ROAD DUST SUPPRESSSANTS RESEARCH RESULTS

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Abstract Road dust suppression has two significant benefits: 1) decreasing a major source of air pollution, 2) prolonging the life of a dirt road. It is well known that a large portion of the particulates in the air are related to dirt roads. And it is known that the use of chemical dust suppressants or even just regular watering increases the time between road maintenance and aggregate replacement. In fact, this research has shown that the use of dust suppressants will decrease aggregate loss between 2-3 times of treated dirt roads versus untreated dirt roads.

The purpose of this paper is to discuss the research results from Colorado State University of the effects of the use of chemical dust suppressants on dirt road life and fugitive dust emissions. The dust suppressants tested were lignonsulfanate, magnesium chloride, calcium chloride and calcium chloride special. During the initial stages of the research it was determined that the use of the conventional bucket surveys would not be sufficient and could not generate enough quantitative data for the research to find the most effective dust suppressant. As a result, the Colorado State University Dustometer and a field test protocol were developed to generate a large amount of data to determine which dust suppressant is most effective for the given conditions. The road test sections were one mile, the vehicle, driver and vehicle speeds remained unchanged throughout the research. In another test, the Dustometer was used to quantitatively assess the impact of the vehicle velocity on dust emissions. And as part of the research the tons of aggregate loss per vehicle per mile per year was quantified as well. While the untreated road lost 2.59 tons/mi/ADT/yr, the road treated with lignonsulfanate lost 1.01, $CaCl_2$, 1.49 and $MgCl_2$, 1.04. In terms of dust generation, the lignonsulfanate was the most effective for about three months but deteriorated rapidly. In the economic analysis for the given cost of aggregate and the existing ambient conditions, $MgCl_2$ was the best choice when the ADT was greater than 120. The relationship between dust generation and vehicle velocity was also established. Increasing the vehicle speed from 30 mph to 50 mph almost doubled the amount of dust production and although it appears to be linear, visual observations in the field indicate it is more probably nonlinear and quite possibly exponential. What is not known which future research could answer is the effect of vehicle weight and tire dimensions on dust production and the relationship between dust production and aggregate loss. More fundamentally there are no data that the suggested application rates and field procedures recommended by the suppressants distributors are optimal.

Although the Dustometer was developed specifically for this research replacing and improving upon bucket surveys and other measurement techniques, it may, in fact, be better suited and more applicable as a management tool to generate data on site prior to road dust management decisions.

INTRODUCTION

There are over 2.6 million miles of roads and streets in the United States which carry low traffic volumes and over one million miles of these roads are unpaved road (FHWA, 1992). The loss of fines, a primary source of fugitive particulate emission in the air and the cause of deterioration of unpaved roads often lead to high maintenance costs especially in the form of aggregate replacement cost. In terms of air pollution alone, the problem of unpaved road dust can not be overlooked due to health issues and governmental regulations to meet atmospheric air quality standards. In terms of dirt road life, high maintenance cost, increased road user cost, public awareness of road dust problems, and the loss of fines from the road surface, among other things, have raised concerns about the quality of unpaved roads. These have led to increased interest in reevaluating current dust control management practices.

The objective of dust control is to stabilize the road surfaces by causing the finer soil particles to be firmly bounded to the coarser aggregates. Not only is road life prolonged, but less particulate air pollution results. Currently, dust palliation is achieved by the reduction of vehicular speed, spraying of water on the road surface and the use of dust suppressing chemicals. Although dust control studies have been ongoing for several decades now with numerous attempts to measure and quantify dust from unpaved roads, there is lack of any uniform, standard, repeatable/reproducible and quantitative method or technique for measuring road dust.

The purpose of this paper is to discuss the research results from Colorado State University on the effects of the use of chemical dust suppressants on dirt road life and fugitive dust emissions and the “Colorado State University Dustometer” a mobile dust collector developed specifically for this research (Sanders and Addo, 2000). Four chemical dust suppressants, Lignosulfanate, Calcium Chloride, Magnesium Chloride and Calcium Chloride

Special. were tested and their effectiveness is compared to an untreated road. After initial tests, Calcium Chloride Special was not tested in the second year.

EXPRIMENTAL DESIGN

The tests were performed on four unpaved section of CR12/29 near the city of Loveland in Larimer County, Colorado (Figure 1). Each test section was 1.25 miles long and 33 feet wide. The choice of this site was due to the fact that the road had never been treated with a dust suppressant except for water and the relative closeness to Colorado State University. Figure 1 shows the research site and the treatment of each section.

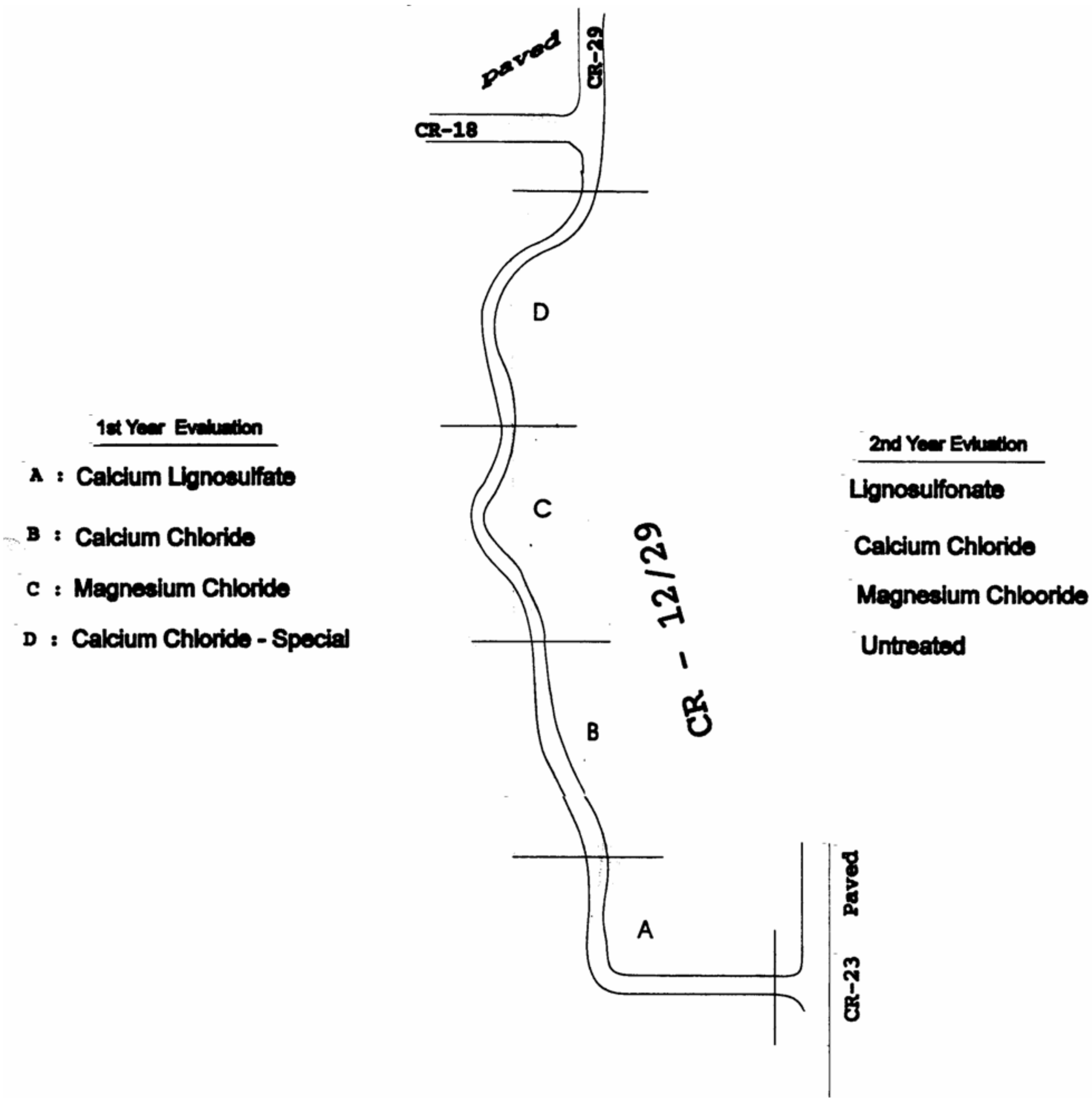

Figure 1 Location of Test Sections and treatment.

To perform the testing, a ¾ ton truck (Figure 2) provided by the Larimer Country Road & Bridge Department was used. The vehicle was operated by the same driver at a constant speed of 45 mph during the hottest and driest time of the day when most dust would be generated. The dust measurement was carried out over 1 mile of the 1.25 mile test section. The 0.25 miles of each test section was used as the start and stop distances of the test vehicle. The vehicle was brought up to the desire speed of 45 mph before turning on the Dustometer (Addo, 1995). After the first year's tests, 6 inches of new aggregate was placed on the road test sections by the county. This allowed a second year's test on a virgin, untreated road.

Three tests per section of each treatment were conducted on the same day about the same time of day once-a-week for an entire summer. Averages were calculated and are presented in the paper. At the beginning and end of the summer tests of the second year, the cross section road elevations of the test roads were measured to estimate the loss of aggregate. Vehicle counters were located at the beginning and end of each test section so that the aggregate loss per mile per vehicle could be determined.

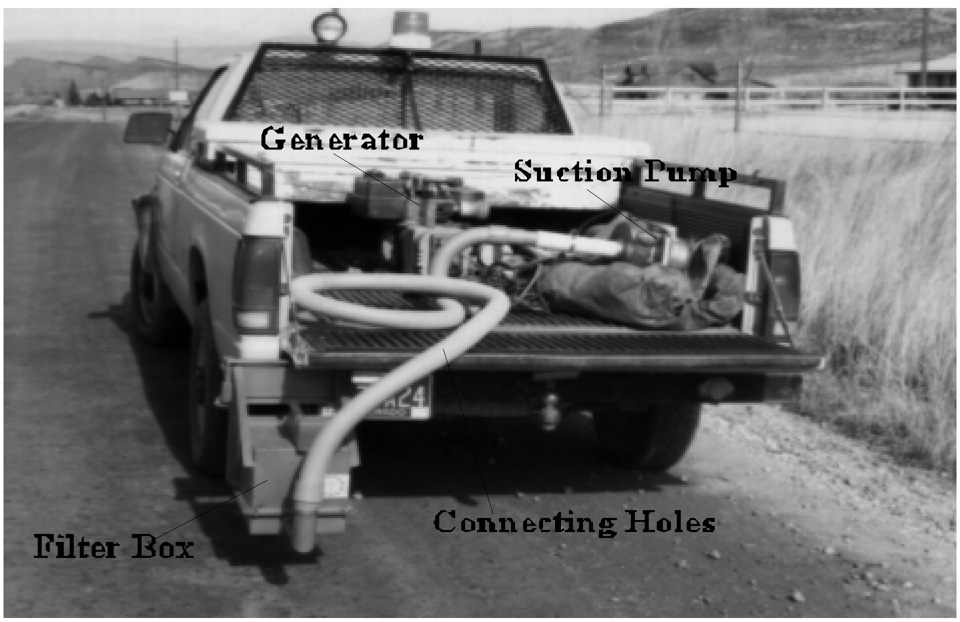

Figure 2. The ¾ ton truck used in all the tests.

RESULTS

Before the tests of the dust suppressants were initiated, the precision of the Dustometer as an experimental road dust measurement device was evaluated. Nine replicate sample measurement were taken on the 1-mile, untreated test section. Table 1 shows the data and its distribution. A mean of 2.74 g was obtained with a standard deviation of 0.21, a variance of 0.04 and a coefficient of variation of 7 % at a speed of 45 mph. It is obvious from the data that the Dustometer is precise especially when it is considered that it is a field measurement devise and not a lab instrument. During the initial testing of the Colorado State University Dustometer, it became quite obvious that the speed of the vehicle was related to dust production. The faster the vehicle traveled, the more dust is generated. In order to quantify this observation, three dust test measurements were taken for each of the four different speeds. Figure 3 presents the average amount of dust generated at speeds of 20, 30, 40, and 50 mph. on the 1-mile, untreated test section. The fit of the data appeared linear.

Sample #	Weight of Dust (g)
1	2.85
2	2.60
3	2.83
4	2.86
5	2.87
6	2.47
7	2.62
8	2.48
9	3.09

Mean = 2.74 g   Standard Deviation = 0.21 g   Variance = 0.04 g

Table 1. Typical Dust Measurement Data
Speed: 45 mi/hr
Length of Run: 1.0 mile
Test Section: Untreated

Because the dust measurement involves the suction of dust as it is generated, the mass of the dust collected is related to how long the suction pump is allowed to run. In order to remove this variable, the amounts of the dust collected for a 3 minute run for each speed were plotted versus speed (Figure 4). The results indicate linearity. To verify this linear relationship of the dust collected vs speed for the collection device additional, runs were made at 25, 35, and 45 mph (Figure 5).

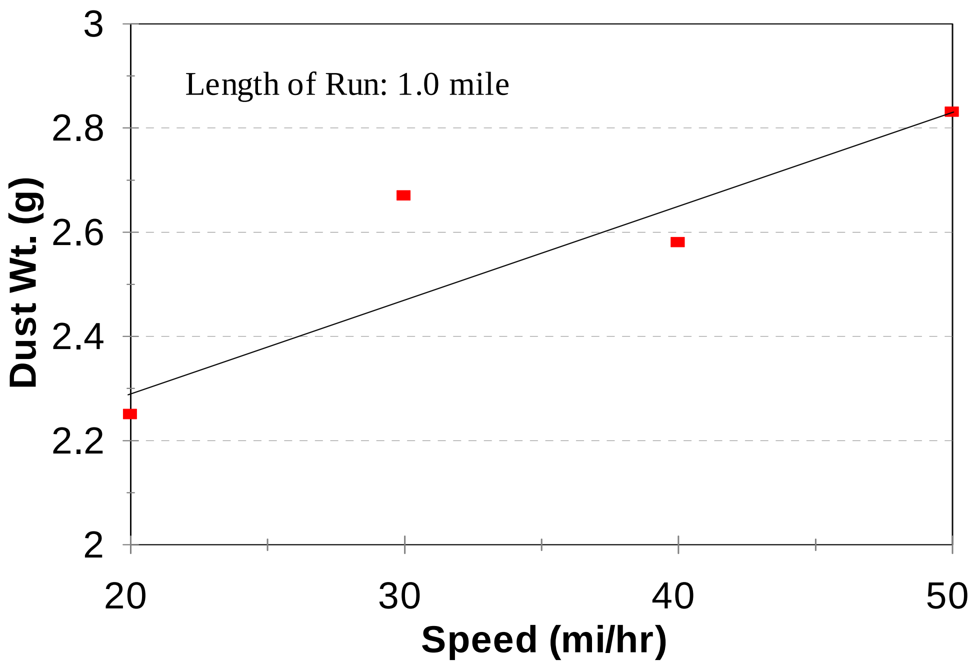

Figure 3. Dust production vs speed for the 1-mile test section.

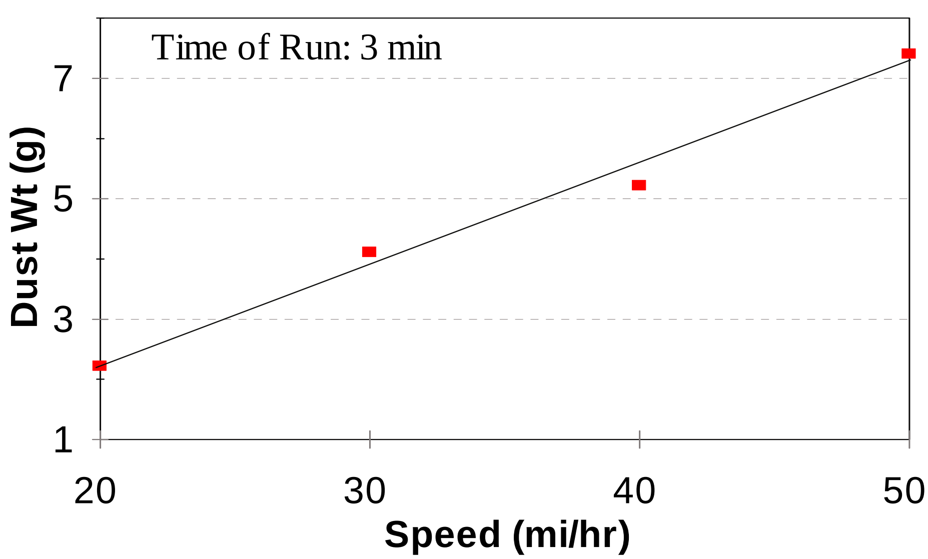

Figure 4. Dust production vs speed for a three minute time period.

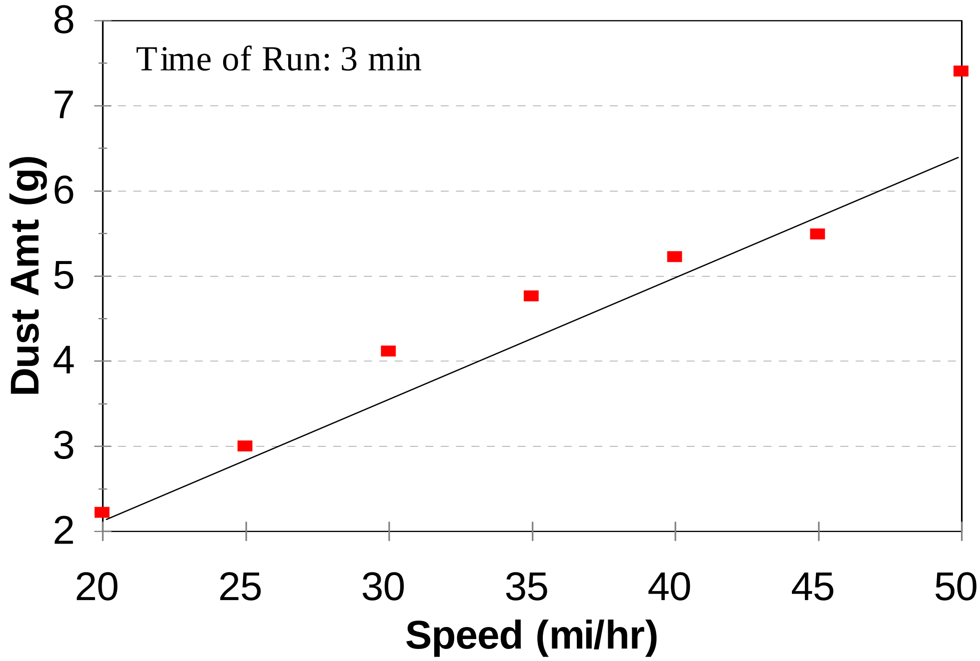

Figure 5. Dust production vs speed for a three minute time period for all data.

Dust Measurements.

The results of the fugitive dust emissions from each of the four tests sections are shown in Figure 6. Each data point in Figure 6 is an average of three test runs made by driving the truck in the wheel path of the same driving lane and in the same direction. It is apparent that all three dust suppressants were effective in reducing the amount of dust generation in comparison to the amount of dust generated from the untreated section.

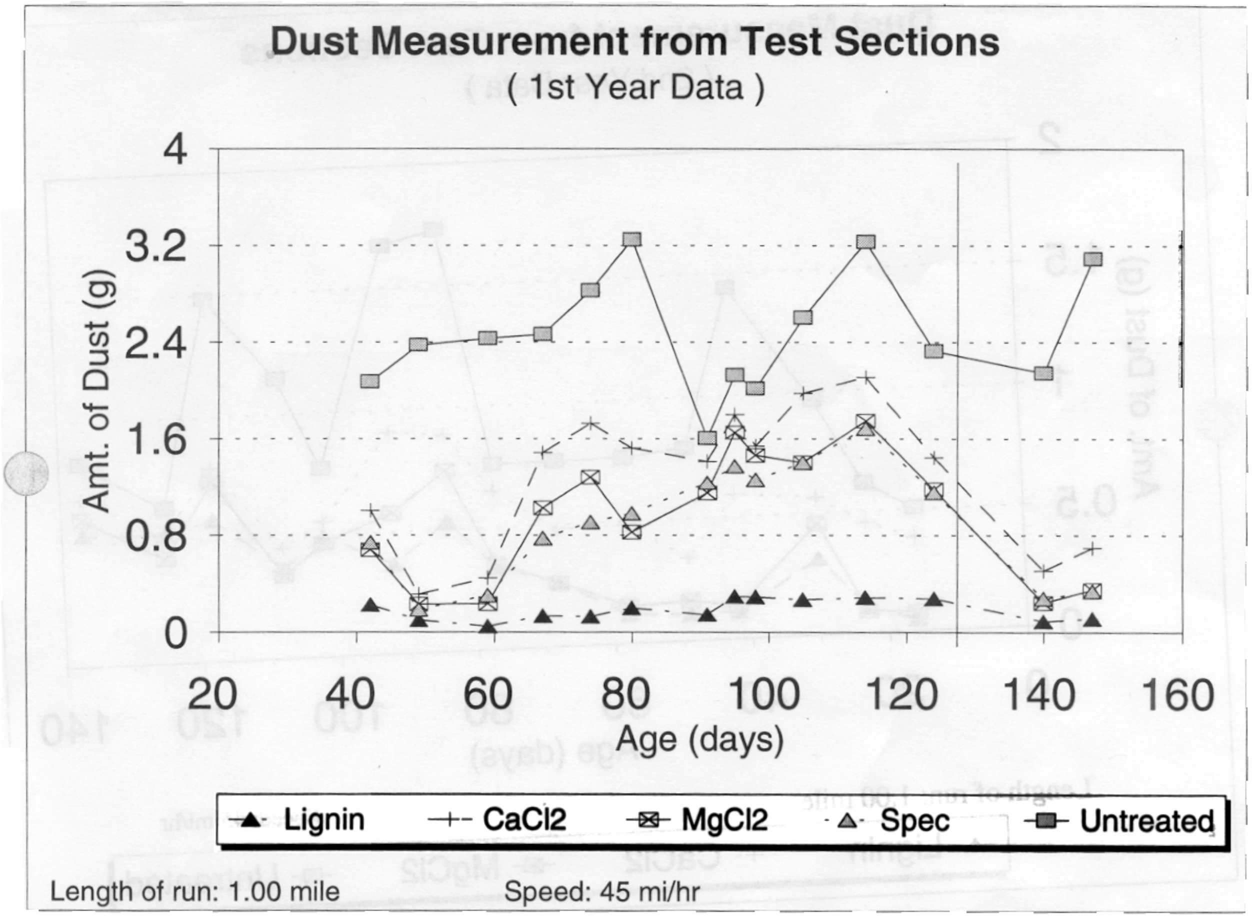

Figure 6. The dust generated at the four test sections during the first year(Addo and Sanders,1995).

It should be noted that as the test sections aged the amount of dust emissions increased but dust emissions would decrease for a short time after a rain storm. The test section treated with the lignin dust suppressant had the least dust emissions in the majority of all tests during the two years of tests. However, toward the end of the tests, the lignin dust suppressant appeared to break down and the test road deteriorated rapidly with a large increase of pot holes.

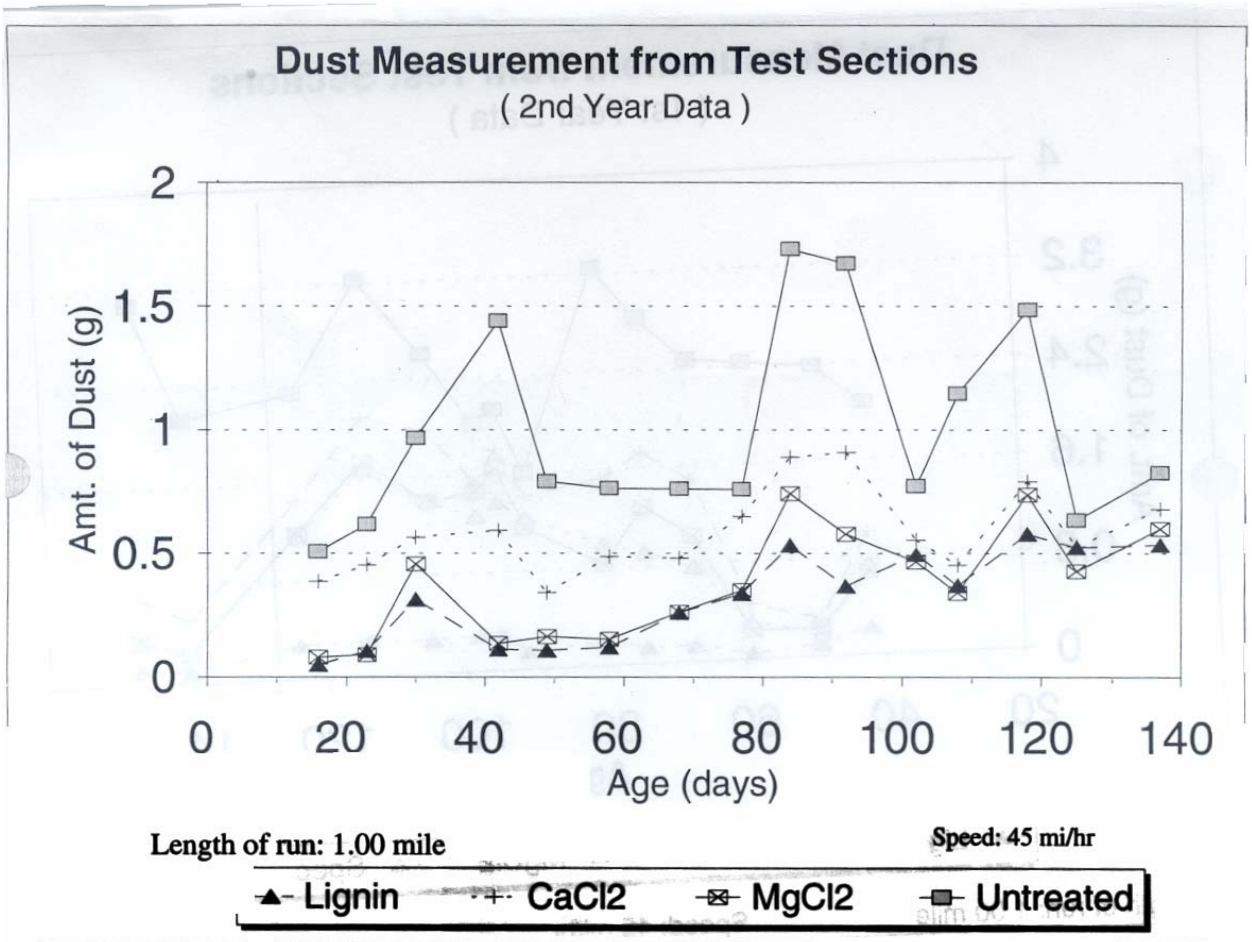

Figure 6. The dust generated from the four test sections during the second year.

Aggregate Loss Measurement

At the conclusion of the research the first year, it was decided to try to estimate the amount of aggregate loss by taking multiple measurements of the pavement elevations before and after the tests. The road surface elevations were measured at three cross sections of each test section. Measurements were made every three feet across the road. Quantitative differences were able to be determined primarily because of the capability of the Larimer County equipment operators to rebuild the road test sections from the displaced aggregate. The aggregate loss was estimated from the elevation differences of the road surfaces before and after the tests (Figure 7).

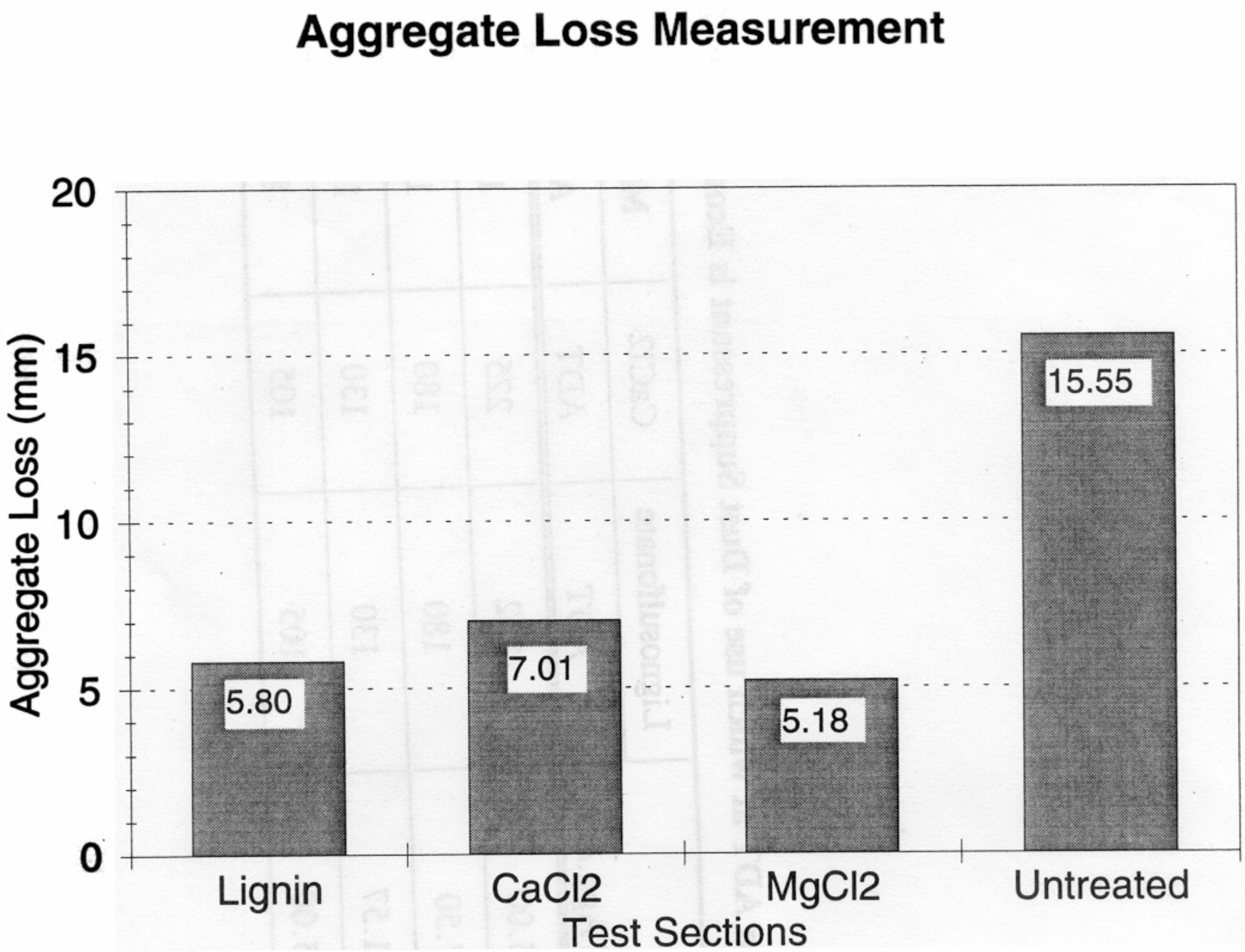

Figure 7. The estimated aggregate loss of each test sections in mm from the second year data.

Figure 7 shows the measured aggregate loss from each of the test sections over the 4.5 month period in which the study was done. The aggregate loss from the treated test sections were measured as 0.23 inches (5.80 mm) for the Lignosulfonate, 0.28 inches (7.00 mm) for $CaCl_2$, and 0.2 inches (5.18 mm) for $MgCl_2$**.** The untreated section had an aggregate loss of 0.6 inches (15.55 mm). Table 2 summarizes the aggregate loss per mile per year per vehicle from the loss data measured and using the ADT traffic measurements. Again it should be noted that all the dust suppressants were effective when compared to the aggregate loss of 2.6 tons/yr/mile/vehicle from the untreated section. The test section treated with Lignosulfonate lost 1 ton/yr/mile/vehicle, the $MgCl_2$ treated section lost 1 ton/yr/mile/vehicle as well and the $CaCl_2$ treated section lost 1.5 tons/yr/mile/vehicle.

Test Section (1)	ADT (2)	Measured aggregate loss per mi for 4.5 months (ft) (3)	Estimated aggregate loss/mi/yr (ft) (4)	Estimated aggregate loss /mi/yr (tons) (5)	Estimated aggregate loss per mi/yr/veh (tons) (6)
Lignosulfonate	515	0.019	0.050	520	1.0
$CaCl_2$	431	0.023	0.061	629	1.5
$MgCl_2$	448	0.017	0.045	465	1.0
Untreated	538	0.051	0.135	1.395	2.6

Table 2. Estimated total annual aggregate loss /mile/vehicle.

Using an aggregate cost of $11.57 ton for replacing the lost aggregate, the cost/mile/yr as a function of ADT is plotted in Figure 8. The plot indicates that if the ADT is less than 120, it is cost effective to not treat the dirt roads with a dust suppressant   And if the ADT is over 120 it is more cost effective to use any of the three dust suppressants and it appears that $MgCl_2$ was the most cost effective.

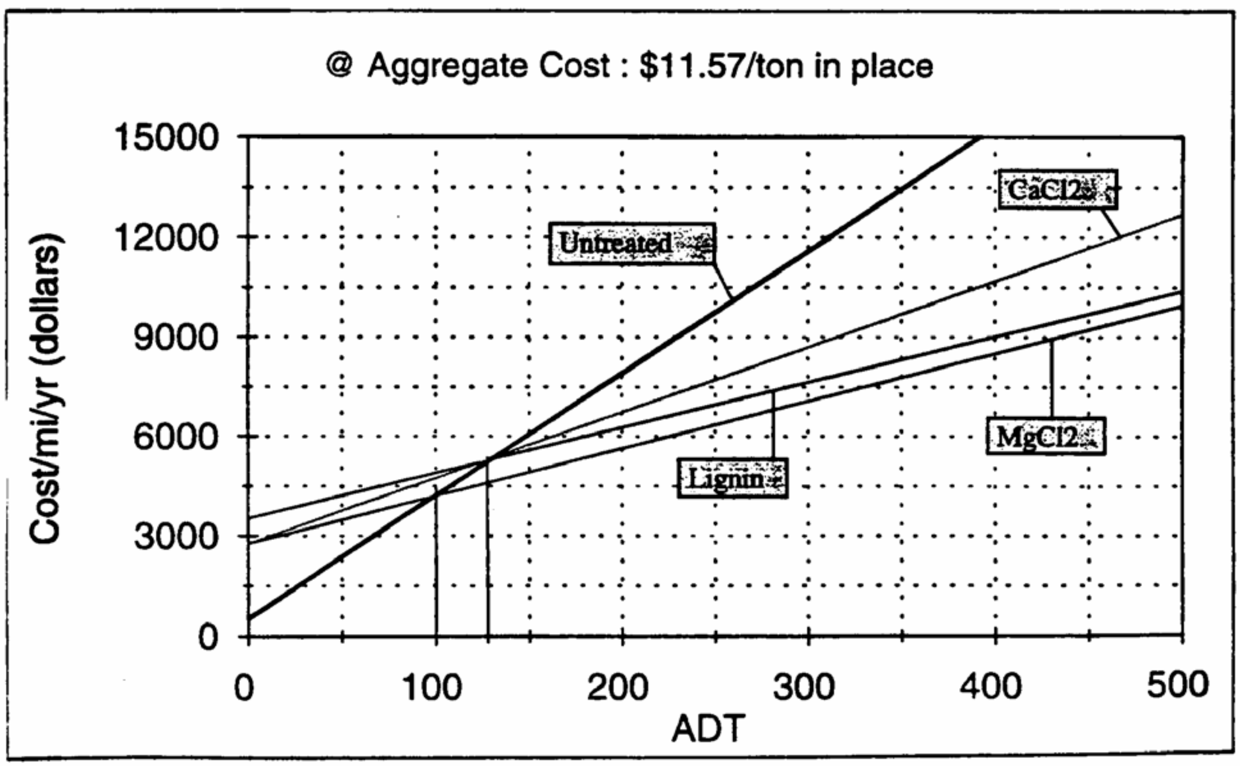

Figure 8. The cost/mile/year for each treatment vs. ADT assuming an aggregate cost of $11.57 (Sanders et al., 2000).

Water Quality impact of the dust Suppressants

Figure 9 list the quality of the runoff during a rainfall event July 7, 1994. Unfortunately there was very little runoff quality data from other storms during two years of research due to the fact that very little measurable runoff occurred.

Date of Rain 07/22/94 Rainfall amt. Av. = 0.42in (10.75 mm)		Test Sections		
	Lignin	$CaCl_2$	$MgCl_2$	Untreated
pH	6.05	6.28	6.98	7.20
E.C. µmhos	1,428.75	8,517.50	7,655.00	485.75
TDS	975.26	5,706.73	5,128.85	325.45
Ca	239.30	1,538.50	90.73	52.75
Mg	58.00	96.53	926.25	18.55
Cl	267.18	2,725.75	3,728.48	83.58
Na	16.55	33.70	20.83	5.78
K	9.70	6.18	6.45	0.63
B	0.40	0.26	4.45	0.11
P	0.25	0.33	4.38	0.10
Al	0.83	0.25	0.90	0.15
Fe	9.73	0.26	0.28	0.07
Mn mg/l	3.09	0.88	0.10	0.03
Cu	0.06	0.01	0.19	0.01
Zn	0.10	0.15	0.01	0.12
Ni	0.09	0.02	0.11	0.02
Mo	0.02	0.02	0.06	0.02
Cd	<0.01	<0.01	<0.01	<0.01
Cr	0.04	0.09	0.07	0.01
Ba	0.26	0.70	0.23	0.05
Pb	<0.05	<0.05	0.11	<0.05
So2	129.10	486.93	455.80	44.45
Hardness as CaCO3	589.92	4,248.44	4,086.19	209.17

Figure 9. Runoff water quality from the different test sections.

Although the concentration of some of the variables appeared to be very high, TDS for example, the amount of mass going back into the environment was extremely small because there was very little runoff from the storms.

CONCLUSIONS
The Colorado State University Dustometer is precise, portable and inexpensive. It also is capable to generate copious amounts of dust emission data.

There was a substantial reduction of dust emissions using any of the tested dust suppressants.

It appears that the dust production measured by the Colorado State University Dustometer was linearly related to vehicle speed.

The lignon based dust suppressant was the best under high temperatures and low humidity (but degraded after several months).

There was a 41-61 percent reduction of aggregate loss using the dust suppressants.

There was also a 30-46 percent reduction in total annual maintenance costs of treated vs untreated roads.

For an ADT over 120 any of the dust suppressants tested was cost effective.

The aggregate loss in tons/mile/year/ADT was, 2.59 untreated, 1.01 Lignon, 1.49 $CaCl_2$, and 1.04 $MgCl_2$.

Water quality impacts were significant but total mass going into the environment was small.

RECOMMENDATIONS
Study the effects of vehicle weight, number and size of wheels on fugitive dust emission.

Determine the relationship of Dustometer dust measurements and total dust production.

Determine optimal application procedures for the dust suppressants to minimize costs.

Determine the relationship between dust production and aggregate loss.

Determine the portion of the dust emissions of the 10 microns (PM_{10}) or less that might cause respiratory problems.

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