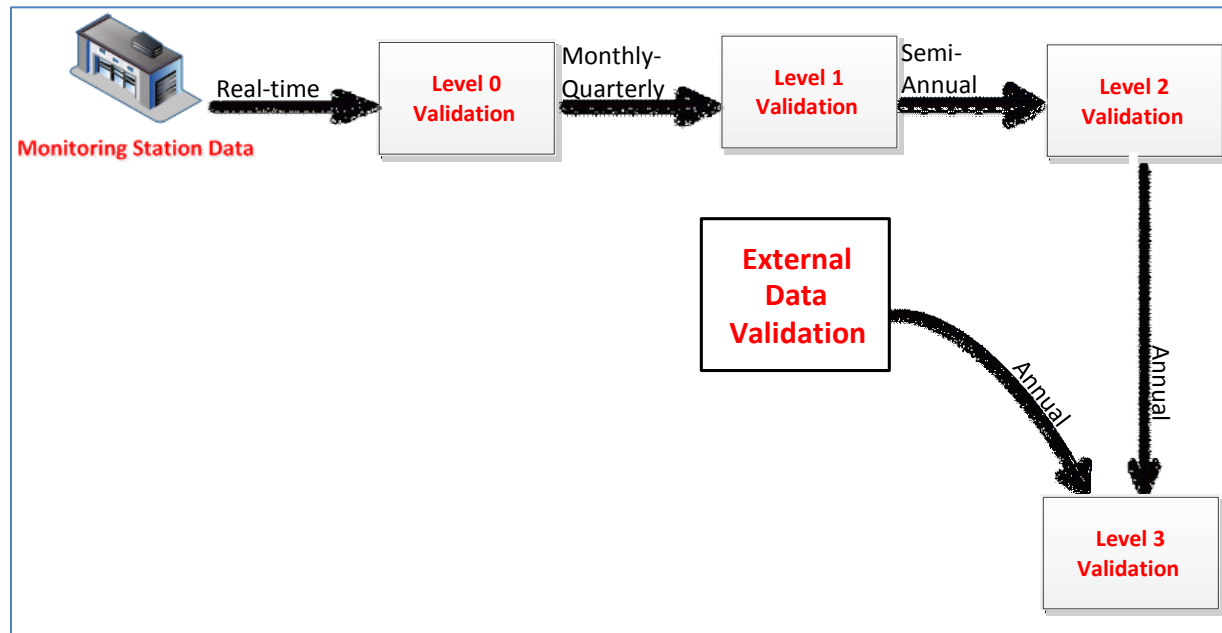


Monitoring Parameters: Ambient Air Quality, Meteorological Data	Title: <b>Standard Operating Procedure for Ambient Air Quality and Meteorological Data Validation</b>
<b>Revision No: Draft</b> <b>Revision Date: 23 April, 2018</b>	<b>Reference No: SOP-12</b> <b>Parent Document: Part B1 – B.C. Field Sampling Manual</b>
<p><b>1. Introduction and Scope</b></p> <p>This Standard Operating Procedure (SOP) serves as operating instructions for the B.C Ministry of Environment and Climate Change Strategy’s (ENV) data validation of ambient air quality monitoring and meteorological data. It applies to all the roles and responsibilities involved with the air quality monitoring program, including but not limited to: (1) ENV Air Monitoring Group; (2) ENV Air Quality Assurance Group; (3) ENV Air Data Management Group; (4) ENV Air Data Reporting and Standard Implementation Group; and (5) permittees required to monitor and their contractors.</p> <p>New National Air Pollutants Surveillance (NAPS) Monitoring and Quality Assurance/Quality Control Guidelines set a national standard for data validation. These standards must be considered for data validation procedures but are not yet finalized. At the time of writing, these guidelines are nearing the final stages of publication, but are not ready for full distribution. ENV’s staff have been involved in the development of the guidelines and understand the direction and intent of the guidelines, and therefore have incorporated that intent into this standard.</p>	
<p><b>1.1 Document Control</b></p> <p>This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance provided by it is based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.</p> <p>This SOP and the B.C. Field Sampling Manual are available at: <a href="http://www2.gov.bc.ca">www2.gov.bc.ca</a>.</p>	
<p><b>2. Overview</b></p> <p>Many factors related to instruments and data acquisition systems may affect data validity, and it is difficult to identify or adjust the anomalous data through a single step. As such, data validation is completed in four steps that subject the data to increasingly detailed levels of scrutiny and analysis. The first level of data validation, Level 0, provides a review of data completeness and validity as it relates to station operations. Level 1 provides assurance of data rationality and consistency specific to station operation and parameter. Level 2 verifies data validity in a broader scope such as pollutant relationship and buddy site comparison, and Level 3 assesses the data using advanced techniques such as modelling and statistical tests.</p> <p>Figure 1 illustrates ENV’s data validation process. Table 1 summarizes data validation activities, frequency, and responsibilities.</p> <p><b>Level 0</b> - a combination of automated data invalidation actions which occur in the data logger, analyzer, and the central polling system, and manual data verification actions taken by site operators and data validation specialists. Level 0 data validation activities are conducted at the highest frequency of near-real time to weekly.</p>	

**Level 1** - a collaborative and continuous effort between the data validation specialist and site operator. Level 1 validation involves a review of calibration results, logbook entries and an assessment of data anomalies. These activities which occur on a monthly to quarterly basis focus on a detailed identification of data issues based on parameter and instrument-specific behaviour, and a correlation of data with station activities. This function requires a technical understanding of instrumentation and factors affecting instrument performance and data quality. The Level 1 data validation process provides the most detailed attention to individual parameters. Detailed electronic logbook entries provided by site operators is a critical component of this process.



**Figure 1.** Timeline schematics of the data validation process for ENV's air quality monitoring and meteorological data.

**Level 2** – occurs on a semi-annual or annual frequency. The Level 2 validation process includes the generation and distribution of statistical summaries to site operators and primary data users including ENVs Air Quality (AQ) Meteorologists and the Clean Air Group. Level 2 data validation activities are also performed by external agencies who transmit their data annually (overwriting all autopollled data for their sites). Level 2 validation is a pre-requisite for verified data applicable for Canadian Ambient Air Quality Standards (CAAQS) reporting and decision making.

Upon completion of Level 2 validation, both imported and validated data are certified with a Final Edit attribute which locks the data from editing. Data validation specialists have administrative rights to unlock this data.

**Level 3** – provides an annual independent evaluation of validated data prior to publication. Level 3 validation is performed by ENV prior to publishing the B.C. Lung report, and the importation of data from B.C. by Environment and Climate Canada which generally occurs in June of the following year.

**Table 1.** Verification and Validation activities and frequency of execution.

**Level 0 Verification**

Validation Activities	Responsibility	Frequency	Description
Digital monitor status validation	Local station logger	Near Real-time	Configured at the local station logger and includes automated flags based on instrument status.
Automated range check	Central polling system	Hourly	Includes automated flagging and data correction for out-of-range values
Overall system and communications check	ENV	Hourly	Includes use of website, DrDashboard and "Last Received" status to determine status of communications, instruments, and the entire system
Review of diagnostics data and investigate suspicious hourly data	Site operator	Daily - weekly	Includes reviewing instrument diagnostics to verify proper operation, and review sub-hourly data (ENV sites)
Review of alarms and alerts (automated email, AQHI+)	Site operator	Daily - weekly	Includes automated email alerts sent by the Central Polling system to warn of instrument issues
Review of verification/calibration results	Site operator	Daily - weekly	Check daily zero and span values
Station/instrument status check	Site operator	During remote checks and station visits	Includes remotely checking the status of the instrument and the corresponding data, and visiting the station and inspecting the site and instruments.
<b>Level 1 Validation</b>			
Validation Activities	Responsibility	Frequency	Description
Review of Level 0 Verification	ENV/ Site operator	Monthly- Quarterly	Review automated invalidation
Review of logbook entries	ENV	Monthly- Quarterly	Manual review of logbook entries and adding/removing data flags
Review of operational and instrument parameters	ENV/ Site operator	Monthly- Quarterly	Review any instrument-specific operational limitations
Adjustment of data and adding comments	ENV	Monthly- Quarterly	Includes baseline adjustments, below zero adjustments, and derived parameter relationship check, and consolidation of logbook entries into data edit
Review of calibration/audit results	ENV	Quarterly/Semi- annual	Verify previous data based on calibration/audit results
<b>Level 2 Validation</b>			
Validation Activities	Responsibility	Frequency	Description
Review of Level 1 Validation	EMRE	Semi-annual	

Review of data summary/statistics/compare historical data	EMRE/site operators/AQ meteorologists	Semi-annual/annual	Creation of statistical summaries. Requires input from the stakeholders, site operators for data outliers and data-affecting events
Examination of meteorological data	AQ meteorologist	Annual	
Examination of relationships between pollutants	AQ meteorologist	Annual	
Comparison of buddy sites	AQ meteorologist	Annual	
Rejection of outlier data	EMRE/AQ meteorologist	Annual	

### Level 3 Validation

Validation Activities	Responsibility	Frequency	Description
Independent party review	Third party/science specialists	Annual	Includes the State of the Air Report created annually by the ENV Clean Air group. This report involves detailed statistical analysis on the historical context, and in the context related to public health (ENV sites)
Dataset comparison	Third party/science specialists	As needed	
Analysis using models and statistical tests	Third party/science specialists	As needed	
Examination of meteorological data	Third party/science specialists	As needed	
Communication of potential issues with primary validators	All stakeholders	As needed	

### 3. Data Validation Tools and Resources

The tools and resources available for data validation are listed in Table 2. These include web-based applications and data that are accessible to the general public, and specialized software that are available inside the ENV network. Other applications can be deployed on-site with physical access to the station's datalogger, or remotely via remote terminal connections.

Personnel performing data validation are not limited to the resources listed in Table 2. Open source resources such as R Programming Language, specialized software packages (e.g., SAS, SPSS), and standard spreadsheet applications are available and capable of facilitating these tasks.

**Table 2.** Tools and Resources ENV Staff Used for Data Validation

Resource	Description	User/Access	Validation Level
Envidas Ultimate Viewer	Displays current data from within the station's logger	Site operator	Level 0
Envidas Ultimate Reporter	Displays data archived in the station's logger	Site operator	Level 0
Minute Data Feed <sup>1</sup>	Contains most recent 2 weeks of sub-hourly data	ENV Staff	Level 0
Minute Data Summary <sup>2</sup>	HTML summary of sub-hourly data, daily zero/span checks	AQ Tech	Level 0
Envista ARM	Tool for data retrieval and basic to advanced analysis	ENV Staff	Levels 0,1,2,3
Envistaweb <sup>3</sup>	Public version of Envista ARM	Public	Levels 0,1,2,3
Open Data Portal (unverified data) <sup>4</sup>	.csv data of unverified hourly data (year-to-date)	Public	Level 0,1,2
Open Data Portal (verified data) <sup>5</sup>	.csv data of validated hourly data (after Level 2)	Public	Level 2, 3
DrDashboard <sup>6</sup>	Snapshot of current system status	ENV System Group	Level 0
SAS Summaries <sup>7</sup>	Statistical summary of annual data	ENV Staff	Level 2,3

1 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/MinuteData/

2 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/MinuteDataValidation/

3 https://envistaweb.env.gov.bc.ca/

4 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/Hourly\_Raw\_Air\_Data/

5 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/AnnualSummary/

6 file share \\sfp.idir.bcgov\s140\S40036\Air\Operations ORCS\Data\DR DashBoard

7 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/SAS\_SUMMARIES/

#### 4. Level 0 Verification

Section 2 of this SOP provides an overview of the Level 0 verification process which includes all of the activities listed in Table 1. This section provides additional information about the automated verification activities performed during the Level 0 verification process including procedures for manually flagging data.

Automated validation processes are configured within a stations data logger. These processes utilize a 'digital monitor status' that is triggered by the self-diagnostics features found in gas and particle analyzers (Table 3). Automated validation processes ensure that measurements are performed under acceptable operating conditions. Whenever instruments operate outside of acceptable conditions, a status flag is generated. All of ENV's core stations are equipped with Envidas Ultimate dataloggers which are capable of capturing and applying these flags. Other loggers, such as the ESC-8816, 8832 and Campbell Scientific, do not have this capability but can be configured to report high or low range values for readings that are invalid. The ENV's data collection system is not able to collect zero, span or logbook entries from all logger makes and models and as such consultation with ENV is strongly recommended prior to acquiring a data logging system.

**Table 3.** Standard Digital Monitor Status Validation in Envidas Ultimate for BC ENV stations.

<b>PARTICULATE</b>	<b>SO2/TRS</b>
<b>SHARP 5030</b>	<b>API100A</b>
Pump Switched off	SAMPPRESS
Sum Status of data and program memory A	SAMPFLOW
Sum status of sampling and measuring system B	RCELLTEMP
Sum status of air flow regulation D	BOXTEMP
Sum status of the sample heater E	PMTTEMP
<b>SHARP 5030i</b>	<b>APIT100</b>
pump	SAMPPRESS
service	SAMPFLOW
<b>TEOM 1400</b>	RCELLTEMP
MasTrand	BOXTEMP
Temp	PMTTEMP
Flow	<b>TEI43</b>
Filter	Internal temp
	react temp
<b>O3</b>	pres
<b>APIT400/APIT400U</b>	flow
PHOTOREF	
O3GENREF	
O3GENDRIVE	
PHOTOSPRESS	<b>CO</b>
PHOTOSFLOW	<b>APIT300U</b>
PHOTOSTEMP	SAMPPRESS
ALTEMP	SAMPFLOW
PHOTOLTEMP	BENCH TEMP
BOXTEMP	WHEELTEMP
<b>TEI49</b>	BOXTEMP
flowa	<b>TEI 48</b>
flowb	internal temp
bench temp	chamber temp
lamp temp	flow
press	press

Digital monitor status items are specific to an analyzer's make and model, and are only enabled for those parameters that may indicate invalid data. Table 3 lists activated flags by instrument type. The activated flags are specific to sample flow and pressure, detector temperature, and detector conditions.

The Central Polling system also performs automated invalidation based on range checks and forced zero that are applied to the database as a phase of each hourly polling cycle. Automated validation criteria are standardized based on instruments and parameters. For particulate matter (PM), PM<sub>2.5</sub> and PM<sub>10</sub> are automatically invalid when values are below -3.49 µg/m<sup>3</sup> and -9.98 µg/m<sup>3</sup> respectively and above 985 µg/m<sup>3</sup>. Forced zeroing of PM is configured to remove the negative values from 0 to -3.49 µg/m<sup>3</sup> for PM<sub>2.5</sub> and 0 to -9.98 µg/m<sup>3</sup> for PM<sub>10</sub>. Gas analyzers are not configured for auto-invalidation but have an above/below alert system triggered by hourly averages below -5 ppb and values above the 99<sup>th</sup> percentile for a particular station. When activated, the site's operator receives an email notification of the unusual high or low value.

Level 0 verification includes station and instrument checks. Whenever data-impacting issues are detected, site operators should mark down the instrument channels to prevent reporting erroneous data to the general public. In addition a centrally generated alert system is configured to notify site

operators of unusually high or low values. The ENV Data Group also regularly checks station and instrument status, and will communicate suspected issues. In order to avoid publishing erroneous data, site operators are required to regularly check stations, alerts, and ENV Data group emails.

- **Envidas Ultimate loggers:** Use Envidas Viewer to mark down the channel at the station; if required, access the terminal remotely.
- **ESC loggers:** Data can be marked down from the configuration settings of the logger panel.
- **Loggers without data flagging capability:** contact the ENV Data Group to request channels be marked down centrally. Once analyzer function is restored, contact the ENV Data Group to remove the flag.

## 5. Level 1 Validation Overview

The original theoretical foundation of the Level 1 validation process performed by ENV was based on the “Ambient Air Monitoring Protocol for PM<sub>2.5</sub> and Ozone” (CCME, 2011) and included operational and instrument specifications considerations.

Level 1 data validation is performed by the Air Data Quality Assurance Specialist (ADQAS) who works closely with operators to help ensure that their instruments are working properly, and that data are annotated and, when necessary, adjusted appropriately. Validation logs are maintained in an Excel spreadsheet that lists all stations and their active analyzers.

### 5.1 Level 1 General Validation Procedure

The following Level 1 validation activities are performed by the Air Data Quality Assurance Specialist (ADQAS):

1. **Review field records** - online logbook within Envista ARM for all ENV stations and a few permittee sites and electronic operator reports sent by email by most of the permittee sites. Contact operators to obtain reports that have been delayed for over three months.

NOTES: Envista ARM logs are in a uniform format whereas reports sent by email are customized by the site operators and as such are stylistically inconsistent. When Level 1 validation is complete all electronic permittee reports are saved in an archive file share listed chronologically by station.

2. **Review AQSLog** - determine which analyzers are active for the station under review. Open the corresponding edit table in Envista ARM. Separate data streams by parameter and parameter type (e.g., gas). Each type of data is handled in a separate edit table, as the three types of parameters follow different validation and adjustment protocols.
3. **Review screening flags** - assigned during Level 0 verification. Reconcile flags with field records. Contact air technicians/operators if issues are found. Review operational acceptance limits for each parameter/analyzer, and determine if any data should be invalidated due to instrument-specific operational limitations.

4. **Review all gaseous parameters** - daily zero/span and multi-point calibration reports provided by site operators, and audit reports provided by the ENV Air Audit Team (where applicable). Review all information sources to ensure measurement uncertainty remained within the acceptance criteria prescribed in the NAPS guidelines.
5. **Ensure data** - are annotated appropriately if special actions were taken according to field reports, e.g. monthly calibration, regular maintenance, ENV audit, etc. Outliers or extreme values are investigated as follows:
  - a) check 1-minute data to verify if the pattern is consistent;
  - b) consult with regional technician/AQ meteorologist to check if an exceptional event occurred;
  - c) if uncertain, keep values valid and flag for review under Level 2 validation.
6. **Adjust data** - apply appropriate methods to adjust data if necessary. Adjustments can include outlier disqualification, baseline adjustments, below zero adjustments, and parameter relationship preservation. Baseline/drift adjustments are usually performed for an entire month or from calibration to calibration depending on presence/absence of zero drift. Baseline adjustments are performed prior to adjustments of negative values to zero.

The general procedure for baseline adjustments of gas analyzer data is as follows:

- a) Plot a timeseries of hourly data for the pollutant and time period (typically one month) under review. Adjust the range of the y-axis to -1 to 10 ppb (-1 to 2 ppb for CO). Review the timeseries for zero drift (i.e. a trend in daily minimum concentration over days/weeks).
- b) Plot the daily zero/span checks for the time period under review to confirm if zero drift has occurred.
- c) Review zero values measured during multi-point verifications (conducted by the site operator) to verify if zero drift is caused by malfunction of the instrument or depletion of scrubber used for zero checks.
- d) For cases where baseline drift has occurred, a constant offset is applied over the affected period (i.e. stepwise adjustment). The magnitude of the offset is typically the average daily minimum concentration (for the parameter and period of interest). However, the minimum daily zero check value and the zero value from the most recent multi-point verification (conducted by the site operator) must be reviewed for verification.
- e) All negative values remaining after the baseline adjustment should be adjusted to zero.

These procedures are applied only when instrument issues are absent. If there is no indication of instrument issue in the logbook and zero checks are drifting or noisy, confirm with the site operator that the instrument was working properly. If no operational issues are reported, professional judgement needs to be applied to determine if the noise/drift is excessive. If so, data may be



invalidated. In these cases, the site operators should be informed so that the issue can be investigated and repaired.

Refer to section 5.2 for additional pollutant-specific information to be used in conjunction with this procedure. PM validation procedures differ from gaseous analyzers and are covered in section 5.2.

7. **Run a monthly matrix report** - detailing each hour's reading against the day of the month (hour for the columns and date for the rows in a month, the descriptive statistics on daily basis or on monthly basis for the same hour are summarized in the report):

a) check the lowest values for the month for those ambient analyzers that should not exhibit negative values; and

b) confirm consistency of diurnal patterns within the month.

8. **Mark data** - with Final Validation Edits in Envista ARM validation settings.

## 5.2 Level 1 Validation Procedure for Criteria Ambient Air Pollutants

### ***NO/NO<sub>2</sub>/NO<sub>x</sub>***

1. If NO/NO<sub>x</sub> zero checks are  $\leq \pm 0.3$  ppb, no adjustments are required with the exception of when negative hourly values (NO/NO<sub>2</sub>/NO<sub>x</sub>) are observed;
2. If NO and/or NO<sub>x</sub> zero checks are  $> \pm 0.3$  ppb, apply zero baseline adjustments for the affected channel(s) as described in Step 6 of Section 5.1. NO and NO<sub>x</sub> are adjusted first. NO<sub>2</sub> is adjusted if necessary to maintain the relationship between parameters ( $\text{NO}_2 = \text{NO}_x - \text{NO}$ ). If a zero baseline adjustment is performed to one channel, then the adjustment must be performed on one or both of the other channels to ensure the relationship is preserved;

**Note:** The NO<sub>x</sub> validation process was implemented in 2017. Baseline adjustments prior to implementation were only performed for NO and NO<sub>2</sub> with a neglect of the relationship preservation.

3. If a few small negative values (e.g. -0.1 ppb) are found, adjust them to 0 using a filter function. If negative values are many and relatively large, baseline adjustments would be performed on affected channels based on an evaluation of zero checks and the most recent multi-point calibration results.

### ***Ozone***

Evaluate the diurnal pattern to ensure that the highest concentrations occur between mid-afternoon and early evening, and the lowest concentrations occur in the early morning. Perform the baseline adjustment procedure as described in Step 6 of Section 5.1.

1. If daily zero performance checks are  $\leq \pm 0.5$  ppb, no adjustments are necessary unless negative hourly values are present (note: negative O<sub>3</sub> raw data readings are rare);

2. If daily zero performance checks are  $> \pm 0.5$  ppb, zero adjustments are applied according to Step 6 of Section 5.1.

### ***SO<sub>2</sub>/TRS***

SO<sub>2</sub>/TRS concentrations are expected to be close to 0 ppb most of the time.

1. If daily zero performance check values are  $\leq \pm 0.3$  ppb, baseline adjustments are not required. Adjust negative values to 0;
2. If daily zero performance check values are  $> \pm 0.3$  ppb, baseline adjustments are required. Follow the procedure outlined in Step 6 of Section 5.1.

### ***CO***

CO analyzers deployed in ENV stations perform an auto zero correction every 12 hours. The automated adjustments are reviewed to ensure the reliability of zero data collected during daily performance checks. Follow the baseline adjustment procedure outlined in Step 6 of Section 5.1.

Note: CO values below 0.1 ppm are unusual; accordingly CO baseline adjustments are based on 0.1 ppm instead of 0.

1. If zero-check values are  $\leq \pm 0.1$  ppm adjustments are not required;
2. If zero-check values are  $> \pm 0.1$  ppm adjust the baseline. The minimum monthly value minus 0.1 ppm is usually applied as the baseline offset.
3. Negative values are invalidated; readings exceeding 2 ppm are suspect and should be scrutinized closely. For example check station temperature for potential correlations with readings exceeding 2 ppm to confirm or refute potential impacts of enclosure/equipment temperatures.

### ***PM<sub>10</sub> and PM<sub>2.5</sub>***

If PM<sub>10</sub> and PM<sub>2.5</sub> are measured at the same site, evaluate them collectively. The magnitude of PM<sub>10</sub> concentrations should be greater than PM<sub>2.5</sub> while both pollutants should follow similar trends over time. It is important to note that cases can occur where PM<sub>2.5</sub>  $>$  PM<sub>10</sub>. This can occur in cases where a TEOM (older technology) is used to measure PM<sub>10</sub> and newer FEM analyzers (e.g. BAM, SHARP) are used to measure PM<sub>2.5</sub>. The anomaly occurs because newer FEM technologies are able to better capture the semi-volatile component of the PM whereas the TEOM heats the sample causing the semi-volatile component to be driven off and not measured.

Small negative values ranging between  $-9.98 \mu\text{g}/\text{m}^3$  and  $0 \mu\text{g}/\text{m}^3$  for PM<sub>10</sub>, and  $-3.49 \mu\text{g}/\text{m}^3$  and  $0 \mu\text{g}/\text{m}^3$  for PM<sub>2.5</sub> are automatically corrected to 0; negative values equal to or exceeding  $-9.98 \mu\text{g}/\text{m}^3$  for PM<sub>10</sub>, or  $-3.49 \mu\text{g}/\text{m}^3$  for PM<sub>2.5</sub> are invalidated automatically when ingested into the database.

PM data does not require a baseline check like gas analyzers. The verification process for PM

generally follows five rules:

1. Review automated corrections carefully for correctness. Correction criteria/alerts should be checked/corrected in Envista Setup if issues are found in the automated corrections.
2. Investigate outliers/spikes. Review 1-minute values and/or consult with the site operator to check if anomalies were caused by a special event such as grass mowing or a wildfire. Add an explicit note to any extreme values that are determined to be valid.
3. Where power failure/tape changes/filter changes occur, review data with added attention to investigate their validity. Events related to sample tape with a BAM or SHARP instrument or extended filter usage with a TEOM instrument may cause invalid readings. Identify the filter usage by filter pressure which is usually maintained under 70% for a TEOM. Invalidate the PM data where the filter pressure exceeds 90%.
4. Look for flat lines or noisy traces in the data. For all cases identified, review field reports and/or consult the site operator. These types of signatures in the data can sometimes indicate equipment failure or other issues (i.e. invalid data).
5. Typical parameter groupings to review for PM validation are:
  - a) PM\_TEOM and filter pressure;
  - b) PM\_BAM and BAM volume;
  - c) PM\_SHARP, OPTIC\_SHARP and BETA\_SHARP where the OPTIC and BETA are used as diagnostics;

Note: OPTIC was validated prior to September, 2017. It has subsequently only been used for diagnostics.

### **5.3 Level 1 Validation for Meteorological Data**

#### ***Temperature/Relative Humidity***

- 1) Hourly temperature and relative humidity are reviewed collectively since the two parameters have a strong (negative) correlation. Review all auto corrections made to the data. Check the range of data and time of day when maximum and minimum temperature values occur, a reversed pattern should be evident for relative humidity.
- 2) Closely scrutinize data when temperatures are less than -35 °C or greater than 40 °C. Temperatures outside this range are uncommon in British Columbia and may indicate invalid data. Relative humidity between 100 and 105% are corrected to 100%, those over 105% are invalidated.
- 3) Closely inspect data that flanks periods when a power failure occurred or periods with extended flat lines. These types of data signatures may indicate operational issues with the sensors (i.e. invalid data).

#### ***Wind Speed/Wind Direction***

1) Hourly wind speed, wind direction (scalar and vector values), and sigma values of wind direction (SigmaALL) are reviewed simultaneously in a month. Check the maximum and minimum value to confirm wind speed/wind direction are in a reasonable range.

2) Review the data for flat lines (constant value over a few hours). Contact the site operator to check if maintenance of sensors or bearings is needed.

3) SigmaALL is the standard deviation of 1-minute wind vector within an hour. If SigmaALL equals 0, invalidate all wind data including wind speed and wind direction.

**Precipitation**

OTT Pluvio

Check the Pluvio status flag. If not zero, invalidate the data. A flag other than zero indicates the gauge was under maintenance or a fault was detected on measurement. Check for spiking and compare the precipitation with the total volume of the rain gauge. Peak precipitation usually results in an increase of water volume in the gauge and an increase of relative humidity.

**Snow Depth**

Campbell Scientific SR-50A

Snow Signal Quality (SSQ) is used as a diagnostic parameter to identify the validity of snow depth data. If SSQ equals zero, the corresponding snow depth readings should be invalidated. Snow Depth sensors should be marked down in the non-snow season.

**6. Level 2 Validation**

Level 2 validation is initiated with the generation and distribution of annual statistical summaries following the completion of Level 1 validation of the previous year’s data. This typically occurs late in the first quarter following the data validation year. ENV uses summaries generated by executing R Statistics scripts and produces the following reports:

- Flatline reports → a summary of data flatlines from valid data entries
- Negative reports → negative values within validated data entries
- Annual Summary → historical data and present year data summaries

**Table 4.** Level 2 validation activities and frequency of execution

Validation Activities	Responsibility	Frequency
Review of Level 1 Validation	ENV	Semi-Annual
Generation and distribution of SAS summaries	ENV	Annual
Review of data summary/statistics/compare historical data	ENV/site operators/ AQ meteorologists	Quarterly/Semi-Annual/Annual
Examination of meteorological data	AQ meteorologist	Annual

Examination of relationships between pollutants	AQ meteorologist	Annual
Comparison of buddy sites	AQ meteorologist	Annual
Rejection of outlier data	ENV/AQ meteorologist	Annual
Examine audit results	EMRE	Quarterly/Semi-annual

Annual summaries contain historic and current year annual means, percentiles, CAAQS exceedance counts (hours, days), and data captures. Summaries are distributed to all ENV groups involved with ambient air data monitoring and validation outlined in Section 2 of this document.

The annual summaries serve as a tool for closer data examination by advanced data users. Suggested actions once summaries are received include:

- Review of data trends (e.g., check increasing or decreasing annual trends, etc.)
- Examination of mean, and percentiles for outliers and other anomalies
- Comparison with neighbouring sites
- Comparison with related parameters (e.g., ozone and NO/NO<sub>2</sub> relations)
- Examination of diurnal and seasonal patterns

Open communications between operational monitoring and reporting groups occur during Level 2 data validation period. This facilitates sharing of software tools, expertise, and details regarding the history and patterns of each station.

Issues with any of the reported data are examined, assessed and flagged, unflagged or adjusted as necessary by the ADQS if necessary. Clean Air also receives the SAS Summaries which they use to conduct an independent evaluation of data.

When all of the concerns regarding data validity have been addressed and data validated by MetroVancouver is incorporated, the following activities take place:

- ENV Air and the Climate Networks Unit informs clients and stakeholders about completion of the data validation process.
- ENV's implementation of the Envistaweb "Welcome" page is updated to denote the latest valid data
- The annual data csv generator is executed to post verified hourly data in ENV's FTP feed. This makes the data available through the BC government's open data portals
- Annual data reporting to the ECCC NAPS data group is coordinated starting with an email notice of the completion of level 2 data validation, and configuring the FTP NAPS export feed

### 7. Level 3 Validation

Level 3 validations is an independent process. For ENV, this occurs on an annual basis prior to the publication of the BC Lung Association's State of the Air Report, CAAQS reporting, and data sharing with ECCC. This process typically occurs mid-year with the publication of the results from the previous

year.

Data validated through Level 2 are exported to ECCC for annual NAPS reporting. Stations and parameters that are included in the Memorandum of Understanding (MOU) between ENV and ECCC are configured in the FTP export listing. Any change in the listing from the previous year are reported to ECCC to configure into their system. An FTP export is then initiated and ENV receives a verification notice once the export is successfully completed. The ECCC's data group closely reviews the data. Anomalies are reported back to ENV for closer examination.

## 8. References

Canadian Council of Ministers of the Environment (CCME) 2011. *Ambient Air Monitoring Protocol For PM<sub>2.5</sub> and Ozone: Canada-wide Standards for Particulate Matter and Ozone*. [www.ccme.ca](http://www.ccme.ca). December 2017.

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0.0

## Approval