Measurement of Road Dust Emissions: The TRAKER and PI-SWERL Tools

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Abstract

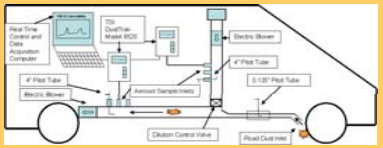
In some regions of the U.S., fugitive dust emissions are responsible for up to 60% of ambient PM_{10}[1]. Dust emissions from paved and unpaved roads can account for a substantial fraction of overall dust emissions. Facility-scale, local, and regional emission inventories are needed to estimate the contribution of road dust to the measured ambient PM_{10} and to ensure compliance with State Implementation Plans (SIPs), operating permits for facilities prone to dust emissions (such as mines and quarries), and transportation conformity rules.

The US EPA has provided guidance in its AP-42 document for estimating PM_{10} and $PM_{2.5}$ dust emissions from paved and unpaved roads[2]. Based on this guidance, measurements or estimates of silt loading and silt content have been widely used to estimate road dust emissions. However, use of silt parameters has several shortcomings: 1) On paved roads it is time-consuming and somewhat unsafe to conduct measurements due to the requirement that traffic be diverted around the measurement locations. 2) The silt parameter (roughly defined as particles smaller than 75 microns in physical diameter) is not a direct indicator for PM_{10} content (defined as particles with aerodynamic diameters smaller than 10 microns). 3) Because of the difficulty of making measurements, it is not always possible to obtain a large number of measurements to adequately represent spatial as well as temporal variations that are known to exist over a roadway network.

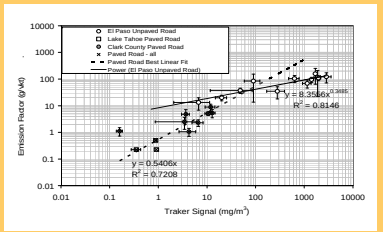
These shortcomings have motivated the development of vehicle-based platforms for more direct measurement of road dust emissions from both paved and unpaved roads. The TRAKER (Testing Re-entrained Aerosol Kinetic Emissions from Roads) is one such system that has been developed and improved over the last decade [3,4,5,6,7,8,9,10]. The principle of the TRAKER is that dust concentrations measured behind the front tires of a test vehicle are related to emissions of PM_{10}. Use of the TRAKER greatly facilitates measuring road dust emission factors over large areas.

More recently, the use of a wind tunnel-type device, the PI-SWERL, on paved roadways has been pioneered by researchers at UNLV. Providing a somewhat different measurement method than the TRAKER, the PI-SWERL allows for quantifying emissions associated with aerodynamic entrainment of particles, benefits of surface treatments, as well as effectiveness of near-road control measures.

TRAKER: Testing Re-entrained Aerosol Kinetic Emissions from Roads

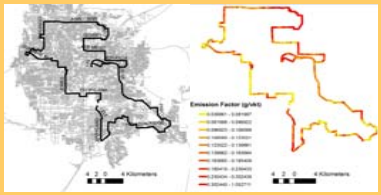


The most recent version of the TRAKER utilizes a 2003 Dodge Sprinter van platform. Air from behind the front tires is drawn in through a sampling line and measured with nephelometer-style instruments with a 1-second time resolution. Using an onboard GPS, the automated system logs location, speed, and road dust emission potential. On unpaved roads, the air sample is diluted with background clean air to avoid overloading the sensors. The system is completely automated, requiring minimal user intervention once measurements begin.



Using an upwind/downwind tower technique similar to the one used to derive the AP-42 silt equations[2], studies[7,11,12] have shown that the relationship between the TRAKER measurement and emission factors is linear for paved roads. On unpaved roads where emissions are much higher (indicated by the white circles in the figure above), the emission factor scales with the cube root of the TRAKER signal.

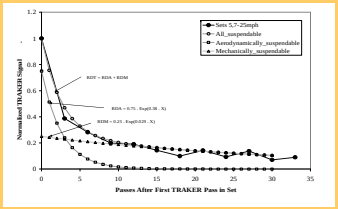
Time series of TRAKER emission factors (upper traces) and snowfall measurements (lower trace) on paved roads at Lake Tahoe, Nevada[12]. Traction control materials have a clear effect on emissions.



Route map of TRAKER measurements as part of a paved road study in Las Vegas, Nevada (left) and measured emission factors by road segment (right)[13].

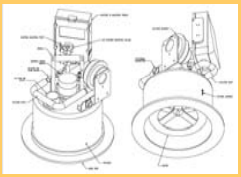
Unpaved road dust emissions measured using the TRAKER dilution system in the Paso Del Norte region (June, 2008). Green dots correspond to paved roads traversed en route to unpaved roads.

Emission inventory for all paved roads on a segment by segment basis for Boise, Idaho[8]. A subset of roads with different characteristics (roadway type, urban/rural, summer/winter) were measured with TRAKER. Roadway characteristics were then used in conjunction with a traffic demand model to assign emission factors to every road segment in the network.



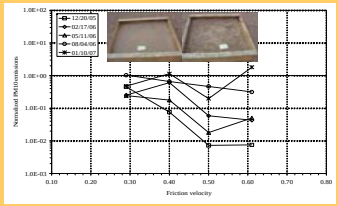
Measurements on a controlled surface in Clark County, NV[11] led to a hypothesis of two distinct mechanisms for road dust emissions: aerodynamic suspension and mechanical lifting by tires. Aerodynamic emissions previously observed for emissions from unpaved shoulders when trucks pass.

PI-SWERL: Portable In-Situ Wind ERosion Laboratory

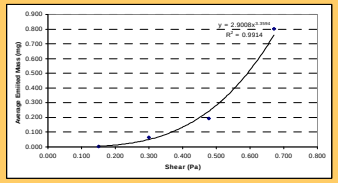


The PI-SWERL (US Patent 7,155,966) measures the amount of dust emitted from a surface when a known amount of wind shear is applied. A flat annular blade inside the chamber rotates at prescribed speeds to simulate different amounts of surface shear stress. Although it uses a different principal of operation, it can be thought of as analogous to a miniature wind tunnel.

The PI-SWERL was collocated with the University of Guelph large field wind tunnel at seventeen sites in the Mojave desert, spanning graveled roads to silty playas[14]. Agreement between the two methods of estimating dust emissions was good with a correlation coefficient of 0.76 and a nearly 1:1 slope.



PI-SWERL data: PM_{10} dust emissions from a chemically treated test plot (right photo) normalized to dust emissions from a test plot that has not been treated (left) over 1 year exposure[15] . X-axis: friction velocity (m/s) – a measure of surface wind shear.



PI-SWERL data: rapid non-linear increase in PM10 emissions with increase in aerodynamic shear (Pascals, N/m^2, proportional to wind speed or tire stress) applied to paved road surface[16], indicating value of keeping speed limits low.

Summary

TRAKER and PI-SWERL are relatively new tools for measuring, characterizing, and understanding road dust emissions. TRAKER is a mobile system for measurement of road dust emissions from paved and unpaved roads. Advantages over silt sampling methods include the ability to measure over many miles of road, measurement of PM_{10} instead of a surrogate parameter, and increased safety for personnel conducting sampling.

PI-SWERL allows for elucidation of effects of specific road characteristics with respect to dust emissions. It can be used to assess the effect of pavement properties on dust emissions, potential for windblown dust on unpaved roads, effectiveness of surface treatments on reducing emissions, emissions from road shoulders, and potential for aerodynamically driven emissions for vehicles traveling at different speeds.

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Acknowledgements

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