Monitoring Parameter: **Particulate Matter (PM)**	Title: **Standard Operating Procedure for the Non-Continuous Measurement of Particulate Matter in Ambient Air – by High Volume Sampler** DRAFT
Revision No: Draft **Revision Date: 6 July, 2017**	**Reference No: SOP-05d** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the discrete non-continuous ambient monitoring of total suspended particulates (TSP) and particulate matter of 10 µm or less in aerodynamic diameter (PM_{10}), within the provincial jurisdiction of British Columbia (B.C.).

These guidelines and instructions have been written specifically for the monitoring of particulate matter that is 10 µm or less in aerodynamic diameter (PM_{10}) and particulate matter that is 2.5 µm or less in aerodynamic diameter ($PM_{2.5}$).

This SOP describes particulate matter measurements using a high-volume sampler. Operating guidelines and instructions for particulate matter measurements using other analytical methods are provided in SOPs-5a through 5c and SOP-5e. Subsequent analysis of the sample filter by an analytical laboratory is required to complete the measurement of PM using this method. The laboratory analysis procedure is not covered in detail within this SOP.

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a high volume sampler within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the BCFSM, the manufacturer's manual, and this document.

2. Principle of the Sampling Method

High Volume Filter Collection and Gravimetric Mass Determination

The high-volumer sampler can be fitted with a TSP or PM_{10} inlet head to provide selective sampling of the particulate size fraction of interest. The sampler draws ambient air through the inlet head and filter which traps any particulate matter that may be present in the air stream. The sample filter is pre-conditioned, inspected and pre-weighed before sampling. The sampler draws air through the filter at a controlled flow rate of between 1.13 m^3/min^{-1} and 1.70 m^3/min^{-1}. After sampling the filter is re-conditioned and re-weighed. The difference in filter weight before and after sampling provides the mass of the particulate matter in the sampled air.

During the sampling period the elapsed sampling time is recorded. The flow rate and elapsed time are used to calculate the total sample volume in cubic meters (m^3). The mass of particulate matter and the sample volume are used to calculate the average particulate concentration in micrograms per cubic meter ($\mu g/m^3$) over the sampling period.

A high volume sampler employs one of the following types of flow control systems:

- Mass flow control system
- Volumetric flow control system
- Electronic flow controller

Mass flow controlled samplers use a hot wire anemometer probe to monitor the volumetric flow rate within the sample collection chamber and the sampler adjusts the motor speed to maintain the desired volumetric flow rate.

A volumetric flow control system uses a choke-flow orifice of a specific size that is calibrated to maintain a predetermined volumetric flow rate. The orifice is calibrated to draw constant volume under a given average temperature and pressure.

An electronic flow controller uses internal temperature and pressure sensors and a microprocessor to electronically control the motor to adjust the volumetric flow rate.

3. Interferences

Potential interferences with this sampling method include filter contamination and damage, particulate accumulation on the size selective inlet, extraneous objects, liquid aerosols, reactant residue, filter selection, motor dust, sample particulate size range, accumulated snow, flow rate variation over the sampling period and air leakage.

Filter contamination and damage

Filter contamination can interfere with measurement results. The filter should be secured and kept clean prior to filter installation. After the sampling event the filter should be removed as soon as practical. To minimize contamination it is recommended that powderless nitrile gloves be worn when handling filters. Any damage to the filter during handling will invalidate the measurement. Filter damage is commonly associated with filter media sticking to the faceplate gasket.

Particulate accumulation on the size selective inlet

Particle size selective inlets provide a stable cut-point as long as they are routinely serviced to minimize particulate accumulation on the inlet surface. Inadequate maintenance of the size selective inlet may result in a shift of the particle size cut-off, or undesired particle re-entrainment.

Extraneous objects

Objects such as insects may get drawn into the sampler and be weighed as PM.

Liquid aerosols

Liquid droplets such as fog can be drawn into the sampler and be retained by the filter. If the amount of liquid droplets is significant, the filter becomes wet and will not function as designed.

Reactant residue

A gas constituent within the sampled air may react with the filter medium, or sorb onto the filter. This action may cause a residue to be retained and weighed as PM.

Filter selection

High concentrations of ambient SO_2 and NO_2 can interference with glass fibre filters.

Motor dust
ASTM, 2009 report that dust containing metals from sampler motors, particularly copper, can significantly contaminate samples.

Particle size range
The high volume sampling method allows particulates of up to 100 µm in diameter to be collected. Collection efficiency decreases for particles greater than 20 µm in diameter and consequently particulate sample collection can be biased to the smaller particulate sizes.

Accumulated snow
Snow can accumulate on the filter during winter conditions and special care is required for filter handling in this circumstance to ensure that particulates captured on the filter are not removed.

Flow rate variation
This interference is specific to a sample collection approach that uses an average flow rate calculated from a discrete flow rate measurement recorded at the start and end of a sampling period. Throughout the sampling period as the PM accumulates on the filter, the flow rate through the filter is gradually reduced. If at some point in the sampling period a significant drop in flow rate occurs, then the average of the flow rate at the start and end of the sampling period will not accurately represent the total sample volume. This is not a potential interference for samplers that continuously monitor and record flow rate throughout the sampling period or samplers that sense a decrease in air flow as the particulate builds up on the filter and makes adjustments to maintain the flow rate (such as a mass or electronic flow controller). Inadequate flow can also result from voltage loss in extension cords. When using extension cords for sampler power, 12 gauge wire is recommended and extra care is required when using extension cords beyond 15 metres.

Air Leakage
If the faceplate gasket is improperly sealed (e.g. due to deterioration, dirt or improper installation) the measurement will be invalidated.

4. Precision and Accuracy

The precision of an analysis is generally considered to be the 'repeatability of the measurement'.
ASTM, 2009 report that the relative standard deviation (coefficient of variation) for multi-laboratory variation is 3.7%.

The accuracy of an analysis is generally considered to be a measure of the 'deviation from true'. The accuracy of this method is unknown.

5. Recommended Equipment and Apparatus

The following instruments are commercially available and suitable for use within the provincial jurisdiction of B.C.:

- Ecotech HiVol 3000 High Volume Air Sampler
- Tisch Environmental High Volume Air Sampler (Various models including mass flow controlled, volumetric flow controlled and electronic based controller)

Note that different makes/models allow for different data collection and recording over the sampling period. Some samplers allow for documentation of flow rate at the start and end of the sampling period, whereas other samplers provide a continuous record of operating parameters throughout the sampling period using either a chart recorder or electronic datalogger. A sampler's data collection and recording capabilities should be considered during equipment selection to ensure monitoring objectives are met. Samplers that provide a continuous record of operating parameters during sample collection are preferred over samplers that only allow for documentation of flow rate at the start and end of sampling.

A calibrator kit is required to calibrate the sampler.

Filters should generally:

- collect more than 99% of TSP that passes through,
- be strong enough to minimize leaks,
- not react with the air or particulate passing through it,
- be thermostable (i.e. not have differing efficiencies based on temp fluctuation), and;
- not contain high levels of the targeted compound to be monitored.

There are a variety of filter types with differing effectiveness relative to these criteria. In selecting the appropriate filter it is important to take into account the monitoring environment, monitoring objectives and required filter analysis. Generally a glass-fibre filter is used, however, silica fiber filters, cellulose paper and polyvinyl chloride (PVC) filters can be used depending on the analysis required. If further metals analysis on the sample filter is required, a TX40 (Teflon coated glass fibre filter) is recommended. A glass fibre filter is not recommended if analysis to determine silica content is required. Some sampler types (such as the Ecotech) use a filter cassette to hold the filter in place.

This list does not necessarily exclude other commercially available high volume air samplers. It is highly recommended however that you consult with B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy a non-continuous PM sampler that is not listed above. Regardless of the instrument deployed, all samplers should meet the specifications described within this document.

6. Measurement Range and Sensitivity

By using different sample inlets, high volume samplers can be used to collect TSP and PM_{10} samples.

ASTM, 2009 report that the minimum amount of particulate detectable is 3 milligrams (mg). For a sampler operated at an average flow rate of 1.70 m^3/min, this results in a lower concentration limit of 1 to 2 µg/m^3. B.C. ENV, 2013 report that an estimated upper concentration is at least 780 µg/m^3 and 420 µg/m^3 for TSP and PM_{10} respectively.

7. Site Requirements

Sampling site specifications should be developed to ensure that the data obtained from the site meets the intended or established sampling objectives. It is recommended that sampling site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with sampling objectives. As a preliminary guideline site selection should consider and address: sampling objectives, representativeness of the region, interference from the surrounding area, zone type (residential, commercial, industrial) of the location. Refer to Section XX of the BCFSM for further information on site selection. In addition, the high volume sampler has specific siting requirements that are outlined in Section 8.

8. Installation Requirements

Follow sampler specific installation requirements discussed in the manufacturer's manual. The installation should also conform to the following:

- The sampler inlet should be located at a height of 2 m to 7 m above ground level.
- If the sampler is located on a roof or other structure the inlet should be at least 2 m from walls or parapets and not near any building vents or flues.
- The sampler should be located away from structures such as trees and buildings. The distance between any obstacle and the sampler should be at least twice the height of the obstruction.
- There should be unrestricted flow in 3 of the 4 wind quadrants.
- The appropriate size fraction separator should be installed onto the instrument for PM_{10} monitoring.
- The sampler should be located away from localized sources of particulate that could influence monitoring results such as unpaved roads and temporary generators unless identified as a source of interest when establishing monitoring objectives.
- If the sampler has a motor and a metals analysis of the sample is required, consideration should be given to venting the exhaust motor away from the sample inlet.
- High volume samplers draw a considerable amount of electricity and care to select an appropriate extension cord is required. Extension cords should not exceed 15 metres and be constructed with 12 gauge conductors (wire). Ensure power is supplied in a manner consistent with all applicable electrical codes. Consider installing dedicated power for extended sampling programs (e.g., outlet with cover at sampler).

9. Operational Requirements

Follow instrument specific operational requirements discussed in the manufacturer's manual. Exact requirements will vary by sampler, however in general the following activities should be performed by the operator of a high volume sampler:

Action	Time/Frequency	Description	Record Keeping
Sampling Frequency	At installation	• Sampler to operate every 6th day on the North American standard, unless an alternative schedule has been agreed with the B.C.	• Record in logbook
Sampling Period	At installation	• Samples should be collected over a 24 hour period (midnight to midnight).	Record in logbook
Sampling Start	At the start of each sample period	• Perform flow verification to verify the flow rate is within 1.13 to 1.70 m^3/min. If the flow rate is outside this range a calibration should be performed. • Use filter within 30 days of conditioning by the laboratory. • Record sampler ID, filter ID's and date. • Record start time, flow rate,	• Record in logbook • Complete Chain of Custody (COC) information required by the analytical laboratory.

		ambient temperature and ambient pressure	
	After each use	• Clean as per manufacturers operation manual • Inspect inlets and clean if required. • Inspect the filter screen and remove any foreign deposits. • Inspect the faceplate gasket and ensure it is clean and in good condition to allow a correct seal. Do not overtighten the faceplate gasket as filter damage may occur.	• Record in logbook
Data Retrieval	At filter retrieval	• Visually check for any leaks, damage or other possible interferences during the sampling period (e.g. vegetation clearing occurred). • Retrieve filter within 5 days of the sampling event. • Record end and elapsed time, flow rate, sample volume, ambient temperature and ambient pressure.	• Record in logbook • Complete COC information required by the analytical laboratory.
Routine checks and Maintenance	Every 400 to 500 running hours	• Check motor brushes and change if required (for samplers that have motor brushes)	• Record in logbook
	Every 1500 running hours or after replacing motor brushed two times	• Replace motor	
	Every 800 running hours	• Inspect top and bottom motor gaskets and replace if necessary. • Inspect flow meter tubing and replace if necessary. • Check Rotameter and clean if required (for samplers that have rotameters)	
Calibration	• At installation • After the sampler fails for any reason • After maintenance or change of motor or motor brushes • After a flow	• As per Section 11 of this SOP	• Record in logbook

	verification indicated that the flow is outside of the acceptable range. • After a manufacturer specified number of sampling hours (e.g. Tisch Environmental 2015, specify 360 hours) • At least quarterly		

10. Zero and Span Checks

This section is not applicable to this measurement method.

11. Calibration

Calibration should be performed in accordance with Section XX of the BCFSM and following the manufacturer's manual. Certain aspects specific to the high volume sampler's calibration are included in this section. Exact calibration procedures will vary by sampler make/model and type, for example calibration procedures vary between mass flow controlled and volumetric flow controlled samplers.

Several parameters require calibration including flow, ambient temperature, ambient pressure, clock and date. The calibration procedure comprises the following sequential steps:

- Step 1 – As-found verification of flow, temperature and pressure
- Step 2 – Leak check
- Step 3 – Multi-point verification; calibrate if necessary.
- Step 4 – As-left verification

Step 1 verification is used to determine that prior samples were taken under valid conditions. The verification comprises a check against a known standard. The flow verification should be performed using a flow meter which is calibrated or certified annually against a National Institute of Standards and Technology (NIST) traceable standard. Similarly, temperature and pressure verification should be performed using a temperature and pressure standard which is calibrated or certified annually against a NIST traceable standard.

In Step 2 a leak check is undertaken to ensure there are no leaks in the sample train before undertaking a calibration. If leaks are detected during this step they should be addressed, and the flow re-verified as in Step 1. The pass criteria for all parameters for Steps 1 and 2 are provided in the following table.

Parameter	Pass Criteria
Flow	Between 1.13 m^3/min to 1.70 m^3/min with a correlation coefficient of 0.990 or better.
Temperature	As stated within the manufacturers manual for a specific sampler.
Ambient pressure	As stated within the manufacturers manual for a

	specific sampler.
Clock and date verification check	Clock should be within ±2 minutes of standard time, and the date should be correct.
Leak check	No air leakage detected by operator

Parameters that do not meet the pass criteria in the table above should be adjusted in Step 3. After adjustment a final verification (Step 4) is undertaken to confirm parameters are within the required criteria.

12. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Alaska Department of Environmental Conservation 2011. *Standard Operating Procedures for Lead monitoring Using a TSP High-Volume Sampler*. Division of Air Quality Air Monitoring and Quality Assurance Section.

American Standard Test Method (ASTM) 2009. *Standard Test Method for Determination of Total Suspended Particulate Matter in the Atmosphere (High-Volume Sampler Method)*. Designation D4096-91 (Reapproved 2009).

Ministry of Water, Land and Air Protection 2013. *British Columbia Field Sampling Manual Part B Air and Air Emissions Testing.* Water, Air and Climate Change Branch.

EcoTech 2013. *HiVol 3000 High Volume Air Sampler User Manual*. Version 1.8.

Environment Canada 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

State of California Air Resources Board 2008. *Air Monitoring Quality Assurance Volume V Audit Procedures for Air Quality Monitoring Appendix D Performance Audit Procedures for High Volume Samplers*. Monitoring and Laboratory Division.

State of California Air Resources Board 1992. *Standard Operating Procedures for Air Quality Monitoring Appendix E High Volume Sampler*. Monitoring and Laboratory Division.

Tisch Environmental not dated. *Operations Manual TE-5170 Total Suspended Particulate Mass Flow Controlled High Volume Air Sampler.*

United States Environmental Protection Agency (US EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

US EPA 1999. *Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air Compendium Method IO-2.1 Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and*

PM_{10} Using High Volume (HV) Sampler. Center for Environmental Research Information Office of Research and Development.

United States Code of Federal Regulations 2013. *Title 40 Part 58 Appendix E, Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring.* Prepared by the US Government Publishing Office.

Revision History: 0.0 (New document)
Approval