Impact of Cruise Ship Air Emissions in Juneau, Alaska

Quality Assurance Project Plan

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Introduction and Purpose

The State of Alaska Department of Environmental Conservation (DEC) Air and Water Divisions are collaborating to address increasing public complaints regarding cruise ship emissions in Juneau. The Air Monitoring and Quality Assurance Program (AMQA) will conduct a saturation study in downtown Juneau prior to and during the summer cruise ship season of 2019 focusing on the overall ambient air quality. A saturation study places many air monitors throughout a study area to evaluate the local air quality patterns. Fine particulate matter ($PM_{2.5}$) and SO_2 are indicators for diesel plumes. DEC will establish a dense network of approximately 20 Purple Air PA-II-SD real time particulate matter sensors and 10 Ogawa passive SO_2 samplers to assess $PM_{2.5}$ and SO_2 levels close to the docks, in 'the Flats', and in downtown Juneau.

The study objectives are:

- to address ambient air quality complaints centered on cruise ship emissions;
- to determine which areas of downtown Juneau are most affected by PM and SO2;
- to assess if the scale in terms of frequency, duration, spatial variability and severity of these impacts has the potential to significantly affect public health and/or violate Clean Air Act air quality standards.

Problem Statement and Background

Cruise ship air emissions have been of public interest since before the Commercial Passenger Vessel Environmental Compliance (CPVEC) program began in 2001. A high level of public involvement in the 1990's led to the creation of a cruise ship initiative with EPA and the Coast Guard. Two air monitoring studies designed to assess impacts resulting from airborne emissions from cruise ships have previously been conducted in Juneau in 1995 and 2000-2001. The 1995 study collected SO_2 data at two sites from May through September. The 2000 study collected SO_2 and $PM_{2.5}$ data from three sites and NO_X data from one site from mid-August through September, 2000. The monitoring timeline was expanded in 2001 from approximately May through the end of the year. The overall conclusions from both studies were the same; that existing air quality in Juneau was good and pollutant concentrations were significantly less than the National Ambient Air Quality Standards (NAAQS) (the NAAQS have been developed by EPA to protect human health, including sensitive individuals).

During the past few years, public concern and complaints regarding cruise ship emissions have increased and complaints may continue to rise due to the installation and use of exhaust gas cleaning systems (scrubbers), larger size of ships, and increasing number of port visits in southeast Alaska.

Downtown Juneau is located on Gastineau Channel which is oriented northwest to southeast and bordered by mountains on both sides. The cruise ship docks and anchorages are located directly down channel from downtown Juneau so when wind flows are upchannel, which is the predominant condition, the cruise ship emissions are transported to the downtown area. Air pollution levels vary depending on meteorological conditions with higher levels expected to occur during clear, low wind periods and lower levels seen when rain and/or higher winds disperse air pollutants.

Project Description

Over the course of the summer season, the community will experience variability in air quality. The impacts will depend on the local meteorology, the number of ships at the docks and maneuvering around the docks, the ship emissions, which in turn depends on the ships emission sources, their activity and type of fuel, as well as surrounding activities in the community that can contribute to localized pollution (for example increased bus traffic along Egan Drive). Variability in weather is one of the dominating factors for whether an area is impacted and for how long. The other factor is the emission source.

AMQA will use approximately 20 PurpleAir PA-II PM Sensors (https://www.purpleair.com/sensors) distributed throughout Downtown Juneau and 'the Flats' to identify areas of high, medium and low impact. For this study $PM_{2.5}$ is considered a tracer for plumes. Additionally AMQA will establish a network of 10 Ogawa passive SO_2 samplers. AMQA selected passive SO_2 samplers that do not require electrical power and are significantly less expensive and time intensive to operate than conventional SO_2 analyzers. SO_2 is a common constituent of diesel exhaust.

To better distinguish which diesel source is contributing to the measurements, AMQA has identified 5 meteorological sites around the study area. The data is part of the Meso West network. Meso West is operated by the University of Utah Atmospheric Science Department. The data from these sites will be used in the analysis of the air quality measurements, along with the number of ships in the areas at the time and their activity as well as any other information about other potential sources.

Figure 1 shows a map of the $PM_{2.5}$ and SO_2 sampling locations. Sampling locations might be changed during the study, especially for SO_2, if lab analysis shows low sample concentration at the given location. An updated map will be provided with the final report.

Figure 1: Locations of the PurpleAir sensor sampling sites in Juneau.

Quality Objectives and Criteria for Measuring

The sampling design has been optimized to fit the budget and scope of the study. The following data quality indicators will be used for the assessment of the Measurement Quality Objectives (MQOs):

- Precision
- Bias
- Representativeness
- Completeness
- Comparability

Based on our experience with these measurements, the following data quality objectives have been assigned for this study:

$PM_{2.5}$ data

Bias, precision, and comparability

Purple Air (PA) sensors are low-cost portable air sensors designed for use in non-regulatory applications. They are factory calibrated and cannot be adjusted by the end user. No in-field calibrations or adjustments will occur during the study.

Sensor performance will be evaluated by collocating all PA sensors used in the study against the Federal Equivalent Method (FEM) $PM_{2.5}$ BAM monitor at Floyd Dryden for at least 48 hours before and after the monitoring effort. The data averaging time for the analysis will be 1-hour to be similar to the $PM_{2.5}$ measurements from the BAM. Data from the PA sensors can be correlated against the BAM values to assess the accuracy of the PA readings.

However, the key goal of the study is to relate measurements of the sensors in the PA network to each other. Collocated measurements of all PA sensors will be used to verify sampler performance and comparability under actual field conditions. Linearity checks between PA sensors will be conducted by temporarily deploying all monitors side-by-side for at least 48 hours, indoors and outdoors, prior to the study. The outdoor linearity check will provide 5-minute averages for each of the individual sensors from which the slope and intercept of each sensor will be calculated and compared to the mean of all of the sensors from the outdoor test. The two samplers showing the best agreement with the mean will be deployed and collocated at the DEC office and designated “the standard” to which all other PA samplers will be compared. Adjustment factors will be calculated for normalizing all samplers to this reference monitor.

Following the end of the field study another outdoor linearity check of all PA sensors will be conducted for at least 48 hours to verify that sampler response characteristics have not changed significantly.

Collocated data, from both the collocation comparisons at the beginning and end of the study, will thus be representative of both bias (relative to study goals) and precision. We expect agreement for the samplers to be within ±30% of the PA sensors at the DEC office for hourly averages.

Precision will also be assessed by the collocated PA monitors at the DEC office site. Periodic checks will be performed by calculating the mean difference and standard deviation of the values collected by both monitors to assess precision or repeatability.

One PA monitor will be designated as an audit device and used to assess performance of the field samplers. An audit of each field sampler will be performed at least once during the study and additional audits of some samplers will occur if data looks unreasonable or suspicious. The

audit sampler will periodically be collocated with the Floyd Dryden BAM between audits to verify performance.

Representativeness and completeness

Deployment of 20 monitors to collect hourly PM values throughout downtown Juneau for approximately five months before, during and after the visitor season will provide the measurements needed to identify potential hotspots and assess what concentration of particulates residents are breathing at different locations and under a variety of meteorological conditions and cruise ship movement.

The data completeness goal is ≥ 75 % data recovery for hourly averages from late April to early October.

SO_2 Sampling

Passive SO_2 samplers containing a coated collection filter will be deployed at 10 sites, one of which will have collocated samplers to assess for precision. Field blanks will be deployed with each sampling period throughout the season to assess potential contamination and demonstrate proper handling, deployment and transport procedures are followed.

The SO_2 sampling schedule periods will be chosen to capture the highest concentrations based on the number of cruise ship visits, meteorological conditions and previous laboratory analytical results. Two sampling runs for the entire SO_2 sampler network will be conducted either prior to the cruise ship season or during periods without cruise ship impact. Filter exposure time in the field may be optimized during the study if values from early season samples are below or well above laboratory minimum detection limits.

Experimental Design

Since the last study in 2000/2001 EPA has revised the NAAQS. Not only did the concentrations change, but also the averaging timeframes were reduced. EPA created hourly NAAQS for SO_2 and NO_2. Even though the averaging period for $PM_{2.5}$ remained at a 24-hour period, in this study PM is used as a tracer for the plume and hourly concentrations will be assessed in lieu of the gaseous criteria pollutants. The objective of the saturation study is to determine high impact locations within the study area and to evaluate if sufficient impact can be measured to warrant a future in-depth study.

At a public meeting on January 29, 2019 residents shared empirical information about visible plumes and odors during the 2018 cruise ship season. Based on this information AMQA focused the site location on three major areas: near the dock, in a residential area in downtown Juneau and in the 'Flats'. Sampling locations were chosen to provide a dense network of measurements

with the goal to identify areas of maximum impact. See Figure 1 for a map of the proposed $PM_{2.5}$ and SO_2 sampling locations.

The PA sensors will be equipped with a wireless transmitter, which will report the instantaneous reading to the PurpleAir website. Data will be displayed on the PurpleAir map website. AMQA will create a second interactive map posted on the Air Quality website, which will display the hourly averaged data. The map will be updated hourly. The hourly averaged data will be compared to meteorological data, cruise ship movements and local transport patterns, to evaluate source contribution. The samplers will be set up prior to the first cruise ship arriving to collect background information. The samplers will be left in field collecting data during the entire cruise ship season and a week beyond to evaluate the difference in air quality before, during and after the tourist season.

The PA sensors are also equipped with a SD card that stores all data. These cards will be downloaded to the state network at least monthly, so that if the wireless connections fail, no data are lost.

The Ogawa passive SO_2 samplers will be collocated at 10 of the PM sites. Immediately after each exposure the extracted sample will be sent for analysis. The passive SO_2 data will be included in the draft report after the sampling season.

Sampling Methods

$PM_{2.5}$ Measurements

$PM_{2.5}$ concentrations will be measured using the PurpleAir PA-II PM Sensor (https://www.purpleair.com/sensors, performance specification are presented in Table 1). The PA sensor uses a fan to draw air past a small laser. The reflections of the light from the particles in the air is counted. The PA-II is equipped with two sensors which measure and report particle concentrations in six sizes between 0.3µm and 10µm diameter. Each sensor measures a one second long particle count approximately every 80 seconds. The second sensor count is offset by 30 seconds from the first allowing for the one second averaged particle measurements. Temperature, relative humidity and pressure values are also recorded. The sensors are calibrated by the manufacturer to associate a particle size with particle mass and estimate total mass for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}. Readings are then uploaded to the cloud approximately every 80 seconds where they are stored for download and display on the PurpleAir map.

The PA samplers have been compared to continuous $PM_{2.5}$ analyzers in previous studies (http://www.aqmd.gov/aq-spec/sensordetail/purpleair) and have shown high correlation and linearity. For this study PA sensors will be correlated to the $PM_{2.5}$ BAM at the Floyd Dryden SLAMS site prior and after the cruise ship season, and indoor and outdoor comparisons of all PA sensors to each other will be conducted. The outdoor check will be used to compare linearity

between PA samplers by calculating averages for each sensor that can be compared to the mean response of all the sensors.

Table 1: PurpleAir PA-II specifications.

Range of measurement	0.3~1.0; 1.0~2.5; 2.5~10 Micrometer (μm)
Counting Efficiency:	50%@0.3μm 98%@>=0.5μm
Effective Range:	0~500 μg/m³
Maximum Range:	* ≥1000 μg/m³
Resolution:	1 μg/m³
Maximum Consistency Error:	±10%@100~500μg/m³ ±10μg/m³@0~100μg/m³
Standard Volume:	0.1 Liter (L)
Single Response Time:	≤1 Second
Total Response Time:	≤10 Seconds

SO2 measurements

The Ogawa passive SO_2 samplers will be collocated at 10 of the PM sites, with one site housing two SO_2 samplers for precision information. Initially the samplers will be exposed to ambient air for 48 hours. If lab analysis shows that concentrations are well above the detection limit, short exposure times may be considered. If lab analysis reveals that concentrations are below the detection limit, exposure times in the field will be lengthened.

Sample Handling and Custody

PM measurements

This study does not include the collection of particulate samples requiring handling procedures.

SO_2 measurements

Pre-coated sample pads will be stored frozen until removed from the freezer approximately 24 hours before exposure to equilibrate to ambient temperature. After washing the sampler components with 18 Mohm water, the site operator will assemble each sampler in the DEC Air Quality lab as described by Ogawa (http://ogawausa.com/wp-content/uploads/2014/04/assembly.pdf). The sample IDs and date should be recorded on the Ogawa chain of custody spreadsheet (see Appendix A; http://ogawausa.com/analysis-instructions-forms/).

SO_2 filters must be kept out of direct exposure to sun and rain. The loaded samplers will be bagged and placed in brown airtight containers, transported to monitoring sites and deployed inside opaque shelters to protect them from moisture during exposure (sampling). The start time of exposure will be recorded. For each sampling period a field blank will be collected. Field blanks will be treated the same as sample filters except they will be deployed at the monitoring site for 1 minute before transporting back to the lab.

Exposed filters will be transported to a clean, dry laboratory environment in sealed plastic bags and immediately pads will be transferred to 80mL plastic vials for shipment to RTI. Samples will be stored out of direct light while in the laboratory. The Ogawa chain of custody form will be completed (including relative humidity and temperature of the exposure period) and emailed to Ogawa staff with the proposed shipping date to give the lab advance notice of sample arrival. Samples will be shipped via FedEx within five days of exposure or as soon as practical for ion chromatography (IC) analysis.

Analytical Methods

Filter analysis for SO_2 will be conducted by Ogawa's contract lab, RTI laboratories, using a Dionex 4000i Ion Chromatograph (http://ogawausa.com/wp-content/uploads/2017/11/prono-noxno2so206_206_1117.pdf). The analyses should be completed within 14 to 21 days after the exposure period.

Quality Control

The key component of the study's quality control program will be collocated measurements of all PurpleAir samplers in order to verify sampler performance and comparability under actual field conditions. All samplers will be temporarily installed within 4 meters of the Floyd Dryden $PM_{2.5}$ BAM inlet and at essentially the same height of the inlet for at least two days prior to the field study. The collocation will be repeated for at least two days immediately following the study to verify that sampler response has not changed significantly.

Samplers will also be normalized relative to each other for a minimum of two days in an indoor environment and at least two days outdoors prior to the study. Based on this linearity check of individual sensor performance, adjustment factors will be calculated for each sensor and used to normalize values to the reference monitor at the DEC office.

An audit of each field sampler will be performed at least once during the study, and additional audits of some samplers will occur if data looks unreasonable or suspicious. One PA monitor will be designated as an audit device and used to assess performance of the field samplers. The audit sampler will be collocated with the Floyd Dryden BAM prior to and between audits to verify performance. A correlation factor will be calculated following collocation with the BAM and applied to the PA audit device. This correlation value will be used as the true value when auditing each field sampler.

Each PA-II sampler contains two factory-calibrated PM sensors which measure particulate matter. Data from both sensors will regularly be compared to each other to check for drift. If PM values from sensors within the same sampler are found to markedly diverge over time, an audit of the sampler will be conducted. If one sensor shows excessive drift from the true audit

value it will be replaced. If data from both sensors are unreasonable the sampler will be replaced with a spare. Two spare samplers will be available for swapping. If additional spare sensors are needed during the study they will be ordered.

Data from the samplers will be reviewed daily or as practical for consistency and reasonableness in order to identify any potential instrument related problems. If a problem is noted it will be promptly investigated and remedied or the sampler will be replaced.

Proper siting and operation according to manufacturer's recommendations will increase the likelihood of collecting good data. Sensors will be regularly inspected and cleaned to prevent buildup of bugs, dirt, cobwebs, etc. Sensor data will be reviewed for odd patterns, a decrease in overall response or other unusual features and sensors will be replaced if these anomalies occur.

Temperature and relative humidity values collected by the PA sensors will be verified periodically throughout the season against a NIST-traceable RH and temperature meter.

A logbook will be used to record any sensor and site maintenance and issues as well as weather conditions during site visits.

Instrument Testing and Maintenance

All equipment will be verified to be functional and accurate before placed in the field. Should the instrument appear to be operating out of specifications, the manufacturer will be contacted.

Instrument Calibration

As noted above, the PA samplers are factory calibrated and cannot be adjusted in the field. The calibrations will be checked and verified prior to and after deployment in the field by collocation with an FEM monitor, and evaluated by audits during the field study.

Non-direct Measurements

This section addresses data not obtained by direct, study-specific measurements. This includes both outside data and historical monitoring data. It is anticipated that routine data collected by the Alaska DEC will be used during analysis. Additional "non-direct" data could include the following elements:

- Sampler operation and manufacturers literature
- Geographic location
- Meso West and NWS meteorological data
- Webcams

Data Management

Upon completion of the field sampling, the data will be reviewed and validated to provide a data set with any invalid data removed. Adjustment factors for each PA sampler will be finalized based on the results of the collocated monitoring and applied to the data. Comma delimited files will be generated for all data, with "time-ending" time stamps.

Data Review and Validation

Data validation is a combination of checking that data processing operations have been carried out correctly and of monitoring the quality of the field operations. Data validation can identify problems in either of these areas by reviewing data for accuracy, completeness and internal consistency. Once problems are identified, the data can be corrected or invalidated, and corrective actions can be taken. As noted in sections above, the data will be reviewed on a regular basis, during which most data validation issues will be identified.

Data will only be invalidated for known, identified instrument issues, as documented by the field technicians. Hourly averaged data must contain valid data points for at least 75% of the averaging period. As there is a possibility of slight negative drift in the responses of the PurpleAir samplers, negative values will not be altered.

The primary means of validating the collected data will be through review of data downloaded into Excel spreadsheets. This allows for the displaying of data in a variety of ways to facilitate the review process. Again, the validation process is a regular, ongoing effort throughout the monitoring period. The review process will incorporate the following:

- Range checks
- Internal consistency between samplers
- Reasonableness checks based on reviewers experience
- Consistency with QC documentation

A checklist may be developed and used for each monitoring site to assure that validation of the data is documented and performed consistently.

Reporting

The data results will be conveyed to the end users via the data reports. These reports will contain results from data assessment and validation tasks, along with case narrative summaries of operations. The quality of the reported data and any limitations on use will be defined and reported in objective measures. If the defined data quality objectives are inadequate for the intended use of the data, these issues will be discussed in the data summary and analysis section of the data reports. A draft report will be available for public comment by the end of CY

2019. A final report will be issued after all data have been completely reviewed and comments addressed.