Measuring the Impact of Port of Charleston Activities on Local Air Quality

Extended Abstract # 324

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INTRODUCTION

Ports are a critical feature of the nation's economy; port commerce supports 13 million jobs and contributes $3.15 trillion to the economy. The value of goods shipped through seaports represents 11% of the gross domestic product (GDP).[1] The U.S. has 360 commercial ports, including 150 deep-draft seaports.[1] Figure 1[2] shows the principal seaports of the U.S. Ports may be considered multi-modal transportation facilities as they typically have truck and rail yard facilities for the shipment of goods to and from the port. Multiple air pollutant species such as carbon monoxide (CO), oxides of nitrogen (NO, NO_2, NO_X), particulate matter with an aerodynamic diameter ≤ 10 µm (PM_{10}), particulate matter ≤ 2.5 µm in diameter ($PM_{2.5}$), and black carbon (BC) can be emitted from these multi-modal facilities. Near-source air pollution measurements have established that large emission sources may impact local air quality several hundred meters away. Near-source research has also shown elevated air pollution levels within a few hundred meters of busy roadways, and health effects have been associated with these near-road exposures.[3-10]

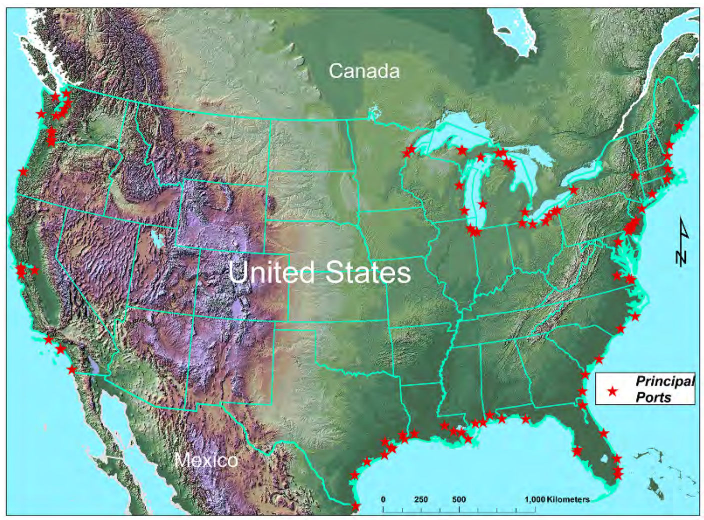

Figure 1. Principal Ports of U.S.

PANAMA CANAL EXPANSION

Originally anticipated to be completed in 2014, the expansion of the Panama Canal with a third set of locks is scheduled to be completed in 2016. This expansion will double the existing capacity of the canal and will allow for the transit of larger vessels (i.e., Post-Panamax). As shown by Figure 2[11], Post-Panamax vessels can haul approximately 2.5 times as many containers as a

Panamax vessel.[11, 12]

Ports are expanding across the U.S. in anticipation of the completion of the Panama Canal expansion and the anticipated growth in freight volumes. Terminals exhibit a wide-range of activities including off-loading freight from ships using large overhead cranes, moving multiple containers using yard fork-lifts, moving freight within the terminal area using service cranes/vehicles, moving freight into and out of the terminal area using rail cars/trucks, etc. Once the freight is off-loaded from the ship, the terminal staff move the freight to warehouses or waiting rail cars/trucks as soon as possible to facilitate service for the next ship that needs to load freight or off-load freight. Bulk cargo, ro-ro (roll on-roll off), terminals operate in much the same way—moving freight/goods into and out of the terminal area to accommodate the next shipments.

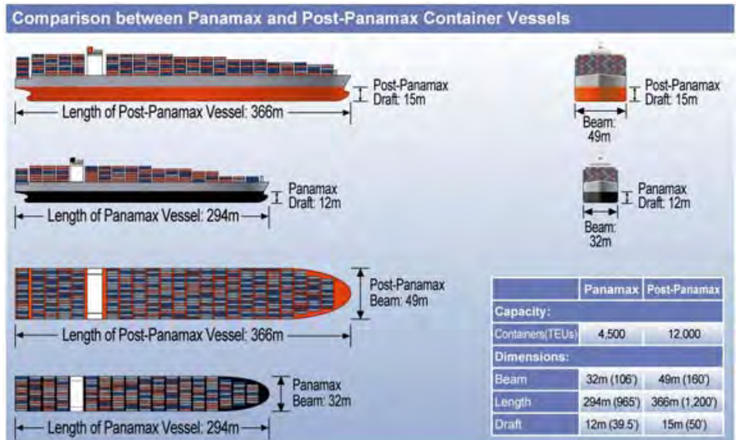

Figure 2. Panamax versus Post-Panamax Vessels

ENVIRONMENTAL CONCERNS AND DRIVERS

Near-source research has been focused primarily on highways (i.e., near-road). Near-road research has observed local-scale pollution gradients and associated adverse health endpoints.[3, 5, 9] Vulnerable populations including school children, and the elderly have been shown to experience adverse health effects from air pollution especially when living near major roadways.[4]

To address these air pollution concerns, EPA's recent research has extended into characterizing rail yard and port environments. A past research study[13] noted local-scale air pollution impacts as well as environmental justice concerns. EPA Regions have noted issues beyond current near-road research including:

1. Concern regarding local-scale air pollution and communities (including environmental justice issues);
2. Impact of rail yards on local air quality and PM nonattainment;
3. Need for additional analysis on local-scale air pollution impacts due to port activity expansion;
4. Need for data-driven (as opposed to solely modeled estimates) documentation of port-area emission changes;
5. Need for simplified community-scale tools able to provide rapid scenario assessments for mitigation strategies, modal shifts, etc.; and
6. Need to determine the impact of existing emission reduction strategies and assess the need for additional emission reduction strategies.

SCIENCE QUESTIONS

As freight volumes grow and port activities increase communities near the port and along roadways may experience increased local-scale air pollution due to increased traffic. Moreover, increased freight volumes and subsequent higher truck traffic and rail yard volumes may lead to unanticipated air quality impacts further along the freight distribution chain. Science questions that have been identified leading to research that may support the estimation of impacts of port activities on local air quality include the following:

1. What is the spatial and temporal nature of air pollution emissions and near-source concentrations associated with rail yards or ports, and related truck traffic?
2. What is the spatial extent of local air pollution elevated over the background, downwind of a major port facility (e.g., Charleston, SC)?
3. What is the spatial and temporal variability of near-port air pollution, under different meteorological conditions and source emission characteristics?
4. How can the signal from one source of interest be isolated in a complex environment of clustered confounding sources?
5. How can increases (e.g., increased freight-handling activity related to Panama Canal expansion) or decreases (e.g., port voluntary programs, rail yard engine improvements) in source emissions from a port or rail yard be detected using a combined air pollution measurement and modeling strategy?
6. What mitigation strategies can provide meaningful improvement in near-source air pollution for ports, rail yards, or related intermodal transportation?
7. How can transferable research tools for EPA Regions be developed to use in assessing progress towards emission improvements and addressing environmental justice concerns for specific sources of interest?

In addition to these science questions, research gaps that have been identified highlighted the need for hybrid regional-local-scale models; screening tools for rapid scenario assessments; freight activity and freight route data; and local-scale air quality, population and health data.[14]

RESEARCH STRATEGIES

Strategies to address these science questions and research gaps may include a combination of: stationary measurements, mobile measurements, geographic information systems (GIS) analyses, monitor/model hybrids, and low-cost sensors (emerging technology). As shown in the Table 1 each of these techniques has associated pros and cons. Thus, a combination of strategies would provide the most “bang for the buck”.

Table 1. Research Strategies, Pros and Cons

Assessment Strategy	Pros	Cons
Stationary, fixed site measurements	Predominately Federal Equivalent Method/Federal Reference Method (FEM/FRM) analyzers	High cost; infrastructure; operation

Assessment Strategy	Pros	Cons
Mobile monitoring – GMAP – Geospatial Measurements of Air Pollution	Electric vehicle; High-resolution—spatial and temporal	Short term sampling; moderate cost; "data snapshot"
GIS analyses	Data visualization, spatial resolution	Data quantity/quality may need improvement
Monitor/model hybrids	Screening tools for evaluating air pollution impacts	Spatial/temporal resolution may be limited due to data inputs
Low-cost sensors	Lower cost; potential for higher spatial and temporal resolution	Emerging technology; sensor quality; data quality issues

PORT OF CHARLESTON STUDY STRATEGY

In 2013, EPA conducted a field study to measure ambient air qualtiy for the assessment of port activities in the Charleston, SC area (Figure 3[15]). The purpose of this study was to:

1. measure neighborhood-scale gradients in air pollutants that may be affected by localized emissions from the port and related sources in the harbor area;
2. provide a spatially-resolved data set for comparison with a Community Air Quality Screening (COMAQS) Model – Community (C-PORT) source model;

The specific research questions addressed by this research study included:

1. What is the spatial extent of local air pollution elevated over the background, downwind of a major port facility (i.e., Charleston, SC)?
2. What is the spatial and temporal variability of near-port air pollution, under different meteorological conditions and source emission characteristics?

Figure 3. Port of Charleston Area.

The Port of Charleston is the fourth largest U.S. container port in terms of twenty-foot equivalent units (TEUs) and has a wide-range of activities including off-loading freight from ships using large overhead cranes,; moving multiple containers using yard fork-lifts, moving freight within the terminal area using service cranes/vehicles, and moving freight into and out of the terminal area using rail cars/trucks. Terminal facilities include cruise, container, ro-ro (roll on-roll off)--(car/truck), bulk, break bulk and project cargo operations. Charleston port activities occur all along the waterfront and can generally be classified into areas controlled by the South Carolina Ports Authority and areas controlled by commercial/industrial entities. Project team discussions determined that this project would be confined to those areas controlled by the South Carolina Ports Authority. Facilities not controlled by the Ports Authority include bulk petroleum and dry-dock, as well as bulk terminals. In addition, manufacturing facilities are located along the waterfront (e.g., paper mill).

For the Charleston, SC study, terminal areas of interest included: Wando Welch, Columbus Street, Union Pier, North Charleston Terminal and Veterans Terminal. Veterans Terminal while not shown on the map above is slightly north of the Columbus Street Terminal on the Cooper River. Veterans Terminal is a decommissioned Navy base that is being developed as a commercial container facility. The North Charleston Terminal was not included in the field study as there was a nearby paper mill that would have confounded the mobile measurements. As may be seen in Figure 4 (Wando Welch Terminal) multiple ships are loading/unloading containerized freight using massive overhead cranes.

Figure 4. Wando Welch Terminal.
Source: http://www.scspa.com/

The mobile measurement campaign was conducted using an electric vehicle (GMAP) outfitted with real-time air monitoring instruments (Table 2). This vehicle has an on-board battery and inverter supporting driving and powering the air monitoring instruments. Daily sampling duration, limited by power availability, is usually limited to approximately 2-3 hours of driving mode sampling. Sampling days were repeated and routes were driven multiple times during the sampling period.

Driving routes were developed using geospatial tools such as Google Earth Pro. The routes were selected based on proximity to a terminal facility, rail yard, residential area(s) or other nearby sources. Four routes were developed based on their proximity to Wando Welch Terminal, Columbus St. Terminal/Union Pier, Veterans Terminal, and Bennett Rail Yard. The routes included neighborhood streets, arterials, and interstate highways in proximity to these emission sources. "Ground-truthing" by driving the proposed routes during a field site visit to Charleston, SC, ensured that the routes were safe for the driver/vehicle and that the routes would meet the goals of the research study.

Several considerations guided the sampling regime:

- Port Activity Hours – 7 am to 7 pm when ships are being loaded/unloaded.
- Electric Vehicle Range – 3-4 hours depending on route to be driven, laps, and road speed.
- Non-Port Activity Hours – Coordinated with Port Authority of Charleston.
- Weekdays (Monday – Saturday) – Sampling events were planned for Tuesday-Saturday, with Monday used as a preparation or sampling makeup day in case of weather-related cancellation or technical issues.
- Avoidance of sample start times coinciding with typical commute hours.
- Sample start times – Week 1: 4 am sampling start each day; Week 2: 1:30 pm sampling start; Week 3: 9 am sampling start.
- Meteorology – Local meteorological data collected using a portable meteorology station at a stationary location in the vicinity of route driven. Stationary site was selected to account for micrometeorological effects, and the route selection for sample day was based on predominant winds for that day (e.g., if winds from south or west, then drive routes in the vicinity of Wando Welch Terminal).

Table 2. Parameters Measured, Sampling Rate, and Instruments.

Measurement	Sampling Rate	Instrument	Stationary/ Mobile
NO_2	1 s	Visible (450 nm) absorption (CAPS, Aerodyne Research, Inc, Billerica, MA, U.S.)	**Mobile**
Carbon monoxide (CO)	1 s	Quantum cascade laser (QCL, Aerodyne Research, Inc., Billerica, MA, U.S.)	**Mobile**
Carbon dioxide (CO_2)	1 s	Li-COR 820 NDIR, (LI-COR, Lincoln, Nebraska U.S.)	**Mobile**
Particle number concentration (size range 5.6-560 nm, 32 channels)	1 s	Engine Exhaust Particle Sizer (EEPS, Model 3090, TSI, Inc., Shoreview, MN, U.S.)	**Mobile**
Particle number concentration (size range 0.5-20 µm, 52 channels)	1 s	Aerodynamic Particle Sizer (APS, Model 3321, TSI, Inc., Shoreview, MN, U.S.)	**Mobile**
Black carbon	1-5 s	Single-channel Aethalometer (Magee Scientific, AE-42, Berkeley, CA, U.S.)	**Mobile**
Longitude and latitude	1 s	Global positioning system (Crescent R100, Hemisphere GPS, Scottsdale, AZ, U.S.)	**Mobile**
3D wind speed and direction	1 s	Ultrasonic anemometer (RM Young, Model 81000, Traverse City, MI, U.S.)	**Stationary**
SO_2	1s	Ecotech 9850 (Ecotech, Knoxfield, Victoria, 3180, Australia)	**Stationary**

SUMMARY

Field sampling was conducted during February/March 2014 in Charleston, SC. Four routes were driven over a period of 22 sampling days. Routes included neighborhoods in close proximity to Wando Welch Terminal, Columbus St. Terminal/Union Pier, Veterans Terminal, and Bennett Rail Yard. This study utilized a combination of measurement strategies: fixed-site measurements (local-scale meteorology); GIS analyses (site/route selection); mobile measurements (GMAP); modeling (screening tool under development using data collected during study). Future measurement strategies may include low-cost sensors as this technology becomes more accurate and robust relative to reference monitors.

The study yielded a rich data set that is undergoing analysis and is being used to develop a screening modeling tool (C-PORT) for near-source air quality assessments. Future work may include expansion of the C-PORT model to be used for other multi-modal transportation facilities.

ACKNOWLEDGEMENTS

The U.S. Environmental Protection Agency through its Office of Research and Development funded and conducted the research described here through Contract EP-C-09-027 with ARCADIS, Geraghty & Miller. Mention of trade names or commercial products does not constitute endorsement or recommendations for use. Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

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KEY WORDS

Near-source, multi-modal, ports, air quality