4.8	N/A
Acrylonitrile	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Allyl Chloride	ug/m3	< 0.1	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
Benzene	ug/m3	< 0.4	< 0.4	< 0.4	< 0.4	N/A	< 0.4	< 0.4	< 0.4	< 0.4	N/A
Bromobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromodichloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Bromoform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromomethane	ug/m3	< 1.7	< 1.8	< 1.7	< 1.7	N/A	< 1.7	< 1.7	< 1.8	< 1.7	N/A
Butadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Carbon Disulfide	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Carbon tetrachloride	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloroethane	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Chloroform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloromethane	ug/m3	< 2	< 2.1	< 2	< 2	N/A	< 2	< 2	< 2.2	< 2.1	N/A
cis-1,2-dichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Dibromochloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dibromomethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dichlorodifluoromethane	ug/m3	< 0.6	< 0.6	< 0.6	< 0.6	N/A	< 0.6	< 0.6	< 0.6	< 0.6	N/A
Dichloromethane	ug/m3	< 4.3	< 4.3	< 4.2	< 4.2	N/A	< 4.2	< 4	< 4.5	< 4.2	N/A
Ethyl acetate	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Ether	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Methyacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Ethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Hexachlorobutadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Hexachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Isopropylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
m&p-Xylene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Methacrylonitrile	ug/m3	< 0.1	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
Methyl acrylate	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Methyl cyclohexane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl Methacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl tert-butyl ether	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Naphthalene	ug/m3	< 0.9	< 1	< 0.9	< 0.9	N/A	< 0.9	< 0.9	< 1	< 0.9	N/A
n-decane	ug/m3	< 2	< 2.1	< 2.1	< 2.1	N/A	< 2.1	< 2	< 2.2	< 2.1	N/A
n-hexane	ug/m3	< 1.9	< 1.9	< 1.9	< 1.9	N/A	< 1.9	< 1.8	< 2	< 1.9	N/A
Nitrobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
o-Xylene	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Styrene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Tetrachloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Tetrahydrofuran	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Toluene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
trans-1,2-Dichloroethene	ug/m3	< 0.1	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.1	< 0.2	< 0.2	N/A
trans-1,4-dichloro-2-butene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichlorofluoromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Vinyl Chloride	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.4	< 0.3	N/A
VHv nC6-nC13	ug/m3	< 93.5	< 97.1	< 95.2	< 95.2	N/A	< 95.2	< 91.7	< 101	< 95.8	N/A
Sample Volume (L)	L	10.7	10.3	10.5	10.5		10.5	10.9	9.9	10.4	

Table A-5 Analytical Data – PVC Pipe

Analyte	Units	PVC Pipe Unscratch					PVC Pipe Scratched				
		pvc probe-1	pvc probe-2	pvc probe-3	Ave	RSD	Scratched	Scratched	Scratched	Ave	RSD
1,1,1,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,1-trichloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2,2-tetrachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,1,2-trichloroethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,1-dichloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,2,3-trichloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.5	0.3	0.1	0.3	64%
1,2,4-trichlorobenzene	ug/m3	< 0.5	< 0.5	< 0.5	< 0.5	N/A	< 0.5	< 0.5	< 0.5	< 0.5	N/A
1,2,4-trimethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.5	0.4	0.2	0.4	29%
1,2-dibromo-3-chloropropane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dibromoethane	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
1,2-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,2-dichloroethane	ug/m3	< 0.2	< 0.1	< 0.2	< 0.2	N/A	0.3	< 0.1	< 0.2	0.2	N/A
1,2-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,3,5-trimethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.2	0.2	0.1	0.2	15%
1,3-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
1,3-dichloropropane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,3-dichloropropene (total)	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
1,4-dichlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
2-butanone	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	1.7	2.7	0.4	1.6	73%
2-chlorotoluene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
4-methyl-2-pentanone	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Acetaldehyde	ug/m3	2.4	2.6	1.3	2.1	32%	41.1	31.0	26.9	33.0	22%
Acetone	ug/m3	< 5.1	< 4.8	< 5.2	< 5	N/A	24.8	34.1	14.3	24.6	40%
Acrylonitrile	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Allyl Chloride	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Benzene	ug/m3	< 0.4	< 0.4	< 0.4	< 0.4	N/A	0.8	0.4	< 0.4	0.5	56%
Bromobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromodichloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Bromoform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Bromomethane	ug/m3	< 1.9	< 1.8	< 1.9	< 1.8	N/A	< 1.8	< 1.8	< 1.9	< 1.8	N/A
Butadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Carbon Disulfide	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	4.2	1.8	2.1	2.7	48%
Carbon tetrachloride	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chlorobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Chloroethane	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Chloroform	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.1	0.1	< 0.1	0.1	1%
Chloromethane	ug/m3	< 2.2	< 2.1	< 2.2	< 2.1	N/A	< 2.1	< 2.1	< 2.2	< 2.1	N/A
cis-1,2-dichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Dibromochloromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dibromomethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Dichlorodifluoromethane	ug/m3	< 0.6	< 0.6	< 0.6	< 0.6	N/A	< 0.6	< 0.6	< 0.6	< 0.6	N/A
Dichloromethane	ug/m3	< 4.5	< 4.2	< 4.5	< 4.4	N/A	< 4.4	6.4	< 4.5	< 4.4	N/A
Ethyl acetate	ug/m3	< 0.3	< 0.3	< 0.4	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Ether	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Ethyl Methyacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Ethylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.3	0.5	< 0.1	0.3	55%
Hexachlorobutadiene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Hexachloroethane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Isopropylbenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	2.7	1.2	< 0.1	1.3	79%
m&p-Xylene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	1.1	2.0	0.4	1.2	66%
Methacrylonitrile	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Methyl acrylate	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	< 0.3	< 0.3	< 0.3	< 0.3	N/A
Methyl cyclohexane	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl Methacrylate	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Methyl tert-butyl ether	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Naphthalene	ug/m3	< 1	< 0.9	< 1	< 1	N/A	< 1	< 1	< 1	< 1	N/A
n-decane	ug/m3	< 2.2	< 2.1	< 2.2	< 2.2	N/A	< 2.1	< 2.1	< 2.2	< 2.2	N/A
n-hexane	ug/m3	< 2	< 1.9	< 2.1	< 2	N/A	4.9	5.3	3.7	4.7	18%
Nitrobenzene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
o-Xylene	ug/m3	< 0.3	< 0.3	< 0.3	< 0.3	N/A	0.5	0.7	0.4	0.5	31%
Styrene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	0.1	0.1	< 0.1	< 0.1	N/A
Tetrachloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Tetrahydrofuran	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Toluene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	4.9	7.3	3.8	5.4	33%
trans-1,2-Dichloroethene	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
trans-1,4-dichloro-2-butene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichloroethene	ug/m3	< 0.1	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	N/A
Trichlorofluoromethane	ug/m3	< 0.2	< 0.2	< 0.2	< 0.2	N/A	< 0.2	< 0.2	< 0.2	< 0.2	N/A
Vinyl Chloride	ug/m3	< 0.4	< 0.3	< 0.4	< 0.4	N/A	3.4	3.0	2.5	3.0	15%
VHv nC6-nC13	ug/m3	< 102	< 96.2	< 103.1	< 100.3	N/A	421.8	440.8	210.2	359.6	36%
Sample Volume (L)	L	9.8	10.4	9.7	10.0		10.1	10.3	9.8	10.1	