

CASSIAR TUNNEL QUALITY ASSURANCE PROJECT PLAN (QAPjP) and QA Report for Pacific 2001

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15. References:

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Steven Rogak, University of British Columbia, Department of Mechanical Engineering, 2324 Main Mall, Vancouver, British Columbia, V6T 1Z4. (SF6 tracer and physical measurements inside tunnel)

Al Percival, Air Quality Department, Greater Vancouver Regional District, 4330 Kingsway, Burnaby, BC, V5H 4G8 (MAMU gaseous measurements outside tunnel)

Carol Burelle and Sandra Bayne, Transportation Systems Branch, Environment Canada, Place Vincent Massey, Hull, Quebec. (Remote sensing measurements)

Dennis Smith, Jimmy DeShazo, MD-Lasertech, 2024 McMillan St. Tuscon, Az., 85705. (Remote Sensing Contractor)

Measurement Program

1. Filter pack measurements of SO₂, NH₃, PM_{2.5} mass, PM₁ mass, organic/elemental carbon (OC/EC), organic acids, trace organic species, organic ions, inorganic ions, trace metals.
2. FTIR Spectrometer analysis of CO, CO₂, SF₆, NO, NO₂, N₂O, CH₄, SO₂,

NH₃.

3. DNPH Cartridge analysis of C₁ – C₇ carbonyls, NO₂.
4. Summa Canister analysis of volatile organic compounds (VOCs), CO, CO₂, N₂O, SF₆, CH₄.
5. Tenax Cartridge analysis of semi-volatile organic compounds (SVOCs).
6. Optical Scattering Probe (OSP) analysis of particle number size distribution.
7. Differential Mobility Analyzer (DMA) detection of particle number size distribution.
8. Remote sensing measurements of CO, CO₂, NO_x, THC in vehicle exhaust plumes, vehicle speed, acceleration and vehicle identification.

Measurement Species and Units

Filter Packs	SO ₂ , NH ₃	µg/m ³ at 0°C, 1 atm
	Organic acids	µg/m ³ at 0°C, 1 atm
	PM _{2.5} & PM ₁ mass	µg/m ³ at 0°C, 1 atm
	OC/EC	µg/m ³ at 0°C, 1 atm
	Trace organic species	µg/m ³ at 0°C, 1 atm
	Organic & Inorganic ions	µg/m ³ at 0°C, 1 atm
	Trace metals	µg/m ³ at 0°C, 1 atm
FTIR Spectrometer	CO, CO ₂ , NO, NO ₂ , N ₂ O, SO ₂ , NH ₃ ,	ppm
	CH ₄	
	SF ₆	ppb
DNPH Cartridge	C ₁ – C ₇ carbonyls	µg/m ³ at 0°C, 1 atm
	NO ₂	µg/m ³ at 0°C, 1 atm
Summa Canister	VOCs	µg/m ³ at 0°C, 1 atm
	CO, CO ₂ , N ₂ O, CH ₄	µg/m ³ at 0°C, 1 atm
	SF ₆	µg/m ³ at 0°C, 1 atm
Tenax Cartridge	SVOCs	µg/m ³ at 0°C, 1 atm
OSP	Particle number size distribution	#/cm ³ at 0°C, 1 atm
DMA	Particle number size distribution	#/cm ³ at 0°C, 1 atm
Remote Sensing	CO, CO ₂ , NO _x , THC	ppm

Representative Size Range (if PM)

Filter Pack (91 lpm cyclone)	< 2.5 μm
Filter Pack (45 lpm cyclone)	< 1.0 μm
OSP	0.12 – 3 μm
DMA	6 – 300 nm

Measurement Platform (surface, airborne)

All instruments and sampling equipment will be located on the surface, inlets to instruments and other sample collection equipment suspended 1m down from the tunnel roof, approximately 6m above ground level.

Measurement Sites (surface only)

All instruments will be located at the Cassiar Tunnel. Two of each type of instrument will be used, with one at the tunnel entrance and one at the tunnel exit.

Measurement Objective(s)

1. The purpose of filter packs, FTIR spectrometer, DNPH cartridge, Summa canister, and Tenax cartridge is to measure the mass emission rate of the previously specified species from mobile sources in the Lower Fraser Valley.
2. The purpose of the DMA, and OSP is to determine the size distribution of particles emitted from mobile sources in the Lower Fraser Valley.

Measurement Details

1.1. Field Measurements

Measurement Principle

CO	FTIR spectrometry, Summa Canister – GC/FID
CO ₂	FTIR spectrometry, Summa Canister – GC/FID
SF ₆	FTIR spectrometry, Summa Canister – GC/ECD
NO	FTIR spectrometry

NO ₂	FTIR spectrometry, DNPH Cartridge – HPLC
N ₂ O	FTIR spectrometry, Summa Canister – GC/ECD
CH ₄	FTIR spectrometry, Summa Canister – GC/FID
SO ₂	FTIR spectrometry, K ₂ CO ₃ coated filter – IC
NH ₃	FTIR spectrometry, Citric Acid coated filter – IC
PM _{2.5} & PM ₁ Mass	Teflon filter – Microbalance
OC/EC	Quartz filter – Thermal Optical Transmittance
Organic acids	KOH coated filter – IC & CE
Trace organic species	Emfab filter – GC/MS
Organic ions	Teflon filter – IC & CE
Inorganic ions	Teflon filter – IC
Trace Metals	Teflon filter – XRF
C ₁ – C ₇ Carbonyls	DNPH Cartridge – HPLC
VOCs	Summa Canister – GC/FID & GC/MS
SVOCs	Tenax Cartridge – GC/FID
Particle Size Distribution	OSP, DMA

Instrumentation (Manufacturer/Model)

Filter Packs and cyclones	URG #2000-30FG 47 mm diameter 2-stage filter packs URG #2000-30FJ 90 mm diameter 2-stage filter packs URG #2000-30HD 4-port manifold URG #2000-30HE 2-port manifold URG 2000-30ENB cyclone 2.5 µm cut at 91 lpm URG 2000-30EH cyclone 1.0 µm cut at 51 lpm
FTIR	Midac 'I 1100' Industrial FTIR Spectrometer with 10m (nominal) gas cell, KBr beamsplitter, MCT detector Midac 'I 0340' heating jacket and insulation for gas cell Midac 'I 0173' pressure transducer Midac 'I 0171' controller for pressure and temperature Autoquant software, Version 3.0

DNPH Cartridge	Prepared in laboratory using: Aldrich Chemical Co. 2,4-Dinitrophenylhydrazine (~97% moist solid, 20% moisture by weight) J.T. Baker HPLC grade Acetonitrile J.T. Baker ACS grade ~38% Hydrochloric Acid Sep-Pak Silica Cartridges, Waters Cat # WAT51900
Summa Canister	SIS Canisters, 6L and 1.8 L volumes Veriflo Corp. "SC423XL" critical orifice
Tenax Cartridge	Tenax tube, SKC Cat # 226-35-03
OSP	
DMA	

Flow System

The flow inlet to the first filter system is a PM_{2.5} cyclone, which feeds through a flow straightener to a manifold holding four 2-stage filter packs. The flow to each filter pack is maintained with a mass flow controller with a set point of 22.75 lpm, resulting in a total flow 91 lpm (0° C, 1atm).

The flow inlet to the second filter system is a PM₁ cyclone, which feeds through a flow straightener to a manifold holding two 2-stage filter pack systems. The flow to each filter pack is maintained with a mass flow controller with a set point of 22.5 lpm, resulting in a total flow 45 lpm (0° C, 1atm).

The flow inlet to the third filter system is a PM_{2.5} cyclone, which feeds through a flow straightener to a single 2-stage filter pack system. The flow to this filter pack is maintained with a mass flow controller at a set point of 91 lpm (0°C, 1atm).

The FTIR, DNPH & Tenax cartridges, Summa canister receive flow from the same inlet of approximately 7 m of Teflon tubing. Flow to each instrument (at 0°C, 1atm) is maintained as follows:

FTIR: rotameter and valve system set to approximately 2 lpm

DNPH: mass flow controller set to 1 lpm

Tenax: mass flow controller set to 0.5 lpm

Summa: critical orifice set to draw approximately 0.025 lpm

A pump is located downstream of these instruments, which exhausts to

the atmosphere.

The OSP and DMA receive sample from approximately 7 m copper tubing. Flow is controlled by controllers and pumps internal to each instrument.

Inlet Height Above Ground (if surface)

All sampling inlets will be located 6m above ground level from a point 1m below the inside roof of the tunnel.

Nominal Flow Rate

Teflon membrane	22.5 & 22.75 lpm
Citric acid coated cellulose	22.75 lpm
K ₂ CO ₃ coated Cellulose	22.75 lpm
Quartz filter	22.5 & 22.75 lpm
KOH coated Quartz filter	22.5 lpm
Emfab filter	91 lpm
FTIR	2 lpm
DNPH Cartridge	1 lpm
Summa Canister	0.025 lpm
Tenax Cartridge	0.5 lpm
OSP	1 – 5 lpm
DMA	1.5 lpm

Flow Measurement/Control

Instruments that require accurate flow measurements for future concentration calculation (i.e. the filter packs, DNPH cartridges, and Tenax cartridges) will be equipped with mass flow controllers.

The FTIR will be equipped with a rotameter and needle valve system. The instrument is equipped with temperature and pressure monitors that allow the measured concentrations to be corrected to standard conditions of 0°C and 1 atm.

The Summa canisters will be equipped with a critical orifice flow controller. The flow into the canister is not critical, but it is required to be

constant and that the canister does not reach ambient pressure before the end of the sampling period.

Flow Temperature and Pressure

All flow measurements will be corrected to 0°C and 1 atm.

Sampling Times/Period/Frequency

Filter pack DNPH Cartridge Summa Canister Tenax Cartridge	3 samples per day, each for 3 hours from 06:30-09:30, 11:00-14:00, 15:30-18:30.
FTIR Spectrometer OSP	Continuous measurement, with 1 sample per minute for 12 hours per day (06:30-18:30)
DMA	Continuous measurement, with 1 sample every 3 minutes for 12 hours per day (06:30-18:30)

Sampling Methods

Please refer to ETC SOP No: 9.6/1.0/S entitled “Sample Management”.

Teflon filters and Emfab filters are pre-weighed, serial numbered, and stored in petri dishes before and after sample collection.

Coated filters and quartz filters are kept in doubled plastic bags or foil packages prior to sampling. After sampling, the filters are placed in serially numbered petri dishes. The petri dishes are double bagged in plastic for storage after sampling.

Filter packs have identification numbers and these numbers are recorded on sampling log sheets with the serial numbers of the filters that are installed. Flow rates and other sample collection information is recorded on these log sheets.

Tenax tubes and DNPH cartridges are labeled with sampling date, time and location using pre-printed labels. Relevant information is also recorded on the sampling log sheet.

Tenax tubes, after sampling have the supplied caps installed and are

stored in doubled plastic bags. DNPH cartridges are stored before and after sampling with end-plugs installed and sealed in glass vials with Teflon lined silicone septa lids.

All media is stored in a refrigerator below 4 °C after sampling. Quartz and Emfab filters are stored in a freezer at -10°C after sampling.

Canisters are stored at room temperature after sampling.

Filter Type/Coating Type/Reagent Type

Teflon Membrane	Mass, Ions, Metals
Citric Acid coated Cellulose	NH ₃
K ₂ CO ₃ coated Cellulose	SO ₂
Quartz filter	OC/EC
KOH coated Quartz filter	Vapour phase organic acids
Emfab filter	Detailed organic analysis

Planned Changes to Instruments or Methods During Study

No changes anticipated.

Laboratory Measurements (If Applicable)

Laboratory Name and Address

ERMD & AAQD, Environment Canada
Environmental Technology Centre
3439 River Road South
Ottawa, ON
K1A 0H3

Natural Resources Canada
CANMET Energy Technology Centre
1 Haanel Drive
Nepean, Ontario

Natural Resources Canada
 Mining and Mineral Sciences Sudbury Laboratory

Analytical Method(s)

Filter Pack	SO ₂ NH ₃ Organic acids Organic ions Inorganic ions	AAQD Method 6.3/3.0/M "Multi (3) IC"
	Trace organic species	PERD Particles POL "Detailed Organic Compound Analysis by GC-MS"
	Trace Metals	AAQD Method 3.1/2.0/M "EDXRF"
DNPH Cartridge	NO ₂ C ₁ – C ₇ Carbonyls	ERMD Method 4.1/1.1/M "Carbonyl Compound Analysis for Vehicle Emissions"
Summa Canister	CO CO ₂ N ₂ O SF ₆	CO and CO ₂ by GC-FID with nickel catalyst N ₂ O and SF ₆ by GC-ECD with cryogenic preconcentration
	CH ₄ VOCs	ERMD Method 4.3/1.1/M "Methane and Light Hydrocarbon Analysis for Vehicle Emissions" and 4.4/1.1/M "Non-Methane Hydrocarbon Analysis for Vehicle Emissions (Volatile and Semi Volatile)"
Tenax Cartridge	SVOCs	

Sample Extraction or Work-up

All samples will be returned to the laboratory for analysis.

Filter Pack	SO ₂ NH ₃ Organic acids	Extraction with H ₂ O
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	Organic ions Inorganic ions	Isopropanol wetting followed by sonication with H ₂ O
	Trace organic species	Dionex ASE
DNPH Cartridge	NO ₂ C ₁ – C ₇ Carbonyls	Elution with acetonitrile through an Acrodisc filter
Summa Canister	VOCs, N ₂ O, SF ₆	Cryogenic pre-concentration
Tenax Cartridge	SVOCs	Extraction with pentane

Analytical Detection Limits

Please refer to the following attached tables:

Table A-1: Filter Pack Detection and Quantitation Limits

Table A-2: FTIR Spectrometer Detection Limits

Table A-3: DNPH Cartridges Detection Limits

Table A-4: Summa Canister Detection and Quantitation Limits

Table A-5: Tenax Cartridges Quantitation Limits

Quality Assurance/Quality Control

1.2. Field Quality Assurance/Quality Control

Traceability

Sample flow rates for filter packs, DNPH cartridges and Tenax tubes will be controlled using MKS mass flow controllers. All flow rates will be checked at the beginning and end of each sampling period using a DryCal flow meter (primary standard).

The flow rate for the canister samples will be determined by the critical flow orifice and will be measured using an electronic flow meter prior to sampling.

Calibration

Calibration of the FTIR instruments will be done using certified standards purchased from Megs Specialty Gases. When available, the measurements will be verified by analyzing a second gas standard. The calibration will be done before the study and monitored daily throughout

the study.

Mass flow controllers (unless new) are cleaned and calibrated by MKS prior to the study. Flows will be checked before each sampling period.

Zeros and spans

For the FTIR analyzers, a background will be collected on an evacuated sample cell at the beginning of each sampling period. A CO standard will be run each day to verify instrument performance. It is assumed that if the background meets acceptability criteria and that the result for the CO standard is acceptable, then the instrument is functioning correctly for all other species.

Blanks

Lot blanks and field blanks will be collected for each sample media type with the exception of canisters.

Field Quality Control procedures

Filter packs will be loaded and unloaded on site in the GVRD mobile lab, protected as much as possible from contamination. Forceps will be used to handle all filters. Filters were inspected for holes during pre-weighing procedures and will be checked again before loading in filter packs. Filter packs will be checked for tightness to avoid leaks. The filters have individual identification numbers that will be used to ensure they are loaded into the correct positions on the sampling manifold.

Precision determination

Duplicate PM mass measurements will be made at each location for each sampling period.

Comparison with other measurements

For many species and measurements, two independent measurements

will be made using different filters or different techniques (e.g. FTIR and canister samples for CO, CO₂, N₂O, CH₄ and filter and FTIR measurements for SO₂, NH₃)

Inspections and Audits

The sample collection records for each location will be reviewed by personnel operating the other location to ensure completeness and to detect discrepancies with procedures used at either location.

1.3. Laboratory Quality Assurance/Quality Control

Traceability

This information can be found in the analytical method documentation attached.

Calibration procedures

This information can be found in the analytical method documentation attached.

Blanks

This information can be found in the analytical method documentation attached.

Other lab QC

Please refer to the analytical methods listed in section 10.2.2 for quality assurance procedures for each method.

Precision determination

This information can be found in the analytical method documentation

attached.

Comparison with other methods

For some species, measurements will be made using two independent methods. This data will be used to compare methods.

Audits

The ERMD and AAQD laboratories are accredited under CAEAL.
The NRCan laboratories are accredited under ISO 9002.

Data Management and Quality Control

1.4. Raw Data Recording

For filter packs, DNPH & Tenax cartridges, and Summa canisters, time of sample and media identification will be manually recorded on site on a prepared log sheet.

Data gathered by the FTIR will be automatically recorded by the instrument software.

Data gathered by the OSP/DMA will be automatically recorded by the instrument software.

1.5. Final Data Reporting

For filter packs, DNPH & Tenax cartridges, and Summa canisters, 3 hour samples will be recorded and reported.

For the FTIR, 1 minute average concentrations will be recorded and reported.

For the DMA, data will be continuously recorded and reported as time series and as average size distributions over the sampling period.

For the DMA, data will be continuously recorded and reported as time series and as average size distributions over the sampling period.

1.6. Data Quality Control and Validation

All reported data will be flagged as valid (V) or invalid (I). Raw data will be inspected and all instrument and power failures will be flagged as invalid. Data will be zero and span corrected at the beginning of each sampling period.

1.7. Validity Flags

The following NARSTO flags will be used:

- V0 Valid value
- V1 Valid value but comprised wholly or partially of below-MDL data
- V2 Valid estimated value
- V3 Valid interpolated value
- V4 Valid value despite failing to meet some QC or statistical criteria
- V5 Valid value but qualified because of possible contamination (e.g., pollution source, laboratory contamination source)
- V6 Valid value but qualified due to non-standard sampling conditions (e.g., instrument malfunction, sample handling)
- M1 Missing value because no value is available
- M2 Missing value because invalidated by data originator
- H1 Historical data that have not been assessed or validated]

1.8. Below Method Detection Limit Values

Values that are below detection limits will be reported as <DL or <QL as appropriate with the detection limit or quantitation limit quoted with the corresponding indicator.

1.9. Derived Parameters

1.10. Explanation of Zero or Negative Data

Zero and negative values will be reported as measurements less than the detection limit of the instrument.

Data Quality Objectives (Pre-Study)

1.11. Accuracy

Accuracy of the overall measurement is difficult to determine. Flow measurements are expected to be accurate to within 5% of set-point. Analytical accuracies are method dependent and are documented within each method.

1.12. Precision

The flow rates on different channels for different samples with the same nominal set point should agree within 5% of that set point.

The two FTIR analyzers will be run side by side before the study. The results should agree within 5%.

The particle size distribution instruments will be run side by side before the study. The results should agree within ???.

1.13. Comparability

1.14. Representativeness

The measurements at the Cassiar Tunnel will be representative of the mass emission rates and particle number distribution from light duty traffic in the Lower Fraser Valley.

1.15. Completeness

We fully expect to have 100% completeness for all data, barring power failures and equipment failures.

1.16. Other Quality Information

End of Pre-Study QAPjP

Start of Post-Study QA Report

Significant Changes to Site, Instruments or Methods During Study

Post-study Data Quality Indicators (DQIs)

Accuracy

Precision

Comparability

Representativeness

Completeness

1.17. Blank correction (describe whether done and method used):

1.18. Other Quality Information

References:

Table A-1: Filter Pack Detection and Quantitation Limits ($\mu\text{g}/\text{m}^3$)

Filter	Grouping	Compound	DL	QL
Citric Acid Coated	N/A	NH ₃	0.044	0.147
K ₂ CO ₃ Coated	N/A	SO ₂	0.017	0.056
Teflon	N/A	PM mass	1.2	-
Quartz		OC/EC	0.6	-
KOH Coated	Organic Acids	Malonic	0.131	0.435
		Succinic	0.207	0.694
		Glutaric	0.011	0.036
		Adipic	0.195	0.649
		Acetic	0.084	0.279
		Azelaic	0.207	0.694
		Lactic	0.323	1.079
		Formic	0.311	1.037
		Glycolic	0.210	0.701
		Propionic	0.175	0.585
		Phthalic	0.351	1.168
		Benzoic	0.521	1.736
		Maleic	1.556	5.185
		MSA	0.018	0.060
		Oxalic	0.023	0.079
Glyoxylic	0.015	0.049		
Emfab	Organic Acids	Malonic	0.052	0.175
		Malic	0.047	0.158
		Succinic	0.084	0.277
		Glutaric	0.042	0.143
		Adipic	0.079	0.259
		Pimelic	0.057	0.190
		Acetic	0.035	0.111
		Azelaic	0.084	0.277
		Lactic	0.128	0.432
		Formic	0.126	0.415
		Glycolic	0.084	0.281

	Propionic	0.059	0.195
PAHs	AL	0.61* 10 ⁻⁴	-
	AE	0.61* 10 ⁻⁴	-
	FL	0.61* 10 ⁻⁴	-
	MFL	1.22* 10 ⁻⁴	-
	PHE	0.61* 10 ⁻⁴	-
	AN	1.22* 10 ⁻⁴	-
	FLT	0.61* 10 ⁻⁴	-
	PY	0.61* 10 ⁻⁴	-
	B(a)FL	1.22* 10 ⁻⁴	-
	B(b)FL	1.22* 10 ⁻⁴	-
	MPY	1.22* 10 ⁻⁴	-
	B(ghi)F	3.05* 10 ⁻⁴	-
	B(a)A	3.05* 10 ⁻⁴	-
	Tri	3.05* 10 ⁻⁴	-
	Chysene	3.05* 10 ⁻⁴	-
	C&T	???	???
	MB(a)A	6.11* 10 ⁻⁴	-
	B(b)FLT	6.11* 10 ⁻⁴	-
	B(k)FLT	6.11* 10 ⁻⁴	-
	B(b)F & B(k)F	???	???
	B(e)P	6.11* 10 ⁻⁴	-
	B(a)P	6.11* 10 ⁻⁴	-
	PER	6.11* 10 ⁻⁴	-
	MCH	12.21* 10 ⁻⁴	-
	IP	6.11* 10 ⁻⁴	-
	D(ah)A	6.11* 10 ⁻⁴	-
	B(b)C	6.11* 10 ⁻⁴	-
	B(ghi)P	6.11* 10 ⁻⁴	-
ANT	12.21* 10 ⁻⁴	-	
Sulphur PAHs	Thionaphthene	0.31* 10 ⁻⁴	-
	DBT	0.31* 10 ⁻⁴	-
	N(2,1b)T	0.31* 10 ⁻⁴	-
	2-MDBT	0.18* 10 ⁻⁴	-
	8-MN(2,1b)T	0.18* 10 ⁻⁴	-
	5-MN(2,1b)T	0.18* 10 ⁻⁴	-
	4,6-DMDBT	0.31* 10 ⁻⁴	-
	1,8-DMDBT	0.18* 10 ⁻⁴	-
	1,3-DMDBT	0.18* 10 ⁻⁴	-
	Pa(4,3b)T	0.31* 10 ⁻⁴	-

		Pa(3.4b)T	0.31* 10 ⁻⁴	-
		Pa(2,1b)T	0.31* 10 ⁻⁴	-
		Pa(2,3b)T	0.31* 10 ⁻⁴	-
		A(2,3b)T	0.31* 10 ⁻⁴	-
		10-MBbN(2,1d)T	0.18* 10 ⁻⁴	-
		2-MBbN(2,1d)T	0.18* 10 ⁻⁴	-
		8-MBbN(1,2d)T	0.18* 10 ⁻⁴	-
		5-MBbN(2,1d)T	0.18* 10 ⁻⁴	-
		6-MBbN(2,1d)T	0.18* 10 ⁻⁴	-
		8-MBbN(2,3d)T	0.18* 10 ⁻⁴	-
		11-MBbN(2,3d)T	0.18* 10 ⁻⁴	-
	Other	Alkanes	0.003	-
		Biomarkers	6.11* 10 ⁻⁴	-
Teflon	Organic ions	MSA	0.054	0.176
		Pyruvic	0.042	0.137
		Glyoxylic	0.049	0.166
		Benzoic	0.042	0.137
		Oxalic	0.010	0.029
		Phthalic	0.042	0.137
	Inorganic ions	Chloride	0.032	0.107
		Nitrite	0.017	0.059
		Bromide	0.024	0.078
		Nitrate	0.015	0.049
		Sulphate	0.012	0.039
		Phosphate	0.027	0.088
		Lithium	0.006	0.021
		Sodium	0.020	0.066
		Ammonium	0.021	0.069
		Potassium	0.044	0.146
		Magnesium	0.012	0.039
		Manganese	0.034	0.144
		Calcium	???	???
		Strontium	0.053	0.177
	Trace metals	Sodium	0.469	-
		Magnesium	0.022	-
		Aluminum	0.019	-
		Silicon	0.018	-
		Phosphorus	0.013	-
		Sulphur	0.009	-
Chlorine		0.028	-	
Calcium		0.040	-	

	Scandium	0.056	-
	Titanium	0.068	-
	Vanadium	0.050	-
	Chromium	0.038	-
	Manganese	0.029	-
	Iron	0.030	-
	Cobalt	0.023	-
	Nickel	0.013	-
	Copper	0.026	-
	Zinc	0.010	-
	Gallium	0.014	-
	Germanium	0.007	-
	Arsenic	0.006	-
	Selenium	0.006	-
	Bromine	0.005	-
	Rubidium	0.004	-
	Strontium	0.004	-
	Yttrium	0.004	-
	Zirconium	0.004	-
	Niobium	0.004	-
	Molybdenum	0.004	-
	Palladium	0.006	-
	Silver	0.006	-
	Cadmium	0.007	-
	Indium	0.007	-
	Tin	0.008	-
	Antimony	0.009	-
	Tellurium	0.011	-
	Iodine	0.014	-
	Cesium	0.021	-
	Barium	0.025	-
	Lanthanum	0.027	-
	Cerium	0.025	-
	Promethium	0.022	-
	Neodymium	0.024	-
	Tungsten	0.045	-
	Mercury	0.010	-
	Lead	0.011	-

Table A-2: FTIR Spectrometer Detection Limits

Compound	DL
CO	

CO ₂	
NO	
NO ₂	
N ₂ O	
SO ₂	
NH ₃	
CH ₄	
SF ₆	

Table A-3: DNPH Cartridges Detection Limits

Compound	DL
C ₁ – C ₇ carbonyls	1.67*10 ⁻³ to 2.78 * 10 ⁻³ ug/m ³
NO ₂	50 ppb

Table A-4: Summa Canister Detection and Quantitation Limits

Compound	DL	QL
VOCs	-	0.05 ug/m ³
CO	0.1 ppm	-
CO ₂	0.1 ppm	-
N ₂ O	1.0 ppb	-
CH ₄	-	100 mg/m ³
SF ₆	1.0 ppb	-

Table A-5: Tenax Cartridges Quantitation Limits

Compound	QL
SVOCs	0.556 ug/m ³