THE ARIZONA CONSTRUCTION EMISSIONS FIELD STUDY

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1. INTRODUCTION

Diesel-powered construction equipment is a significant and relatively unregulated source of air pollution. In 2005, diesel construction equipment emitted an estimated 778,000 tons of nitrogen oxides (NO_x) and 64,000 tons of coarse particulate matter (PM_{10}) emissions in the United States (U.S. Environmental Protection Agency, 2008). Although EPA's NONROAD model is available to generate county-level estimates of emissions from construction equipment, there are no consistent and widely accepted guidelines for estimating emissions from road construction projects for National Environmental Policy Act analysis and State Implementation Plan and transportation conformity plan development.

To better understand PM_{10} and fine particulate ($PM_{2.5}$) emissions and the resulting air impacts from transportation construction projects, the Arizona Department of Transportation (ADOT) contracted with Sonoma Technology, Inc. (STI) to conduct a field study to quantitatively assess the air quality impacts from a rural road-widening project in southern Arizona. The selected project involves widening State Road 92 (SR92) from two to four lanes on a four-mile stretch south of Sierra Vista, AZ **(Figure 1)**. This project was chosen because there are few local emissions sources in the immediate vicinity, making it easier to isolate the air quality impacts of construction activities.

The objectives of the field study are to characterize and quantify the contributions from various phases of the construction project **(Table 1)** to $PM_{2.5}$, PM_{10}, and particulate precursor emissions, with a view toward developing a framework for estimating air quality impacts from future construction projects and identifying cost-effective methods to reduce project-based emissions.

Emission estimates are being prepared on the basis of construction equipment activity as assessed through GPS units and fuel consumption logs. Near-field pollutant concentrations are being characterized through the collection of air quality and meteorological data at four monitoring stations near the roadway.

Fig. 1. Location of the SR92 road widening project.

Table 1. Roadway construction project phases.

Construction Phase	Description
Land clearing and grubbing	Removing trees, vegetation, and other material from the construction area.
Roadway excavation	Excavating, grading, and disposing of soil and other material for the construction of roadway elements such as shoulders and through lanes.
Structural excavation	Excavating, grading, and disposing of soil and other material for the construction of structural elements such as retaining walls.
Base and subbase	Constructing the road bed foundation with soil and gravel hauled to the construction site from other locations.
Structural concrete	Constructing the structural elements of the project (e.g., retaining walls and curbs).
Paving	Applying asphalt or concrete on a prepared road bed foundation.
Drainage and landscaping	Drainage work, erosion control, planting, and irrigation.

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2. METHODOLOGY

2.1 Emissions Activity Data

In past studies of emissions from construction equipment, a variety of approaches have been used to collect the equipment characteristics and activity data needed to estimate emissions, including surveys, time-lapse photography, and on-board monitoring equipment. All data collection methods have inherent strengths and weaknesses, and it is unlikely that any one method will provide the full range of information needed to accurately estimate emissions from construction activities. Therefore, this field study was designed to collect data from a combination of sources: field inspector diaries, equipment instrumentation, fuel consumption logs, and on-site observations. Each of these data collection methods is described in the sections that follow.

2.1.1 Field inspector logs

ADOT policies require that field inspectors maintain daily diaries on each active construction project that document the type of work performed on a given day, the location of the work, an inventory of equipment used (including estimated hours of usage), and summaries of work completed. These diaries are being provided to STI on a weekly basis, and STI staff members are converting the records into a database that can be used to track progress through the various phases of the project and identify the equipment being used during each phase.

The SR92 road-widening project began in October 2008 and is expected to last 18 months. However, heavy equipment usage will primarily occur during calendar year 2009, so data collection efforts for the air quality impacts study began in January 2009 and will continue through December 2009.

2.1.2 Equipment instrumentation

To gather detailed information on equipment usage patterns, STI outfitted selected pieces of equipment with GPS units **(Figure 2)** that track equipment locations, movements, and engine status (off, idle, etc.). These units report equipment locations at 5-minute intervals to a project website, where daily reports of total engine hours and idling times are also available.

In December 2008, STI installed instruments in 23 pieces of equipment, including backhoes, scrapers, loaders, motor graders, excavators, compactors, and water trucks. These 23 pieces of equipment represent virtually all the construction vehicles dedicated to the project. Non-instrumented equipment, including vehicles used by subcontractors and seldom-used equipment, are being tracked with other data collection methods (e.g., field inspector logs).

Fig. 2. GPS unit mounted in the cab of a John Deere 615C scraper.

2.1.3 Fuel logs

For billing purposes, the construction contractor in charge of the SR92 widening project keeps records on the daily fuel consumed by each vehicle. These records are generated at the end of each workday when a fuel truck visits the job site and refills each vehicle that was used during the day. These records are being provided to STI and serve as a way to corroborate and augment the GPS data.

2.1.4 On-site observations

Although the use of field observers is labor-intensive and may create safety issues on a job site, STI is making limited use of on-site observations to document progress on the construction project and to “ground-truth” data obtained from other sources. Specifically, a field technician visits the job site every one to two weeks to take photographs and make notes on how equipment is being used.

2.1.5 Traffic counts

To separate the contributions of on-road vehicles, especially heavy-duty diesel trucks, from the contributions of construction equipment to ambient pollutant concentrations downwind of the construction zone, STI is using ADOT traffic count data to estimate emissions from on-road vehicles. ADOT set up traffic counters at the north and south ends of the construction project, and these counters report vehicle counts and speeds by vehicle type every 15 minutes.

2.2 Emissions Estimation

2.2.1 Construction equipment

Emission estimates for construction equipment are typically prepared by using EPA's NONROAD model, which employs the following formula to calculate emissions for a given equipment type:

$$E = \sum (POP \times HRS \times HP \times LF \times EF) \qquad (1)$$

where E is emissions of a given pollutant in grams per year, POP is the population of a given equipment type in the region of interest, HRS is the annual hours of operation, HP is the engine horsepower rating, LF is the engine load factor, and EF is the pollutant-specific emission factor in grams per horsepower-hour.

NONROAD also contains fuel consumption factors in units of gallons per horsepower-hour that can be substituted for the EF variable in Equation 1 to estimate fuel consumption. These fuel consumption factors can also be used to convert NONROAD's mass-based emission factors to a fuel basis (i.e., grams/gallon).

Frey et al. (2008) collected field data for in-use consumption and emission rates for 15 types of construction equipment and found that fuel-based emission factors derived from in-use data were comparable to fuel-based emission factors derived from the NONROAD model. Frey also found that fuel-based emission factors are less sensitive to engine loads than time-based emission factors and are, therefore, a more robust basis for estimating emissions when fuel consumption data are available.

Therefore, emission estimates for construction equipment used on the SR92 project were based on fuel consumption data, with activity data derived from GPS and field logs used to identify the location and timing of equipment activities. Fuel-based emission factors in g/gal were derived from the NONROAD model for each piece of equipment used on the SR92 project, and these emission factors were applied to daily fuel consumption data for each piece of equipment to estimate daily emissions.

2.2.2 On-road vehicles

Emission estimates from on-road vehicles travelling along SR92 are based on ADOT traffic count data for SR92 and emission factors derived from EPA MOBILE6 model. MOBILE6 is being run with temperature data collected at one of the ambient monitoring stations, speed data collected from ADOT traffic counters, and local data on fuels characteristics, vehicle age distributions, etc.

2.3 Ambient Data Collection

In addition to collecting emissions activity data, STI is also collecting ambient air quality and meteorological measurements at the construction site. In January 2009, we established four monitoring sites near S92: two sites west of the roadway and two sites east of the roadway. The sites are situated along a straight line perpendicular to SR92, with two sites about 100 feet from the road centerline and two sites about 200 feet from the road centerline **(Figure 3)**. This arrangement allows for both upwind and downwind monitoring under all wind conditions, except during periods when the wind is parallel to the roadway.

Parameters measured at the monitoring sites include $PM_{2.5}$, PM_{10}, black carbon, NO_x, carbon monoxide, carbon dioxide, and particulate polycyclic aromatic hydrocarbons. Meteorological variables measured include wind speed, wind direction, relative humidity, temperature, and solar radiation.

Fig. 3. Monitoring trailers set up on the west side of SR92.

For daily review of continuous and semicontinuous monitoring data, STI staff developed a web-based data retrieval system that retrieves data from each site by cell modem at least once per hour and transfers the data to STI's web server. The data then undergo auto-screening quality assurance procedures and are posted in graphical format to a password-protected web page for viewing by authorized personnel **(Figure 4)**.

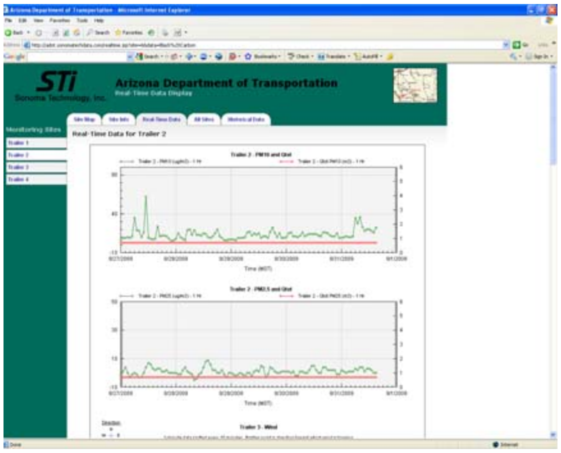

Fig. 4. Screen shot of the real-time, web-based data display for the ADOT construction project.

3. PRELIMINARY RESULTS

Though data collection is ongoing through calendar year 2009, preliminary estimates of emissions from construction equipment have been prepared for the first six months of the project (January through June). Because all phases of construction are being completed on the east side of the roadway before work on the west side of the roadway begins, all phases of construction are represented in the first six months of data. However, it should be noted that the emission estimates described below are for construction equipment exhaust only and do not include emissions from on-road vehicles or fugitive dust associated with construction activities.

Over the first six months of the project, we estimate that construction equipment at the SR92 project emitted 118 tons of PM_{10} and 1,551 tons of NO_x. Almost half the PM_{10} emissions are associated with the roadway excavation phase of construction **(Figure 5)**. However, because the phases of construction overlap in time (i.e., roadway excavation is happening on one section of the roadway while land clearing and grubbing is happening on another section), monthly emissions are fairly constant over the first half of the project **(Figure 6)**. Across equipment types, graders, scrapers, loaders, and excavators account for about two-thirds of the total PM_{10} emissions over the first half of the project **(Figure 7)**.

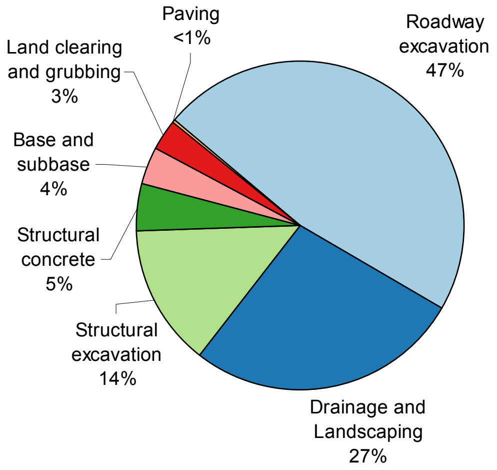

Fig. 5. Breakdown of construction equipment PM_{10} emissions by phase of construction.

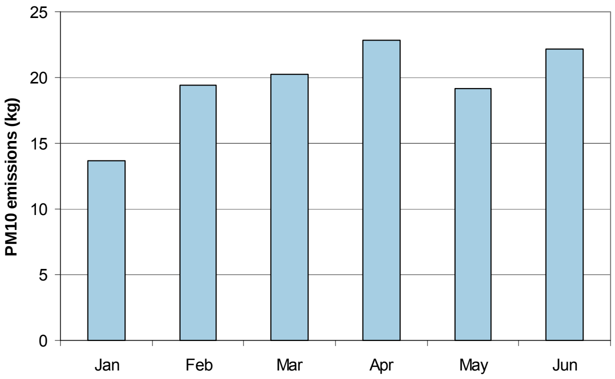

Fig. 6. Breakdown of construction equipment PM_{10} emissions by month.

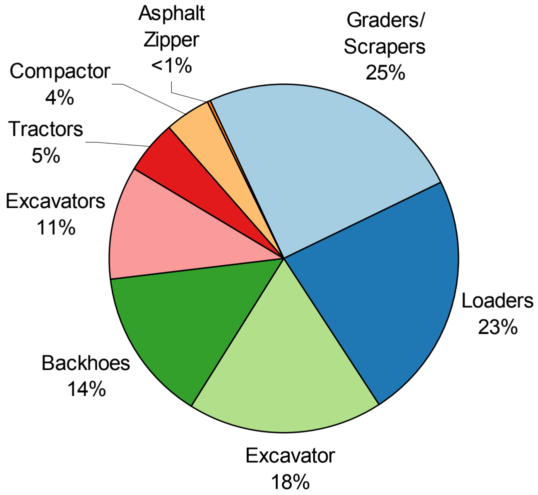

Fig. 7. Breakdown of construction equipment PM_{10} emissions by equipment type.

4. SUMMARY AND CONCLUSIONS

Preliminary results for this project indicate that the data collection methods employed are providing a robust data set for evaluating emissions associated with a road construction project. Emission estimates by phase of construction and equipment type will be useful for identifying potential mitigation strategies for road construction projects in Arizona.

Next steps for the project include collecting data for the remainder of the construction project; estimating emissions for on-road motor vehicles; estimating PM emissions from fugitive dust; and comparing emission estimates with ambient monitoring data collected at the construction site.

5. REFERENCES

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