# Road Dust Control Performance Monitoring

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## Abstract

Traffic-generated dust emissions from unpaved roads constitute a major national source of $PM_{10}$ emissions. Unpaved road dust emissions can be reduced by a variety of means including the application of petroleum-derived and other chemical binders to the road surface. The performance of chemical stabilizers depends on the structure of the road base and the surface material including the degree of surface compaction. Control performance also depends on the traffic conditions, including vehicle weight and speed and the average daily traffic count. The accepted surrogate for road dustiness is the silt content of loose surface material, which is defined as the fraction of the material passing a 200-mesh screen upon dry sieving. Typically, chemical stabilizers or other forms of dust control need to be reapplied periodically to maintain the desired average emission control efficiency.

This paper describes a field testing program that was conducted to determine the long-term control effectiveness of common types of chemical stabilizers applied to unpaved roads. This program was conducted as part of EPA's Environmental Technology Verification Program. The test road segments were located on a driver training course at Ft. Leonard Wood in southeast Missouri and on a public unpaved road in Maricopa County, Arizona. The application of each dust suppressant followed the recommendations of the manufacturer.

A mobile monitoring system on a test vehicle was used to determine average control efficiencies over treated road segments. Prior to performance testing of road dust suppressants, the mobile monitoring system was validated against the traditional EPA reference method to assure statistical comparability. Dust suppressant performance testing measured seasonal variations in control effectiveness, noting whether the dust controls had been reapplied during the period between testing. Uncontrolled road segments were used to establish the comparison baseline for road dust control performance. The paper presents information on road dust control performance for the five chemical stabilizers tested.

## Background

Characterizing the dust control effectiveness of palliatives requires measuring the source emission strength of both the treated unpaved road surface as well as the untreated road (i.e., experimental control). However, several features inherent to open dust sources (as opposed to more traditional stack sources) complicate the situation:

1. Unlike stack emission sources with "end of the pipe" controls, it is not feasible to measure the uncontrolled emissions and the controlled emissions simultaneously on the same road. If simultaneous testing is performed, two road segments of the same characteristics are required.
2. Next, all unpaved road dust suppression is time-dependent, decaying from roughly complete control at the time of application to essentially no control after some period of time (ranging from hours in the case of watering to months for chemical dust suppressant and years for paving). Thus, no single set of measurements can characterize the long-term, average control performance.
3. The extended period of time necessary because of item 2 further complicates the situation. The treated road surfaces are exposed for a long period of time to the environmental conditions (ranging from precipitation to water erosion from roadside areas) that may affect performance of the palliatives.

Historically, road dust control performance data have been gathered using a technique known as roadside plume "exposure profiling." Roadside plume profiling relies on simultaneous multipoint measurements of particulate concentration and wind speed over the vertical extent of the dust plume to determine the mass of particulate matter that is emitted by a "unit" of vehicle activity on the roadway. Profiling produces an emission factor in terms of pounds per vehicle-mile-traveled (lb/vmt). The emission factor indicates that "*x*"pounds of airborne particulate are generated by a vehicle traveling a distance of 1 mile over the road.

Although profiling produces the most reliable emissions rate information, the method suffers from some disadvantages. First of all, profiling measurements are labor-intensive, and the inherent decay in unpaved road dust suppressants requires that the measurements be undertaken several times after application. Next, profiling places severe physical constraints on acceptable test sites. For example, roads suitable for exposure profiling must (1) be located in areas with open wind fetch; (2) be oriented perpendicular to the prevailing wind direction; (3) have no more than a gentle curve; and (4) have no significant upwind particulate matter (PM) sources in the immediate vicinity. Thus, in terms of defining control performance, the profiling approach provides very accurate data but at relatively high cost and at the exclusion of many potential test locations.

However, because quantifying dust control performance does not require absolute emission rates, there are other simpler on-board test procedures with significant labor savings that provide information on **relative** rather than **absolute** emission rates. These procedures are also suitable for determining road dust control efficiencies by testing controlled and uncontrolled roadway segments and determining emission reductions attributable to the dust control.

This paper describes an on-board mobile sampling method for evaluating road dust control performance, as developed by Midwest Research Institute (MRI) with funding from the US Army Construction Engineering Research Laboratory (CERL). The on-board method was subsequently used to evaluate five chemical dust suppressants for unpaved roads, under EPA's Environmental Technology Verification Program at test sites in Missouri and Arizona.

**Conceptual Design and Development**

In designing the new test method, initial conversations with CERL confirmed that the mobile sampler should have the following attributes:

1. **The device should collect samples in the three particle size ranges of regulatory interest: PM-10, PM-2.5, and PM-30.** As used in this context, "PM-*x*" refers to particulate matter no greater than *x* microns in aerodynamic diameter.
2. **The device should be based on a well-characterized sampler.** Such a sampler, MRI's "hybrid sampler," is described below.
3. **The focus must be on particulate matter that is airborne and capable of being transported away from roadway.** Other samplers developed to mount directly behind a wheel and only slightly (approximately 1 ft) above the road surface [1,2] are directed toward the quantification of total roadway material depletion and nearby deposition. By contrast, the mobile sampling system is positioned farther behind the vehicle and well above the road surface to place it in the vehicle wake dust plume.
4. **The method should be as reproducible as possible.** To the extent practical, sampler operation should avoid or "even out" potential systematic biases and minimize measurement variability
5. **The device should not require extensive amounts of equipment, be relatively easy to operate and require no more than approximately 1 hr per test.** Exposure profiling tests of highly controlled unpaved surfaces typically require 2 to 4 hr of sampling duration.

MRI's "hybrid sampler" constituted the focal point for the mobile sampling system. The hybrid sampler was first developed in 2000, originally for use in an EPA-sponsored test of emissions from mud/dirt tracked out onto public streets from construction sites[3]. The device incorporates a commercially available PM-2.5 sampler into a high-volume air sampler to simultaneously collect and aerodynamically separate collected airborne dust into PM-10, PM-2.5, and total particulate (TP) size fractions.

Figure 1 shows a schematic representation of the device in which a URG-2000-30EH cyclone is coupled with the high-volume cyclone preseparator. The high-volume cyclone preseparator exhibits a $D_{50}$ cutpoint of approximately 10 micrometers in aerodynamic diameter (µmA) at a flow rate of 40 actual cubic feet per minute (acfm)[4], and thus collects a PM-10 sample on an 8-in by 10-in glass fiber filter. The URG device exhibits a $D_{50}$ cutpoint of 2.5 µmA at a flow rate of 16.7 liters per minute (lpm) and thus captures PM-2.5 on a 47-mm filter. By positioning the URG intake below the outlet tube of the high-volume cyclone, the URG unit was protected from large particles entering the cyclone that might otherwise overwhelm the URG unit. In this arrangement, the URG unit samples a small portion (approximately 1 to 2 %) of the cyclone effluent. As part of the 2000 EPA study, the hybrid sampler underwent field and laboratory evaluations to determine reproducibility of the device in a "near-source" (i.e., high concentration) service environment and to confirm the URG's cutpoint when sampling the effluent of the high-volume cyclone.

In addition to the PM-10 and PM-2.5 samples, the high-volume cyclone body collects coarse particulate matter (> PM-10). To determine the weight of material that collects on the interior of the cyclone, the cyclone is washed with distilled water. The entire wash solution is passed through a Büchner-type funnel holding a tared glass fiber filter under suction. This ensures the collection of all suspended material on the filter.

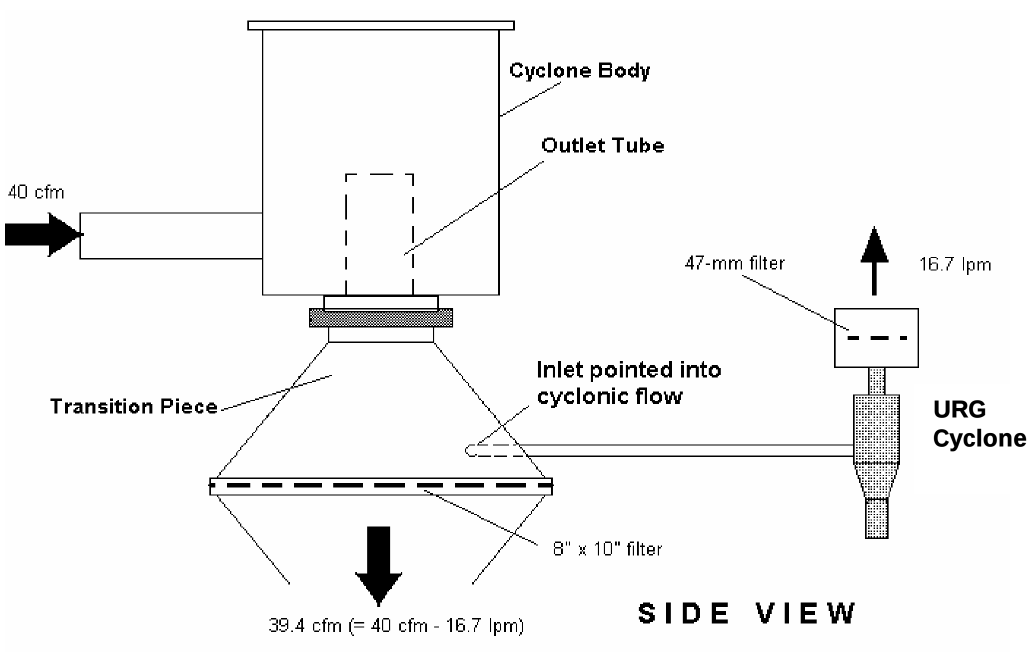


Figure 1. Hybrid PM-10/PM-2.5 Sampler

Adaptation of the hybrid sampler to mobile use required several logistical issues be addressed, including

- Physical placement and support of the sampler
- Operating procedures

The physical placement of the sampler relative to the vehicle is one of the most important differences between the mobile sampling system and devices used in the past. The focus is on PM that is truly airborne and thus capable of contributing to PM fence line concentrations.

Figures 2 and 3 show views of the sampling and support systems, respectively, used during preliminary tests of the mobile sampler. As a practical matter, the sampler needed to be attached (a) as far back as practical from the truck and (b) high enough above the road surface to collect truly airborne material but (c) close enough to the surface to collect adequate sample mass. The physical dimensions of the aluminum box tube, cyclone preseparator, and the mounting carriage combined to limit placement of the cyclone inlet no more than 2.5 m behind the truck's endgate, and between 0.7 to 1.3 m above the road surface. A sampling intake height of 1 m was selected because, based on MRI's past exposure profiling experience, 1 m is representative of the peak PM-10 exposure (i.e., wind speed multiplied by particulate concentration) immediately downwind of an unpaved road. As such, the suspended dust at that height is airborne and capable of being transported downwind.

A set of operating procedures needed to be established to avoid confounding influences from wind. These included the following:

- The truck travel speed should be well above ambient wind speeds so that plume flow dynamics at the sampling point are dominated by the vehicle wake rather than ambient winds.
- A nozzle should be used to match the sampling intake velocity to the truck travel speed.
- A test should consist of multiple trips in both directions along the test road to "average out" the effect of ambient wind direction.

Furthermore, to keep results as reproducible as possible, the desire to use the same truck, tires, and driver during all sampling runs at a location became apparent.

The next set of operating parameters involved the specific details about the truck and how it should be driven in order to collect the desired sample mass in each particle size fraction. The parameters of interest included travel speed, travel distance, and length of the treated road segment.

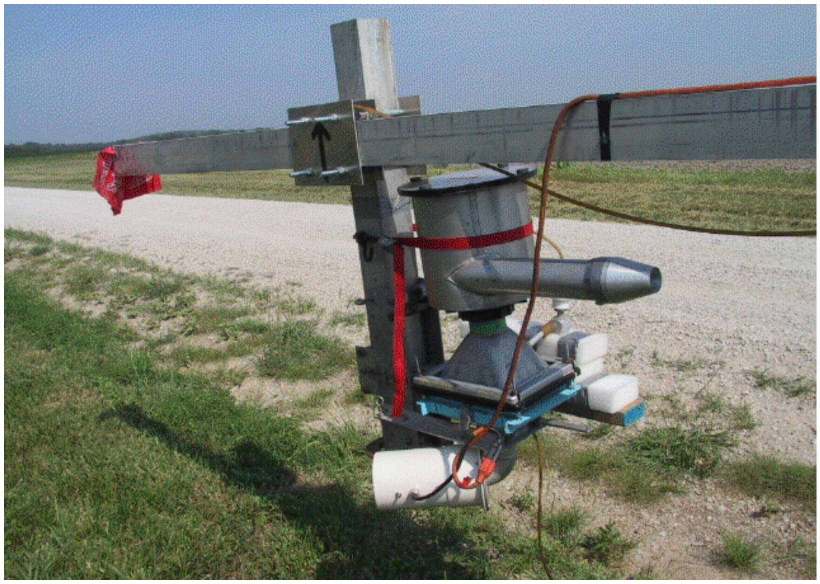

Figure 2.  Sampling System used in Preliminary Tests

Figure 3.  Support System used in Preliminary Tests

Preliminary tests were conducted on rural roads in Cass County, Missouri.  Based on practical experience gained through the preliminary tests, a final design and set of operating procedures were selected for use at Ft. Leonard Wood.

Those procedures are given below:

1. Load the 8-in by 10-in filter cartridge and 47-mm filter holder.
2. Start the vacuum pump and allow it run for at least 1 min.
3. Set the flow at 16.7 lpm through the URG using a rotameter.
4. Start the high-volume sampler and check the back plate pressure.
5. Adjust the autotransformer ("variac") to set the flow through the high-volume sampler to nominally 40 cfm.
6. Turn off the high-volume sampler.
7. Position the truck to start the test.
8. As the truck passes the start of the 500-ft test section, activate the high-volume sampler using the autotransformer (check the red light to ensure that generator circuit breaker has not tripped).
9. As the truck passes the end of the 500-ft test section, deactivate the sampler using the autotransformer.
10. Slow the truck gently and reposition for another trip over the test section (in opposite direction).
11. Repeat Steps 8 through 10 until 6 to 24 passes (depending upon the level of control) have been completed.
12. Stop the truck and briefly reactivate the high-volume sampler to read the back plate pressure.
13. Shut off the high-volume sampler and the vacuum pump.
14. Recover filter cartridge and holder.

Figure 4 shows a schematic of the mobile sampler. Figure 5 presents a photograph of the sampler as deployed at Fort Leonard Wood.

**Field Test Comparison with Exposure Profiling**

Once the prototype had been evaluated, the mobile sampler underwent a multi-month field-testing program at Fort Leonard Wood, located in Pulaski County, Missouri. Six test sections along the "Driver's Course" (DC) in training area (TA) 236 were treated with six different chemical dust palliatives October 2001.

On three of the six test sections, both exposure profiling and mobile sampling tests were conducted. Results from contemporaneous measurements at these locations were used to determine the relationship between results from the two different methods. Details on the test program, including a thorough discussion of exposure profiling and mobile sampling procedures as well as results, are provided elsewhere[5].

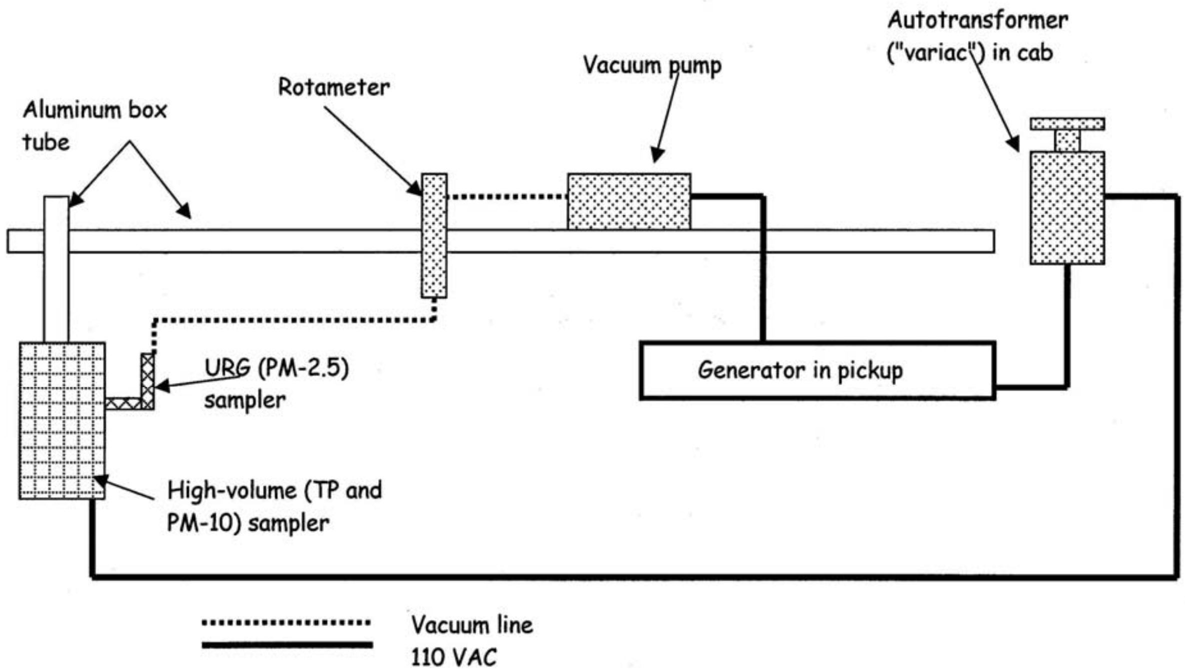


Figure 4. Schematic diagram of mobile sampler components

Figure 5. Mobile Sampler in Use at Fort Leonard Wood

Figure 6 plots the average of the replicate exposure profiling emission factor test results against the average of the two associated mobile sampler results.

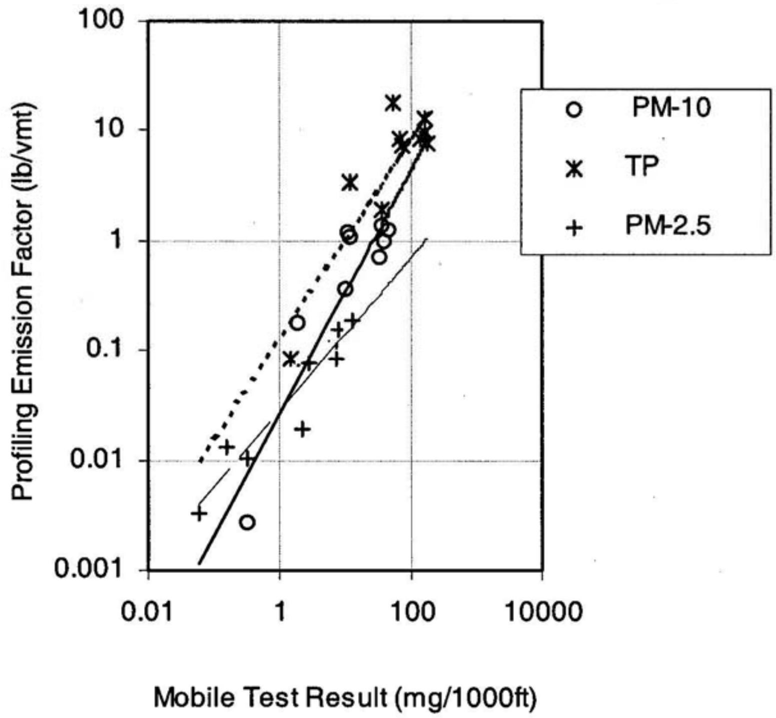


Figure 6. Exposure Profiling Results vs. Mobile Sampler Result

Also shown in the figure are the least-squares (log-log) lines of best fit for the three size ranges. Summary information on those lines is given in Table 1 below:

Table 1. Comparison of Mobile Sampling and Profiling Test Results

| Size range | Line of best fit [a] | $R^2$ |
|---|---|---|
| PM-10 | $y = 0.0268\ x^{1.10}$ | 0.810 |
| TP | $y = 0.129\ x^{0.910}$ | 0.794 |
| PM-2.5 | $y = 0.0282\ x^{0.697}$ | 0.905 |

[a] "y" represents the emission factor in lb/vmt, "x" denotes the mobile sampler test result in mg/1000 ft.

All three relationships are significant at well beyond the 1% level. There is a roughly linear relationship between the mobile and the exposure profiling results for PM-10 and TP. The relationship for the PM-2.5 is slightly sublinear.

Table 2 presents summary information obtained from the three-month test at Ft. Leonard Wood. Note that, for the third test period (99-100 days after application), the average control efficiency was found to be higher than at the second period (50-51 days after application). This unexpected behavior is believed to be due to the fact that cold wintertime controlled emission levels were compared against uncontrolled emission obtained during a much warmer period. To better reflect the control efficiency at any given time, the decision was made to base control efficiency values on uncontrolled emissions measured during each test period.

Table 2. Average Control Efficiency Values for Method Comparison

| | | Average Control Efficiency (%) Reported | | |
|---|---|---|---|---|
| Test Period | Days After Treatment | Total Particulate | PM-10 | PM-2.5 |
| 1 | 22-23 | 68 | 73 | 80 |
| 2 | 50-51 | 58 | 70 | 66 |
| 3 | 99-100 | 76 | 71 | 94 |

The field test comparison showed that

- The mobile dust sampler, operating over a fixed distance of 500 ft, may be used to develop relative control effectiveness information for TP, PM-10, and PM-2.5.
- Mobile sampler results for all three particle size ranges are highly correlated with results derived from exposure profiling measurements. There is approximately a linear relationship between the two methods.
- Control effectiveness values based on mobile sampling are highly correlated with control efficiency values developed with exposure profiling test data. The correlation is significant at the 1% level.
- The mobile test method should be revised to include measurements of uncontrolled emissions during each test period. Control efficiency values should be based on the uncontrolled emission levels measured during individual field campaigns.

**Field Evaluations of Road Dust Suppressants**

Based on the success from the field comparison[6], the mobile sampler was subsequently used in a field study of dust suppressant performance on unpaved roads at Fort Leonard Wood (FLW), Missouri, and on a public unpaved road in Maricopa County (MC), Arizona. These field investigations were conducted as part of EPA’s Environmental Technology Verification (ETV) program and the Air Pollution Control

Technology Verification Center (APCTVC). Research Triangle Institute (RTI) served as EPA's verification partner in this effort and MRI was RTI's testing subcontractor.

The field test program was designed by MRI and RTI to evaluate the performance of five dust suppressant products manufactured or distributed by three firms. The goal of each test was to measure the performance of the products illustrated in Table 3, relative to uncontrolled sections of road over an approximate 1-year period. Table 3 also gives the Internet addresses for each of the test reports. The reports were kept separate to discourage cross comparisons without studying the details of road surface treatment procedures for each dust suppressant.

Table 3. EPA/ETV-Sponsored Field Tests of Road Dust Suppressants
Using the MRI On-Board Monitor[7]

| Dust Suppressant | Test Location*/Date | EPA/ETV Verification Test Report |
|---|---|---|
| EK-35, Midwest Industrial Supply, Inc. | FLW Oct 2002<br>FLW May 2003<br>FLW Oct 2003<br>MC May 2003<br>MC Aug 2003 | http://www.epa.gov/etv/pubs/600r05128.pdf |
| EnviroKleen, Midwest Industrial Supply, Inc. | FLW Oct 2002<br>FLW May 2003<br>FLW Oct 2003<br>MC May 2003<br>MC Aug 2003 | http://www.epa.gov/etv/pubs/600r05134.pdf |
| DustGard, North American Salt Co. | FLW Oct 2002<br>FLW May 2003<br>FLW Oct 2003 | http://www.epa.gov/etv/pubs/600r05127.pdf |
| PetroTac, SynTech Products Corp. | FLW Oct 2002<br>FLW May 2003<br>FLW Oct 2003 | http://www.epa.gov/etv/pubs/600r05135.pdf |
| TechSuppress, SynTech Products Corp. | FLW Oct 2002<br>FLW May 2003<br>FLW Oct 2003 | http://www.epa.gov/etv/pubs/600r05129.pdf |

* FLW—Fort Leonard Wood, MO
* MC—Maricopa County, AZ

The schedule of activities during the EPA/ETV test program is shown in Table 2.

Table 2. Schedule of Activities during EPA/ETV Test Program

| Date | Location | Activity |
|---|---|---|
| Early 2001 | Multiple | Stakeholder meetings |
| Fall 2001 | FLW | Preliminary tests to develop a cost-effective technique to measure the relative performance of seven dust suppressant products |

| | | |
|---|---|---|
| March 2002 | Multiple | Site survey and vendor meetings |
| Oct 2002—July 2003 | Kansas City/RTP, NC | Test/QA Plans |
| June 2002 | FLW<br>MC | Initial treatments of selected unpaved road segments with dust suppressants |
| 2002-2003 | FLW | Quarterly tests of performance efficiency—five dust suppressants from three vendors |
| 2003 | MC | Quarterly tests of performance efficiency—two dust suppressants from one vendor |
| Winter 2004 | Kansas City/RTP, NC | Test analysis |
| 2005/2006 | Kansas City/RTP, NC | Verification reports |

Test sections at both the Fort Leonard Wood and the Arizona locations were initially treated with dust suppressants during June 2002. Tests were planned at quarterly intervals for a period of one year after application. In keeping with the findings from the three-month method comparison study at Fort Leonard Wood, uncontrolled tests were conducted during each field campaign. Furthermore, all control efficiency values were to be based on five replicate measurements made on both the treated and uncontrolled surfaces.

**Conclusions**

A new on-board mobile monitoring method was developed for reliable testing of the performance of dust suppressants for unpaved roads. The new method was shown to correlate with the traditional standard test method known as roadside plume "exposure profiling." The mobile monitoring method characterizes a full segment of treated road segments, as opposed to depending on the selection of representative points of the road for application of the traditional method, and at a fraction of the cost of implementing the traditional method. The new method was verified and accepted as a standard test method for EPA's ETV program for evaluating commercially available dust control technologies.

The on-board mobile monitoring method was used to test the performance of five chemical dust suppressants for unpaved roads. The products were tested on base roads within the Ft. Leonard Wood in southeast Missouri, and on a public road in Maricopa County, Arizona, near Phoenix. The test reports are available on the Internet. Because of some differences in application methods and frequencies, no overall comparison report for the five products was prepared under the ETV program.

## References


1. Sanders, T. G., et al., "Relative Effectiveness of Road Dust Suppressants," *Journal of Transportation Engineering*, Vol. 123, No. 5, pp. 393-397, September/October 1997.

2. Sanders, T. G., and J. Q. Addo, "Experimental Road Dust Measurement Device," *Journal of Transportation Engineering*, Vol. 126, No. 6, pp. 530-535, November/ December 2000.

3. Midwest Research Institute. "Characterization of PM Emissions From Controlled Construction Activities: Mud/Dirt Carryout," EPA Contract 68D7002, Work Assignment 3-07, February 2001.

4. Baxter, T. E., D. D. Lane, C. Cowherd, Jr., and F. Pendleton, "Calibration of a Cyclone for Monitoring Inhalable Particulates," *Journal of Environmental Engineering*, 112(3), 468 (1986).

5. Midwest Research Institute. "Evaluation of a Mobile Sampler to Characterize Unpaved Road Dust Palliatives," final report prepared for the US Army Construction Engineering Research Laboratory, CERL Order No. DACA42-01-F-0062, MRI Project No. 110144, August 5, 2002.

6. ETV. 2002. Reports of 3-Month Test of Dust Suppression Products, Preliminary Testing. RTI International, Research Triangle Park, NC and Midwest Research Institute, Kansas City, MO. November. http://etv.rti.org/apct/documents.cfm

7. Midwest Research Institute and Research Triangle Institute. EPA/ETV Verification Test Reports and Statements for each of five dust suppression products. Available at http://www.epa.gov/etv/vt-apc.html#dsssp. Cited on October 6, 2008.