November 2002

Environmental Technology Verification

Report of 3-Month Test of Dust Suppression Products - Preliminary Testing

Midwest Industrial Supply, Inc.
EK®35

Prepared by

MRI
Midwest Research Institute

RTI
INTERNATIONAL

Under a Cooperative Agreement with

U. S. Environmental Protection Agency

EPA

ETV ETV ETV

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EPA Cooperative Agreement No. CR82615201-3

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Notice

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Availability of Report

Copies of the public Verification Report are available from

1. Research Triangle Institute
   P.O. Box 12194
   Research Triangle Park, NC 27709-2194

   Web site: http://etv.rti.org/apct/documents.cfm

2. USEPA/APPCD
   MD-4
   Research Triangle Park, NC 27711

   Web site: http://www.epa.gov/etv/verifications/verification-index.html

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Abstract

Dust suppressant products used to control particulate emission from unpaved surfaces are among the technologies evaluated by the Air Pollution Control Technology (APCT) Environmental Technology Verification (ETV) Program. The APCT program developed the *Generic Verification Protocol for Dust Suppressants and Soil Stabilization Products* (GVP) to provide guidance on the verification testing of specific dust suppressant products. The critical performance factor for dust suppressant verification is the dust control efficiency, specifically, how the dust control efficiency decays over time following application of the dust suppressant. Two particle size fractions were evaluated: particulate matter less than 10 micrometers in aerodynamic diameter (PM_{10}) and particulate matter less than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$). In addition, total particulate (TP) was measured. The GVP was developed by RTI and MRI, with input and review by a technical panel of experts, and approval by the U.S. Environmental Protection Agency (EPA). The protocol states the critical data quality objectives for verification of a dust suppressant's performance as well as other noncritical (but still important) performance parameter measurements.

Midwest Industrial Supply, Inc., submitted the EK®35 dust suppressant to the APCT ETV Program for testing. A test/quality assurance (QA) plan, prepared in accordance with the GVP, addressed the site-specific issues associated with this 3-month test. The testing was conducted during the 3-month period from October 20, 2001, to January 27, 2002, at the drivers course in Fort Leonard Wood, Missouri. This was a preliminary test program and will be followed by a 1-year test of product performance. The dust control efficiency of this product, based on both the mobile sampler and the profiling method, remained above 85 percent (with most values above 90 percent) during all test series. Other important test conditions were also measured and documented. A comparison was also made between alternative dust emission measurement methods (exposure profiling and mobile dust sampling). This comparison is documented in Reference 3 and complete documentation on this test is contained in References 1 and 2.

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List of Acronyms/abbreviations

APCT	air pollution control technology
CE	control efficiency
cfm	cubic feet per minute
cm	centimeters
DAS	data acquisition system
DC	drivers course
DQO	data quality objective
EPA	Environmental Protection Agency
ETV	environmental technology verification
FLW	Fort Leonard Wood
ft	feet
g	grams
gal	gallons
GVP	generic verification protocol
hi-vol	high volume
hr	hours
in	inches
kg	kilograms
km	kilometers
kph	kilometers per hour
L	liters
Lpm	liters per minute
lb	pounds
m	meters
mg	milligrams
ml	milliliters
mph	miles per hour
MRI	Midwest Research Institute
MSDS	material safety data sheet
PM	particulate matter
PM_{10}	particulate matter equal to or less than 10 micrometers in aerodynamic diameter
$PM_{2.5}$	particulate matter equal to or less than 2.5 micrometers in aerodynamic diameter
QA	quality assurance
QC	quality control
RMSE	root mean square error
RSD	relative standard deviation
RTI	Research Triangle Institute
s	seconds
SOP	standard operating procedure
TP	total particulate
µg	micrograms
yd	yards

1.0 Introduction

The objective of the Air Pollution Control Technology (APCT) Environmental Technology Verification (ETV) Program is to verify, with high data quality, the performance of air pollution control technologies. A subset of air pollution control technologies is products used to control dust emissions from unpaved roads. Dust suppressant products are designed to alter the roadway by lightly cementing the particles together, either by increasing the particles' weight so that they are less likely to move under traffic or wind or by forming a surface that attracts and retains moisture. Control of dust emissions from unpaved roads is of increasing interest, particularly related to attainment of the ambient particulate matter (PM) standard. The U.S. Environmental Protection Agency (EPA) recently issued a new ambient standard for particulate matter that specifies new air quality levels for particulate matter less than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$).

A field test program was designed by Research Triangle Institute (RTI) and Midwest Research Institute (MRI) to evaluate the performance of dust suppressant products. Seven dust suppressants, manufactured/distributed by three firms, were the subject of this test. One of those dust suppressants was EK®35 developed by Midwest Industrial Supply, Incorporated of Canton, Ohio. The host facility for the field test program was Fort Leonard Wood (FLW), Missouri, a U.S. Army base. The test site at FLW was the drivers course used to train recruits to drive heavy vehicles.

A Test/ quality assurance (QA) plan for the field testing was developed and approved by the EPA on October 3, 2001.[1] The goal of the test is to measure the performance of the products relative to uncontrolled sections of road. A comparison is also made between alternative dust emission measurement methods (exposure profiling and mobile dust sampling). Field testing was conducted over a 3-month period from October 20, 2001 to January 27, 2002. This was a preliminary test in this program to verify the performance of dust suppressant and soil stabilization products. It will be followed by a more thorough 1-year test of product performance.

A description of the EK®35 dust suppressant is presented in Section 2. The procedures and methods used for the test are discussed in Section 3. The conditions over which the test was conducted are presented in Section 4. The results of the test are summarized and discussed in Section 5, and references are presented in Section 6.

This report contains only summary information and data related to the dust control efficiency measured for EK®35 using the mobile dust sampler. Complete documentation of the test results is provided in a separate data package.[2] This documentation report includes the raw test data from product testing and supplemental testing, equipment calibration results, and QA/ quality control (QC) activities and results for the 3-month FLW test program. No verification statements were prepared for the products tested during the 3-month test program at FLW because is was a preliminary program designed, in part, to correlate exposure profiling measurements to mobile dust sampling measurements so that the mobile dust sampling method could be used alone in future test programs. A separate report that documents the correlation between exposure profiling measurements and mobile dust sampler measurements (which was used to calculate the control efficiencies in this report) has been prepared.[3]

2.0 Description and Identification of Product

The following description was provided by the vendor.

The Midwest Industrial Supply, Inc. EK®35 is an intense use continuous life dust control agent and a synthetic fluid with a proprietary ingredient formulation. It is supplied as a ready-to-use liquid that can be sprayed directly over surfaces such as dirt roads. The material safety data sheet (MSDS) for EK®35 indicates that it is "non-hazardous" and that, when applied properly, EK®35 "is not known to pose any ecological problems." A copy of the MSDS is retained in the project files.

3.0 Procedures and Methods Used in Testing

The generic verification protocol (GVP) for testing dust suppressants established the guidelines for the verification test design, the data quality objective (DQO) for the primary verification parameter, and the test methods to be used.[4] The primary verification parameter for this verification test is dust suppressant control efficiency (CE). This section details the test design and the test methods used for the verification test of Midwest Industrial Supply's EK®35 dust suppressant.

3.1 Test Design

This test program is designed to determine the CE of dust suppressants applied to unpaved roads. The test approach is to measure the source emission strength of both the treated and untreated unpaved road surfaces. The uncontrolled testing was performed on a separate (but similar) section of the test road from the controlled test. Road conditions and any potential effects from ambient conditions and human intervention were monitored.

The test on the uncontrolled surface was conducted once (triplicate measurements). Testing of the dust suppressant CE was conducted three times (once per month) over the 3-month test campaign. Duplicate measurements were made for each of the three CE tests and the results are presented relative to time.

3.2 Sampling Methods

Table 1 lists the measurement methods used.

Table 1. Measurement Methods

Factor to Be Verified	Parameter to Be Measured	Measurement Method	Frequency
Dust suppressant control efficiency relative to uncontrolled emissions	Uncontrolled dust emissions	Mobile dust sampling[a]	Once (triplicate test runs)
	Controlled dust emissions	Mobile dust sampling[a]	Thrice (duplicate test runs)
Dust suppressant application intensity	Number of sampling pans	Recordkeeping	Once/treatment
	Sampling pan tare mass/final mass	Balance	Once/treatment
	Sampling pan area	Measuring tape	Once/treatment
	Material density	Graduated cylinder and balance	Once/treatment
Product application resources	Description of equipment	Recordkeeping	Once/treatment
	Labor	Recordkeeping	Once/treatment
Method of application of product	Amount of water added to product	Recordkeeping	Once/treatment
	How each product was applied		
Climatic conditions during dust emission measurement	Ambient temperature	Thermometer	Thrice (duplicates)
	Wind speed and direction	Wind station	
Road surface samples	Silt loading	Dry sieving[4,5]	Once/day during testing
	Moisture content	Weight loss test[4,5]	Once/day during testing
Traffic	Vehicle type Vehicle weight Number of axles Vehicle passes	FLW recordkeeping	During training activities and tests
Size of uncontrolled and controlled test sections	Length and width	Measuring device	Once
Area climatic conditions	Wind speed and direction, rainfall, and ambient temperature	Local records of climatic conditions	Continually over test

a - The Test/QA plan referred to the mobile dust sampler as an on-board sampler.

3.2.1 Sampling Locations

Figure 1 shows the test site and test sections used during testing of dust suppressants. The test site is located along the drivers course (DC) in the downrange area of Fort Leonard Wood, Missouri. The DC is a three-mile long serpentine unpaved road with one-way traffic. The test sections were separated by a distance to avoid cross-contamination from one treated surface to another. The numbers in the diagram refer to the test sections. Sampling using the profiling method was performed on those sections indicated with a "P". Midwest Industrial Supply's EK®35 was tested on test section 1P.

The DC is used to train Army recruits to drive trucks and other wheeled vehicles over winding roads. The test site was exposed to two sets of traffic during the field test: (1) long-term, repeated travel by heavy Army vehicles during the training day and (2) "captive" light truck passes made by MRI during distinct testing periods. To avoid interference with the Army's training programs, testing was performed after normal daylight training hours or on weekends.

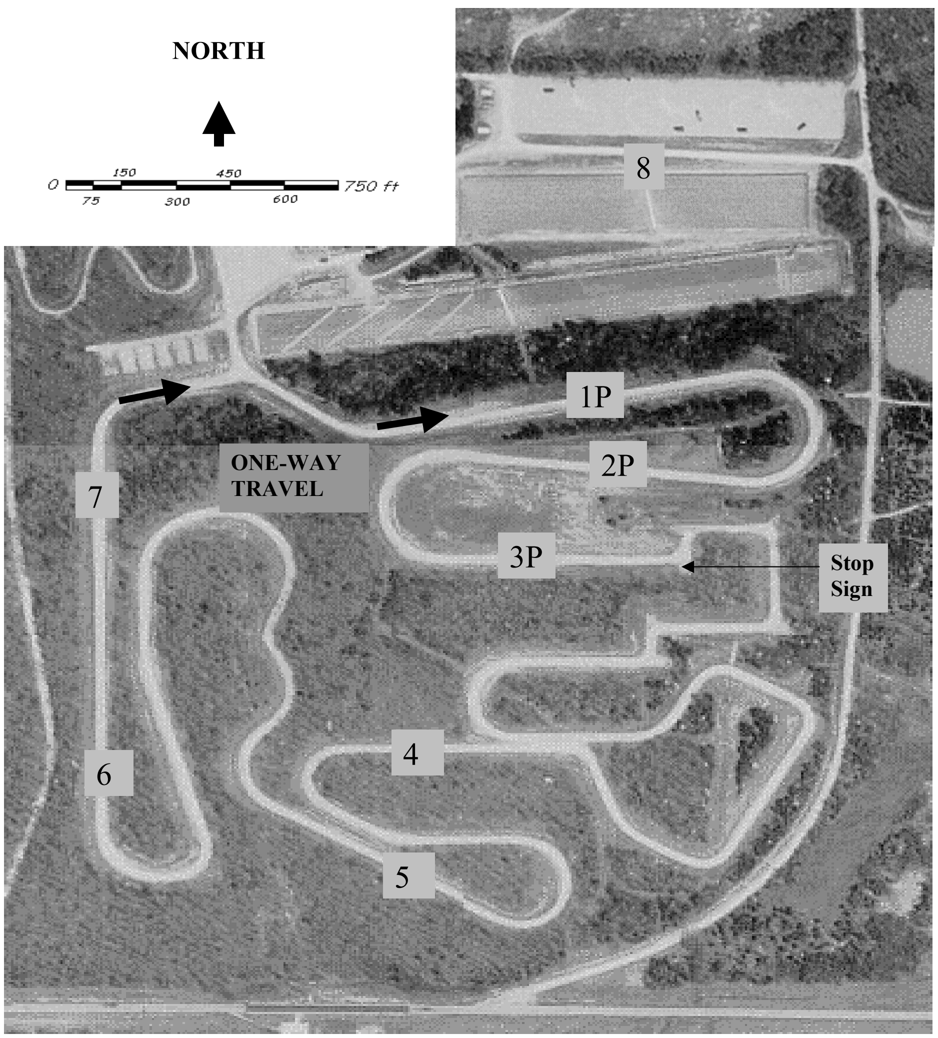

Figure 1. Location of Test Sites.

3.2.2 Sample Collection and Handling

Mobile Dust Sampling. Mobile dust sampling is described in Section B2.2 of the Test/QA plan. The air sampling device consists of a high volume (hi-vol) air sampler with one sampler for particulate matter less than 10 micrometers in aerodynamic diameter (PM_{10}) (a cyclone preseparator) and one $PM_{2.5}$ sampler. Total particulate (TP), PM_{10}, and $PM_{2.5}$ samples were collected and analyzed. The hi-vol sampler was mounted on a beam behind a pickup truck and was located above the heaviest portion of the dust plume, where it sampled material that is windblown. The truck was driven at a constant speed of 40 kilometers per hour (kph) [25 miles per hour (mph)]. Depending on the anticipated level of control, 6 to 24 trips over 150 m (500 ft) of the test sections (see Section 4.1 for the total length and width of the test sections) were completed for each test run.

A background PM sampler was also operated in an open area between Sections 2 and 3 of the test road. It was operated throughout the test days except during periods when mobile sampling was conducted on test sections immediately upwind of the background sampler. It was covered during those periods and restarted after tests on the upwind section were completed. No other traffic was on the test road upwind of the background sampler during its operation.

Visible Emissions. Visible emission observations were made using Michigan Method 9D.[5]

Surface Sampling. MRI collected surface samples from the test section on the days that air sampling occurred. The samples were analyzed for both moisture and silt. Sample collection and analysis conform to EPA guidance in Appendices C.1 and C.2, respectively, to AP-42.[6,7]

Ambient and Service Environment Records. The CE achieved by a dust suppressant depends on several factors. These factors include how the suppressant was applied, service environment or vehicle traffic, and the meteorological conditions experienced during testing. Training traffic over the DC from the time that suppressants were first applied through the end of testing was provided by FLW. Ambient meteorological data for the testing period were provided by the Army and its contractors from nearby meteorological monitoring stations. These records include daily precipitation, minimum and maximum temperatures, and wind speed and direction. See section 4.1.2.

Dust Suppressant Application Intensities. The application intensity, or rate, was determined following the procedures in Section B.2.2.6 of the Test/QA plan. The application intensity for each product was recorded in the field notebook and project files along with data forms and photos of the application event. This information is discussed in Section 4.2.

Sample Handling. Sample integrity was maintained by following the sample handling procedures in Section B3 of the Test/QA plan. Prior to and following the field testing, PM filters and PM samples were labeled, weighed, and stored according to these precise procedures. Surface material samples were also labeled and stored according to specific procedures discussed in Section B3 of the Test/QA plan. Complete information on all samples can be found in the data package.

3.2.3 Sample Analysis

All analytical methods required for this testing program are gravimetric methods in which the final and tare weight measurements affect the CE determinations. Documented procedures were followed for all sample-related weighing; the specific procedures are described in Section B4 of the Test/QA plan. Full information on all samples can be found in the data package.

3.2.4 Quality Control

Specific QC procedures were followed for this testing program. These QC procedures are identified in the tables in Section B5 of the Test/QA plan. Quality control procedures for the sampling media (PM filters) are listed in Table 5 of the Test/QA plan; QC for the sampling equipment are listed in Table 6 of the plan, and QC procedures for miscellaneous instrumentation are listed in Table 7 of the plan. The operation, inspection, and maintenance requirements for sampling equipment are included in Table 6 of the Test/QA plan. Calibration and frequency requirements for the balances used for mass measurements, for air samples, and for miscellaneous instruments are provided in Section B7 of the Test/QA plan. The primary and secondary volumetric standards for calibration of hi-vol samplers' flow rates are also discussed in Section B7.

The primary supplies and consumables necessary for the field test included air filters and collection media. Prior to stamping and initial weighing, each filter was visually inspected and was discarded if any pin-holes, tears, or other damage was found.

3.3 Data Acquisition and Data Management

Data acquisition and management includes activities from the initial pretest QA steps through long-term data storage, and these activities are discussed in detail in Section B10 of the Test/QA plan. Data for these tests were collected by the data acquisition system (DAS) and by manually recording in a lab notebook; printouts from the DAS were added to the lab notebook. After the field sampling was completed, MRI made a copy of all data and reviewed the data for completeness and errors.

All test data, calibration data, certificates of calibration, assessment reports, and test reports will be retained by MRI for a period of not less than 7 years. Raw test data, equipment calibration results, and QA/QC activities and results for the 3-month FLW test program are included in a separate document.[2]

4.0 Test Conditions

4.1 Test Site Conditions

Figure 1 in Section 3.2.1 of this report shows the test site and test sections used during dust suppressant testing. Test section 1P was used for testing of Midwest Industrial Supply's EK®35. The uncontrolled test measurements were conducted on test section 2P before section 1P was treated with dust suppressant. Test sections 1P and 2P are each 230 m (750 ft) long and approximately 8.5 m (28 ft) wide (including the shoulders). The test period lasted from October 20, 2001, to January 27, 2002.

4.1.1 Traffic

All sections of the test site were exposed to two sets of traffic during the field test – long-term, repeated travel by heavy Army vehicles and incidental traffic related to distinct testing events. Table 2 describes the traffic traveling over the test site. Note that the Army vehicles carry loads, and the vehicle size and mass were provided by the Army.

The test vehicle was a rental unit and had two types of tires: Goodyear Wranglers on the passenger side and WalMart Liberators on the drivers side.

4.1.2 Area Climatic Conditions

The climatic and atmospheric conditions and, especially, soil moisture may affect the performance of dust suppressant products. Ambient meteorological data were supplied for the Bailey site, which is located approximately 4 km (2.5 miles) west of the test site, for the 3-month test period. Precipitation data were supplied for the Forney airport, which is located within FLW, approximately 6 km (3.7 miles) north-northeast of the test site. Table 3 summarizes weekly minimum, maximum, and average temperatures and wind speeds, based on all readings for the week. Precipitation totals are also provided in Table 3. Figure 2 presents data on the wind direction for the 3-month testing period.

4.1.3 Background Particulate Concentration

During all tests series the measured TP, PM_{10}, and $PM_{2.5}$ background concentrations were below 30 µg/m^3. Based on a typical sampling time of 30 minutes for a mobile sampling test and the nominal sampling rates, which were 1133 Lpm (40 cfm) for the high-vol cyclone and 16.7 Lpm for the unit from URG Company, the background particulate level would account for no more than 1.0 mg (0.015 grains) of PM_{10} or TP sample mass or 0.015 mg (0.00023 grains) for the $PM_{2.5}$ sample mass. These maximum background contributions are roughly the same magnitude as the blank corrections applied to the test results.

Table 2. Test Site Traffic

Vehicle type	Approximate vehicle mass (weight), kg (lb)	No. of wheels	No. vehicle passes during 3-month test	Typical speed, kph (mph)
Army vehicles (naturally-occurring traffic)				
5-ton cargo trucks	9,500 (21,000)	6	1,617	16 (10)
2.5-ton cargo trucks	8,600 (19,000)	4	1,661	16 (10)
Sport-utility vehicle (Chevy Blazer)	1,800 (3,900)	4	418	16 (10)
Test vehicle				
Truck (Ford F-150)	1,800 (4,000)	4	400[a]	40 (25)

[a]Approximate value based on mobile test passes. An insignificant amount of exposure profiling test traffic and incidental traffic related to sampling on other test sections is not included.

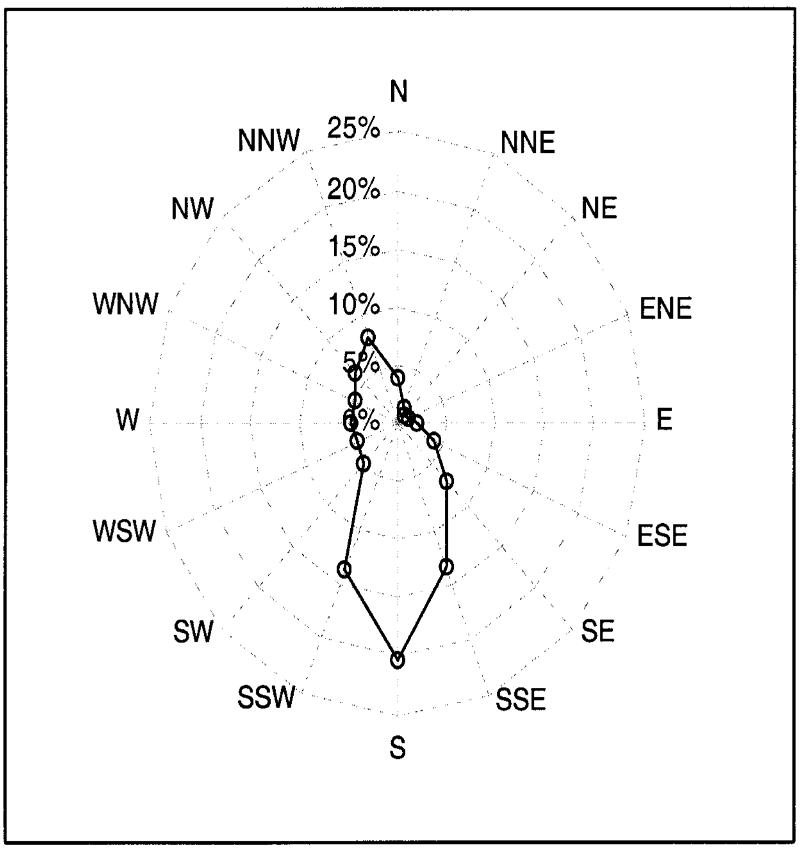

Figure 2. Wind Rose Showing Wind Direction During 3-month Test Period

Table 3. Temperature, Precipitation and Wind Data During 3-month Test Period at FLW

Week no.[a]	Dates	Temperature, ºC			Temperature, ºF			Precipitation total for week, cm (in)	Wind speed, m/s			Wind speed, mph		
		min	max	average	min	max	average		min	max	average	min	max	average
1	10/21-10/27/01	-6.7	25	13	20	76	56	0.46 (0.18)	0.134	9.510	3.119	0.300	21.27	6.977
2	10/28-11/3	-0.47	23	14	31	74	58	1.2 (0.46)	0.134	10.29	3.317	0.300	23.02	7.421
3	11/4-11/10	-5.2	24	11	23	75	52	0 (0)	0.134	5.910	1.500	0.300	13.22	3.356
4	11/11-11/17	-1.7	23	13	29	74	55	0 (0)	0.134	6.921	1.805	0.300	15.48	4.037
5	11/18-11/24	-7.4	21	10	19	69	49	3.6 (1.4)	0.134	9.580	3.528	0.300	21.43	7.893
6	11/25-12/1	-1.8	17	5.6	29	62	42	1.4 (0.55)	0.134	8.760	2.703	0.300	19.60	6.046
7	12/2-12/8	-3.2	22	12	26	72	53	0.051 (0.020)	0.134	9.510	3.145	0.300	21.27	7.035
8	12/9-12/15	-10	18	4.4	14	64	40	2.9 (1.1)	0.134	11.52	2.148	0.300	25.77	4.805
9	12/16-12/22	-6.2	17	5.5	21	62	42	2.9 (1.1)	0.134	9.630	3.009	0.300	21.54	6.732
10	12/23-12/29	-14	7.9	-3.4	6.2	46	26	0 (0)	0.134	7.690	2.623	0.300	17.20	5.868
11	12/30-1/5/02	-18	5.9	-7.0	-0.60	43	19	0 (0)	0.134	6.026	1.685	0.300	13.48	3.770
12	1/6-1/12	-1.5	27	14	29	80	56	0 (0)	0.134	6.886	1.886	0.300	15.40	4.219
13	1/13-1/19	-0.066	22	14	32	72	57	0.30 (0.12)	0.134	10.28	2.908	0.300	23.00	6.504
14	1/20-1/26	-10	23	4.7	15	74	40	1.1 (0.43)	0.134	8.990	3.223	0.300	20.11	7.210

[a]Only full weeks from Sunday to Saturday are included in the table. The EK®35 was applied to test section 1P on October 20, 2001. The temperature range (average) on October 20 was 7.7-24 (16)ºC, or 46-75 (61)ºF; there was no precipitation; and the wind speed range (average) was 0.134-5.846 (2.140) m/s, or 0.300-13.08 (4.788) mph. The last test occurred on January 27, 2002. The temperature range (average) on January 27 was 3.2-18 (10)ºC, or 38-64 (51)ºF; there was no precipitation; and the wind speed range (average) was 1.33-11.19 (6.452) m/s, or 1.850-15.55 (8.969) mph. The total precipitation for the period between the uncontrolled test (10/07/01) and the product application (10/20/01) was 2.9 cm (1.1 in).

4.2 Application of Dust Suppressant

MRI observed and documented all steps in the application of EK®35 to the road test section. The product was applied only once at the start of the 3-month test period. Midwest Industrial Supply applied EK®35 to test section 1P on October 20, 2001 at 1609 hours and completed the application to the 230 m (750-ft) section by 1700. As EK®35 is available in ready-to-use liquid form, no water was mixed with it for application. The density of the product as applied was 0.90 g/ml (7.5 lb/gal). The product was applied to the test section surface by a spray truck in four application passes, with each pass consisting of separate 3.7-m (12-ft) wide spray swaths in each direction. The test section was allowed to cure for approximately 37 hours (i.e., 1700 hr on Saturday until 0800 hr on Monday) without vehicle traffic. Although several people were on-site to oversee and monitor the application, approximately 1 man-hour (i.e., 1 driver for 1 hour) was required to apply the EK®35 to the 230-m (750-ft) long test section surface in four passes.

Table 4 presents the application intensity as determined through use of 12.7 cm x 12.7 cm (161 cm^2) (5 in x 5 in, or 25 in^2) sampling pans located as a grid three rows wide along the test section as the EK®35 was applied. None of the sampling pans were crushed by the spray truck. There were no discernible differences in product application intensity from one side of the road to the other or from one end of the test section to the other. Midwest Industrial Supply also applied heavy amounts of their Road Pro NT dust suppressant product on the buffers at the beginning and end of test section 1P.

Figure 3. Application of EK®35.

Table 4. Product Application Intensity

Sampling Pan ID	Mass of liquid collected, g	Amount of EK®35 applied, L/m^2 (gal/yd^2)
A1	31	2.1 (0.46)
A2	29	2.0 (0.44)
A3	27	1.9 (0.42)
A4	27	1.9 (0.42)
A5	26	1.8 (0.40)
A6	26	1.8 (0.40)
A7	30	2.1 (0.46)
A8	32	2.2 (0.49)
Mean [standard deviation]	29 [2.3]	2.0 [0.16] (0.44 [0.04])

4.3 Conditions During Dust Suppressant Testing

Table 5 presents the dates and times when dust suppressant testing was conducted on the uncontrolled test section 2P and the controlled test section 1P. Two road surface samples were collected on the days when air sampling was conducted. The surface samples were analyzed for moisture and silt (i.e., fraction passing 200 mesh upon dry sieving). Table 5 presents the average moisture content and silt loading results for the surface samples collected from test sections 1P and 2P. Table 5 also presents the climatic conditions during the dust emissions tests. These data were obtained from the Bailey site located at FLW.

Table 5. Conditions During Dust Suppressant Testing

Run	Test date	Time	Road surface samples		Climatic conditions during dust emission measurement		
			Moisture content, %	Silt loading, g/m^2	Ambient Temperature, °C (°F)	Wind speed, m/s (mph)	Predominant wind direction
Uncontrolled Tests -- Test Section 2P							
CGO-01	10/07/01	1152-1158	0.17	367.5	15.3 (59.5)	4.1 (9.2)	S
CGO-02	10/07/01	1327-1338			16.8 (62.2)	4.1 (9.2)	SSE
CGO-04	10/07/01	1829-1837			15.5 (59.9)	2.7 (6.1)	SSE
EK®35-controlled Tests -- Test Section 1P							
CGO-41	11/17/01	1553-1620	0.15	0.3	20.9 (69.6)	2.3 (5.1)	SW
CGO-42	11/17/01	1637-1654			20.0 (68.0)	1.0 (2.2)	SSW
CGO-55	12/08/01	1621-1647	0.25	<0.1	6.3 (43.3)	3.1 (6.9)	NW
CGO-56	12/08/01	1700-1725			5.6 (42.0)	2.2 (4.9)	NNW
CGO-75	1/27/02	1039-1112	0.26	1.3	12.2 (54.0)	4.5 (10)	SSW
CGO-76	1/27/02	1121-1145			13.3 (55.9)	5.1 (11)	SSW

5.0 Summary and Discussion of Results

A verification test of Midwest Industrial Supply's EK®35 dust suppressant was conducted from October 19, 2001, to January 27, 2002, in Fort Leonard Wood, Missouri. The purpose of the verification test is to evaluate the dust emissions control performance for the EK®35 dust suppressant. The test was conducted according to a Test/QA plan[1] that was approved by the EPA on October 3, 2001.

The results of the verification test are summarized in Section 5.1. An important part of the verification test was the extensive QA applied to this field test. The results of all the QA and QC checks performed during this verification test are summarized in Section 5.2. A few deviations from the test plan were encountered, and those are discussed in Section 5.3.

5.1 Verification Results

Table 6 presents the results for each test series. The table shows the days after product application, the controlled and uncontrolled emissions values, the resulting control efficiencies, and the uncertainty (half-width of the 90 percent confidence interval) on the efficiency.

Table 6. Data for Verification Test Series

Test Series No.	Time after product application, days	Emission values, mg/1000 ft			Control efficiency (Uncertainty), %		
		TP	PM_{10}	$PM_{2.5}$	TP	PM_{10}	$PM_{2.5}$
Uncontrolled	0	52.2	11.2	2.38			
1	29	1.42	0.32	0.16[b]	97 (0.7)	97 (0.7)	93 (1.9)[b]
2	50	1.30	0.002[b]	0.29[b]	98 (0.6)	100 (0.1)[b]	88 (3.5)[b]
3	100	3.28	0.57	a	94 (1.5)	95 (1.3)	100[a]

[a] Controlled emission value was negative.
[b] Controlled emission value was below estimated detection limit.

The uncontrolled emission values for the Mobile Dust Sampler are means of triplicate measurements and the controlled emission values are means of duplicate measurements. Emission values that were negative and those below detection limits are footnoted in Table 6. Detection limits set at two standard deviations above average filter weighing blank levels were 0.70, 0.23, and 0.66 mg/1000 ft for TP, PM_{10}, and $PM_{2.5}$, respectively. Corresponding efficiencies calculated using these detection limits are 99, 98, and 72% for TP, PM_{10}, and $PM_{2.5}$, respectively. The dust emissions control efficiency is calculated from the following equation.

$$CE = 100 * (e_{um} - e_{cm})/e_{um}$$

where:

CE = control efficiency, percent,
e_{um} = uncontrolled emission value expressed as sample mass divided by the cumulative length of road traveled by the mobile sampler and
e_{cm} = controlled emission value expressed as sample mass divided by the cumulative length of road traveled by the mobile sampler.

Figure 4 shows the variation in control efficiency over time. The control efficiency of this product remained above 85 percent (with most values above 90 percent) during all test series.

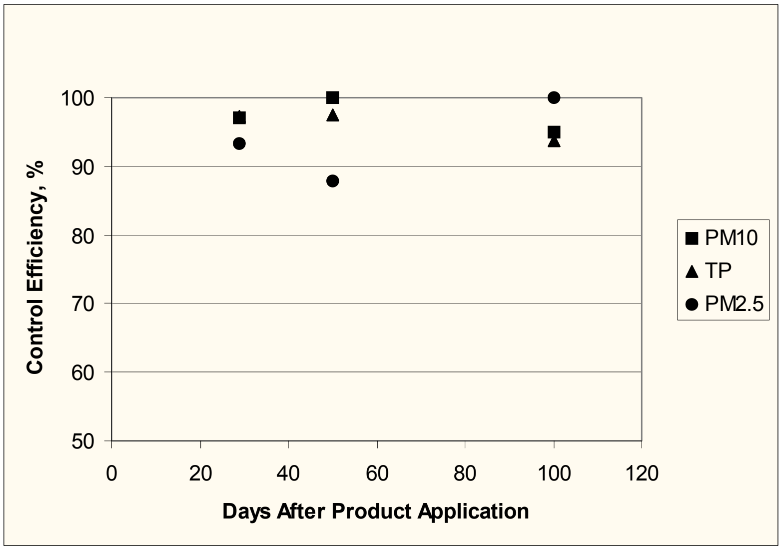

Figure 4. Dust Control Efficiency Over Time.

The uncertainty of the CE values is estimated as the half-width of the 90-percent confidence interval for these values. A small uncertainty indicates that the uncontrolled section measurements had good agreement among themselves as did the corresponding controlled section measurements, and a large uncertainty indicates greater variability of these measurements. The half-widths were calculated by a statistical analysis of variability of the CE values for all products that were tested during the three-month period. SAS statistical analysis software (Base SAS, SAS is a registered trademark of SAS Institute, Cary NC) was used to estimate variability of CE as a function of the CE value.

The calculation of the half-width of the confidence intervals for CE was accomplished by first deriving an algebraic expression that approximates the variance of CE in terms of the component means, variances, and sample sizes. A Taylor series approximation was used. The means and standard deviations of the duplicate measurements (and the time 0 triplicates) were then computed and plotted. These plots clearly showed that standard deviations increased as the (mean) levels increased. It appeared that a relationship of the form s=Bx between the standard deviation (s) and the mean (x) would be adequate for approximating the variance of the measurements. Substitution of this model into the variance expression for CE led to the following: $Var(CE) \approx (5/6)B^2(1-CE)^2$. The constant 5/6 comes from the sum of the reciprocals of the sample sizes. B was estimated as the geometric mean of the relative standard deviations (RSDs). Taking the square root of the Var (CE) yields an estimated standard error for CE. The half-width of the 90% confidence interval on CE was, therefore, computed by multiplying the square root of Var(CE) by the upper 95th percentile of the t distribution with k degrees of freedom. The degrees of freedom, k, was taken to be equal to the number of RSDs upon which the estimated B was based. The formation of confidence intervals in this manner assumes that CE is approximately normally distributed.

5.2 Discussion of QA/QC and QA Statement

QA activities in this dust suppression testing program were designed to meet EPA QA Category III requirements[8]. These requirements are more stringent than apply to a typical emissions test. The following QA and QC were applied:

- A DQO for the dust control efficiency measurement,
- Test method QC and
- An audit of data quality (10 percent of the data) to evaluate all components of the data gathering and management system

The results of each of these QA and QC checks are presented in Sections 5.2.1 through 5.2.3.

5.2.1 Dust Control Efficiency Measurement DQO

The DQO for the dust control efficiency measurement was specified in the Test/QA plan as follows:

> For the dust suppression performance, the root mean square error (RMSE) of the first-order linear regression of CE versus vehicle passes may not exceed 15 percent.

This DQO is calculated as the model RMSE based on a first-order regression of control efficiency vs. vehicle passes or time. These regressions were estimated for each particle size group and each test section, for a total of 18 regressions. The calculated RMSE values ranged from 1.6 to 64. The 15-percent DQO was met for 13 of the 18 values. The RMSE results for test section 1P are 2.4 for TP, 2.6 for PM_{10}, and 5.1 for $PM_{2.5}$.

Based on the overall RMSE and correlation (R^2-values) results, it is clear that a first-order linear model is not appropriate in most instances. In only 6 of the 18 cases does the chosen model approximate the data. In those cases, the DQO of 15 percent is met. The RMSE is an estimate of the standard deviation of the random error in the estimated CE, and its value is highly model dependent. In light of the poor model fits, the RMSE of a first-order regression is not an appropriate DQO.

The RTI quality manager has determined that nonattainment of the data quality objective for the dust control efficiency measurements does not represent a significant deviation from the

Test/QA plan because this 3-month, preliminary test program was designed mainly to evaluate measurement methods for use in future tests rather than fully determine the performance of the dust suppression products.

5.2.2 Comparison of Mobile Dust Sampler with the Profiling Technique Results for Control Efficiency

Table 7 presents the CE results for each test series based on correlation of the mobile sampler results with the profiling results. Reference 4 contains a description of the profiling technique. The table shows the days after product application, the mobile dust sampler control ratios (controlled emissions / uncontrolled emissions), and the resulting control efficiencies.

Table 7. CE Data Based on Correlation to Profiling Technique

Test Series No.	Time after product application, days	Mobile Dust Sampler ratio, M_R			Control efficiency, %		
		TP	PM_{10}	$PM_{2.5}$	TP	PM_{10}	$PM_{2.5}$
1	29	0.027	0.029	0.066	100	100	100
2	50	0.025	0	0.121	100	100	100
3	100	0.063	0.051	0	100	100	100

The value for the Mobile Dust Sampler ratio is a mean of duplicate measurements. The dust emissions control efficiency is calculated from the following equation.

$$CE = 130 - 110\ M_R$$

Where:

CE = control efficiency, percent and

M_R = ratio of controlled to uncontrolled mobile sampler emission rates

This equation was developed by correlating the sampler ratio with control efficiency measurements made with the profiling technique. When the calculated control efficiency using the above equation is above 100 percent, the value is presented as 100 percent. This correlation is documented in a separate report.[3] These results are not used directly to verify control efficiency, but are valuable to show that the mobile sampler verification results compare favorably to the more established profiling technique. The relative magnitude and change in efficiency from test to test are consistent between the two methods. In this case, all results show high efficiencies and there is little change from test to test.

5.2.3 Test Method QC

The test methods used to measure dust control efficiency have specific QC criteria that are listed in Tables 5, 6, and 7 of the Test/QA plan. The method QC criteria ensure the accuracy and stability of the measurement system. All of the QC procedures that are discussed in the Test/QA plan for the sampling media, sampling equipment, and miscellaneous instrumentation were followed. All of the procedures for checking the sampling media were followed, and the accuracy requirements discussed in Table 5 of the Test/QA plan were met. For the sampling equipment, all of the procedures specified in Table 6 of the Test/QA plan were followed and met. The procedures for QC checks of instrumentation were also followed, and each of the requirements in Table 7 of the Test/QA plan were met.

5.2.4 Audits

Independent systematic checks to determine the quality of the data were performed on the activities of this project. These checks include a data audit as described below. This audit and the evaluation of the method's QC data allowed the assessment of the overall quality of the data for this project. MRI's Test Leader managed and reviewed the field data as detailed in Section C of the Test/QA plan.

The data audit, an important component of a total system audit, was completed to determine if systematic errors were introduced. The data audit was performed by randomly selecting approximately 10 percent of the data and following it through the calculations. The scope of the data audit was to verify that the data-handling system was correct and to assess the quality of the data generated. The data review and data audit were conducted in accordance with an MRI standard operating procedure, SOP MRI-0208 – "Review and Audit of Data and Study Reports."

In addition to the data audit, a data review was performed. The data review was conducted to find errors in transposing data from the raw data printouts to the calculation sheets in the Microsoft Excel spreadsheets. Data were reviewed for completeness, and the method QC results were checked for acceptability. The results of the data audit included requests for additional organization and summary of the data; highlighted discrepancies and typographical errors in transposing raw data to the electronic spreadsheets; and alignment of time periods for the wind and emissions data for each run. The MRI Test Leader provided additional summary information and corrected data entries on the electronic spreadsheets.

The MRI Task QA Officer also reviewed the experimental design, the test plan, and procedures as well as personnel qualifications, adequacy and safety of the facilities and equipment, SOPs, and the data management system. The MRI Task QA Officer inspected the analytical activities and determined their adherence to the SOPs and the Test/QA plan. Field test data, instrument calibration data, and other related documentation were reviewed as part of the QA requirement to obtain verifiable data of sufficient quality and quantity. The data packets that were obtained for review included calibration forms, field and laboratory test data as written on data forms and in laboratory notebooks and as recorded by computer systems, and spreadsheets with other data and calculated values. Over 10 percent of the quantitative data obtained from the field were reviewed.

The MRI Task QA Officer issued audit reports on January 2 and March 26, 2002. The first report reviewed data from 2001 only. The second report reviewed new data obtained in December 2001 and January 2002 in addition to a selected rereview of earlier data. The MRI Test Leader responded to the first review comments on January 10, 2002 and the second review comments on April 22, 2002. The major issues discovered during the audits included (1) outliers for wash blank filter weights influenced blank weight correction, and (2) wash filters did not meet audit limits because the SOP does not apply to this type of filter. Resolution of the outlier issue included proving the value was an outlier and removing it before calculating the mean blank weight correction. For the wash filters issue, a corrective action notice was issued in November 2001 prior to QA review, and MRI SOP 8403 is being revised. Several other issues were also discovered during the audits, and each of these issues was corrected or addressed. Resolution of these other issues included providing instructions to staff, completing and initialing data records, clarifying travel distances, and explaining background sampling times.

5.3 Deviations from Test Plan

There were three main deviations from the Test/QA plan:

- A standard, reproducible watering scenario was intended as an alternate to the uncontrolled baseline. Creating and reproducing such a standard watering scenario proved impossible given the need to test in varying weather and soil moisture conditions. Also, the need to test only on weekends and after training hours made it impossible to schedule the Army's watering truck. (Table 2 & 4 of the Test/QA plan).

- Michigan Method 9D was specified in the Test/QA plan for visible emission observations. It was modified by the observer to record the maximum opacity reading that occurred within each 15-second interval rather than the initial reading at the start of each 15-second interval. This modification was made because, during each 15-second interval, there was, at most, a single test vehicle generating a dust plume that would dissipate very quickly. If the normal observation method had been used, there would be many more zero readings. Also, the opacity readings were difficult to make because the plume from a single vehicle was not uniform in nature and would dissipate within seconds. When observing a plume, it was difficult to instantaneously select that part of the plume with the maximum opacity. Fugitive dust observations are not part of "smoke school" training, and the non-steady state characteristics of these fugitive plumes result in different interpretations of opacity. Because of these problems, the visible emission observations were discontinued.(Table 4 of the Test/QA plan).

- The DQO based on a RMSE calculation was judged inappropriate and was not used (see discussion in Section 5.2.1).

Other deviations from the Test/QA plan were as follows.

- Four fewer profiling tests were conducted than planned because of poor weather and unacceptable wind conditions. These data were intended for developing the correlation between profiling and mobile sampler methods. These missing profiling tests were not a problem because, with little degradation in dust control over the test period, they would have only added more data at control levels already characterized. (Tables 2 & 4 of the Test/QA plan).
- Equation 7 in the Test/QA plan was not used to calculate traffic volume, but rather traffic counts were obtained from the Army. (Section B2.2.1 of the Test/QA plan).
- Samples of product for density measurement were obtained from the spray bar tap on the application truck rather than from the sampling pans. (Section B2.2.6 of the Test/QA plan).
- The Test/QA plan indicated the performance data for each product would be plotted versus time and a regression line, using a zero time, 100% control data point, would be calculated. Due to the small amount of data and limited degradation of product performance over the 3-month test, a regression line was judged not meaningful and was not calculated. The control efficiency data were presented versus time. (Section B10.4 of the Test/QA plan).
- The Test/QA plan indicated the performance data for each product would be calculated using a correlation of the mobile sampler results to the profiling results. Due to the large uncertainty in this correlation, direct calculation of efficiency from the mobile sampler results was judged to provide a more certain answer. The correlation was used to show the mobile sampler provides data that is correct relatively, i.e., same rough magnitude and data trends.
- The term "mobile dust sampler" is used in this report while the Test/QA Plan used the term "on-board sampler;" these terms are synonymous. Mobile dust sampler will be used in the future.

The RTI quality manager has determined that none of the main or minor deviations from the Test/QA plan are significant enough to compromise the results of this preliminary test program. The above deviations led to an improved test design and DQO for future verification tests, including use of only the mobile dust sampler to measure performance.

6.0 References

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5. Michigan Department of Environmental Quality, Environmental Assistance Division Clean Air Assistance Program, *Managing Fugitive Dust: A Guide for Compliance with the Air Regulatory Requirements for Particulate Matter Generation*. Lansing, MI, 1994.

6. EPA. *Compilation of Air Pollutant Emission Factors, AP-42, Volume I, Fifth Edition, Appendix C.1, Procedures for Sampling Surface/Bulk Dust Loading.* http://www.epa.gov/ttn/chief/ap42/appendix/app-c1.pdf. Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC. July 1993.

7. EPA. *Compilation of Air Pollutant Emission Factors, AP-42, Volume I, Fifth Edition, Appendix C.2, Procedures for Laboratory Analysis of Sampling Surface/Bulk Dust Loading Samples.* http://www.epa.gov/ttn/chief/ap42/appendix/app-c2.pdf. Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC. July 1993.

8. EPA. *Preparation Aids for the Development of Category III Quality Assurance Project Plans*. EPA-600/8-91-005. Office of Research and Development, February 1991.

Appendix

These pictures were furnished by the vendor.

Figure 5. EK® 35 on Road

Figure 6. Truck with Mobile Sampler on Treated Road