Expanded Abstract: Deploying Mobile Sampling Technologies to Develop Emissions Inventories for Air Pollution Control Plans

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Air agencies across the county are continuously looking for ways to improve the accuracy of their comprehensive emissions inventories in support of State Implementation Plans (SIPs) and Regional Transportation Plans (RTPs). One critical element in a comprehensive emissions inventory for fine particulate matter is road dust. Only recently has Mobile Sampling Technologies (MST) matured into an effective tool for improving the accuracy of road dust emissions inventories.

Road dust emissions are influenced by a number of factors, including road functional class, road surface conditions, the presence or absence of paved road shoulders, and the mix of adjacent land uses. Emissions are further influenced by vehicle speed, weight and number of wheels/axles per vehicle. Emissions inventories for road dust are typically quantified by grams per vehicle mile traveled multiplied by total miles traveled to obtain total mass emissions.

A primary factor that influences road dust emission rates is road functional class. Typical road functional classes in urban areas may include local, major/minor collector, minor arterial, principal arterial, and freeways. As such, emission rate and total emissions are typically developed for each functional road class and the totals combined to characterize total road dust emissions

Other factors that influence emission rates include the presence or absence of paved road shoulders, curbs and gutters, and the condition of road surfaces. These factors can be characterized as a subset of each functional road class. Adjacent land uses of particular concern are mining and quarrying facilities, industrial facilities where vehicles use unpaved yard areas and commercial facilities with unpaved parking areas. Silt materials from unpaved surfaces are tracked on to the adjacent roads, increasing the road dust emissions near these facilities.

Knowing and understanding the objective of deploying MSTs is critical to the success of improving the accuracy of any road dust emissions inventory. Where the objective is to develop a comprehensive road dust emissions inventory for a SIP or a RTP, then the sampling route should encompasses all of the functional road classes and sampling segments within each functional road class. Furthermore, the sampling route should reflect the varied infrastructure conditions present in the domain for which the SIP or RTP is developed. On the other hand, if the study objective is development of an emission inventory for a major stationary source, then the sampling plan will focus on specific roads or specific types of roads related to the source. If the focus of the study is simply to quantify the road dust emissions from specific types of road side sources such as construction activities, sand and gravel mining, or mineral processing operations, then care must be taken to insure that track-on from other nearby sources do not mask, magnify or otherwise confound the results. Ideally, sampling would be conducted on a road segment adjacent to an isolated roadside source of road dust track-on. In this ideal sampling situation, the decay of elevated emissions from the source track-on is measured until the emissions rate reached background levels and total track-on emissions quantified. Unfortunately, sources are often grouped in close proximity, precluding road dust emissions measurements in the ideal situation, and requiring careful data analysis to separate source on source impacts.

Enhancing the robustness of the road dust emissions inventory can also be accomplished by employing a statistician to assist in the development of the sampling plan in order to ensure that a statistically significant number of miles are sampled in each road class and to assist in analyzing the data sets.

The use of maps of the road network by road functional class may be helpful in conceptualizing the study objectives and are necessary for planning the detailed sampling route. Once study objectives are finalized, road infrastructure information, such as paved shoulders, curbs and gutters, and pavement condition are needed to supplement road network classification maps. It is increasingly common for this type of information to be maintained as spatial data in a GIS system, particularly in large metropolitan areas, allowing for the generation of custom maps to aid in developing the sampling route. Where road infrastructure information is not readily available, then it may be necessary to conduct a field survey to obtain this information. Use of air photos, street level photos, and satellite imagery can supplement and in some instances supersede the need to conduct a field survey to obtain infrastructure information. Use of basic road classification maps and air photos/satellite imagery available from sources such as Google Earth should be used to narrow the focus of a detailed field survey when one is required.

Obtaining information on the locations of major sources of dirt track-on and current construction sites is also helpful for planning the sampling route and to better quantify road dust emissions impacts from specific source types. Where this information is not available in a GIS data base, it can be developed through use of Google Earth and zoning maps in combination with the field survey.

Another key component of designing a viable sampling route is traffic data, typically in the form of vehicle miles traveled (VMT) by road segment. Ideally, this information would be broken down at a minimum by hourly increments to allow determination of peak traffic periods and diurnal traffic patterns. In general, vehicle road dust emission rates increases when traffic volumes are low and decrease when vehicle passes are more frequent. This phenomenon relates to the buildup and depletion of road surface silt loading related to vehicle passes. This generalization must be utilized with some caution and discernment, however. For example, for road segments with adjacent track-on sources, increased numbers of vehicles exiting the source site during peak travel periods may significantly increase road surface silt loadings and therefore vehicle road dust emission rates during these peak traffic periods.

MST have certain inherent technical limitations that must be considered in the design of the sampling route. The concept behind these systems is to measure road dust entrained by vehicle movement. The physics of vehicle movement and dust entrainment on a paved surfaces and the sensitivity of the sampling systems dictate a minimum sampling speed of approximately 12 miles per hour (mph). Rapid acceleration and deceleration also affect the measured emissions and the data processing systems in better systems are set up to flag data points collected under these conditions as determined by the GPS readings. The systems cannot accurately measure emission rates during turns and data points recorded during turns should also be flagged by the system based on GPS data and excluded from emission rate computations. The continuous samplers used in these systems typically sample at a rate of once per second, although the systems are often set up to record data on a six to ten data point running average in order to smooth the data. This sampling rate conveniently matches the output rate of most commercial GPS units, but places some significant practical limits on the minimum length of a road segment from which valid measurements can be obtained. For example, in order to sample on a local street at 25 mph you must travel 366 feet after acceleration in order to collect 10 data points and also allow for room to decelerate prior to reaching the end of the street. Sampling on a collector street at 35 mph or an arterial street at 45 mph requires travel of 513 and 660 feet respectively, excluding distance for acceleration and deceleration. The acceleration, deceleration and cornering characteristics of the specific MST also influence the practical limits on sampling segment length. All of the MST characteristics must be factored into the sampling plan design, along with margins for safety and duplication to allow for situations where traffic conditions disrupt a sampling run.

An issue that affects most sampling domains in urban and sometimes rural areas is street sweeping schedules. Emissions measurements should be made when road silt loadings are at typical levels rather than on a recently swept street. While sweeping is generally thought to decrease measured emissions, particularly on streets with high silt loadings, Clark County documented one situation where sweeping actually increased emissions measured by three types of MST and profile measurements taken to calibrate the MST on a very clean arterial roadway segment. Street sweeping is documented to skew emissions rates, sometimes in an unexpected fashion, and as a rule of thumb, sampling should not be scheduled for at least two days following a street sweeping operation.

Any scheduled road maintenance and major public events should be accounted for prior to finalizing a sampling route and study date, although the best efforts at due diligence cannot anticipate and account for emergency street work resulting from events such as the failure of a water or sewer main located in a street. Obtaining road construction schedules form public works agencies with jurisdiction over roads under consideration for sampling will minimize the risk that a costly emissions measurement study will be interrupted, compromised or otherwise rerouted after the sampling plan is finalized. Scheduling a road sampling study during a major holiday or during a major public event should be avoided as both traffic volumes and patterns will differ from those that occur during most days of the year. This can also true when a major public event or convention is held in a city. For example, a major trade show or a presidential visit may result in multiple road closures and impact traffic patterns over a wide area.

Once a candidate sampling route is identified based on the total miles of road network by functional class, road infrastructure development and condition, location of track-on sources, VMT data, MST sampling characteristics and limitations, and known road construction activities, it is necessary to drive the proposed route to establish real world driving times and evaluate traffic patterns from the vehicle operator's perspective. For development of a comprehensive emission inventory for use in a SIP or RTP, weekend sampling to account for any differences in weekday and weekend emission rates is highly desirable as significant variations have been documented between weekend and weekday emission rates. Where weekend sampling is contemplated the candidate-sampling route should be driven on the weekend as well to verify any significant differences in driving times and traffic patterns.

In summary, road network functional class maps coupled with road infrastructure information, the location and numbers of sources of dirt track-on impacting the road network, VMT data, and MST sampling characteristics are the key building blocks for designing the sampling route. The specific emphasis placed on the specific data sets will depend on the specific emphasis and comprehensiveness of the study effort.

Following, or in parallel with finalizing the sampling plan, is development of operational plans for the study. These include procedures for equipment checks, contingencies for equipment breakdown and repair, plans for quality assurance and quality control, and study safety procedures. Where permitted by applicable vehicle codes, use of amber warning lights may provide additional safety; particularly if more then one MST is used in tandem in order to improve date quality.

On the day before commencement of sampling, the study route should again be driven to determine that no road blockages exist due to unanticipated road construction activities. During execution of the sampling study, safe operation of the MST is paramount. At the risk of stating the obvious, it must be noted that operators of the MST must understand that vehicle and pedestrian safety trumps data quality in every situation.

After sampling is completed, the measurement and GPS data is compiled and analyzed. The measured emissions, apportioned by road class, subclass and VMT, are used to build the road dust emissions inventory. A qualified statistician can assist in assigning an appropriate weighting to the respective emissions factors developed from the study measurements based on the representation of the sampled segments in the overall road network.

To date, no entity has used MST for development of a comprehensive SIP or RTP road dust emissions inventory for a major metropolitan statistical area. Other studies and publications have documented the many technical, cost and efficiency advantages provided by MST for this purpose. This paper sets forth the conceptional framework, information and planning requirements, and practical considerations necessary for deploying MST to develop a comprehensive SIP or RTP road dust emissions inventory.