Monitoring Parameter: **Particulate Matter (PM)**	Title: **Standard Operating Procedure for the Continuous Measurement of Ambient PM Using Integrated Nephelometry and Beta Attenuation**
Revision No: Draft **Revision Date: 08 March, 2018**	**Reference No: SOP-05b** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides guidelines and instructions for the continuous ambient monitoring of particulate matter within the provincial jurisdiction of British Columbia (B.C.).

These guidelines and instructions have been written specifically for 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 nephelometry and beta attenuation measurement techniques. Operating guidelines and instructions for particulate matter measurements using other analytical methods are provided in SOPs 5a, and 5c through 5e.

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 PM analyzer within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer's manual, and this document.

2. Principle of the Measurement Method

Nephelometry and Beta Attenuation Monitor

The principle detection and quantification method deployed in monitoring ambient mass concentrations of particulate matter involves nephelometry and beta attenuation. Monitors are set to a size fraction of interest, typically PM_{10} or $PM_{2.5}$, by attaching a size-selective inlet which allows ambient air to be drawn through the analyzer at a rate of 16.7 litres per minute (l min^{-1}). The sample initially passes through an 880 nm light beam within the nephelometer. The nephelometry response is proportional to the concentration of particulate matter present in the sample. The sample then passes through the beta attenuator where particulate matter, if present in the sample air, is deposited onto a glass fibre filter tape. A radioactive source within the analyzer emits beta rays that pass through the glass fibre tape to a scintillation counter. The presence of particulate matter will attenuate the beta rays which are detected and measured by the scintillation counter. The level of attenuation caused by the particulate matter is proportional to the ambient concentration of particulate matter. The beta attenuation chamber measures alpha emissions from the accumulated particles and excludes negative mass artifacts associated with the presence of daughter nuclides from radon gas decay. A more detailed description of the particulate matter measurement principle is typically provided within the manufacturer's operation manual.

3. Interferences

Particulate matter measurements can be interfered with by dust accumulation on the optical sensor, debris in the BAM sample chamber, moisture buildup, temperature, inlet and sample tube loss, and system leaks.

Dust Accumulation on Optical Sensor

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Dust accumulation on the optical sensor may interfere with the measurement of PM. This can occur after heavy dust storm events or incrementally over time. To mitigate potential interference by dust the nephelometric chamber should be cleaned once per year.

Moisture

Conditions in which the relative humidity (RH) is high can result in an accumulation of water vapour on the filter tape. This results in a mismeasurement of PM as the water vapour attenuates beta rays. This interference can be minimized by using a dynamic heating system (DHS) to maintain the relative humidity of the air passing through the filter tape. Typically RH will be controlled to 35% to prevent vapour condensation on the filter tape.

Inlet and Sample Tube Loss

The particle size-selective inlets have a stable cut-point as long as they are routinely serviced to minimize inlet surface particle accumulation. Poor maintenance of the inlet may result in a shift of the particle size cut-off, or undesired particle re-entrainment. Excessive particulate build up on the inner walls of the sample tubing can affect the PM concentration measurements. Scheduled preventive maintenance routines will significantly mitigate the potential for this type of interference.

Flow tolerance

Size selective inlets are designed to operate with an airflow rate of 16.67 l min^{-1}. This flow rate is required to prevent particulate matter that exceeds the inlet cut size from entering the sample stream. Airflow must be maintained within ± 4% of 16.67 l min^{-1} to ensure that only the desired particulate fraction (i.e. $PM_{2.5}$) is being measured.

System Leaks

Air leaks in the sampling system can result in reduced PM measurement. The PM analyzer must pass a leak check to produce valid data. The leakage rate must be less than 0.8 l min^{-1}. Consult the manufacturer's operation manual for leak check instructions specific to the analyzer.

4. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy. The precision of a measurement is generally considered to be the 'repeatability of the measurement'.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The SHARP 5030 and 5030i Thermo Scientific manufacturer reports the hourly precision to be ± 2 µg/m^3 for measurements less than 80 µg/m^3 and ± 5 µg/m^3 for measurements greater than 80 µg/m^3. The reported accuracy of the 5030 model is ± 5% compared to a 24 hour Federal Reference Method. The accuracy of the 5030i model is reported as ± 5% using NIST-traceable mass foil set.

5. Recommended Equipment and Apparatus

The following are commercially available combined Nephelometry and Beta Attenuation analyzers considered to be suitable for use within the provincial jurisdiction of B.C.:

- Thermo Fisher Scientific Model SHARP-5030
- Thermo Fisher Scientific Model 5030i

This list does not necessarily exclude other commercially available PM analyzers, and analyzers

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recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. In deed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy instruments not listed above. Regardless of the instrumentation deployed, all analyzers should meet the specifications described within this document.

6. Measurement Range and Sensitivity

Thermo Fisher Scientific report that the SHARP Models 5030 and 5030i can operate at a user selectable range of 0 mg/m³ to 10 mg/m³. The detection limit is less than 0.5 µg/m³ for a one hour time resolution.

7. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, zone type (residential, commercial, industrial) of monitoring location.

Refer to Section XX of the B.C. Field Sampling Manual for further information on site selection method. In addition, the SHARP monitor has some specific probe siting requirements that are outlined in Section 8.

8. Installation Requirements

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

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- A data acquisition system (DAS) should be connected to the analyzer to record or download the measurement data from the analyzer. The DAS must also record and monitor any alarm conditions of the analyzer. The monitor should be set to monitor in hybrid mode.
- The analyzer must be placed in a weather resistant enclosure that is vented, heated and cooled to maintain a stable temperature preferably in the range of 20°C to 30°C but must ultimately be capable of maintaining a temperature range of 4 °C to 50 °C (5030i Instrument spec). The enclosures temperature should not deviate by more than 2 °C over a one hour period.
- At locations where a straight intake from the sample inlet point to the analyzer is not possible, locating the analyzer in an outdoor enclosure should be considered. The outdoor enclosure should be temperature controlled. The appropriate size selective-inlet must be installed onto the inlet tube.
- A temperature controller and temperature sensor system must be installed on the inlet.
- The instrument's front panel should be oriented to the north to avoid direct sunlight.
- The portion of the inlet tube within a shelter or building should be adequately insulated to avoid condensation build up within the sampling tube.

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- The inlet probe configuration should conform to the following criteria.

Probe Requirement	Condition
Height above ground	2 m to 15 m
Distance from support structure	> 2 metres
Distance from trees	> 20 m or twice the height of trees above the inlet elevation, whichever is greater
Distance from any air flow obstacles (i.e., buildings)	> twice the height of obstacles above the inlet elevation, whichever is greater
Airflow restrictions	Unrestricted in at least 3 of the 4 wind quadrants
Local source influences	Local source influences must be considered in locating the site for ambient PM

9. Operational Requirements

The following activities should be performed by the operator of a SHARP-5030 and 5030i PM analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Operational Parameter Set Up	At installation	• RH nominal value 35% • Filter change mass = 1500 µg • Filter change hours = 24 • Filter cycle = 8 hours • Temp control system set to ON • Air flow = 1000 l hr^{-1}	Record in logbook
Calibration • Temperature, RH and barometric sensor calibration • Flow rate • Mass foil calibration • Nephelometer zero	Annually or after repairs	As per Section 11 of this SOP. Leak check prior to calibration	Record in logbook, see example calibration activity record (Field Procedures Manual, Appendix 1)
Verify Operational Parameters	Weekly	Check operation of instrument, record operating parameters	Record in logbook
Sample Filter Change	Inspect monthly, change as required (typically 6 months)	As per manufacturers operation manual. Sites with heavy PM concentrations may need more frequent filter change.	Record in logbook
Self-test	After each filter tape change	As per manufacturers operation manual	Record in logbook
Logged Concentration	Weekly	Compare DAS concentration value with the concentration displayed on the	Record in logbook

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		analyzer. The values should be within 1 µg/m³	
Leak Check	• Monthly • Before calibration • Before and after nozzle cleaning • After each filter tape change out	As per manufacturers operation manual. A display of less than 0.8 l min^{-1} passes the leak check.	Record in logbook
Nephelometer Zero	Monthly	As per instrument manual	Record in logbook
Flow Check	Quarterly	As per manufacturers operation manual	Record in logbook
Clean $PM_{2.5}$ inlet cyclone & PM_{10} inlet Inspect O-Rings	Every 3 months	As per manufacturers operation manual	Record in logbook
Clean air inlet system Replace Inlet O-Rings	Annually	As per manufacturers operation manual	Record in logbook
Inspect/change pump vanes	Annually	As per manufacturers operation manual	Record in logbook
Replace Muffler	As required	As per manufacturers operation manual	Record in logbook
Clean the Nephelometer	Annually	As per manufacturers operation manual	Record in logbook
Sample Path Inspection (Probe to Analyzer)	Monthly	Where necessary replace with new lines, tighten loose connections, clean manifold if required	Record in logbook

10. Zero and Span Checks

This section is not applicable to this measurement method.

11. Calibration

Verification and calibration should be performed in accordance with the manufacturer's manual.

PM analyzer verification generally require:

- Pre-verification leak check (as per manufacturer's instructions)
- Verification of ambient temperature and pressure sensors
- Verification of internal RH and temperature sensors (if required by manufacturer)
- Verification of volumetric flow
- Mass foil verification using a series of null and span foils
- Nephelometer zero verification

Verifications must demonstrate compliance with the following acceptable tolerance levels:

Instrument	Leak Tolerance	Flow Tolerance	Temperature Tolerance	Pressure Tolerance	RH Tolerance
5030	<0.42 l in^{-1} (±2.5%)	4%	± 2° C	± 10 mmHg	10 %

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	5030i	<0.42 l in^{-1} (±2.5%)	4%	± 2° C	± 10 mmHg	10 %	

12. References

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

Environment Canada (EC) 2010. *Operating Procedures for BAM Samplers for $PM_{2.5}$ Monitoring in the NAPS Network*. EC National Air Pollution Surveillance (NAPS) Operations Unit.

Environment Canada (EC) 2014. Thermo SHARP5030 Monitor Operating Instructions, Environment Canada, NAPS Operations.

Thermo Fisher Scientific 2013. *Model 5030 Instruction Manual Synchronized Hybrid Ambient Real-time Particulate Monitor*.

Wood Buffalo Environmental Association (WBEA) 2013. Standard Operating Procedure, Procedures for operating continuous Thermo Scientific SHARP 5030 PM_{10} and $PM_{2.5}$ Analyzers.

Revision History: 0.0 (New document)

Approval

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