EFFECTIVENESS AND ENVIRONMENTAL IMPACT

OF ROAD DUST SUPPRESSANTS

by

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Disclaimer

EXECUTIVE SUMMARY

This report is an interim report for the first phase of an ongoing project entitled "Effectiveness and Environmental Impact of Road Dust Suppressants" on the cooperative research of Colorado State University and the Larimer County Department of Roads and Bridges. The research was initiated in the summer of 1992 and will be completed by June 1994. The original project was extended due to the inability to collect dependable quantitative water quality and dust data in the first several months of the project.

Although preliminary in nature the research results indicate that, 1) road suppressants have an impact on the water quality concentrations of runoff from the treated road surfaces, 2) road dust production increases linearly with vehicle speed, 3) the lignin based suppressants appeared to perform better than the calcium chloride and magnesium chloride based suppressants, and 4) the measuring device, the Colorado State University Dustometer, developed in this research is a precise research tool which can be used in future dust studies, out performing easily the stationary bucket method for collecting dust samples.

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CHAPTER I

INTRODUCTION

Background and Statement of Problem

Out of the 3.8 million miles of road in the continental US, it is estimated that over 47 percent are aggregate and earth surfaced roads (Colorado Transportation Information Center. #5, 1989). Depending on which part of the country one is located the percentage of the road networks that is unpaved could vary between 30 and 70 percent. For example, here in Colorado approximately 65 percent of public roads are unpaved. Most of the unpaved roads are classified as low-volume roads and are located in the rural and forest areas of the country. While unpaved roads carry a small portion of the country's traffic, they provide a vital first link in the county's economy.

One major and obvious problem associated with all unpaved roads is dust. To residents living along unpaved roads the airborne dust can penetrate their homes causing a nuisance and health problems such as hay fevers and allergies. Dust can also be a conveyor of other diseases (United Nations, 1979). The fine suspended dust particles contribute significantly to the particulate loading in the atmosphere making road dust one major source of air pollution. The dust cloud formed when vehicles use these roads can impair the visibility and cause a hazard to motorists. The fine abrasive particles can also greatly increase the wear and tear on the moving parts of vehicles. The dust can also pollute nearby surface waters and stunt crop growth by shading and clogging the pores of the plants (Colorado Transportation Information Center. #3, 1989).

Besides polluting the environment, the generation of dust means the loss of fines which act as road surface binders. This represents a significant material and economic loss. The severity of the dust problem is determined primarily by the speed of vehicles, the abrasive resistance of the road aggregates and the amount of fines in the initial aggregate mix (Colorado Transportation Information Center. #3, 1989). The volumes of traffic and the climatic condition of the region are also important parameters of the equation. Long dry spells of semiarid and arid regions can also aggravate the road dustiness.

The lost of fines from the road surface as dust led to the coarser aggregates becoming loose and therefore can be thrown or washed away from the road surface. The resulting road is one that is full of corrugations and potholes that require maintenance with a high cost. One source quantifies the dust problem well: "For every vehicle traveling one mile of unpaved roadway once a day, every day for a year, one ton of dust is deposited along a 1,000-foot corridor centered on the road" (USDA Forest Service, 1983). The high maintenance cost in terms of aggregate replacement, with increased public awareness of pollution problems and increased road user cost, has lead highway agencies to have a renewed interest in dust control measures. The frequently used dust control methods include reduction of vehicular speed, application of water and the use of dust suppressing chemicals. Although dust control has been in practice for decades now, quantitative studies on the effectiveness of the dust suppressing methods and their environmental impact have virtually been nonexistent. The purpose of this research project therefore is to determine the impact of dust suppressants on the environment.

Objectives

The main goal of dust control is to stabilize the road surface; reducing the rate of aggregate loss and the money spent annually in replacement. Methods for dust suppressing ranges from the use of dust suppressing chemicals, chiefly chloride compounds and resinous adhesives to utilization of geotextiles in the road surface during construction. There are a number of these dust suppressants on the market now, notable among them lignin derivatives - waste from paper production operations, calcium, magnesium, and sodium chlorides - deliquescent and hygroscopic by nature, Cohorex - a proprietary product, bitumens/tars and many others. So far, many good claims on the effectiveness of these chemicals are being made and any assessments of these claims have only been qualitative.

The objectives identified for this research project therefore are:

1) Development of a device that would provide a standard, quantitative and reproducible method of measuring dust from unpaved road surfaces.

2) Measure the relative effectiveness of the different dust suppressants in controlling dust clouding taking into consideration the prevailing climatic condition also all possible field conditions.

3) Assess the environmental impact in terms of possible water quality effects resulting from the use of the various dust suppressants.

Scope of Study

Control of dust on gravel roads is an important operational and maintenance need. To enable the said objectives to be met, an extensive study of the pertinent literature is carried out to review any previous work done in this area of dust control. Five test sections of 1.25 miles each are constructed, four are treated with four different suppressants and one is untreated which serves as the control. The four suppressants used in the research are calcium lignosulfate, calcium chloride, magnesium chloride and calcium chloride special. The Colorado State University Dustometer, a device attached behind the rear wheel of the research vehicle and samples dust continuously as it is generated is used to measure the dust amount from each of the test sections during the dust production season - late May to October. A monitoring program is setup to sample and analyze runoff from the surface of the test sections as well as runoff from the non-road surface during rainfall events.

Some process variables in this research include, how much dust suppressing chemical is used, how much dust is reduced, what percentage of the chemicals stays on the road, and what is the concentration in the runoff. What is the varying distribution of dust suppressant as a function of the distance from the road and time. How much suppressant remains associated with the dust particles and how much becomes dissolved and mobile and finally what are the concentrations in the non-road runoff. In addition, the seasonal aspects of timing of treatment are of interest, particularly as related to prevailing dry and wet seasons.

CHAPTER 2

LITERATURE REVIEW

Problem of Road Dustiness

Nearly 50 percent of America's roads are unpaved, besides an even larger percentage of private roads and parking lots. Here in Colorado approximately 65 percent of the public roads and over 70 percent of local roads are unpaved. These unpaved roads are located in the agricultural and forest areas and in cities, town and villages. Although they are low-volume and low load bearing roads they are a vital first link in the local economy (Colorado Transportation Information Center. #1, 1989)

A gravel road can be said to consist of a mixture of gravel, sand and fines (silt and clay) in the proportions of 40-80 percent stone or gravel, 20-60 percent sand and 8-15 percent fines (Woods, 1960). The aggregates are blended and compacted into a strong dense surface crust - hard enough to resist breaking down under traffic. A crown is provided at the center of the road and ditches are provided at the shoulders to facilitate drainage.

The problem associated with gravel roads is traffic-generated dust. This involves public economics and environmental quality and is also a nuisance to the public (Hoover J.M. et al., 1981). But even then dust is more than just a nuisance from unpaved roads:

1. By obscuring the vision of drivers, dust clouds are traffic hazards.
2. Dust particulate can be carried several hundreds of feet, penetrating nearby homes and covering crops. Crop growth can be stunted due to the shading effect and clogged plant pores.
3. In human health dust is a common cause of allergies and hay fever and a conveyor of diseases according to a United Nation study (United Nations, 1979).
4. The fine dust particles can be abrasive and therefore greatly increase wear of moving parts of vehicles.
5. The losses of fines (road binder), as dust, represent a significant material and economic loss (Colorado Transportation Information Center. #3, 1989).

6. The fine dust particles are washed off during precipitation and carried into streams, creeks and lakes increasing their respective turbidities.

The severity of a dust problem is determined primarily by the amount of speed of traffic on the unpaved road. The condition can be aggravated by long dry spells, softer road aggregates and initially excessive soil binder in the road surface. Without binder material (enough fines) and adequate moisture, the coarser material will be thrown and washed away from the road surface. When that happens the road begins to ravel, rut and washboard leading to costly repairs.

In 1978, Iowa's 99 county secondary road departments spent $32,267,661 for aggregate replacement, a condition due in large part to traffic abrasion losses from limestone (Hoover, J.M. et al., 1973). Iowa Highway Research Board project HR-151 quantified dust sources and emissions created by traffic on unpaved roads and identified control and surface improvement techniques (Hoover, J.M., 1981). Average dust generation from unpaved roads was found to be one-ton/mile/year vehicle of average daily traffic within 1000 foot wide corridor centered on the roadway (USDA Forest Service 1983).

The problem of road dustiness is a worldwide problem and here in the United States as early as 1909, the "Office of Public Roads", suggested clay-bound stone as the surfacing for roads to alleviate dusting and raveling (U.S. Dept. of Transportation, 1976). Portland cement and asphaltic concrete further stimulated technical solutions to the dust and surface improvement problems. Historically, however, the combination of high initial cost and low traffic volumes on gravel roads did not provide sufficient cost-benefit ratios, a situation that has not significantly changed. Short term relief from dust, raveling and washboarding of gravel roads has thus been accomplished through trial and error technology by a variety of dust suppressants and additives. Such methods have generally been limited in scope and success, with the vast majority of gravel roads receiving only intermittent blading and occasional aggregate replacement.

Mckee, H.C.(1969), showed that evidence exists that suspended particulate have the potential to alter weather patterns and affect human health. A study commissioned by the American Petroleum Institute in 1971 estimated that soil dust from tillage and unpaved roads contributed approximately 10 percent of the annual total particulate emissions on a global scale (Robinson, et al., 1971). Governmental regulations in recent years have accelerated the rate of air quality monitoring and control. For example here in Colorado the Clean Air Act of 1982(Title 25) specifically section III.D.2.a(i.)(B) of Regulation 1 - the general requirements states that, "Any owner or operator responsible for construction or maintenance of any (existing or new) unpaved roadway which has vehicle traffic exceeding 200 vehicles per day in attainment areas or 150 vehicles per day in non-attainment areas (averaged over any consecutive 3-day period) from which fugitive particulate emissions will be emitted shall be required to use all available practical methods which are technologically feasible and economically reasonable in order to minimize emissions resulting from the use of such roadway." All this can have a considerable impact on local government's maintenance and/or construction procedures for unpaved roads.

Literature concerning atmospheric pollution from dust appears to center on two areas of study: 1) atmospheric modeling and prediction, and 2) field measurement and quantification. Several studies have proposed mathematical models for generation and distribution of particulate emissions from various sources (Robinson, E. et al., 1971) and Becker, D.C., 1978). Becker, D.C., (1978) examined a Gaussian plane model applied to dust generated from unpaved roads in Iowa and Kansas. Included were limited field measurements, using a high volumetric sampler and mechanical analysis of collected particulate.

Types of Dust Suppressants

Presently, methods of dust control range from spraying the roads with chemicals, chiefly chloride compounds and resinous adhesives to using geotextiles in the road reconstruction (Colorado Transportation Information Center. Bulletin #3, 1989). The use of these dust suppressants can be justified when:

1. the traffic is low or paving is not feasible for lack of funds,
2. the cost of suppressant and application is low, and
3. when stage construction is planned.

The commonly used dust suppressants are lignin derivatives, calcium chloride, magnesium chloride, sodium chloride, road fabric, resinous adhesives, water and etc. The selection of a particular suppressant depends not only on its performances characteristics, but also on the type and volume of traffic, roadway condition and product cost to achieve the desired level of dust control (Colorado Transportation Information Center. #3, 1989).

Hygroscopic salts such as Magnesium Chloride and Calcium Chloride especially have been used to treat unpaved road surfaces since the last century. Because of their hygroscopic properties they do not only retard evaporation from the road surface during the heat of the day, but draw moisture from their surrounding (environment) to produce a brine that in turn keeps the road surface moist (Larkin Laboratory, 1986). Results from a study comparing Magnesium Chloride with Calcium Chloride shows that although both agents work the same way, there are still some differences between the materials that effect their performance and efficiency. The key criterion for judging these dust control agents is their ability to produce a brine under adverse conditions, such as high ambient and road surface temperatures and low humidity. These conditions generate the worst traffic dust, and it is under these adverse conditions that the properties of Calcium Chloride make it a more suitable alternative than Magnesium Chloride (Larkin Laboratory, 1986).

The solubility of Calcium Chloride compared to Magnesium Chloride increases more rapidly with increasing temperature. This means that Calcium Chloride will produce a brine at low relative humidities and under hot dry conditions that cause the greatest dust control problems. A study done at the Swedish Royal Institute of Technology quantified the difference between the two dust control agents on actual gravel roads and found Calcium Chloride to be 18 percent more effective than Magnesium Chloride (Reyier, J., 1972). Other chlorides are widely used particularly for stabilizing the surfaces of haul roads. Calcium Chloride is relatively expensive so usually a mix of common salt and Calcium Chloride is used to cut cost while controlling dust effectively.

The adhesive and waterproofing characteristics of bituminous materials are well known, but they are very expensive to use. Lignin derivatives are natural cements that bind dust particles. They are aided by associated sugars that act as hygroscopic agents. Various hybrid products are emerging (e.g. a bitumen-lignin dust control agent) which pose opportunities for cooperative test projects.

Effectiveness of Dust Suppressants

Two primary dust suppressant application methods are commonly used. 1) surface or topically sprayed, and 2) mixed-in-place. Surface or topically sprayed involves spraying the suppressant on the road surface after the road surface has been maintained (bladed). The method is simply and fast (Woods, K.B., 1960). Suppressants applied by this method turn out to be effective for short periods of time resulting in the need for repeated applications during a single season. Calcium Chloride, Magnesium Chloride, lignin and cutback asphalts are usually applied using this method.

Mixed-in-place is another method involving the addition of the suppressant to the road surface material in-situ. This is achieved by mixing the suppressant with the aggregate after the road surface has been scarified. The method does not only achieve palliation but provides improved road surface resulting in reduced maintenance cost from continued palliative applications and/or aggregate surfacing replacement (Hoover, J.M. et al., 1973). Furthermore in-depth stabilization may improve the sub-base or base for future higher type pavements.

Laboratory tests on many dust suppressants and surface improvement agents lead to the selection of six agents that were placed in road test sections in Poweshiek, Linn and Clinton Counties (Iowa) for controlled experimentation. The dust control agents used were MC-800 cutback asphalt, a cationic asphalt emulsion, lignin, lignin plus alum, lignin plus lime and a residual waste product of the Chemplex Plastic Co., Clinton Iowa (Hoover, J.M. et al., 1981). The experiments showed that there was approximately one-third to more than 80 percent reduction in dust from the treated roads as compared to the untreated roads, with amount of dust reduction depending on the method of treatment. Aggregate pullout from the road surface was also reduced to as little as one-fourth of that of untreated surface (Hoover, J.M. et al., 1981). Thus, it was shown that dust generation can be controlled, and annual aggregate replacement could also be reduced by a factor of 2 to 4, the latter alone offering a potential annual cost saving of several thousand dollars per mile. Reduction of dust and aggregate loss was also coupled with significant reduction in normal weekly to monthly blading and grading for the palliation sections, and generally no blading operations were required in the mix-in-place applications, a definite maintenance cost saving.

Research was done on six test sections using lignin, lignin plus a herbicide, two cationic emulsions, and a proprietary chemical called Kelpak in a mix-in-place application and the sixth was calcium chloride in a surface application. Several weeks after construction, volumetric dust sampling measurements on the test sections revealed that the lignin and lignin plus herbicide sections produced less than 10 lbs. of dust per million ft^3 of air. Both cationic emulsions produced less than 3 lbs/million ft^3 of air while the control section for all the above treatments methods produced more than 55 lbs./10^6 ft^3 of air. The proprietary chemical produced 6.5 lbs with its control producing 13 lbs./10^6 ft^3. A year later, the lignin, lignin plus herbicide and both asphalt emulsions still produced significantly less dust as compared to the control while the proprietary chemical was producing dust about equivalent of its control. Initial data on the calcium chloride section and its control were 12 and 27 lbs. of dust/10^6 ft^3 of air respectively. In less then a year the calcium chloride section was producing as much dust as its control (Hoover, J.M., et. al., 1981).

In a cost benefit study on road dust conducted in the Seattle Industrial Valley, Robert, J.W. (1975) reported that dust emissions on 19 miles of gravel road and 110 miles of dusty paved roads contributed an estimated 2700 tons/year of particulate, of which 700 tons were of a particle size of less than 10 microns (0.01 mm). He suggested that paving roads having an average daily traffic (ADT) over 15 were the least costly methods for reducing dust, and it was a good investment when the traffic exceeded 100 ADT. Paving or oiling the road was estimated to produce benefit of nearly $3.9 million yearly in household cleaning, health care, vehicle operation, sewer and road maintenance costs, coupled with increased property values.

The effectiveness of lignin was discovered in a study on three test sections in Taylor county - Iowa, using 0.75, 1.00 and 1.25 percent by soil weight of Bindtite, a lignosulfonate, (Blunck, T.R., 1975). The sections ranged in length from 0.25 to 1.25 miles and before the treatments, they were experiencing complaints of dust, potholes, washboarding, frost heaving and general deterioration of the surface. Pre-construction consisted primarily of blade dressing of the road shoulders and ditch line and reclaiming of aggregate pullout. Finally the surface was scarified, mixed with the lignin and compacted into a 6-inch thick wearing course. The treated sections did not receive a seal coat until way over a year after construction. During this period, all the sections remained nearly free of dust, potholes or washboarding and the surfaces remained relatively dry and solid after each rain.

From various laboratory and field studies done on dust palliative, it can be concluded that for a chemical dust palliative to be effective, it must provide significantly increased physico-and surface-activity in order for the fine particulate to remain in an aggregated form under adverse conditions of both weather and traffic (Hoover, J.M.,et al 1973). For example calcium chloride and lignin improve capillary cohesion while rain does not occur. When mixed-in-place, the lignin and calcium chloride have already been noted as showing greater longevity. For asphalt, the electric potential created by varying the type of emulsifier within an asphalt produces variations in strength also potential effectiveness as a dust stabilizer for a given soil.

CHAPTER 3

DATA GATHERING

Test Sites

Five test sections were evaluated in this project, all of which are located in Larimer County - Colorado. The treated sections are four in number and are located on the same stretch of road in the Loveland area of the County. The stretch is County Road (CR)12 which changes into County Road (CR)29. The untreated test section is located on CR-40 which is in the Fort Collins area. CR-40 and CR-12/29 are within 20 mile radius of each other. Figure 1 shows part of the map of Larimer County with the locations of the test sites highlighted.

The climatic condition of this region can be described as semiarid with annual precipitation in the test site area being approximately 14 inches/year. The generalized soil/aggregate characteristics of the sites can also be termed glacial till/some silty clay/gravel. The average daily high temperature during the dust production season - late May to October is approximately 78^{o}F with a relative humidity of about 33 percent.

The treated test section CR-12/29 is a five-mile stretch and has an average daily traffic (ADT) of about 400. This unpaved road links two paved roads in the area CR-23 and CR-29. Carter Lake which is a recreational area is also within a 15-mile radius of CR-12/29 thus the treated sections besides serving a rural community of livestock owners, carry a substantial portion of the traffic visiting the lake. The composition of the traffic on this road vary from cars to light trucks to heavy tandem axle vehicles. The untreated test section CR-40 like CR-12/29 links Horsetooth and Harmony roads both carry very high volume traffic. It also serves a historic site - the Strauss Cabin and a small recreation lake in the area. The average daily traffic (ADT) is about 200, and the composition of the traffic can be said to be of all types and sizes of vehicles.

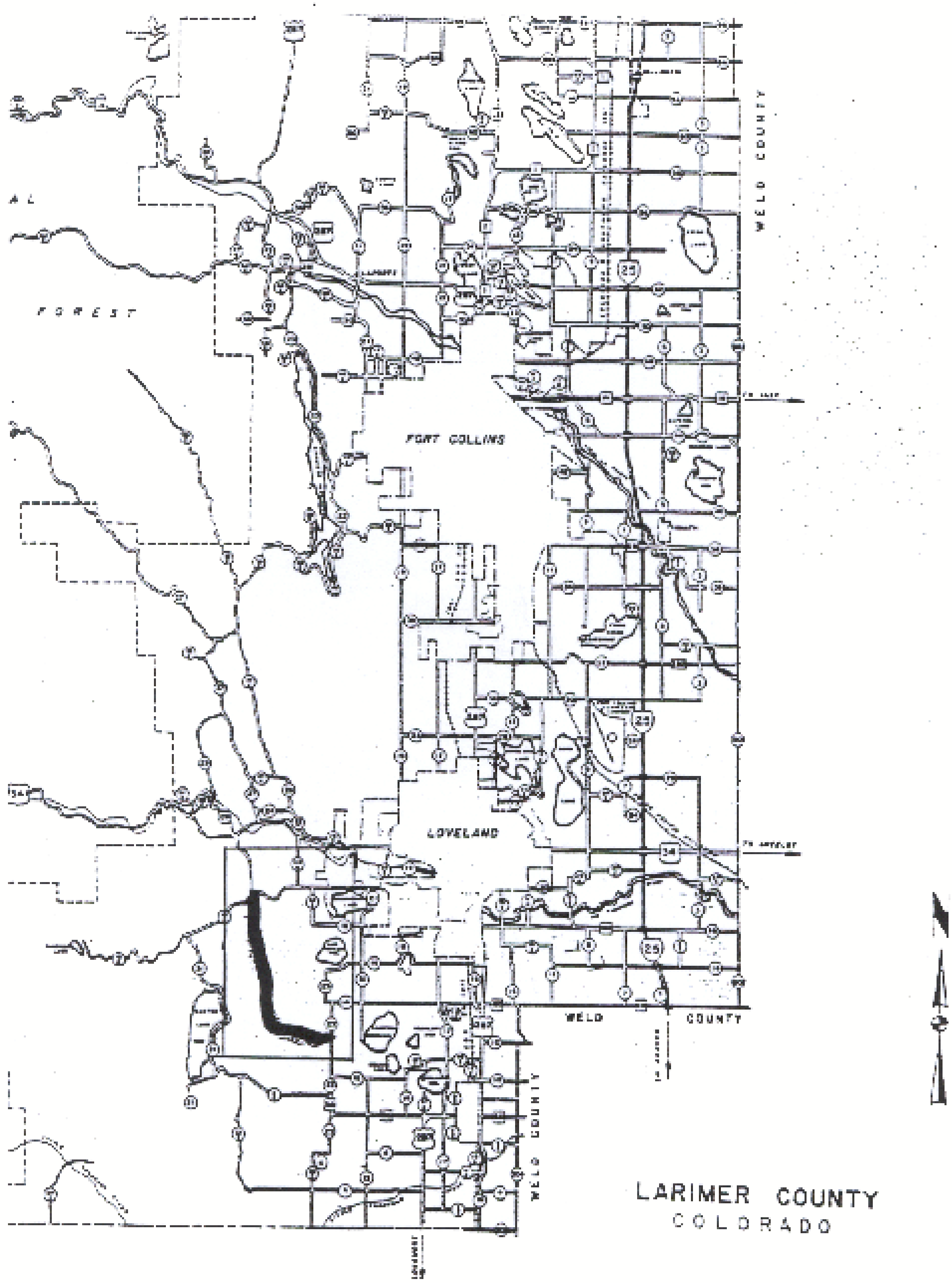

Figure 1. Map of Larimer County

Prior to the start of this research project there was stage construction planning by the Larimer County road officials. The CR-12/29 had been treated twice with Magnesium Chloride, once a year for two years. The treatment evaluated in the research is the third in succession of a road stabilization program that started three years ago. The untreated section did not have any prior treatment.

The construction of the treated test sections followed the procedures recommended in most of the transportation literature and that of the dust suppressants suppliers. Important application techniques for many dust suppressants include; a) road surface scarification, b) adequate grading and smoothing of the road surface, c) application of the dust suppressant in quantities suitable for effective control of dust, and d) proper road finishing procedures that include the forming of the surface crown, optimum compaction of the road surface and proper drainage (Rural Transportation Fact Sheet #84-02, 1984). Preconstruction of these test sections consisted primarily of blade dressing of the road shoulders and ditch line and reclaiming of aggregate pullout. Finally the surface was scarified, mixed with the particular suppressant and compacted to a 6-inch thick wearing course.

The gravel used for the construction of the test sections was from the same gravel pit. Examination of the AASHTO classification indicated a A-2-4 class, rated as good subgrade material. The four dust suppressants evaluated in the research are:

1) Calcium Lignosulfate. A by-product of the paper pulp industry, this form of lignosulfate was supplied by Georgia Pacific Corporation. The application rate was one-half gal/sq yd - supplier's recommendation.
2) Calcium Chloride (35 percent $CaCl_2$ in a water solution). A deliquescent and hygroscopic by nature. The compound was supplied by Hill Brothers Chemical Company. The application rate was one-quarter gal/sq yd - supplier's recommendation.
3) Magnesium Chloride (32 percent $MgCl_2$ in a water solution). A deliquescent and hygroscopic by nature. The compound was supplied by Envirotech Services, Inc. The application rate was one-half gal/sq yd - supplier's recommendation.
4) Calcium Chloride Special. A $CaCl_2$ based compound. The difference between the $CaCl_2$ Special and $CaCl_2$ is that according to the suppliers the $CaCl_2$ Special brand contains no magnesium whereas the $CaCl_2$ brand contains fractions of magnesium. The compound was supplied by Hill Brothers Chemical Company. The application rate was one-quarter gal/sq yd - supplier's recommendation.

The position of each treatment on the stretch is labeled 1-to-4 as shown in Figure 2. The length of each treated test section is 1.25 miles long. Table 1 describes the features in the terrain of each test section.

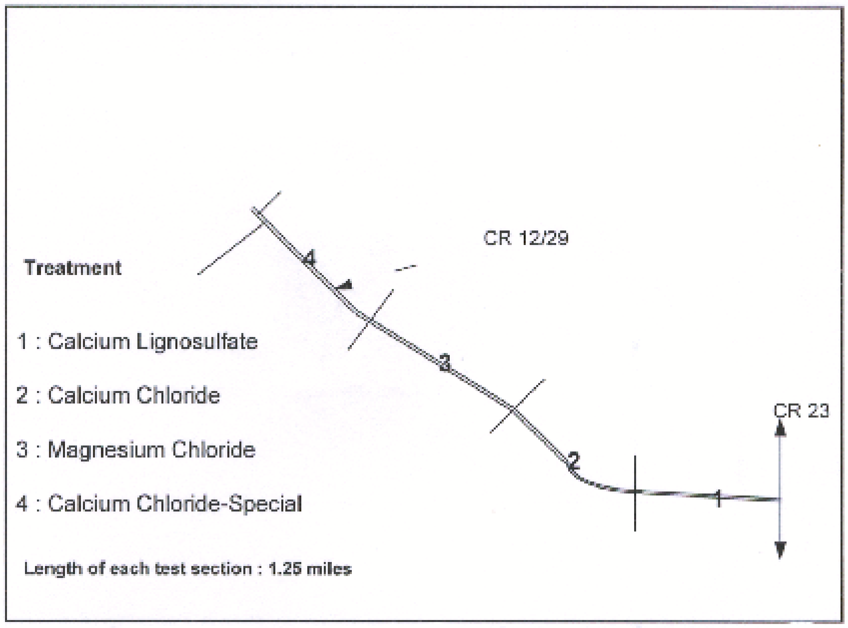

Figure 2. Position of each treated section on unpaved road

Table 1. Test Sections Features

Test Section	Features in Terrain
1. Calcium Lignosulfate	. flat for most part . one main curve . excellent drainage
2. Calcium Chloride	. moderate slopes . two main crowns . one main curve . good drainage for part
3. Magnesium Chloride	. gentle slopes . two main crowns . one main curve . good drainage
4. Calcium Chloride-Special	. gentle slopes . one main curve . excellent drainage
5. Untreated	. straight stretch . flat for approx. 80 percent of stretch . steep slope rest of stretch . excellent drainage

The number of curves, uphills/downhills and how steep the slopes are as well as the drainage condition of a particular test section not to mention the volume of traffic among other things are very important factors that determine how well a treatment holds up. Table 2 shows the volume of traffic measurement in terms of average daily traffic (ADT) on the test sections.

Table 2. **Traffic volume count (ADT) on test sections. Data gathered on CR-12/29 during week of June 14 through June 21, 1993**

Test Section	Weekday ADT	Weekend ADT	Weeklong ADT
Beginning of Lignin	515	541	515
Lignin/$CaCl_2$ split	389	451	416
$CaCl_2$/$MgCl_2$ split	322	381	347
$MgCl_2$/$CaCl_2$ (Spec) split	423	510	460
End of $CaCl_2$ (Spec)	437	503	465

Untreated section ADT is estimated as 200 (personal communication with Bill Heiden-Director Larimer County Roads and Bridges Department).

Dust Measurement

Although road dust research has been going on for several decades now, it is apparent from reviewing previous works that despite all the money and time invested, quantitative measurements of dust from roads have been practically nil. Without any quantitative dust measurement, it is difficult if not impossible to assess the economics and lasting value of dust palliation methods. With the above mentioned problem in mind, one of the said objectives of this project was therefore to develop a dust monitoring method that would be quantitative, reproducible, portable, cost effective and easy to operate.

From the literature review apparently there have been various attempts by different people to develop devices and procedures that would measure road dust. Notable among them are Schultz (1983), Wellman and Barraclough (1972), Hoover et al. (1973), Langdon (1984) and Irwin et al. (1986) to name a few.

Some of the measuring techniques used stationary devices which characterize road dustiness at a particular point while others used moving devices which provided a dust measurements that describe a section of road. The dust quantification method common among all the previous works was either the weighing of the collected dust or the measurement of air opacity using visible light.

In this research project, "Effectiveness and Environmental Impact of Dust Suppressants", early attempts to use the dust collecting bucket method according to ASTM D-1739 (see Figure 3) in the summer and fall of 1992 proved to be ineffective and inefficient. The reasons were: (1) it was difficult to obtain permission from the land owners to setup the dust collectors, (2) the land along the test sections are grazing pastures, and (3) there was the problem of livestock continually tampering with the dust collectors. The method also requires so many vehicles to drive by the buckets before a substantial amount of dust can be collected for quantification and there was a problem with wind.

Figure 3. Dust Collecting Buckets after ASTM D - 1739.

For the dust monitoring program of the project from spring through fall 1993 a decision was made to develop a device and procedure that measures the dust production from the test sections in-situ and on a real time basis. Considering the inherent variability associated with road dust, the method should measure dust along a section of road rather than at a single point. The method should also be quantitative and reproducible. Modeling a device and procedure after Langdon (1984) who used a portable cyclone dust collector mounted on the back of dust generating vehicle, the Colorado State University Dustometer was developed, field tested and used in this research.

The moving dust sampler is illustrated in Figure 4. The device consists of: (1) a quarter-ton pickup truck, (2) a 3,000 watt electric generator, (3) a standard high volumetric suction pump, (4) a fabricated metal box that contains a 10 in by 8 in (25.40 cm X 20.32 cm) glass fiber filter paper, (5) a metal bracket attached to the bumper of the truck, and (6) a 2 in (5.08 cm) internal diameter flexible tube for connecting the suction pump to the filter box. The filter box is rigidly secured to the bumper by way of the bracket behind the left rear tire of the quarter-ton pickup truck. The generator and the high volumetric sampler are secure in the bed of the truck. Figures 5-7 show the components of the setup. The filter box when mounted behind the truck is horizontally aligned with the left rear tire and the distance from the center of the tire to the front of the box is three feet. There is a vertical clearance of one foot between the bottom the box and road surface.

The design of the box and bracket system is such that although the box is rigidly secured to the bumper of the truck after the setup, the box can be mounted and dismounted with relative ease. The bracket is made out of 1/4 in thick 6 in x 6 in steel angle treated with a rust-proof paint. It is fixed to the bumper by two bolts as shown in Figure 7. The filter box is fabricated out of a steel sheet. It has 12 in x 12 in opening that is covered with a 200 micron mesh sieve which faces the tire. The 200 micron sieve prevents any non-dust particles from being drawn onto the filter during dust measurement. The bottom part of the box contains a sieve that supports the filter paper. The box is designed to allow for easy replacement of the filter paper.

To run a typical dust measurement test the device is setup as shown in Figure 4 with the flexible tube connecting the pump to the filter box. The generator is started and by the aid of a switch the pump is turn on and off from the cab of the truck. One mile long sections have clearly been demarcated on the 1.25 mile sections. With the filter box fitted with preweighed filter paper and generator started, the truck is driven at the stipulated speed of 45 miles per hour (MPH). Right at the beginning of the mile mark the pump is turned on and a portion of the dust kicked up by the left rear tire is drawn onto the filter as the truck traverses down the road, at the end of the mile run the pump is turned off and the truck is brought to a stop. Three runs are made in the same driving lane for each test section. The dust laden filters are taken to the laboratory and weighed. The average of the three measurements for each test section are compared to assess the relative effectiveness of the different treatments.

Figure 4. Colorado State Dustometer Dust Sampler (Moving Method)

Figure 5. Electric Generator and High Volumetric Suction Pump in the Bed of Truck

Figure 6. Filter Box and Connecting Flexible Tube

Figure 7. Metal Bracket Fixed to Bumper of Truck

Runoff Sampling

Similar to the problems associated with road de-icing, there may be possible environmental problems of water quality degradation in both surface and subsurface water due to the long term use of dust suppressants. All of the four compounds evaluated in this research are water soluble. A runoff sampling analysis program was designed to help answer some questions about how much of suppressants are being washed off during rainfall events. The sampling technique employed involved the use of plastic containers installed at the shoulders of the test sections. The locations selected for the installation of the containers were such that during a rainfall event and when there is adequate runoff from the road surface some amount of the runoff would enter the containers. For the non-road runoff sampling, containers were installed near the test sections but at a distance far enough up gradient to insure only non-road surface runoff is collected. Figure 8 shows an installed container on the shoulder of a test section. After a rainfall event all the containers are inspected and emptied. The sampling containers are reinstalled and the samples are sent to the laboratory for analysis.

Figure 8. Runoff Sampling Container Installed at Shoulder of Road

CHAPTER 4

DATA ANALYSIS

Dust Quantification

The dust monitoring was carried out from the Spring through the Fall of 1993, the time in which dust generation in the Larimer County is severe. The construction of the test sections was done on the 10th of May, but it wasn't until 40 days later before the dust measurements started. The treated sections were dust free in those early days after the treatment. The development, calibration and field testing of the dust measuring device also took place at the time. Dust measurement was done once a week although there were times when the weather conditions in the field did not permit measurements to take place exactly at one week intervals.

To demonstrate the precision in the dust measurements made using the Colorado State University Dustometer, nine replicate samples were done on the untreated test section at a speed of 45 MPH. Table 3 shows the data and its distribution. A mean of 2.74 grams was obtained with a standard deviation of 0.21 and a variance of 0.04.

It is obvious from field observations that the speed of a vehicle is a very important factor in dust generation from unpaved roads. To help qualify this phenomenon, dust measurements were made at various speeds; 20 MPH through 50 MPH on the untreated test section. For the mile long run the dust amounts at 20, 30, 40 and 50 MPH are shown in Figure 9. Adjusting the dust amounts for a three minute run takes into account the fact that the device setup involves the suction of a dust cloud over the filter, the data in Figure 10 was generated. Surprisingly Figure 10 show a linear relationship between the speed and amount of dust generated. The coefficient of linear regression r^2 for this plot is 0.98. Including more

Speed : 45 mi/hr
Length of run : 1 mile
Untreated Section

Sample #	Wt. (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 = 2.74g +/- 5.8%
Standard deviation = 0.21
Variance = 0.04

Table 3. Typical Dust Measurements

data points during the measurement did not change the linear relationship as shown in Figure 11. Table 4 shows the dust amounts measured on all the five test sections. In all, fourteen measurements were made during the research period. All data points are averages of three replicate samples.

Runoff Analysis

All runoff samples collected from the various rainfall events were analyzed by measuring total dissolved solids (TDS), conductivity, total hardness and the amount of free chloride present in the samples. The procedure used in the analysis were according to the Standard Methods for the Examination of Water and Wastewater, 16th Edition, 1985. Table 5 shows the total hardness measured in all the runoff samples collected from both the road and non-road surfaces. The data analyses is still ongoing and in the final report all the detail analysis will be presented.

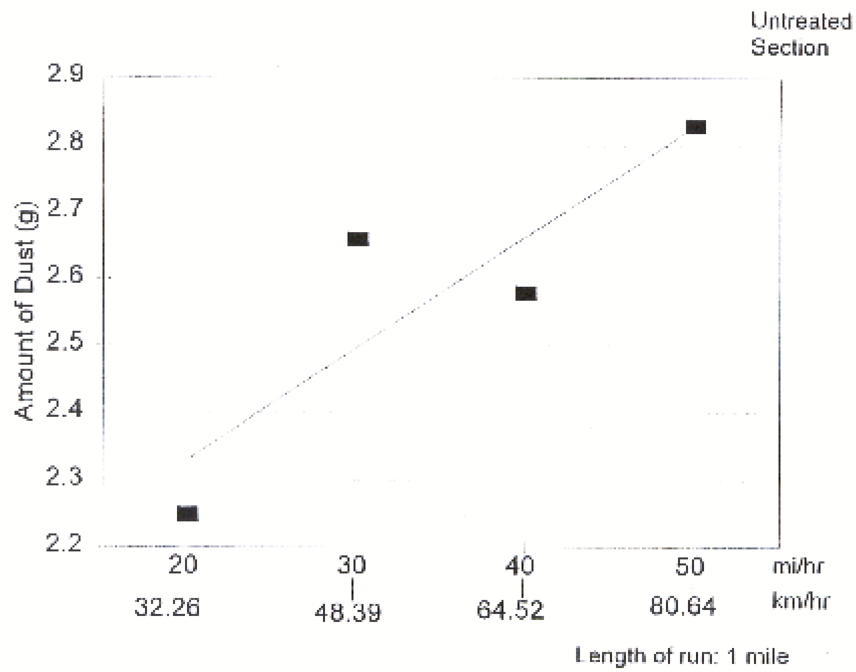

Figure 9. Amount of Dust vs. Speed

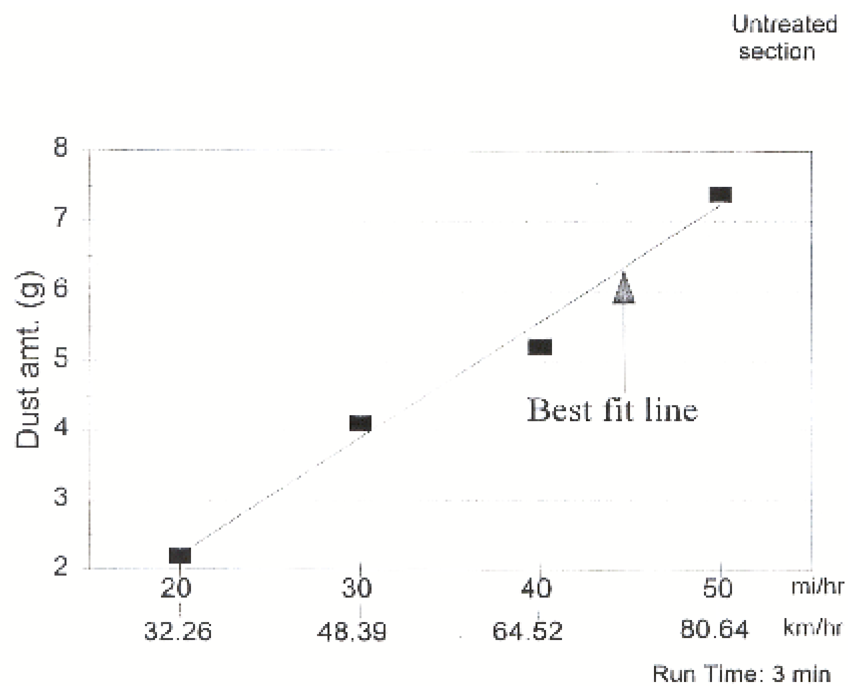

Figure 10. Amount of Dust as a Function of Speed

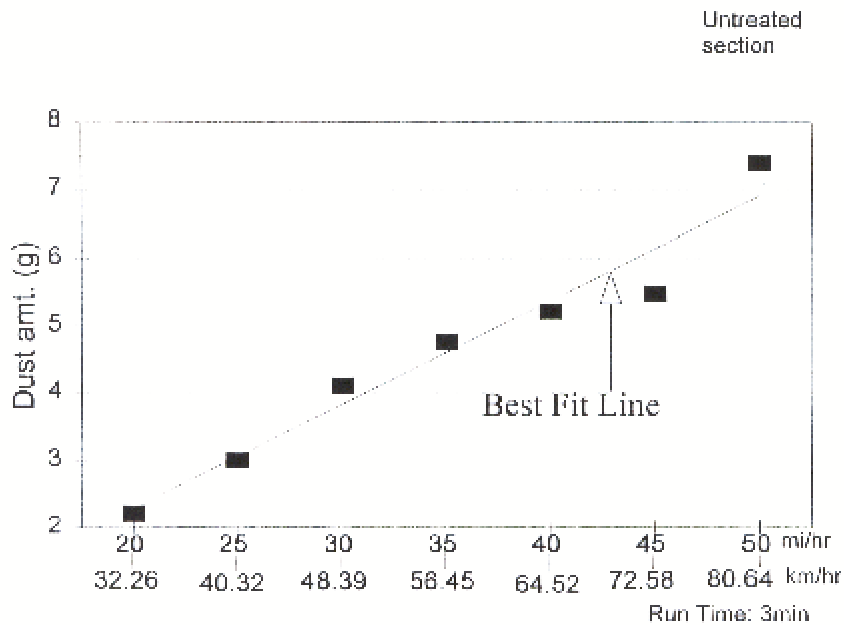

Figure 11. Amount of Dust vs. Speed

Table 4. Dust Measurement

Dust weight = average of 3 measurements
Passes are run in the same driving lane
Length of each treated test section = 1.00 miles
Length of untreated section = 1.00 mile
Treated Sections done on 05-10-93
Speed = 45 mi/hr

				Treated Sections				
Notes	Days After treatment	Date of last rain	Sampling date	Lignin treatment (g)	CaCl2 treatment (g)	MgCl2 treatment (g)	CaCl2 (Spec) treatment (g)	Untreated Hsth (g)
	41	06-18-93	06-21-93	0.2286	1.0024	0.6822	0.7436	2.0777
	48	06-18-93	06-28-93	0.1038	0.3119	0.2350	0.1897	2.3805
	58	06-18-93	07-08-93	0.0507	0.4466	0.2386	0.3052	rain out
	66	07-13-93	07-16-93	0.1358	1.4817	1.0270	0.7760	2.4673
	73	07-20-93	07-23-93	0.1326	1.7273	1.2816	0.9116	2.8310
	79	07-20-93	07-29-93	0.2032	1.5224	0.8270	0.9812	3.2498
	90	08-05-93	08-09-93	0.1464	1.4109	1.1550	1.2364	1.6039
	94	08-05-93	08-13-93	0.2970	1.8050	1.6532	1.3685	2.1326
	97	08-05-93	08-16-93	0.2952	1.5382	1.4650	1.2574	2.0215
	104	08-19-93	08-23-93	0.2697	1.9783	1.4043	1.4018	2.8074
	113	08-19-93	09-01-93	0.2902	2.1132	1.7526	-	3.2319
	123	09-07-93	09-11-93	0.2798	1.4439	1.1784	-	2.3324
PM	139	09-15-93	09-27-93	0.0970	0.5065	0.2451	0.2800	2.1495
	146	09-15-93	10-04-93	0.1145	0.6962	0.3538	0.3397	3.0917

PM : after test sections had been graded, watered and compacted.

Table 5. Water Quality Data from Runoff. Measured in Total Hardness (mg/L as CaCO3)

Date of rain	Amount of rain (in)	Lignin treatment	CaCl2 treatment	MgCl2 treatment	CaCl2(spec) treatment	Nonroad runoff
05-18-93	0.13	-	-	15,666	1,130	-
05-24-93	0.06	-	-	3,400	1,805	-
06-16-93	0.28	840	823	3,128	605	50
06-18-93	0.21	333	475	561	98	35
07-13-93	0.64	675	330	190	156	30
07-20-93	0.06	685	887	1,412	-	-
08-02-93	0.08	-	-	3,040	-	-
08-05-93	0.55	933	543	438	327	-
08-19-93	0.18	790	1,250	780	270	-
09-07-93	0.19	977	320	390	350	32
09-13-93	0.99	970	134	200	120	30
09-15-93	0.83	-	280	112	66	30

Stock solution (mg/L as CaCO3)

Lignin	45,000
CaCl2	454,800
MgCl2	448,000
CaCl2(spec)	310,000

CHAPTER 5

CONCLUSIONS

This project is ongoing at Colorado State University to study **road dust suppressants** with the objective of measuring the relative effectiveness in this semiarid region as well as any water quality degradation resulting from this useage. Five test sections are being evaluated in this research project - four treated and one untreated, which serve as control. The four dust suppressing compounds used are: Calcium Lignosulfate, Calcium Chloride, Magnesium Chloride and Calcium Chloride special.

The following conclusions can be drawn thus far:

a) Dust measurements from all the five test sections indicate that the treated sections produce less dust than the untreated section.

b) The lignin based suppressant appears to perform better than the other suppressants.

c) Water quality analysis indicate suppressants concentrations in runoff samples from the treated road surfaces.

d) The Colorado State University Dustometer, a dust measuring device, developed and used in this comparative study is a portable, quantitative and precise research tool which can be used in future dust studies.

The data analyses is still ongoing and in the final report all detail analysis will be presented.

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