White Deer Creek Road
Dust Suppressant Testing

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EXECUTIVE SUMMARY

The White Deer Creek Road project described here is a joint effort between the Pennsylvania State University's Center for Dirt and Gravel Road Studies, and the PA Bureau of Forestry's Bald Eagle State Forest District. The purpose of this study is to perform a side-by-side comparison of several dust palliatives and application methods in order to test and monitor their performance and longevity. Ten sections of dust suppressants were applied to White Deer Creek Road in western Union County, Pennsylvania. Each treated section of road was approximately 1,500 feet long, with untreated buffer sections of at least 1000 feet in length between all application sites.

Dust collection jars were used to sample the amount of dust generated on all treated and buffer sections of the road over a period of several months after application. The dust collection jars are placed just off of the roadway to collect any dust that is generated by passing cars for a period of 30 days. In an effort to further compare the application sections and develop a simpler method of predicting dust generation, sweep samples were taken on each section monthly. Sweep samples involved the collection of all loose material present on the road surface in a one square foot section in the wheel track.

BACKGROUND

Air quality is an environmental topic of increasing concern. Airborne particulates, or dust, is one of the major contributors to air pollution in less developed areas. The Environmental Protection Agency (EPA) has identified airborne particulates as one of six principal air pollutants. While some atmospheric dust is a natural result of wind and other erosive forces, there are many man-made sources that are contributing excess amounts of dust into the atmosphere. This excess dust generation can adversely affect nearby plants, animals, and even people. EPA estimates show that up to 40% of fugitive dust originates from unpaved roads (*Figure 1*).

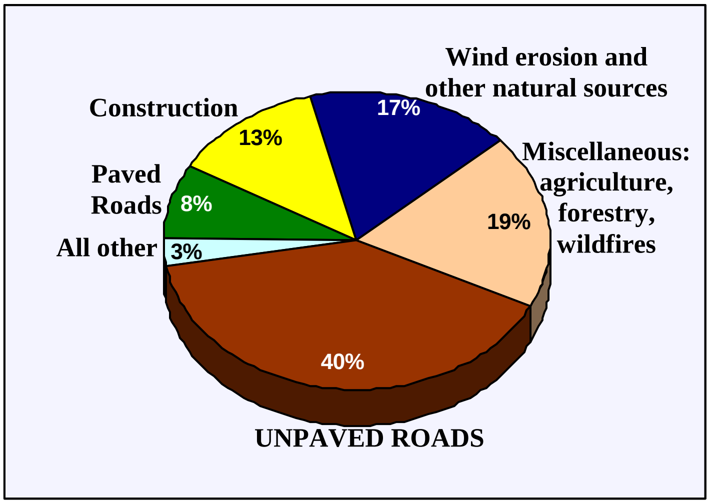


Figure 1. Sources of fugitive dust in the atmosphere.[1] The EPA estimates total fugitive dust emissions at 25 million tons per year. Source: EPA, National Air Quality and Emissions Trends Report, 1997.

The total particulate emissions from stationary sources in 1999 amounted to 1.1 million tons nationally. These stationary particulate sources like boilers, kilns, industrial processes, etc. are the kinds of sources that are principally addressed by the Pennsylvania Department of Environmental Protection's (DEP) Bureau of Air Quality. These stationary sources represent roughly 4% of the 26 million tons per year of total particulates. Unpaved road particulate emissions are estimated to be ten times more by weight than emissions from classic stationary sources of particulates.

An extensive network of unpaved roads throughout the Commonwealth of Pennsylvania provides access for the State's four largest industries of tourism, agriculture, mining, and logging. Pennsylvania has in excess of 21,000 miles of unpaved public roads. Local municipalities and Pennsylvania's Bureau of Forestry own the majority of these roads. In addition to those public roads, thousands more miles of privately owned unpaved roads exist in the form of driveways, field accesses, haul roads, and trails.

There are a number of possible control strategies that are traditionally used to help minimize dust emissions from unpaved roads. The cheapest short-term solution used in many locations is to apply water to the road surface. While inexpensive, results will typically last only a few hours. Traditional oils have been used for dust control in the past with varying degrees of effectiveness and little regard for environmental implications. Another popular variety of dust suppressants are salts such as magnesium chloride and calcium chloride. Salts have the ability to extract moisture out of the air to keep the surface of the road moist. In today's environmentally conscious world, new products are being developed to safely control dust using petroleum emulsions, plastic resins, naturally occurring oils, and other sources while minimizing or eliminating environmental impact. There are several outstanding problems with the use of dust suppressants: 1) The use of dust suppressants is often beyond the financial resources of the responsible parties. 2) The temporary nature of most suppressants requires periodic reapplication. 3) Many of the materials traditionally used as dust suppressants are detrimental to the environment.

Financial costs associated with dust generation cannot be ignored. Not only does the application of dust suppressants cost money, but the road aggregate loss associated with not using dust control costs money as well. Sanders, et al.[4] reports that cost of aggregate replacement necessitated by loss of fine particles to dust can exceed $15,000 per mile per year

Dust control is becoming an increasingly important part of unpaved road maintenance. Excessive dust emissions can be more than a nuisance. Dust can cover roadside plants inhibiting the amount of sunlight they can use. Excessive dust can also lead to health concerns for people who are exposed on a regular basis.

ROAD TREATMENT

SITE SELECTION

White Deer Creek Road is located on the border of Center and Union Counties in the Bald Eagle State Forest in Central Pennsylvania. White Deer Creek Road was chosen for this project for its length and overall uniformity (*Figure 2*). The entire length of road has relatively consistent slope, canopy cover, side slope position, surface material, and drainage characteristics. This overall uniformity was essential to reduce natural variations to measure the effects of each dust suppressant. Approximately eight miles of White Deer Creek Road were used for this project.

Figure 2. White Deer Creek Road

SITE LAYOUT

Ten dust suppressant application sites were identified on White Deer Creek Road. Each application site was approximately 1,500 feet in length. Between each application site was a buffer area of at least 1,500 feet where nothing was applied to the road (*Figure 3*). The dust suppressant application sites were located away from access roads to avoid any possible dust contamination from those roads. Since White Deer Creek is an Exceptional Value waterway and is used as a reference reach for impaired streams in the area, products that had received approval from Pennsylvania's Dirt and Gravel Road Program were used closest to the stream. Products that may have detrimental effects on the environment were placed far from any stream to avoid any possible discharge into the stream. The rest of the products were randomly placed on an application site. (*see Appendix 1 for detailed site map*)

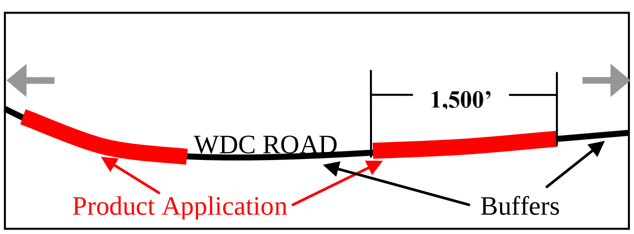


Figure 3. Sample site layout.

ROAD PREPARATION

The Bureau of Forestry grades White Deer Creek Road on an annual basis. The road had been graded earlier in the spring and was in excellent condition prior to the activity described here. The grading technique that is employed in this section of this Forest District is as follows:

1. A single grader pass in each direction pulls the material from the edges of the travel lanes toward the middle of the road forming a windrow.
2. The grader then passes down the center of the road to "spread" the accumulated material.
3. A stone rake is then used to smooth out both travel lanes.

This technique typically develops in areas where native shale or bank run gravel is used as road material. The rake acts as a tool to "groom off" coarse material that naturally comes to the surface during grading operations on these materials. Roads graded with this technique are typically very smooth and have a rounded crown with a fairly flat center. The Bald Eagle road maintenance crew is accomplished with this technique, and produces a very smooth and uniform road.

Several of the vendors expressed a concern about the condition of the road prior to product application. They were concerned that the road was not graded enough. Failure to loosen enough material during the grading operation causes products that are topically applied to be less effective. Many of these products depend on penetration for long-term effectiveness. Several vendors stated that their product was not designed to hold loose unconsolidated material in place. The same grading technique was used on all sections of the road.

Figure 4. Spray application of topical dust suppressants.

Figure 5. Toothed grader blade used on section 6 to incorporate suppressant into road.

SUPPRESSANT APPLICATION

Dust suppressant applications took place on July 9th and 10th of 2001. The dust suppressants were applied as shown in *Table 1*. The dust suppressants were topically applied on sites 1-5, and 8-10. A topical application simply means that the dust suppressant was distributed on the surface of the road according to the manufacturer's standard procedures and application rates (*Figure 3*). Topical applications rely on their ability to penetrate into the road surface.

Sites 6 and 7 were unique in that an attempt was made to mechanically incorporate the dust suppressant into the road material. A "mini-stabilization" was done with Ultrabond 2000 on site 6. This mini-stabilization involved using a grader to incorporate the Ultrabond into the road material (*Figure 5*). Prior to product application and between each of the 2 application passes, the road was turned using a toothed road grader to mix the dust suppressant into the road. A "full-depth stabilization"

Figure 6. – Bomag Road reclaimer used on section 7 to incorporate suppressant into road.

was done on Site 7. The full-depth stabilization utilizes a road reclaimer to grind road material to a depth of 8 inches (*Figure 6*). The road reclaimer functions as a large roto-tiller as it cuts into the road and mixes the material. The road reclaimer was used before product application and between each of the 3 application passes to mix the dust suppressant into the road.

In all cases, the manufacturer was instructed to follow their standard procedures in regards to product application variables such as vehicle speed, application rate, number of passes, etc.

SITE	PRODUCT	TYPE	APPLICATION METHOD	APPLICATION RATE
1	**PETROTAC**	Petroleum Emulsion	topical*	0.57 gal/yd^2 in 3 passes
2	**MAGNESIUM CHLORIDE**	$MgCl_2$	topical	0.50 gal/yd^2 in 2 passes
3	**TECH SUPPRESS**	Resin emulsion	topical	0.65 gal/yd^2 in 3 passes
4	**DUSTKILL**	Soybean Oil	topical	0.25 gal/yd^2 in 1 pass
5	**COHEREX**	Petroleum emulsion	topical	0.75 gal/yd^2 in 3 passes
6	**ULTRABOND 2000**	Paraffin emulsion	mini-stabilization**	1.00 gal/yd^2 in 2 passes
7	**ULTRABOND 2000**	Paraffin emulsion	full-depth stabilization***	1.50 gal/yd^2 in 3 passes
8	**ULTRABOND 2000**	Paraffin emulsion	topical	1.25 gal/yd^2 in 2 passes
9	**SAND AND GRAVEL BINDER**	Paraffin emulsion	topical	0.50 gal/yd^2 in 2 passes
10	**DUSTDOWN**	artificial polymer	topical	0.50 gal/yd^2 in 2 passes

Table 1. Guide to dust suppressant application sites on White Deer Creek Road.

**topical treatments were simply applied to the road surface*.

*** mini-stabilization involves using a grader to incorporate dust suppressant into the road between passes.*

**** Full-depth stabilization uses a road reclaimer to incorporate dust suppressant into the road between passes.*

MONITORING PROCEDURES

DUSTFALL JARS

Figure 7. Typical dust fall jar placement.

BACKGROUND: In order to measure the effectiveness and longevity of each dust suppressant, it was necessary to quantify the volume of dust that was produced on each section of road. The standard method of measuring dust is with "dust fall jars" (ASTM D 1739-98). Each dustfall jar measures five inches in diameter and is seven inches deep. The jars are made of high density polyethylene and coated so dust will not stick to the walls of the jar. A small amount of distilled water (½ inch to 1 inch) is placed in the jars so that strong winds do not blow dust out of the jar. A very small amount of algaecide is included in the water to prevent the growth of algae in the bottles. The water level is periodically checked and refilled if necessary.

The dustfall jars were then mounted about three feet off of the ground and thirty feet from the center of the road. They were allowed to collect dust for a period of thirty days before being collected and replaced. By comparing the amount of dust collected by jars on each section over the same period of time, a comparative analysis can be performed between locations. The photograph in *Figure 7* is an example of a typical dust jar mounted in place.

ASTM standards recommend that jars have a minimum setback of 90 feet from any large objects such as trees or poles. It was not possible to meet these guidelines since White Deer Creek Road is surrounded by forest. Jars were placed in a relatively open area as far away from low hanging trees as possible. A relatively open canopy consisting of about 50% cover over the road was used as a general rule for placing each jar to insure that the section of road being measured by each jar received a similar amount of sunlight. Bank slope was also a factor in jar placement locations. Jars were placed at a location where bank elevation was as close to the road elevation as possible. These factors were all considered in placing the jars to insure equal dust collection opportunity.

PLACEMENT: In order to obtain data for a comparative analysis, two dustfall jars were placed on each of the 10 product application sections and each of the buffer areas in between. One jar was placed on each side of the road to account for variation in wind direction. All jars were mounted approximately three feet off of the ground and thirty feet from the centerline of the road. The jars were placed near the center of each application and buffer site. Actual jar placement varied slightly (less than 200') from the center of the site in some cases in order to place them in an area with relatively consistent canopy cover, vegetation density, and bank slope. *Figure 8* shows the typical placement of dust jars on a section of road.

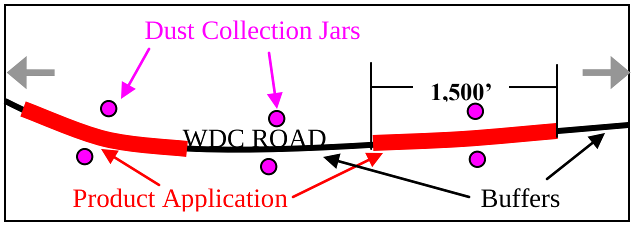


Figure 8. Sample Dustfall jar layout.

In order to measure the amount of background dust that should be expected, three "ambient" dustfall jars were used. These three "ambient" jars were placed in the forest at least 1,500 feet from any road, and were used to measure the general level of dust that is in the area that does not come directly from White Deer Creek Road. Please see the map in Appendix 1 for all jar locations.

The comparative analysis of the 10 dust control products was the main purpose of the dust collection jars. There were, however, other experiments set up at the same time. One experiment was to measure how far dust travels away from the road. The other experiment was to measure the extent to which dust from untreated control sections of road may drift onto treated sections. A brief description of each follows:

Dust Fall Perpendicular to Road

The purpose of this experiment was to determine the extent to which dust traveled away from the road. This experiment was set up on the untreated buffer site between application sites 2 and 3 because that location was generally more open and had a much flatter expanse than any other buffer site. Five different distances were used for this experiment. All jars were placed on the south side of the road to take advantage of the prevailing winds. The five jars were placed at a height of three feet at 30 feet intervals from the center of the road. Jars were located at a distance of 30, 60, 90, 120, and 150 feet from the center of the road (*Figure 9*). By comparing the amount of dust each of these jars collect, we hope to learn details about how far dust travels from the road. See inset on map (*Appendix 1*) for jar locations.

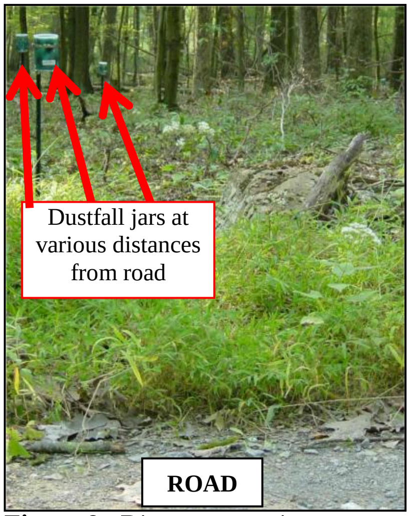


Figure 9. Distance experiment; dust fall jars on buffer site 2-3.

Dust Fall Parallel to Road

The purpose of this experiment was to determine the extent to which dust is carried along the roadway, parallel to the direction of travel. For this experiment, product application site 6, Ultrabond 2000 mini-stabilization was chosen for its uniformity in jar placement opportunities. Five jars were placed at the same height and distance from the road at equal intervals along the western half of site 6. The first jar was placed at the western edge of site 6 at the border between the application and buffer site. The remaining 4 jars were placed at 200' intervals the whole way the center of the application site. By measuring the variations in dust collected by these jars, it can be determined how far dust from the untreated buffer section is drifting onto the jars located on application site 6. This information may be useful for future studies in determining the most economical length of site that can be used without risking contamination from neighboring sites.

SAMPLE COLLECTION:

The dust fall jars were collected on a monthly basis during the fall of 2001 and spring of 2002. During collection, the jars were briefly removed from their stands in the field. Any large organic matter such as insect and leaves was picked out with forceps and rinsed off with distilled water to remove any dust (*Figure 10*). The contents of each dustfall jar were then carefully washed to 500 mL Nalagene™ bottles. Distilled water was used to clean any residue left in the dustfall jars and rinse it into the sample


Figure 10. Contents of a dust fall jar as it was collected in the field.

bottle for return to the lab. The dustfall jars themselves were then thoroughly cleaned and returned to their station in the field.

SAMPLE ANALYSIS: After returning from the field, the sample jars were stored in a refrigerator to further inhibit the growth of algae until testing was complete. The main function of the analysis performed on all samples was to determine the amount of dust that they contained. Total solids were determined as specified in ASTM D1735. The first step in this process was to run the sample through a filter. The material caught on the filter paper (watchman No. 40 ashless) was then dried at 105°C and weighed.

Since much of the material caught in the jars was organic, a Loss on Ignition (LOI) was performed on all of the samples. This process involves slowly heating each sample to over 700°C to burn off any organic matter. The resulting mass was then weighed. In addition to the mass of inorganic material caught on the filter, the ionic conductivity of the solution that passed through the filter was determined and the amount of totally dissolved solids it contained was calculated. The mass of the dissolved solids added to the mass of the filtered sample after LOI makes up the total weight of inorganic matter collected in the jar. In addition to the weight determination described above, the pH and ionic conductivity of the each solution was measured.

Several other tests were conducted on selected samples in an attempt to further understand and characterize the material that was collected in the dustfall jars. To determine the mineral composition of the samples, selected samples were characterized by powder x-ray diffraction analysis. For the analysis the samples were mounted on a zero background slide and then scanned over the range of 5 to 60º2Θ at 2º2Θ/minute.

To determine the size and morphology of the particles collected, some samples were examined using scanning electron microscopy (SEM). One set of samples was examined in a Hitachi S-3500N SEM using secondary electron imaging and energy dispersive x-ray (EDS), providing a qualitative correlation between the bulk chemistry of the particles and their size and shape. A second set of samples was characterized using an automated particle counting and analysis system. The characterization of the second set of samples was performed by the RJ Lee Group[1], Inc. of Monroeville, PA at no charge to the project.

A Thermo-gravimetric Analysis (TGA) was also performed on several samples. The TGA measures the change in weight of a material as the temperature is slowly increased to over 700°C. By examining the mass change at specific temperatures and comparing that to know curves, it is possible to determine what materials are present in the sample. In this case TGA was used to characterize the presence of organic compounds samples collected by dust fall jar.

SWEEP SAMPLES

BACKGROUND: Dust emissions from unpaved roads have been found to vary linearly with the fraction of fines (<75 µm, or passing 200 mesh) particles in the road surface material. *Table 2* gives typical fines contents for a variety of road types. The more material that is loose on the surface of the road, the more potential the road has for generating dust. Large loose stones dig and grind into the road surface under the weight of traffic. Large and medium sized particles eventually ravel of to the sides of the road while the fine material leaves the road as dust. By sampling the loose material directly from the road surface, we hope to be able to characterize the potential of each section of road to generate dust to further compare the effectiveness of the

[1] For more information, contact Steve Schlaegle at (724) 387-1843 or sschlaegle@rjlg.com

various dust suppressants used on White Deer Creek Road. We can also compare the finding of the sweep samples with the findings of the dustfall jars and field observations to compare the two methods of estimating dust generation.

Industry	Road Use	Plant Sites	# of Samples	Fines Content Range	Fines Content Mean
Copper smelting	Plant road	1	3	16 – 19	17
Iron and steel production	Plant road	19	135	0.2 - 19	6.0
Sand and gravel processing	Plant road	1	3	4.1 - 6.0	4.8
	Material storage area	1	1	-	7.1
Stone quarrying and processing	Plant road	2	10	2.4-16	10
	Haul road to/form pit	4	20	5.0-15	8.3
Taconite mining and Processing	Service road	1	8	2.4-7.1	4.35
	Haul road to/form pit	1	12	3.9-9.7	5.8
Western Surface coal mining	Haul road to/form pit	3	21	2.8-18	8.4
	Plant road	2	2	4.9-5.3	5.1
	Scraper route	3	10	7.2-25	17
	Haul road (freshly graded)	2	5	18-29	24
Construction sites	Scarper routes	7	20	0.56-23	8.5
Lumber sawmills	Log yards	2	2	4.8-12	8.4
Municipal Solid waste landfills	Disposal routes	4	20	2.2-21	6.4
Publicly accessible roads	**Gravel/crushed limestone**	**9**	**46**	**0.1-15**	**6.4**
	Dirt	**8**	**24**	**0.83-68**	**11**

Table 2. Typical silt content values of surface materials on industrial and rural unpaved roads[1].

SAMPLE COLLECTION: Sweep samples were taken monthly on each application and buffer site. Sweep samples were collected by carefully measuring out a 1 square foot area, then sweeping the area using a dustpan and whiskbroom (*Figure 11*). A sweep was done en each wheel track and combined to make the sample for each site. The sample locations were selected randomly each time they were taken. The samples were stored in sealed containers for transport back to the laboratory.

Figure 11. Example of 1 foot square used to obtain a sweep sample

SAMPLE ANALYSIS: After returning to the laboratory the samples were first weighed and then dried and weighed again. This provided information about the moisture content of the samples, which is important because some of the dust suppressants function by drawing moisture to the road. The dried samples were then passed through a series of sieves ranging from 3/8” to 200 mesh. The results were recorded as percent remaining. The total material collected and the percentage fines of each sample can be used for further comparative analysis of the dust suppressant application sites.

TRAFFIC COUNTERS

One of the main variables that will affect the amount of dust generated on each section of road is the amount of traffic the road receives. The quantity of dust emissions from a given section of road will vary directly with the volume of traffic. The section of White Deer Creek Road used in this study is about 8 miles long. Traffic can enter from both ends and from one point in the middle via Cooper Mills Road (located on the buffer site between site 4 and 5). To insure that traffic volumes are taken into account, two traffic counters were used on White Deer Creek Road. The traffic counters were placed on either side of Cooper's Mill Road in the center of the project (see map *Appendix 1*). Any differences in traffic volume between the two sections of road will result in a variation in the dust that is generated and will need to be taken into account when analyzing the dustfall jars. One of the traffic counters used was a pneumatic counter that simply counted the number of cars and reported the total. The other traffic counter was a more advanced model that had the capability to keep track of daily traffic totals. This model used a buried electric wire to count vehicles and is shown in *Figure 12*.

Figure 12. Installation of a buried wire traffic counter.

DIRECT OBSERVATION

While clearly subjective, direct observation of the dust suppressant performance over time provides a crucial perspective on their performance. Photo-documentation was used to record the status of the various dust suppressant applications. Pictures of each site were taken before any work was done. Additional photographs were taken monthly when the dust jars were collected. The condition of White Deer during each site visit to collect dust samples was also recorded photographically. *Figure 13* shows the condition of each site on the day after dust suppressant application. For a complete photographic record, see *Appendix 2*.

<u>SITE 1</u>
PETROTAC

<u>SITE 2</u>
MgCl2

<u>SITE 3</u>
TECH SUPPRESS

<u>SITE 4</u>
DUSTKILL

<u>SITE 5</u>
COHEREX

Figure 13a. Photographs of sites 1 day after dust suppressant application.

SITE 6
ULTRABOND
Mini-stabilization

SITE 7
ULTRABOND
Full depth stabilization

SITE 8
ULTRABOND
Topical only

SITE 9
SAND AND GRAVEL BINDER

SITE 10
DUSTDOWN

Figure 13a. Photographs of sites 1 day after dust suppressant application.

RESULTS

DUSTFALL JARS

TOTAL RESIDUE: Dustfall jars were placed in the field and allowed to collect dust continuously for a period of one month. A total of four samples were collected in the following time periods:

Sample Period 1	July 19 – August 17, 2001
Sample Period 2	August 17 – September 17, 2001
Sample Period 3	September 19 – October 19, 2001
Sample Period 4	October 19 – November 19, 2001

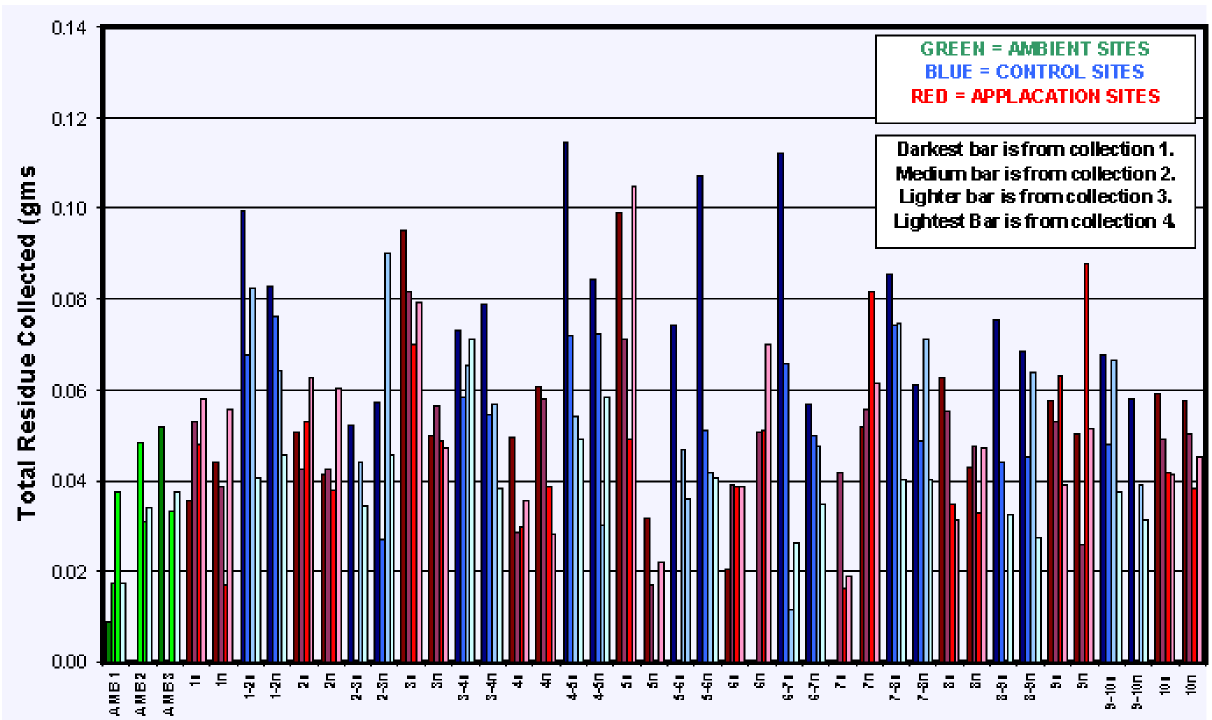
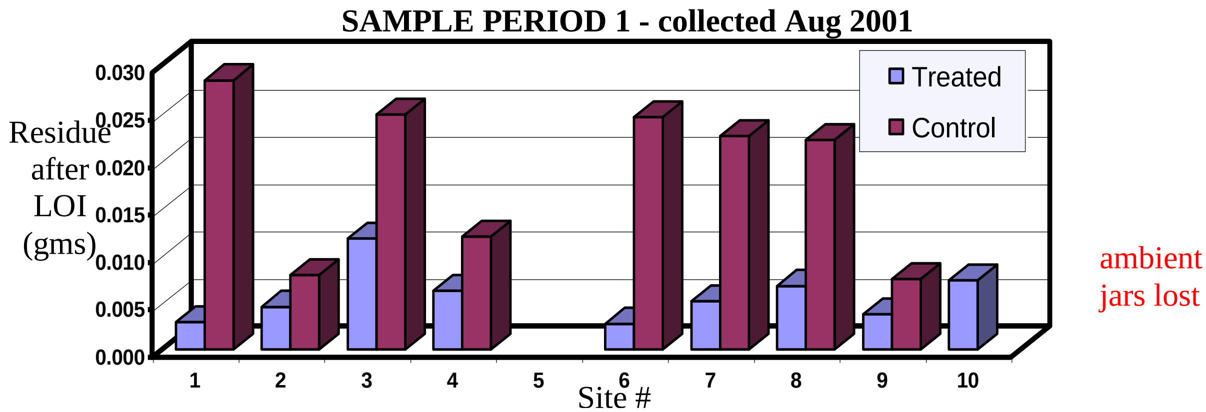


Figure 14. Weight of material collected in dustfall jars. Weight was measured after filtration and drying of residue at 105°C. Total dissolved solids in solution in each sample is also included in the total residue.

The complete data for all dust jar samples can be found in *Appendix 3*. At least one jar from each sample period was not usable due to vandalism or curious wildlife. These samples are noted with "lost" in the data table and are blank in the accompanying graphs. *Figure 14* illustrates the total residue accumulated in the dustfall jars during each sampling period. Included in the total residue accumulated is the weight of residue after filtration and drying, and the weight of the total dissolved solids in solution.

Because of the high and inconsistent organic content in the jars, a clear trend is difficult to identify. The Loss on Ignition test was run on all jars to determine the amount of inorganic material in ease sample.



SITE KEY

1-Petrotac

2-MgCl2

3-Tech Suppress

4-Dustkill

5-Coherex

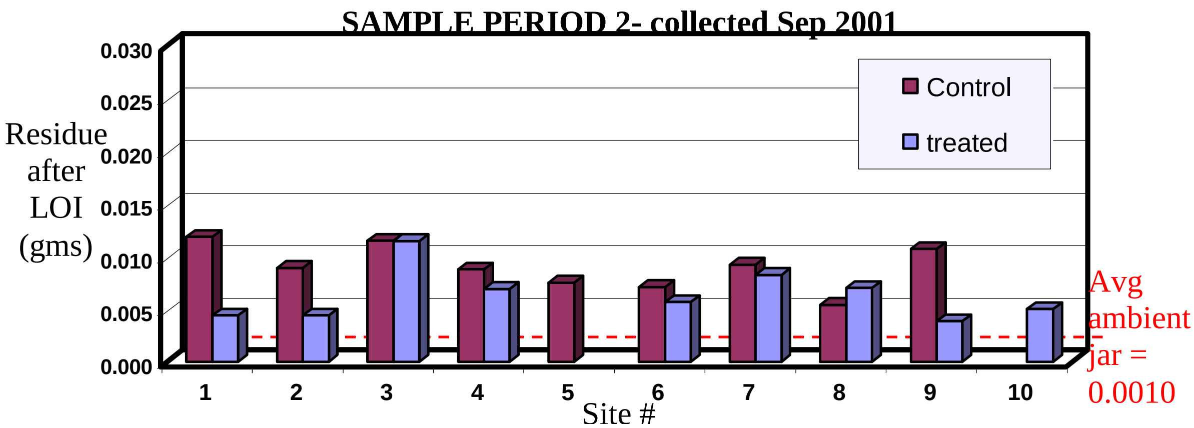
6-Ultrabond 2000 (mini-stabilization)

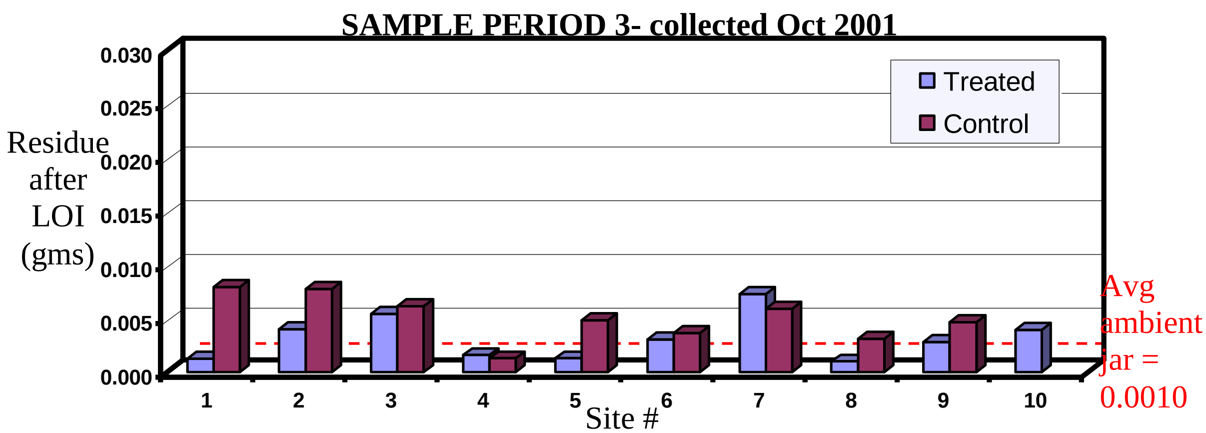
7-Ultrabond 2000 (full-depth stabilization)

8-Ultrabond 2000 (topical)

9-Sand and Gravel Binder

10-Dustdown





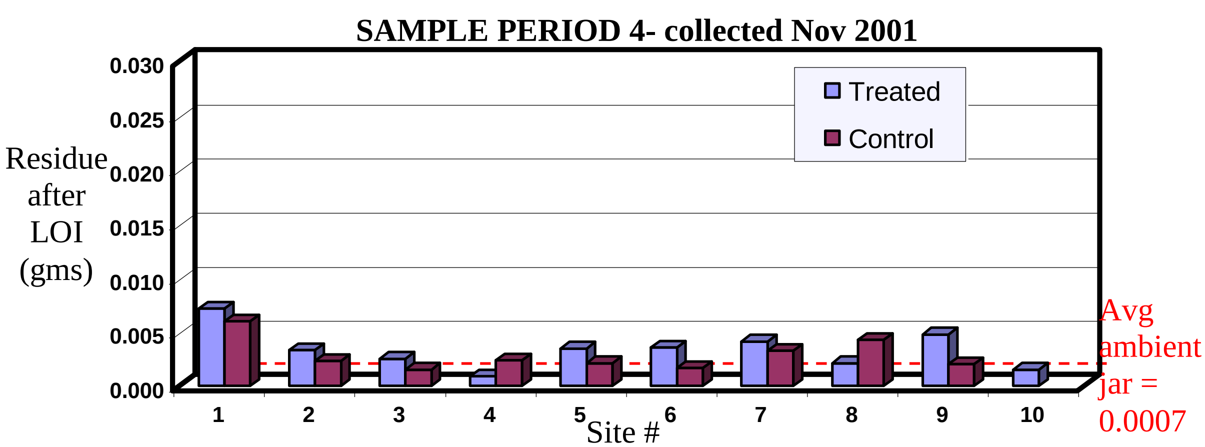


Figure 15. Total residue of sample after Loss on Ignition procedure. Sample from North and South Side of road were averaged for each site.

TOTAL RESIDUE AFTER LOSS ON IGNITION: After the initial filtration, drying, and weighing, each sample underwent further analysis using Loss on Ignition (LOI) procedures. LOI was used to insure that all organic material in the residue was burned off, so only inorganic material remained. *Figure 15* illustrates the total residue left in each sample after the LOI procedure.

The results reveal that from 50-90% of the collected residue was organic material. During the first month (collection 1), the average amount of inorganic material collected on treated sections of road using dust fall jars was approximately 70% less than that collected on the untreated sections. However, by the second month (collection 2), the average reduction was only 24%. During the third month (collection 3), the treated sections produced 37% less emissions than the control. *Appendix 6* contains the full results of the LOI testing. Sample periods 3 and 4 experienced a much higher amount of rainfall than sample periods 1 and 2, which could account for the lower dust collection totals.

Dust Fall Perpendicular to Road

The five dustfall jars used in this study were located on the control site (no treatment) between dust suppressant application sites 2 and 3. Jars were placed perpendicular to the road at intervals of 30 feet and allowed to collect dust for one month at a time. See (*Appendix 1, inset map 1*) for jar locations. The total amount of residue remaining after LOI procedures is shown for each sample distance in *Figure 16*.

Dust Fall Parallel to Road

The five dustfall jars used in this study were located on application site 6 (Ultrabond 2000: mini-stabilization). The jars were placed every 200 feet beginning at the western border of application site 6, and stretching to the center of the site. See (*Appendix 1, inset map 2*) for jar locations. During all sampling periods loss of jars from this experiment occurred. The remaining results were not useful.

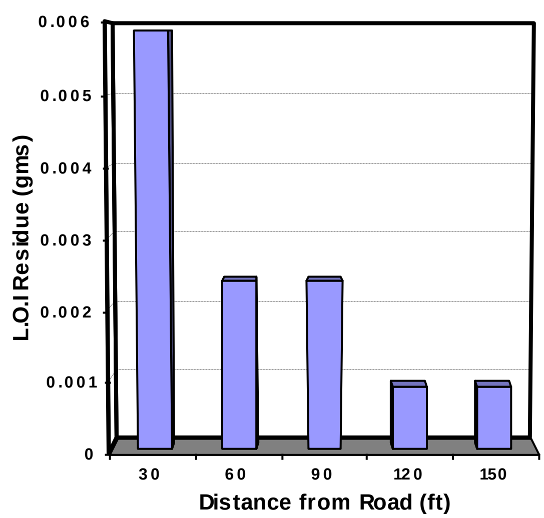


Figure 16. Total residue after LOI procedure for jars placed at 30 foot intervals from the road.

ADVANCED SAMPLE ANALYSIS:

Thermo-gravimetric Analysis

A Thermo-gravimetric Analysis (TGA) of several typical samples was performed to determine the amount of organic materials present in the samples. In the TGA procedure, the weight of the sample is continuously monitored as the temperature is slowly increased from room temperature to over 700 °C. The result is a plot of a sample's weight change vs. temperature. The TGA plot reveals three distinct areas of weight loss at 301, 361 and 414 ºC. These temperature ranges are typical of organic burn-off. The plot also reveals that only a small amount of weight loss occurs after 700ºC. The results of a sample TGA are given in *Figure 17.*

The TGA testing confirmed the suspected abundance of organic matter in the samples. As a result of the high organic content of the samples, the Loss on Ignition (LOI) procedure was used on all samples to eliminate any organic materials.

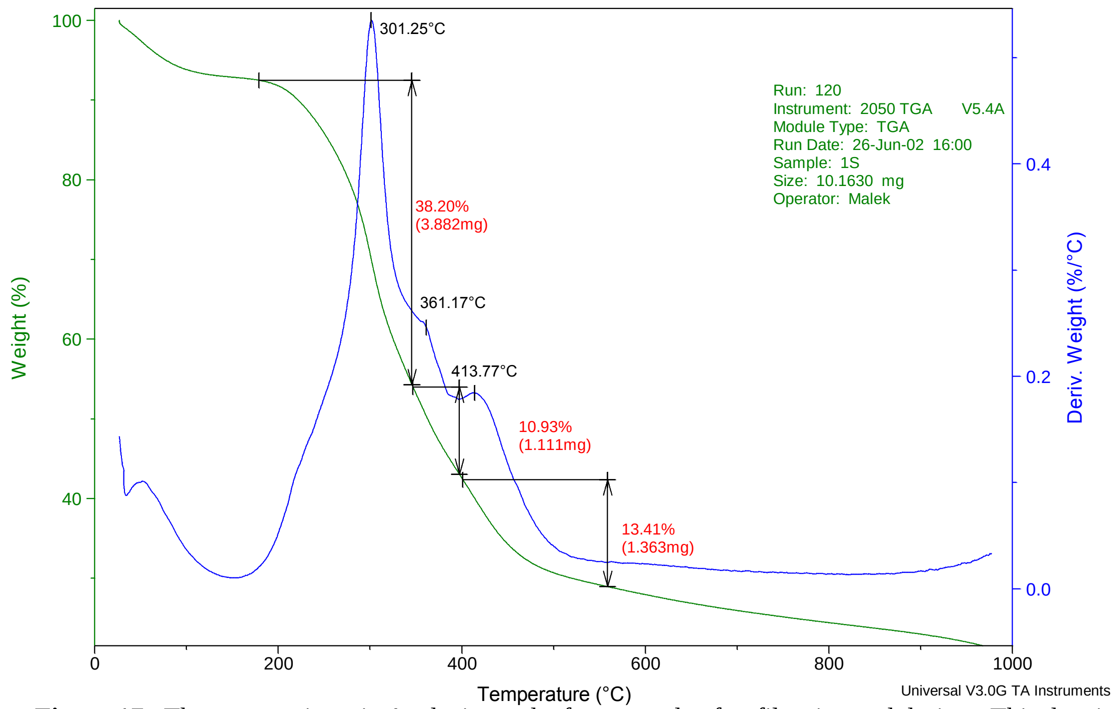


Figure 17. Thermo-gravimetric Analysis results for a sample after filtration and drying. This data is from the dustfall jar located on the southern side of site 1 (Petrotac™) from collection period #1.

Dust particle characterization

In order to characterize the size and composition of any dust particles present in the samples, it is necessary to isolate individual particles. *Figure 18* shows a scanning electron microscope (SEM) image of a section of filter paper after filtering. As can be seen from the image, a film is formed on the filter during filtering. The film makes distinguishing individual particles very difficult. *Figure 19* shows an image of a similar area at a higher magnification. One method used to isolate individual particles is to wash the particles off from the filter paper and then redistribute them onto a support grid. *Figure 20* shows a series of SEM images of individual dust particles after redispersal on a support grid.

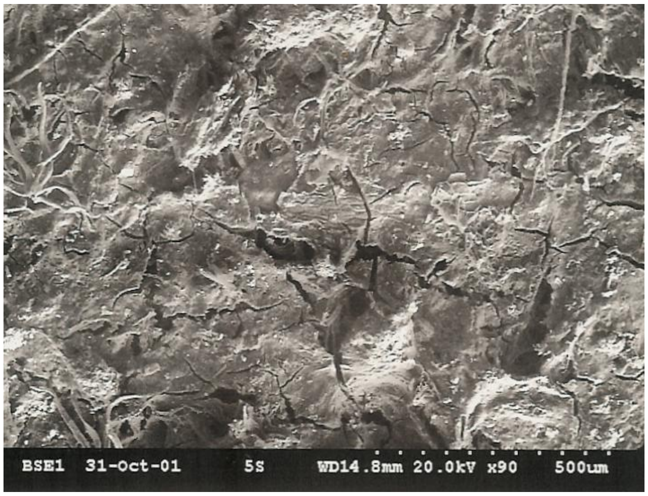


Figure 18. A scanning electron microscope (SEM) image of a section of filter paper after filtering. (90 X magnification)

Figure 19. A scanning electron microscope (SEM) image of a section of filter paper after filtering. .(150X magnification)

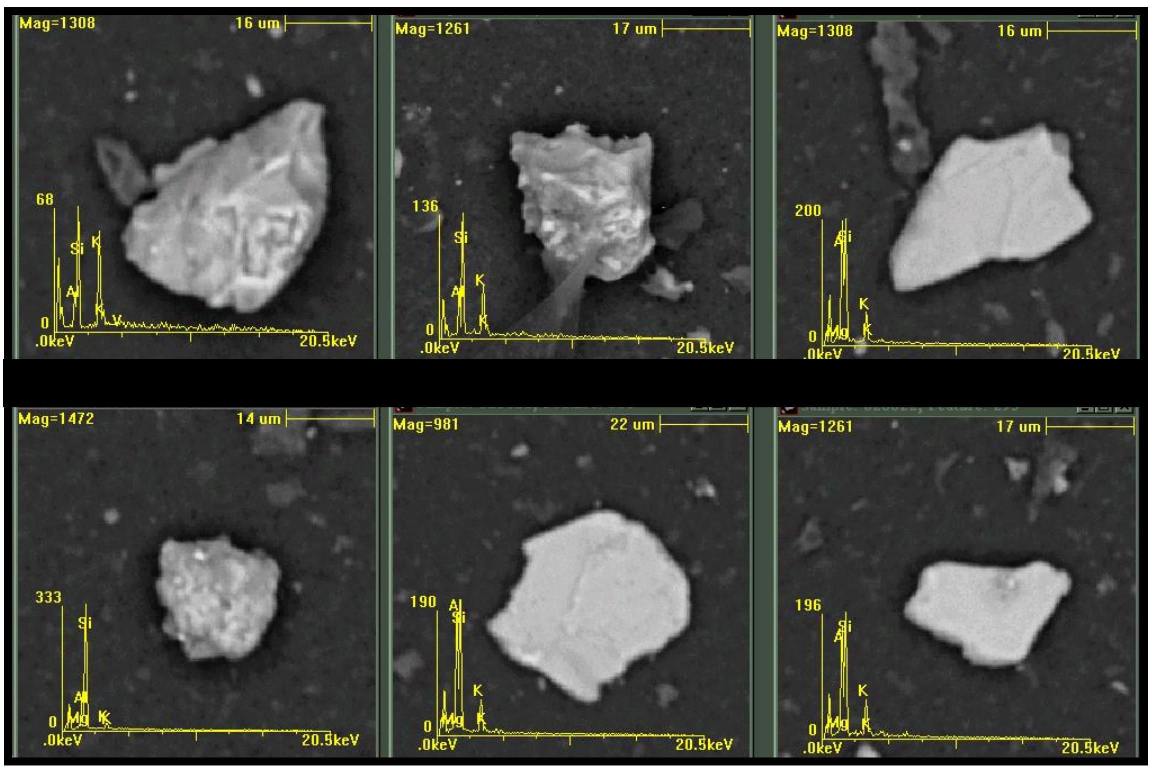


Figure 20. SEM images of dust fall particles after redispersal on a support grid. Overlaid on the images is an EDS scan revealing that the particles are primarily potassium alumino-silicates, most likely clays of some type. (courtesy of RJ Lee Group Inc., Monroeville, PA)

A scanning electron microscope uses a focused beam of electrons to generate an image. As some of the electrons that hit the sample may knock electrons out of the sample. Higher energy electrons then drop down to fill the vacancies, giving off electrons in the form of x-rays. The energy of the x-rays generated is characteristic of the element from which they are coming. An energy dispersive spectroscopy (EDS) detector placed in a SEM allows one to perform chemical analysis. Overlaid on the images in *Figure 20* are EDS scans revealing that the particles are primarily potassium alumino-silicates, most likely clays of some type. An

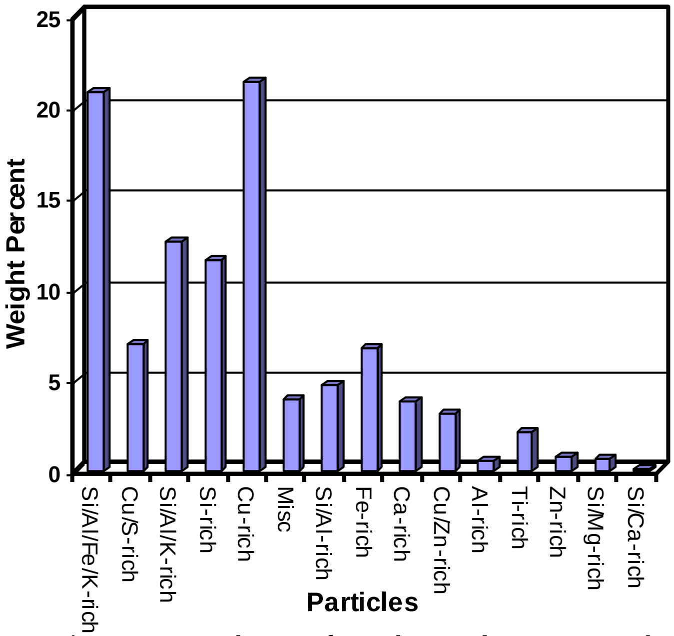


Figure 21. Distribution of sample particle composition by percent weight using energy dispersive spectroscopy.

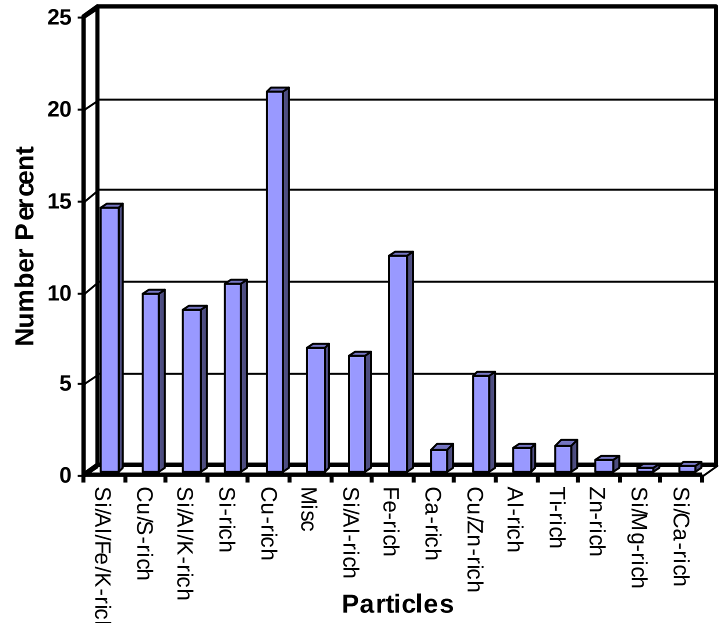


Figure 22. Distribution of sample particle composition by number percent using energy dispersive spectroscopy.

automated particle counting and measuring routine was employed to characterize these particles (*Appendix 3*).

Figures 21 and 22 summarize some of the results of the particle measuring and counting by both weight percent and number percent. The results show that the dust particles are predominately composed of silica containing particles with compositions typical of clays and shales. Bulk chemical analysis reveals that the samples were composed primarily of calcium, potassium, iron and silica. A significant fraction of copper containing particles was also found. *Table 3 and Figure 23* give a breakdown of the number of particles by size. The results reveal that the majority of the particles fall in the 0.5 to 5 µm range. The largest number of particles were around 1 µm.

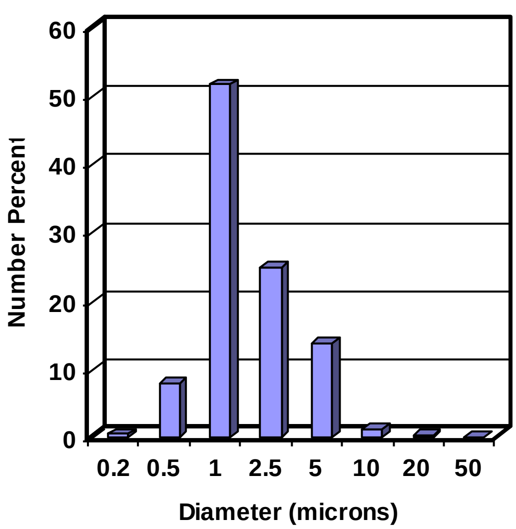
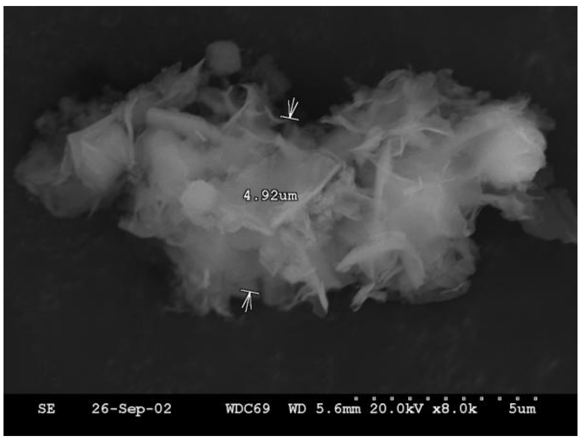


Figure 23. Particle size distributing by average diameter (µm). (courtesy of RJ Lee Group Inc., Monroeville, Pa).

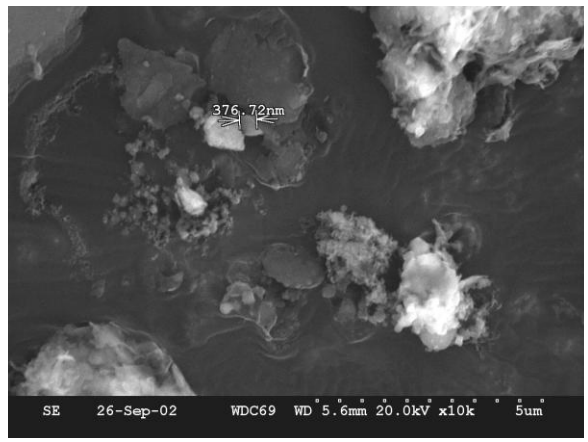
		Particle Diameter (µm)						
Classes	**Number %**	**0.5**	**1.0**	**2.5**	**5.0**	**10.0**	**20.0**	**50.0**
Si/Al/Fe/K-rich	14.5	0.0	2.1	31.1	43.5	20.4	2.5	0.4
Cu/S-rich	9.7	0.0	1.5	21.5	36.4	40.5	0.0	0.0
Si/Al/K-rich	8.9	0.0	0.0	38.9	42.2	16.7	1.7	0.5
Si-rich	10.4	0.0	0.0	66.6	17.1	13.3	2.5	0.5
Cu-rich	20.8	1.7	23.8	59.9	11.4	2.4	0.6	0.2
Misc	6.8	0.0	2.2	39.7	29.0	29.0	0.0	0.0
Si/Al-rich	6.4	0.0	0.0	54.2	34.1	10.8	0.5	0.3
Fe-rich	11.8	0.0	12.7	78.7	6.7	0.8	1.0	0.1
Ca-rich	1.3	0.0	0.0	46.0	30.2	15.1	8.0	0.6
Cu/Zn-rich	5.3	2.8	5.7	70.8	18.6	1.9	0.1	0.1
Al-rich	1.4	0.0	0.0	64.5	14.1	21.2	0.1	0.0
Ti-rich	1.5	0.0	29.8	49.6	19.6	0.0	0.5	0.5
Zn-rich	0.6	0.0	23.1	46.2	15.2	15.2	0.2	0.2
Si/Mg-rich	0.3	0.0	0.0	59.3	39.0	0.0	0.5	1.1
Si/Ca-rich	0.4	0.0	0.0	74.7	24.6	0.0	0.7	0.0
Totals	**100.0**	**0.5**	**7.9**	**51.6**	**24.8**	**13.7**	**1.2**	**0.3**

Table 3. Particle size distributing of each component by average diameter (µm). (courtesy of RJ Lee Group Inc., Monroeville, Pa).

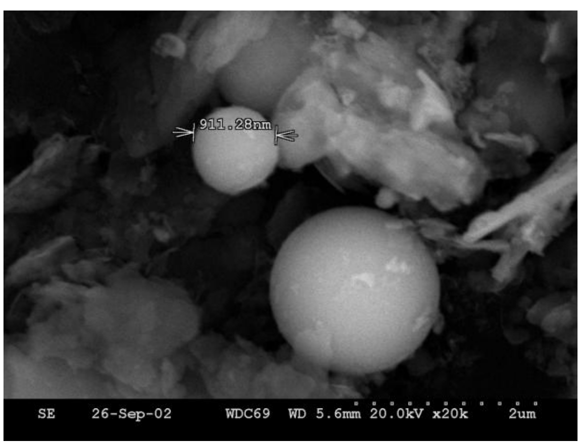
Samples of the material collected in the dust fall jars that had been through the L.O.I. process were examined in the SEM and subjected to characterization by EDS. In *Figure 24(a)* we see an agglomerate approximately 5 µm in cross section. The agglomerate is apparently made up of many fine particles (< 1 µm). *Figure 24(b)*, shows some of the finer particles observed. These particles have a cross section of less than 0.5 µm. *Figure 24(c)*, shows an image of what looks appears to be coal fly ash particles. The round spheres have diameters in the micrometer range. One could speculate that these particles are perhaps residual anti skid material or that they were carried in on the undercarriage of vehicles. *Figure 25* shows an EDS scan characteristic of the particles in *Figure 24, parts a-c*. The scan reveals that the particles are primarily potassium-alumino-silicates. A small amount of copper is also noted. One can speculate that since copper is commonly used as an algaecide that it has found its way onto the roadway via this route.



(a)



(b)



(c)

Figure 24 (a-c). SEM images of dust particles after L.O.I procedure.

SWEEP SAMPLE ANALYSIS

Sweep samples were collected form each treated and buffer section of the road monthly. The full results of this testing are shown in *Appendix 7*. While there was a wide variance, the average amount of loose material found on the treated sections of road was about ½ the amount found on the control sections. *Figure 25* illustrates the typical composition of particles collected during sweep samples. *Figure 26* shows the various amounts of loose material collected by sweep samples two months after product applications. *Figures 27-28* show the size distribution of the loose material collected during sweep samples. *Figures 29-30* illustrate the amount of fine material(less than 140 mesh) collected during the sweep samples. On average, the material from the treated sections of roadway had 35% less material finer than 140 mesh when compared to the control sections. Even after one year (*Figure 30*) there was 14% % less material finer than 140 mesh on the treated sections when compared to the control sections.

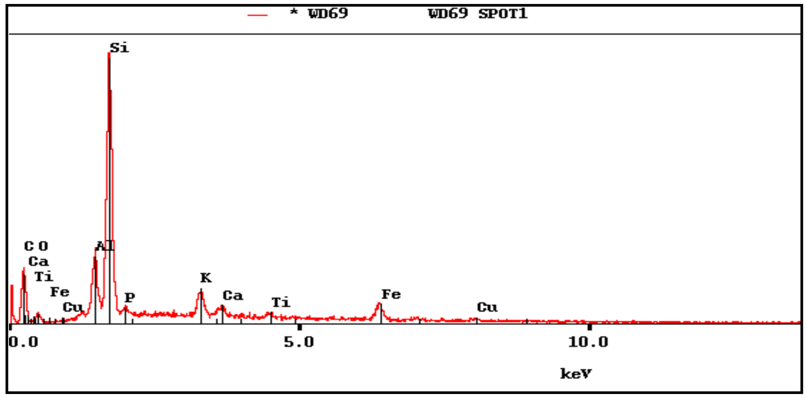


Figure 25. EDS scan typical of the particles collected in the sweep samples.

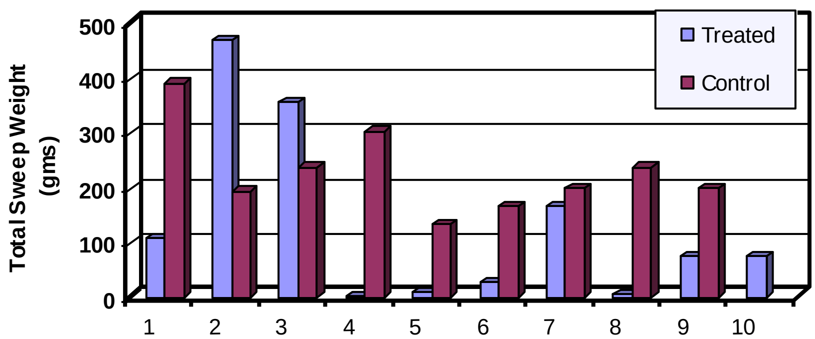


Figure 26. The amount of loose material collected by sweeping a one square foot section of the roadway, two months after the application of the suppressants.

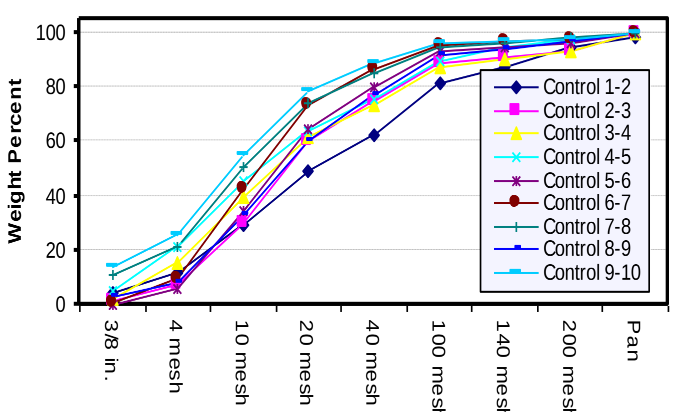


Figure 27. The size distribution of the loose material collected by sweeping a one square foot section of control roadway, two months after the application of the suppressants.

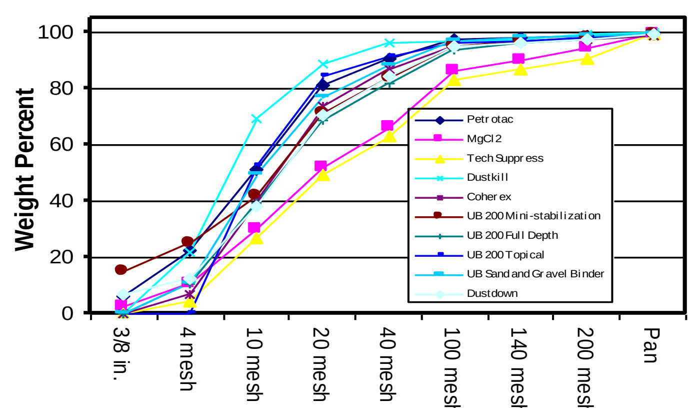


Figure 28. The size distribution of the loose material collected by sweeping a one square foot section of treated roadway, two months after the application of the suppressants.

SITE KEY: 1-Petrotac; 2-MgCl2; 3-Tech Suppress: 4-Dustkill: 5-Coherex; 6-Ultrabond 2000 (mini-stabilization): 7-Ultrabond 2000 (full-depth stabilization); 8-Ultrabond 2000 (topical); 9-Sand and Gravel Binder; 10-Dustdown

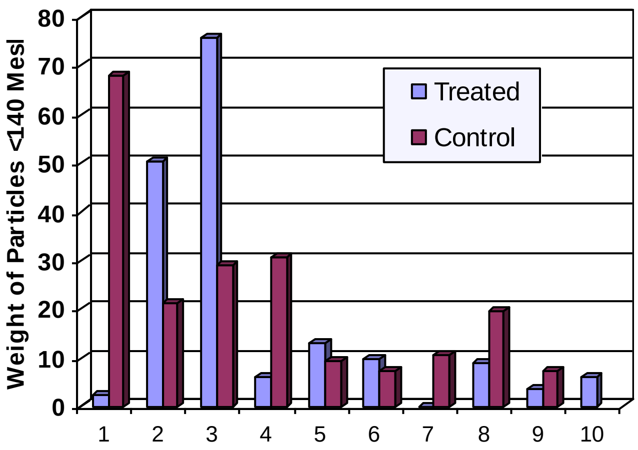


Figure 29. The total weight of loose material that passes a 140-mesh sieve collected by sweeping a one square foot section of roadway, one month after the application of the suppressants.

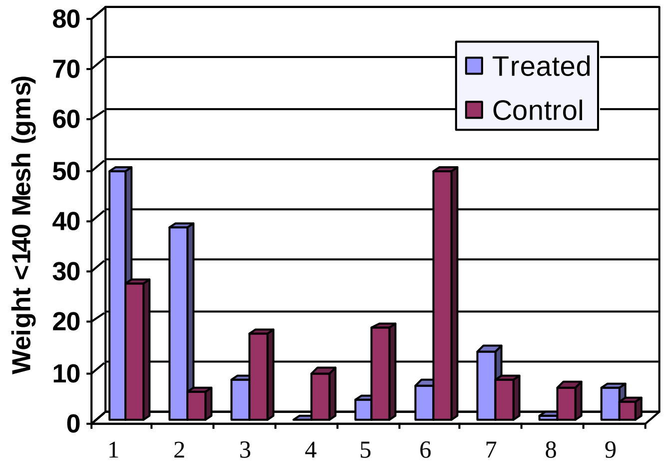


Figure 30. The total weight of loose material that passes a 140-mesh sieve collected by sweeping a one square foot section of roadway, one year after the application of the suppressants.

TRAFFIC COUNTS

When comparing the performance of different sections of roadway, the number of vehicles using a particular section of road is important. During the period July 20 to September 16, 2001, 1003 vehicles traveled the western end of the road and 1263 traveled the eastern end. *Figure 31* summarizes the traffic pattern observed on the east section of the test area. On average, 41 vehicles passed the traffic counter on a typical weekday and 60 on an average weekend day. The traffic ranged from a low of 7 to high of 143 vehicles per day. The detailed traffic count data is given in *Appendix 8*. See map in *Appendix 1* for traffic counter locations.

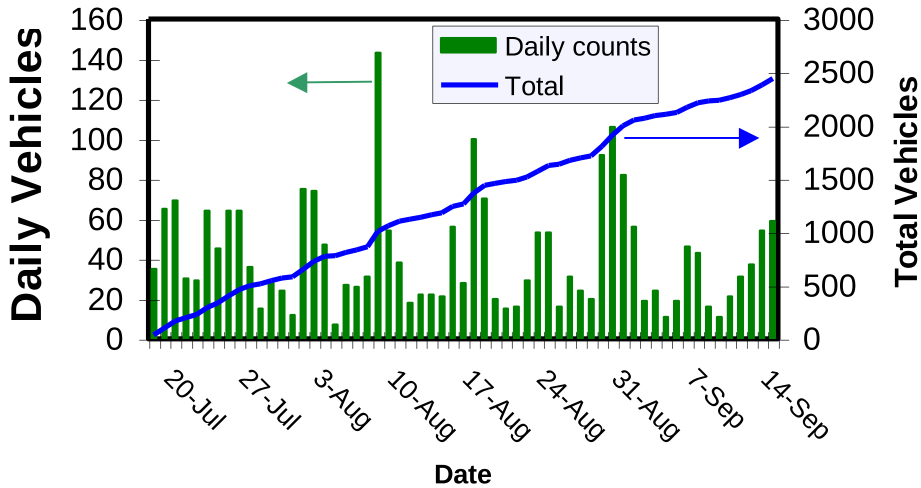


Figure 31. Summary of traffic on the eastern end of White Deer Creek Road for the period July 20, to September 16, 2001.

Summary

The following observations can be made from this study:

- The results show that the dust particles are predominately composed of silica containing particles with compositions typical of clays and shales.
- **50 to 90% of the matter collected in the dust fall jars was organic.**
- While there was a wide variance, the average amount of loose material found on the treated sections of road was about ½ the amount found on the control sections.
- On average, the material swept from the treated sections of roadway had 35% less material finer than 140 mesh when compared to the control sections.
- After one year there was 14% less material finer than 140 mesh on the treated sections when compared to the control sections. sweep
- The size of the dust particles ranged from 0.5 to 50 µm. The largest numbers of particles were observed in the 1-µm size range.
- While traffic on White Deer Creek Road varied from day to day, on average 41 vehicles passed the traffic counter on a typical weekday and 60 on an average weekend day. The traffic ranged from a low of 7 to a high of 143 vehicles per day.
- During the first summer of testing there was an average reduction of approximately 50% of the emission from the treated sections compare to the control.
- The average moisture content found in treated sections of road was about 20 percent higher than in the control sections.
- There did not seem to be any appreciable advantage to the mini-stabilization or full depth stabilization for dust control. However, these techniques may be useful for other applications.
- It was impossible to place all the dust fall collection jars in areas that were free from influences of the surrounding vegetation. This resulted in a high sample to sample variation for the samples collected from the dust fall jars. As a result of the high standard of deviation in the amounts collected it is impossible to draw any statistically significant conclusions about the performance of the individual suppressants.

In summary, the use of new generation dust suppressants can be an effective tool for controlling visible dust. This study does have a limitation in the concentrations of suspended dust which has not been measured. This is of concern since the small particles likely to remain suspended are in the size range most likely to cause health problems.