ARIZONA DEPARTMENT OF TRANSPORTATION

SOIL EROSION AND DUST CONTROL ON ARIZONA HIGHWAYS

Part IV Final Report
Field Testing Program

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16. Abstract
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SOIL EROSION AND DUST CONTROL ON ARIZONA HIGHWAYS

FINAL REPORT - FIELD TESTING PROGRAM

by

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Submitted to

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Phoenix, Arizona 85007

for

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ABSTRACT

Several chemical stabilizers were selected for use in a large scale field application, based on a laboratory testing program. Spray-on application of chemicals to control dust and wind erosion on untrafficable areas were made using eleven chemicals. Five chemicals were used on an unpaved road using a spray-on application to control erosion and dust behind traffic. Three chemicals were also used on the unpaved road using a mixed-in application. Methods of field application are given. Details of monitoring techniques including Hi-Vol dust collection, dust fall collection in cups, and extraction tests are discussed. Results indicate availability of several chemicals that proved successful in controlling dust on untrafficable areas. Only two chemical treatments proved successful to provide long-term dust control behind traffic on unpaved roads.

KEY WORDS: Chemical Stabilization, Soil Stabilization, Erosion Control, Dust Control, Wind Erosion, Traffic Erosion, Dust Collection, Field Applications.

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PROJECT SUMMARY

Statement of the Problem

One problem associated with the potential of the arid and semi-arid climate soils to erode is the movement of cohesionless sandy soils due to wind erosion and the development of sand storms and high levels of dust particulates. These dust storms have been the cause of numerous chain car accidents on Arizona highways due to the severe reduction in visibility during such storms.

In addition, the unpaved "gravel" secondary roads have been a continuous item on the maintenance budget because of the need for periodic grading and replacement of material lost through erosion due to traffic. Experience and road studies indicate that annual losses of road material can reach about 200 cubic yards per mile (95 m^3/Km) for unpaved roads. In addition to these gravel losses, the loss of air-borne silt and clay size particulates was estimated to the order of 5 to 50 grams per vehicular mile. With a traffic volume of 250 vehicles per day the dust pollution may amount to 0.5 to 5 tons of air-borne particulates per mile (0.28 to 2.8 tons/Km) per year.

As we are becoming increasingly aware, the above mentioned problems have already posed severe safety, health, and public relations problems and are expected to continue unless positive measures for erosion control are developed and implemented.

Objectives of the Study

The specific aims of the study are to search for, determine, and identify those stabilizing agents that are best capable of controlling soil erosion due to wind and traffic forces and providing positive dust control measures. These selected stabilizers shall be economical, easy to apply in the field, and durable to withstand various environmental conditions.

The ultimate objective of this investigation is the development and implementation of low cost stabilization techniques that will provide positive dust control measures and will result in better specifications for the construction of erosion-resistant roads and for the protection and maintenance of existing erodible secondary roads.

Interim Reports Submitted

This project started on December 6, 1972; the currently approved completion date is February 4, 1976. Due to the length of the investigation and the different phases of the work, it had been agreed upon to submit interim final reports covering completed phases of the study. The following interim reports have been submitted and approved by ADOT and FHWA.

1. Interim Final Report - Part I: That interim final report covered the completed comprehensive literature survey of the state-of-the-art pertaining to the basic parameters affecting soil erosion and the most acceptable soil erosion control and prevention techniques. A detailed review of previous work done on the use of chemical stabilizers for the control of wind

erosion, water-rain erosion, and traffic erosion was included. The report was dated October 1974.

2. Interim Final Report - Part II: That interim final report presented the results of the completed laboratory testing program. The report covered the criteria for selection of chemical stabilizers, the types of soils used in the laboratory, along with the different tests conducted for dust control studies and traffic erosion control studies. The results of the laboratory studies were also presented, evaluated, and discussed. The report was dated October 1974.

3. Progress Report - Field Testing Program: Based on the results of the laboratory studies, several chemical stabilizers were selected for application in a full-scale field evaluation program. The field tests included dust control studies on non-trafficable areas and traffic erosion studies on an unpaved road. The field testing program started in May 1974, and the progress report presented a summary of the available data from field monitoring until September 1974. The report was labeled as Part III and dated October 1974.

Outline of the Final Report on Field Testing Program

This final report, which follows, presents the results of the completed field testing program. The collected field data are presented and analyzed. Overall conclusions and recommendations based on the project's findings are given, along with a summary statement on research implementation. This report is dated February 1976 and it concludes the project.

SOIL EROSION AND DUST CONTROL ON ARIZONA HIGHWAYS

PART IV

FINAL REPORT - FIELD TESTING PROGRAM

CHAPTER 1

INTRODUCTION

This report presents the results of the completed field testing program. The chemicals used in the field applications were selected at the conclusion, and based on the results of, the laboratory testing phase of the project. The field testing program included a spray-on application of chemicals on untrafficable areas which represents a wind erosion control or a dust control measure only. Road tests for spray-on and mixed-in applications of chemicals were also conducted for traffic erosion control and control of dust due to traffic.

It is pointed out that this report constitutes Part IV in a series of reports submitted covering the results of this project. Part I (Sultan, 1974a) included the state-of-the-art literature review. Part II (Sultan, 1974b) included the results of the laboratory testing phase of the study. Part III (Sultan, 1974c) presented a progress report summarizing the preliminary results of the field study after about 3 months of monitoring the applications. This report, Part IV, presents the detailed results for the completed testing program and is titled as a final report since it completes the project.

SCOPE OF THE FINAL REPORT

In this report a brief summary of the field test activities is given first to provide background for the reader and understanding of the data collected. This summary outlines the chemicals used for each application, the types of field applications, the methods used in applying the chemicals and the various monitoring tests used to evaluate the field performance of the chemical treatments. Most of these items have been previously given in the Progress Report-Part III (Sultan, 1974c) in more detail. The main scope of this report is to present the results of the completed field testing program. The collected data are presented and analysed. The overall conclusions and recommendations based on the project's findings are given. In addition, a summary statement on research implementation is also given.

CHAPTER 2

FIELD APPLICATIONS - DUST CONTROL SITES

The restriction of untrafficability imposed on this application necessitated that the treated areas be protected from pedestrians, drag-racers, pranksters, and animals that would disturb the surface treatment. A site was used at the University of Arizona Agricultural Experiment Station (AES) Farm, in Tucson. Two months after the application of the chemicals at the AES farm site, during which the summer thunderstorms started accompanied with above normal rainfall, weeds started to grow profusely. The growth of weeds obscured the conditions of the sprayed surfaces and affected the dust collection data. Accordingly, another site was sought, prepared, and sprayed with the chemicals along with a weed control agent. This new site was selected adjacent to the ADOT District Maintenance Yard (ADOT Yard), in Tucson.

AES Farm Site

Site Preparation

The northwest corner of the AES farm, at the intersection of Dodge Street and River Road, in Tucson was the location assigned for this site. An area of 120 feet (36.6 m) by 220 feet (67 m) was allocated for use on this project. The site had been previously used for farming and had been disc-harrowed several months prior and was relatively free of weeds. The assigned test area was leveled and smoothed over using a steel drag. The combination of these activities left the top 3 to 6 inches (7.62 to 15.24 cm) reasonably loose. The area was then subdivided into 14 plots of 20 feet by 40 feet (6.1 m by 12.2 m) each, as shown in Figure 1. The physical and mechanical properties of the surface soils encountered at the AES farm site are shown in Table 1.

Chemicals Applied

As pointed out in the Interim Report - Part II, eleven chemicals were decided upon for use in the field application, in addition to the use of water for a control section. Each one of these chemicals is briefly discussed below. For each chemical, the outline includes its major constituents, the dilution ratio, the rate of application and the cost of application per square yard for the chemical only. The number given after the chemical name refers to the number assigned to each chemical during the laboratory testing program.

1. Water (0): Water was applied on a control section at the rate of 1/2 gsy (2.26 liters/m^2).
2. Aerospray 70 (7): Its major constituent is a polyvinyl acetate resin. The dilution ratio is 1 to 20 in water, and the application rate is 1/2 gsy (2.26 liters/m^2). The cost of the chemical application is 5.95 cents and 6.50 cents per square yard (7.12 and 7.77 ¢/m^2), F.O.B. Torrence, California and F.O.B. Tucson, Arizona, respectively.
3. Surfaseal (13): The composition was not given by the manufacturer. The recommended dilution ratio is 1 to 20 in water, and solution applied at 1/3 gsy (1.5 liters/m^2). The cost of this chemical application is 6.3 cents and 6.78 cents per square yard (7.53 and 8.11 ¢/m^2), F.O.B. Daly City, California and

TABLE 1
FIELD SOILS PROPERTIES

Soil Property	Wilmot Road Soil	AES Farm Soil	ADOT Yard Soil
Specific Gravity	2.64	2.60	2.60
Liquid Limit, %	21.0	24.5	29.0
Plasticity Index, %	5.6	4.5	18.2
St. AASHTO, σ_{max}pcf	124.0	-	-
St. AASHTO, W_{opt}%	11.0	-	-
Mod. AASHTO, σ_{max},pcf	131.0	-	-
Mod. AASHTO, W_{opt}%	8.0	-	-
pH value	8.0	7.7	8.3
Soluble Salts, ppm	238.0	1820	987
Nitrates (NO_3), ppm	9.4	1258	18.2
Phosphates (PO_4), ppm	2.7	26.4	8.2
Sulfates (SO_4), ppm	18.0	150	306
Organic Matter, %	0.05	0.79	0.5
Percent Passing, 2 microns	8	15	5.0
Percent Passing #4	99	96	96
Percent Passing #200	28	47	60

1 pcf = 16 Kg/m^3

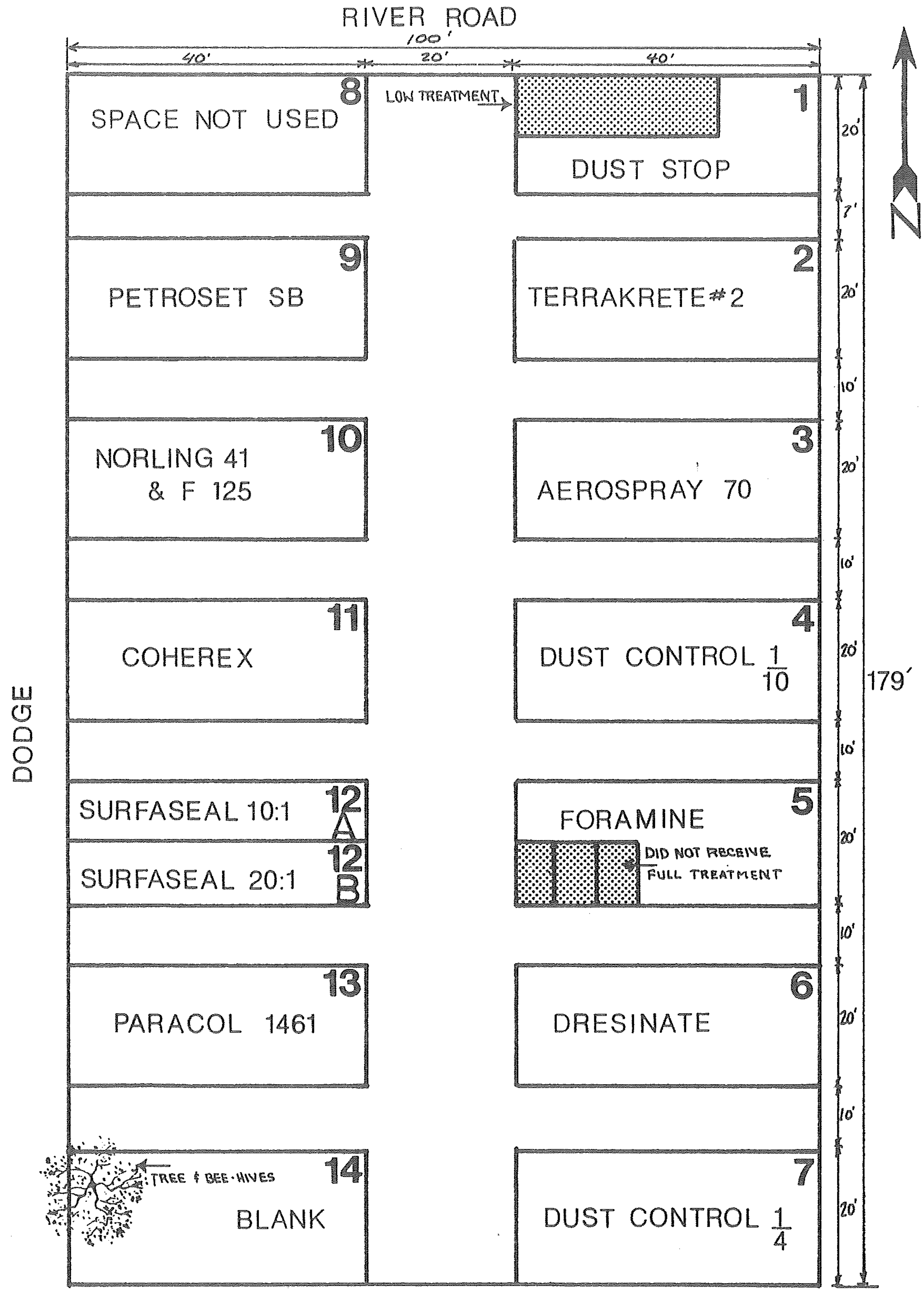


FIGURE 1- LOCATION OF TEST PLOTS, AES FARM SITE

and F.O.B. Tucson, Arizona respectively. At the time of application, the manufacturer was present at the site and requested dividing the allocated plot in two sections. One half was given the recommended application given above, while the other half received the same rate of application, but at a 1 to 10 dilution ratio. The cost of the latter application is 12 cents and 12.94 cents per square yard, (14.35 and 15.47 ¢/m^2) F.O.B. Daly City, California, and F.O.B. Tucson, Arizona respectively.

4. Petroset SB (20): This is a butadiene-styrene rubber and resin tacifier in an oil-water emulsion. The dilution ratio is 1 to 25 in water, and solution applied at 1.0 gsy (4.52 liters/m^2). The cost of this chemical application is 5.8 cents and 6.61 cents per square yard (6.93 and 7.9 ¢/m^2), F.O.B. Borger, Texas and F.O.B. Tucson, Arizona, respectively.

5. Coherex (21): This is an emulsion consisting of 60% semi-liquid natural petroleum resins and 40% wetting solution. The dilution ratio is 1:7 in water, and solution applied at 1.0 gsy (4.5 liters/m^2). The cost of this chemical application is 2.9 cents and 5.8 cents per square yard (3.47 and 6.93 ¢/m^2), F.O.B. Bakersfield, California and F.O.B. Tucson, Arizona respectively.

6. Dresinate DS-60W-80F (25): This is a dispersion of a thermoplastic resin and a viscosity reducer. The dilution ratio is 1 to 9 in water, and solution applied at 1.0 gsy (4.52 liters/m^2). The cost of this application is 3.4 cents and 5.95 cents per square yard (4.07 and 7.12 ¢/m^2), F.O.B. Portland, Oregon, and F.O.B. Tucson, Arizona, respectively.

7. Paracol 1461 (26): This is a wax thermoplastic resin blend. The dilution ratio is 1 to 9 in water, and solution applied at 1.0 gsy (4.52 liters/m^2). The cost of this application is 3.9 cents and 6.52 cents per square yard (4.66 and 7.79 ¢/m^2), F.O.B. Portland, Oregon and F.O.B. Tucson, Arizona, respectively.
8. Terrakrete #2 (27): This is a vinyl acetate acrylic copolymer. The recommended dilution is to make a 6 percent solution in water, and apply it at 1/2 gsy (2.26 liters/m^2). The cost of this application is 5.6 cents and 6.26 cents per square yard (6.69 and 7.91 ¢/m^2), F.O.B. Torrence, California and F.O.B. Tucson, Arizona, respectively.
9. Dust Control Oil (37): This is a mixture of petroleum resin and a light hydrocarbon solvent. It is pointed out that this chemical actually did not pass the laboratory test criteria, however, it was included in the field study due to its superior performance observed by the principal investigator in another field study; Sultan (1974d). Two rates of application were used for this chemical. The first application was using 1/4 gsy (1.13 liters/m^2) at a cost of 3.8 cents and 10.9 cents per square yard (4.54 and 13.03 ¢/m^2), F.O.B. Richmond, California and F.O.B. Tucson, Arizona, respectively. The second application was using 1/10 gsy (0.45 liters/m^2) at a cost of 1.52 cents and 4.36 cents per square yard (1.82 and 5.21 ¢/m^2), F.O.B. Richmond, California and F.O.B. Tucson, Arizona, respectively.
10. Dust Stop (38): This is an acrylonitrile butadiene styrene copolymer. The dilution ratio is 1 to 20 in water, and solution

applied at 1/2 gsy (22.6 liters/m^2). The cost of the application is 2.6 cents and 3.36 cents per square yard (3.11 and 4.02 ¢/m^2), F.O.B. Dover, Delaware and F.O.B. Tucson, Arizona, respectively.

11. Foramine 99-194 (41): This is a urea-formaldehyde resin in water solution. Recommended application was to add 0.18 lb. (81.6 gm) of water to each 1.0 lbs. (453.6 gms) of chemical, and apply the solution at 1.0 lb per square yard (0.54 Kg/m^2). In the field however, additional water had to be added to the same recommended chemical amount in order to be able to spray the solution. The field solution was applied at 1/4 gsy (1.13 liters/m^2) which included 0.82 lb. (0.37 Kg) of the chemical. The cost of this application is 6.8 cents and 10.1 cents per square yard (8.13 and 12.08 ¢/m^2), F.O.B. Tacoma, Washington, and F.O.B. Tucson, Arizona, respectively.

12. Norlig 41 + F-125 (46): This is a mixture of Norlig 41 solution and Formula 125 solution. Norlig 41 is a solution of chemicals and a lignin sulfonate base. Formula 125 is mainly a sodium methyl siliconate with other additives. The recommended application is a mix of (1:4) solution of Norlig 41 in water and (1:40) solution of F-125 in water at the ratio of 4:1, respectively; and applied at 1.0 gsy (4.52 liters/m^2). The cost of this application is 9.1 cents per square yard (10.88 ¢/m^2), F.O.B. Tucson, Arizona.

The chemical solutions were applied in the field using a John Bean mobile sprayer (50 gallons capacity) provided by General Control Company of Tucson, Arizona. It is pointed out that after every application, the sprayer tank and hose were rinsed clean with water, before starting the next chemical solution. Dust Control Oil had to be rinsed with gasoline. The chemicals were applied in the field between May 20-22, 1974

ADOT Yard Site

This site was selected for a second field application after the heavy growth of weeds was encountered at the AES farm site. An isolated area adjacent to the ADOT District Maintenance Yard, west of I-10 and north of Grant Road seemed appropriate for the purpose. The site was cleared of a light grass growth and, to our knowledge, was never used for agricultural purposes before. The site was prepared similar to the AES farm site. A site plan for the new Yard Site is given as Figure 2. Several of the plots were avoided since they were located at a depressed zone and would be flooded during the evaluation period after heavy rainfalls.

This time a weed control agent "Princep-80W" which includes an 80 percent Simazine active ingredient was added to the chemical solution. This chemical agent was recommended and donated by General Control Company of Tucson, Arizona. The recommended rate of application for Princep-80W was set at 10 lbs. per acre. During the application, enough material was mixed in water then added to the chemical water solution. The chemicals, dilutions, rates of application, and method of application used are similar to those discussed and used previously for the AES farm site application. The ADOT Yard site was sprayed on September 28-29, 1974. Properties of the surface soils at this site are given in Table 1.

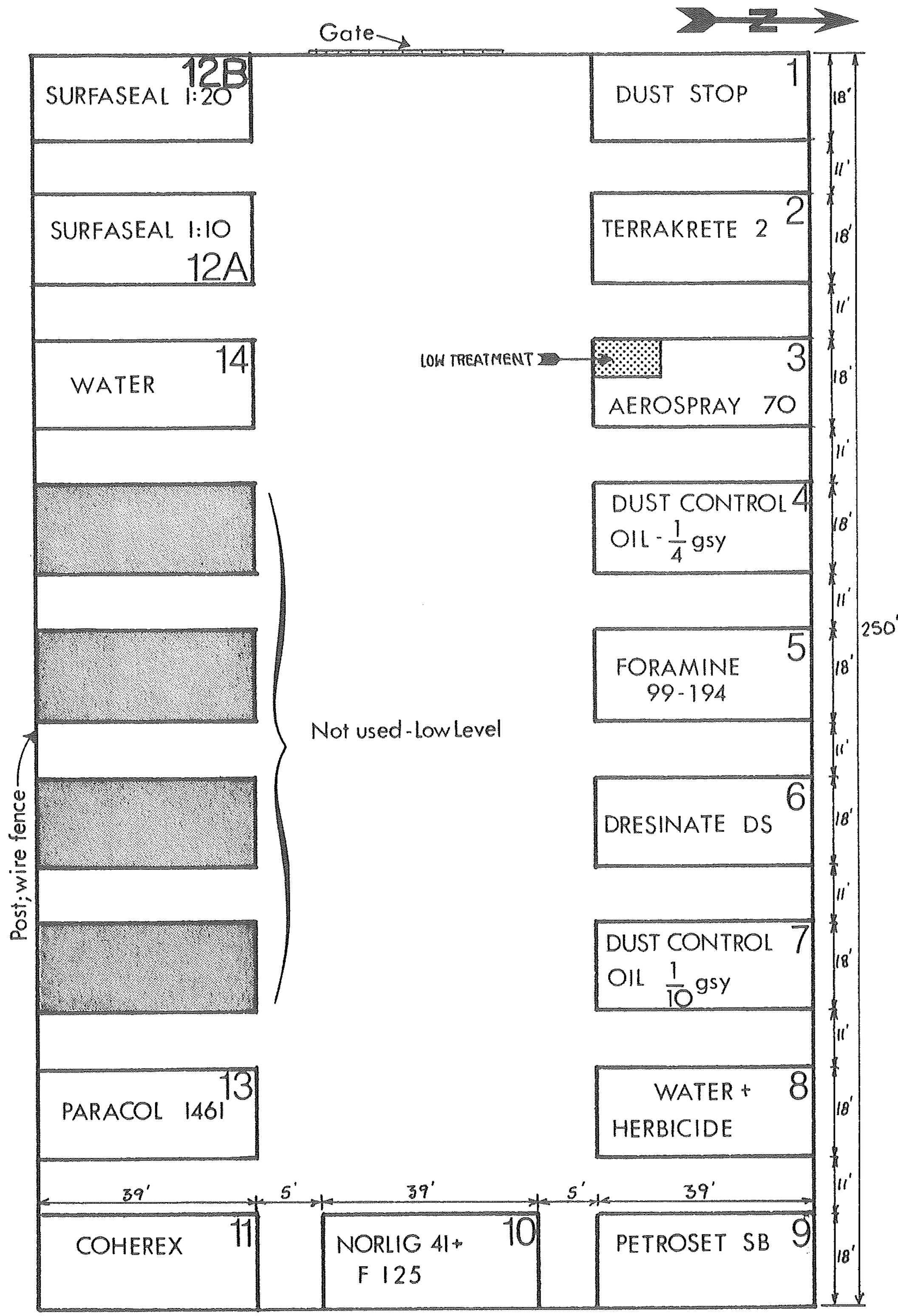


FIGURE 2- SITE PLAN, ADOT YARD-SITE

CHAPTER 3

FIELD MONITORING TESTS - DUST CONTROL SITES

The field evaluation techniques used for monitoring and evaluating the performance of the chemical applications on the dust control sites were similar to those developed and reported previously by the principal investigator, Sultan (1974d). It is pointed out that the field evaluation and monitoring techniques used in this phase were developed and/or modified by the principal investigator, due to the lack of well defined and widely accepted standardized tests that can be used for such monitoring. The methods of evaluation used are briefly outlined below; and were conducted on a bi-weekly basis whenever the weather permitted.

Sampling of Wind Blown Dust (Hi-Vol)

A small Dayton Pole Blower was used as a wind simulator to stir dust particles off the surface. The blower was placed on an inclined steel support such that the air flow would hit the ground surface at an angle of about 40^{o} with the horizontal. The wind velocity at the mouth of the blower was about 12 mph (19.3 Km/hr) and reduced to approximately 8 mph (12.8 Km/hr) at the point of impact on the ground. A High Volume Air Sampler (Harding and Hendrickson 1964 and Air Sampling Instruments 1966, pp. B-1-22- to B-1-26) was placed at a distance of four feet away from the blower along the direction of wind flow. A glass fiber (Gelman Type A) filter paper 8 in. x 10 in. (20.3 cm x 25.4 cm) in size was used to collect the dust particulates on it (Air Sampling Instruments 1966

p. B-2-4). This instrument and filter paper type are used by Pima County Air Pollution Control Division. The same kind of instrument or very similar to it is being used by most air pollution agencies including the National Air Pollution Control Administration.

Sampling was conducted with the wind blower on and the High Volume Sampler (Hi-Vol) drawing air at a flow rate of about 50 cfm (1.4 m^3/min) over a 5 min. period. Both the blower and the Hi-Vol were operated using a gasoline driven electric generator. A schematic drawing of the test set-up is given in Figure 3. The development and modification of this test and the reasoning behind the chosen parameters are given in Appendix A.

After the 5 min. dust collection, the filter paper was removed from the Hi-Vol and weighed in the laboratory. The difference between its final and original weights indicates the amount of dust collected as measured to the nearest milligram (mg). The amount of dust particulates collected during the 5 min. period was computed in micrograms per cubic meter ($\mu g/m^3$) since this unit is the one used by most agencies as a measure of the concentration of dust particulates in the atmosphere.

In the days when the atmosphere seemed to have a reasonably high dust particulate concentration, one reading of the Hi-Vol for a 5 min. period without the blower operating was taken. All readings taken during the corresponding days were corrected by subtracting the atmosphere reading from the actual readings.

In order to evaluate the relative amount of dust fallout from untreated areas on the treated plots, a plywood sheet 4.0 feet (1.22 m) by 6.0 feet (1.83 m) was placed on the ground and left in the field continuously. A Hi-Vol reading was always taken for this plywood sheet in order to take into consideration the amount of accumulated dust other

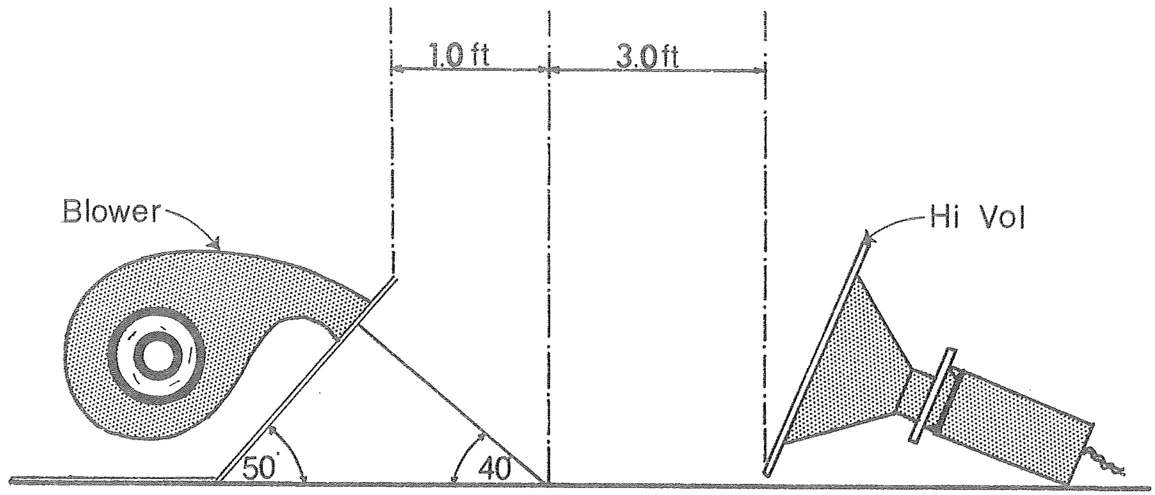


FIGURE 3- SCHEMATIC DIAGRAM OF HI-VOL
AND BLOWER ARRAGEMENT

than wind stirred up dust. A field test set-up for the Hi-Vol test is shown in Fiugre 4. Figure 5 shows a close-up of the filter paper in the Hi-Vol unit with the collected dust particulates on its surface.

It is pointed out that the Hi-Vol readings were conducted at various spots on each plot and not at a specific zone. The later method would have underestimated the amounts of dust collection after the first few readings.

Sampling for Extraction Test

Soil samples from the surface of the treated zones were obtained and used in an extraction test to determine the amount of benzene soluble organic matter present. Comparing the extracted amounts obtained from samples taken at different periods after application, a quantitative evaluation of the degree of leaching of the chemical is obtained.

A thin cup. 2-3/4 in. (7.0 cm) in diameter and 5/16 in. (0.8 cm) high, was pushed into the surface soil using a rubber mallet until its top was flush with the ground surface. The surface soil around the perimeter of the cup was then removed with a narrow spatula. A 3 in. (7.62 cm) wide spatula was then pushed underneath the cup to support the soil within it. The cup, with the soil in it, was then raised from the gound with the spatula, and turned over while the soil was still confined by the spatula. The soil surface in the cup was trimmed flush with the edges of the cup, and the soil was then saved in a tin can. A photograph illustrating the retrieving of a specimen in the field is shown in Figure 6. For each plot, a specific zone where the chemical spray-on application appeared to be quite uniform, was selected to collect the extraction specimens from. This practice was intended to reduce the variability of the amount

FIGURE 4. Hi-Vol Test Set-up for Dust Collection

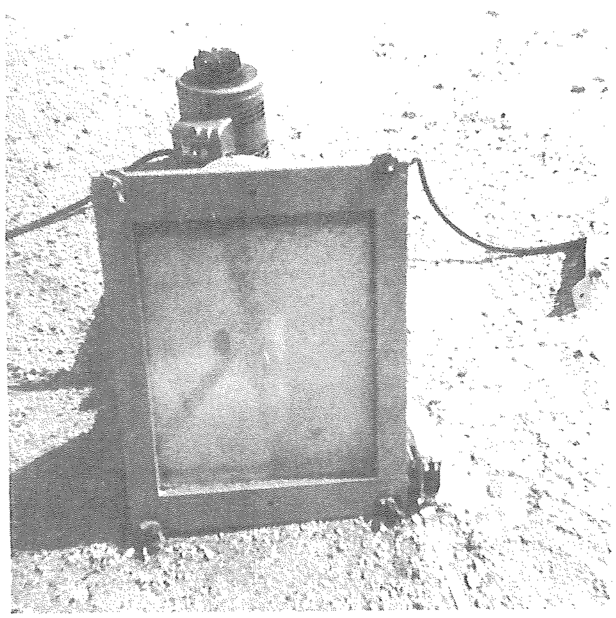


FIGURE 5. Hi-Vol Filter Paper Showing Collected Dust

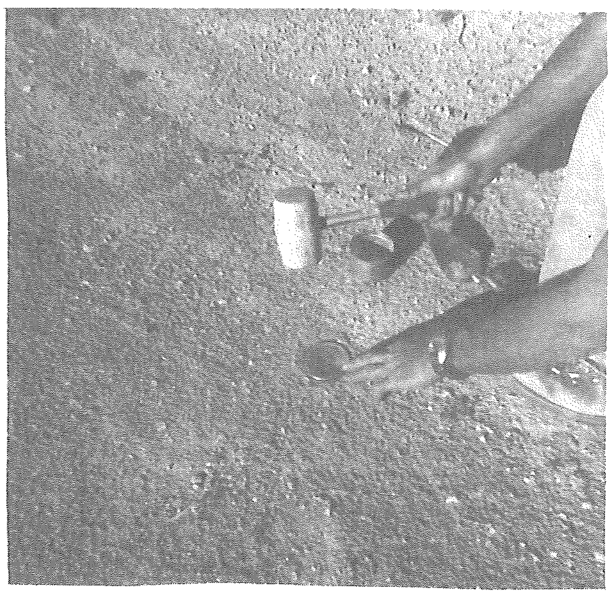


FIGURE 6. Removal of Extraction Specimen

of chemical in the treated soil that may occur due to changes in spray-on rate of application.

It is pointed out that after testing the first set of specimens it appeared that the benzene-extracted materials for most of the chemicals were not in the anticipated order of magnitude, Sultan (1974d). Accordingly, extraction tests using benzene and water as the extracting fluids were run on laboratory-made control specimens. The results of these tests indicated further that the extracted material for most chemicals are still low, except that the water extracted material from the Norlig 41 and F-125 was significantly higher than that extracted by benzene.

Since this test essentially evaluates the degree of leaching out of each chemical individually with time, it was decided to continue the benzene as the extracting fluid, except in the case of the chemical composed of the Norlig 41 and F-125 mixture where water was used instead.

In the laboratory the benzene extraction test was conducted on specimens (run in duplicates) obtained from each application zone. The weight of the extracted organics was measured to the nearest milligram (mg), and converted (according to the area of the cup) into grams per square meter (gm/m^2).

The extraction procedure is outlined in Appendix B and is very similar to that outlined in the Public Health Service Publication No. 978, 1962 (p. 213) and the same as given by Sultan (1974d).

Visual Inspection and Evaluation

In addition to the quantitative evaluation techniques discussed above, a qualitative evaluation was made periodically on the condition of each test plot. This evaluation includes condition of the surface, thickness and firmness of crust, color change, cracks and vegetation growth. This inspection supplemented the other tests and gave a handle in spotting erratic or unexpected results.

CHAPTER 4

FIELD TESTING DATA AND RESULTS - DUST CONTROL SITES

In this chapter the collected field testing data at the dust control sites are presented and discussed. Data collected at the two sites, for each evaluation method, are presented together, analysed, and a comparative evaluation for the chemical treatments is given.

Hi-Vol Dust Collection Data

AES Farm Site

Hi-Vol dust collection tests were conducted at this site at approximately 2-week intervals between June 3, 1974 and July 28, 1975. However, by August 1974 the heavy vegetation (weed) growth encountered at the site made it difficult to rely on the collected dust specimens. The presence of this excessive weed growth appeared to interfer with the wind generated by the blower and thus affected the collected dust particulates. Figures 7 and 8 show the vegetation growth encountered at the Paracol 1461 site and the Terrakrete #2 site, respectively. These photographs were taken on August 10, 1974.

The collected Hi-Vol dust particulates in $\mu g/m^3$ at the AES Farm site are given in Table 2. The accumulated rainfall at the site since the chemicals were applied is given, along with the degree of wetness of the surface soils as observed at the time of the test.

When the collected data were analysed, it was apparent that the dust collected values became increasingly erratic in nature due to the

FIGURE 7 Vegetation Growth at Paracol 1461 Plot

FIGURE 8 Vegetation Growth at Terrakrete #2 Plot

TABLE 2

COLLECTED HI-VOL DUST PARTICULATES ($\mu g/m^3$)
AES FARM SITE

Date Accum. Rain Chemical	6/3/74 0.0"(D)	6/17/74 0.01"(D)	7/6/74 0.17"(D)	7/23/74 1.54"(D)	8/6/74 3.71"(M)
Water (Control	64301	58587	58468	3963	2416
Dust Stop	458	7206	1807	1501	2931
Terrakrete #2	182	614	920	1062	1177
Aerospray 70	846	2025	4439	1076	1011
Dust Control Oil 1/10 gsy	202	509	1708	736	3512
Foramine 99-194	890	2712	4921	2761	3956
Dresinate DS-60W-80F	312	1441	3048	761	1114
Dust Control Oil 1/4 gsy	164	344	1119	747	892
Petroset SB	834	2365	3391	736	1827
Norlig 41 + F-125	467	685	2491	611	823
Coherex	875	1841	4857	1073	935
Surfaseal 1:10	220	475	1034	609	1464
Surfaseal 1:20	639	1473	2792	425	1501
Paracol 1461	989	2464	5152	609	1453

(D) = Dry (M) = Moist (W) = Wet

TABLE 2 (Concluded)

Date Accum. Rain Chemical	8/21/74 3.71"(D)	9/25/74 6.75"(W)	Remarks
Water (Control)	54616	537	Erratic data were collected between 10/17/74 and 7/28/75 due to excessive ween and brush growth. These data were discarded.
Dust Stop	5862	382	
Terrakrete #2	2478	68	
Aerospray 70	8751	156	
Dust Control Oil 1/10 gsy	5094	99	
Foramine 99-194	8921	523	
Dresinate DS-60W-80F	7422	254	
Dust Control Oil 1/4 gsy	3441	339	
Petroset SB	8312	636	
Norlig 41 + F-125	4490	297	
Coherex	2903	368	
Surfaseal 1:10	2972	56	
Surfaseal 1:20	6397	580	
Paracol 1461	8949	269	

(D) = Dry (W) = Wet

TABLE 3

PERFORMANCE RATINGS AND PLOT CONDITIONS, AES FARM SITE

Rating	Chemical	Percent* Control	Description of Plot Condition 9/25/74
1	Terrakrete #2	96.1	Natural color, heavy vegetation, hard crust 1/4', light cracks
2	Surfaseal 1:10	95.4	Brown, light vegetation, v.hard crust 1/4', some cracks
3	Dust Control Oil, 1/4 gsy	94.6	Black, light vegetation, soft crust 5/16', light cracks
4	Norlig 41 + F-125	93.0	Lt. brown, light vegetation, hard crust 3/16', some cracks
5	Coherex	92.4	Natural, v. light vegetation, med. crust 3/16',some cracks
6	Dust Control Oil, 1/10 gsy	92.1	Grey-brn., med. vegetation, med.crust 3/16', some cracks
7	Surfaseal 1:20	90.0	Lt. brown, lt. vegetation, hard crust 3/16',some cracks
8	Dust Stop	88.8	Natural, med. vegetation, hard crust 3/10', some cracks
9	Dresinate DS-60W-80F	88.4	Natural, lt. vegetation, hard crust 3/16', cracks
10	Petroset SB	87.1	Natural, v. heavy vegetation, hard crust 3/16', some cracks
11	Aerospray 70	86.4	Lt. brown, v. lt. vegetation, hard crust 3/16', some cracks
12	Foramine 99-194	86.1	Natural, v. lt. vegetation, v. weak crust 1/16'', many cracks
13	Paracol 1461	86.0	Natural, v. heavy vegetation, hard crust 3/16', cracks

excessive vegetation growth. Accordingly, all dust collection data at this site beyond September 1974 were considered to be not representative of the surface condition and were thus discarded.

The results given in Table 2 indicate the following:

1. During the reported monitoring period of 4 months, and actually during the entire field testing period of 14 months, the applied chemical stabilizers afforded good means for controlling dust due to wind. The degree of control varied slightly among the applied chemicals during the initial 4-month period.
2. The degree of wetness of the treated and untreated surfaces (whether dry, moist, or wet) had a profound effect on the amount of dust stirred-up by the wind. As would be expected the higher the moisture content in the surface soil, the lower were the amounts of dust collected.
3. In general the amount of dust collected at each treated plot increased with time but at variable rates.
4. Based on the results reported for the initial 4-month period, the applied chemicals were rated according to their degree of dust control as compared with the control plot (sprayed with water). This rating for the chemicals, in order of decreasing performance, is given in Table 3 along with the degree of dust control afforded by the treatment at the end of the reported 4-month period. Also given in Table 3 is the general condition of each treated plot including surface condition, color, crust, cracks and vegetation growth.

ADOT Yard Site

Hi-Vol dust collection tests were conducted at this site at approximately 2-week intervals between October 17, 1974 and September 29, 1975. The collected Hi-Vol dust particulates in $\mu g/m^3$ at the ADOT Yard site are given in Table 4. The accumulated rainfall at the site since the chemicals were applied is given, along with the degree of wetness of the surface soils as observed at the time of the test.

The results of the tests given in Table 4 indicate the following:

1. The addition of the weed control agent "Princep-80W" inhibited vegetation growth at all the chemically treated plots.
2. The addition of this weed control agent had virtually no effect on controlling dust particulates stirred-up by wind. This is manifested by comparing the dust concentrations obtained from the untreated plot and that sprayed with a solution of the weed control agent in water.
3. During the reported monitoring period of 12-months, the applied chemical stabilizers afforded means for controlling dust stirred-up by wind. The degree of control, however, varied widely among the applied chemicals by the end of this 12-month period.
4. The degree of wetness of the treated and untreated surfaces (whether dry, moist, or wet) had a profound effect on the amount of dust stirred-up by wind. As would be expected the wetter the surface soil, the lower were the amounts of dust collected.
5. In general, the amount of dust collected at each treated plot increased with time, but at variable rates, however.
6. Based on the results obtained during this 12-month monitoring period, the applied chemicals were rated according to their

TABLE 4

COLLECTED HI-VOL DUST PARTICULATES ($\mu g/m^3$)
ADOT YARD SITE

Chemical / Date Accum. Rain	10/17/74 0.86"(D)	11/6/74 2.09"(D)	11/17/74 2.77"(D)	11/30/74 2.77"(D)	12/19/74 2.91"(D)
Water + Herbicide	36580	36728	35505	37530	38413
Untreated	37653	36265	34304	38915	38890
Dust Stop	537	1357	1880	2357	2693
Terrakrete #2	85	184	385	540	477
Aerospray 70	128	253	547	1428	1262
Dust Control Oil 1/4 gsy	113	165	320	742	790
Foramine 99-194	856	1356	2858	8742	10209
Dresinate DS-60W-80F	762	1250	2428	7088	12325
Dust Control Oil 1/10 gsy	369	387	518	855	929
Petroset SB	545	871	1243	3279	3260
Norlig 41 + F-125	364	448	617	975	1109
Coherex	410	847	1364	3678	4530
Surfaseal 1:10	178	218	393	534	497
Surfaseal 1:20	181	323	518	703	862
Paracol 1461	343	460	757	1035	1408

(D) = Dry

TABLE 4 (Continued)

Chemical \ Date Accum. Rain	1/7/75 3.11"(D)	1/18/75 3.11"(D)	2/1/75 3.64"(W)	2/15/75 3.75"(M)	3/31/75 4.66"(D)
Water + Herbicide	38936	39129	2551	7707	34480
Untreated	37576	39440	2456	6209	34746
Dust Stop	2961	3587	650	1219	2961
Terrakrete #2	608	656	127	232	322
Aerospray 70	1507	1709	163	346	876
Dust Control Oil 1/4 gsy	872	982	152	263	707
Foramine 99-194	11675	20892	2124	5650	9569
Dresinate DS-60W-80F	14710	16848	1742	4781	10997
Dust Control Oil 1/10 gsy	1081	1240	431	941	1104
Petroset SB	4385	6099	1668	3760	7230
Norlig 41 + F-125	1547	1789	547	1187	1923
Coherex	5215	6818	1654	4608	6438
Surfaseal 1:10	792	939	172	345	580
Surfaseal 1:20	1018	1458	368	805	1304
Paracol 1461	1633	1963	483	1016	2244

(D) = Dry (M) = Moist (W) = Wet

TABLE 4 (Continued)

Date / Accum. Rain / Chemical	4/12/75 5.19"(M)	4/26/75 5.26"(D)	5/10/75 5.26"(D)	5/23/75 5.26"(D)	6/6/75 5.26"(D)
Water + Herbicide	6951	35534	36788	37093	38480
Untreated	7516	34304	37597	38177	38732
Dust Stop	1360	3247	8369	8830	9820
Terrakrete #2	159	393	530	686	792
Aerospray 70	550	1329	1986	2226	3018
Dust Control Oil 1/4 gsy	300	839	916	1066	1125
Foramine 99-194	5562	11095	24770	27590	31307
Dresinate DS-60W-80F	4795	9385	13961	18955	22637
Dust Control Oil 1/10 gsy	683	1544	1893	2303	2650
Petroset SB	3166	8901	12958	13537	16081
Norlig 41 + F-125	757	2157	2583	2940	3081
Coherex	4148	6777	9830	11372	14661
Surfaseal 1:10	410	1077	1113	1135	1209
Surfaseal 1:20	865	1392	1662	1829	1888
Paracol 1461	1125	2631	2919	3222	3692

(D) = Dry   (M) = Moist

TABLE 4 (Continued)

Date Accum. Rain Chemical	6/20/75 5.26"(D)	7/9/75 6.1"(W)	7/23/75 8.40"(D)	8/25/75 9.01"(D)	9/11/75 9.77"(D)
Water + Herbicide	32619	2635	31723	33264	35912
Untreated	33222	2245	32621	34232	36435
Dust Stop	12335	621	11421	13229	14212
Terrakrete #2	875	289	676	753	821
Aerospray 70	3312	361	1321	2301	1916
Dust Control Oil 1/4 gsy	1313	275	821	975	992
Foramine 99-194	32129	2380	31612	33292	34770
Dresinate DS-60W-80F	25312	2171	22315	21819	24518
Dust Contorl Oil 1/10 gsy	2821	682	2315	2891	3112
Petroset SB	15983	1323	16831	17259	18311
Norlig 41 + F-125	3211	621	3115	3331	3192
Coherex	16312	2001	16735	18223	19892
Surfaseal 1:10	1197	380	1025	1171	1219
Surfaseal 1:20	1927	473	1737	1882	2031
Paracol 1461	3961	735	2831	3820	4212

(D) = Dry (W) = Wet

TABLE 4 (Concluded)

Date Accum. Rain Chemical	9/29/75 9.83"(D)
Water + Herbicide	35326
Untreated	37636
Dust Stop	13971
Terrakrete #2	894
Aerospray 70	2620
Dust Control Oil 1/4 gsy	1015
Foramine 99-194	33819
Dresinate DS-60W-80F	23873
Dust Control Oil 1/10 gsy	3260
Petroset SB	19021
Norlig 41 + F-125	3650
Coherex	21015
Surfaseal 1:10	1280
Surfaseal 1:20	2052
Paracol 1461	4620

(D) = Dry

degree of dust control as compared with the untreated control plot. This rating for the chemicals, in order of decreasing performance, is given in Table 5 along with the degree of dust control afforded by the treatment at the end of the 12-month monitoring period. Also given in Table 5 is the general condition of each treated plot including surface condition, color, crust, cracks, and vegetation growth.

Discussion of Test Results

1. The results given in Tables 3 and 5 indicate that the best three performing chemicals in the field for controlling dust due to wind are: Terrakrete #2, Surfaseal (1:10 concentration) and Dust Control Oil at 1/4 gsy. These same chemicals maintained the same rating order at the AES Farm site (after 4 months) and at the ADOT Yard site (after 12 months).
2. Several chemicals registered a significant reduction in their degree of dust control with time. After 12 months of field exposure eight chemical treatments indicated a degree of dust control higher than 85 percent. Five chemical treatments afforded a degree of dust control lower than 65 percent.
3. Even though Dust Control Oil did not prove to be a successful treatment based on the laboratory test results, it proved to be one of the best chemical treatments based on its field performance. This chemical showed similarly good field performance for dust control in a previous study, Sultan (1974d). This fact indicates that the laboratory test results may not be necessarily conclusive in predicting field performance of certain chemical treatments for controlling dust due to wind action.

TABLE 5

PERFORMANCE RATINGS AND PLOT CONDITIONS, ADOT YARD SITE

Rating	Chemical	Percent Control	Description of Plot Condition 9/29/75
1	Terrakrete #2	97.7	Natural color, no weeds, hard crust, no cracks
2	Surfaseal 1:10	96.7	Natural color, no weeds, hard crust, no cracks
3	Dust Control Oil, 1/4 gsy	96.7	Dark brown, no weeds, firm crust, no cracks
4	Surfaseal 1:20	94.8	Natural color, no weeds, firm crust, light cracks
5	Dust Control Oil, 1/10 gsy	91.7	Dark brown, no weeds, soft crust, some cracks
6	Aerospray 70	91.6	Natural color, no weeds, firm crust, light cracks
7	Norlig 41 + F-125	90.7	Light brown, no weeds, med. firm crust, light cracks
8	Paracol 1461	88.3	Natural color, no weeds, firm crust, light cracks
9	Dust Stop	64.0	Natural color, no weeds, brittle crust, some cracks
10	Petroset SB	51.8	Natural color, no weeds, thin friable crust, cracks
11	Coherex	46.7	Tan, no weeds, thin friable crust, cracks
12	Dresinate DS-60W-80F	35.8	Natural color, no weeds, loose surface, cracks
13	Foramine 99-194	11.8	Natural color, no weeds, loose surface, cracks

Extraction Test Data

AES Farm Site

Extraction test specimens were taken at this site for a period of 14 months at approximately 2-week intervals between June 3, 1974 and July 28, 1975. The presence of the high vegetation growth at the farm site did not materially affect the specimens, except for exercising additional care in removing these specimens on-site.

The test results obtained from the extraction specimens at the farm site presented as the extraction residue amounts in gm/m^2, are given in Table 6. The accumulated rainfall at the site since the chemicals were applied is also given. The results given in Table 6 indicate the following:

1. There exists a wide range of "organic" extraction residues among the chemical treatments used in the study. Initial residue of 588 gm/m^2 is reported for Dust Control Oil (1/4 gsy); compared with about 17 gm/m^2 for Dust Stop.
2. Based on the field performance of the various treatments and as manifested by the Hi-Vol test results presented previously, it appears that the numerical level of the extracted residue is not directly related to the degree of dust control afforded by the chemical. For example, Terrakrete #2 which was rated best (97.7% control) for dust control as shown in Tables 3 and 5 had its highest extracted residue as 42.5 gm/m^2, while Dust Control Oil-1/4 gsy which was rated third (96.7% control) had its highest extracted residue as 588 gm/m^2.
3. The observation mentioned above points out the possibility that the elements (organic or otherwise) responsible for the soil

TABLE 6

EXTRACTION TEST RESIDUE (gm/m^2)
AES FARM SITE

Chemical / Date / Accum. Rain	6/3/74 0.00 in.	6/17/74 0.01 in.	7/6/74 0.17 in.	7/23/74 1.54 in.	8/6/74 3.71 in.
Water (Control)	5.9	5.8	5.6	5.7	5.4
Dust Stop	16.9	16.8	16.2	14.8	13.4
Terrakrete #2	42.5	42.4	41.8	40.4	39.6
Aerospray 70	48.7	48.9	48.2	46.4	43.5
Dust Control Oil 1/10 gsy	238.5	245.0	241.6	236.5	232.2
Foramine 99-194	30.3	30.5	29.5	27.8	25.7
Dresinate DS-60W-80F	60.2	60.1	59.8	57.2	55.4
Dust Control Oil 1/4 gsy	587.6	588.0	574.2	564.3	553.1
Petroset SB	71.9	70.8	70.7	68.4	67.1
Norlig 41 + F-125	157.6	155.1	156.0	150.6	146.2
Coherex	175.6	174.1	172.4	166.5	161.5
Surfaseal 1:10	53.8	53.1	52.6	51.4	49.8
Surfaseal 1:20	30.8	31.3	30.4	29.1	27.9
Paracol 1461	59.6	58.8	58.0	56.2	55.6

TABLE 6 (Continued)

Date Accum. Rain Chemical	8/21/74 3.71 in	9/7/74 5.67 in.	9/21/74 6.43 in.	10/12/74 7.67 in.	11/2/74 8.90 in.
Water (Control)	5.5	4.9	5.1	4.8	5.2
Dust Stop	13.4	12.5	11.4	10.8	10.7
Terrakrete #2	39.5	37.9	37.4	36.8	36.0
Aerospray 70	43.7	42.6	41.8	40.9	40.8
Dust Control Oil 1/10 gsy	230.3	226.6	224.2	219.8	219.6
Foramine 99-194	24.8	23.0	22.2	21.6	21.0
Dresinate DS-60W-80F	54.7	52.2	51.4	50.4	48.5
Dust Control Oil 1/4 gsy	557.8	546.3	540.3	534.6	532.6
Petroset SB	66.4	62.9	61.4	60.2	59.6
Norlig 41 + F-125	145.0	141.9	140.3	138.6	136.7
Coherex	159.6	155.2	150.2	144.3	137.7
Surfaseal 1:10	49.2	44.6	43.2	41.4	41.2
Surfaseal 1:20	27.4	26.7	26.1	24.8	23.9
Paracol 1461	55.3	53.9	51.6	51.2	50.4

TABLE 6 (Continued)

Chemical \ Date / Accum. Rain	11/16/74 9.58 in	11/30/74 9.58 in.	12/19/74 9.72 in.	1/7/75 9.92 in.	1/18/75 9.92 in.
Water (Control	4.9	4.8	4.7	4.9	5.0
Dust Stop	9.7	9.2	8.9	8.9	8.3
Terrakrete #2	35.4	35.5	35.1	34.6	34.5
Aerospray 70	40.1	39.6	39.4	39.2	39.0
Dust Control Oil 1/10 gsy	217.7	216.8	215.7	212.5	212.8
Foramine 99-194	20.1	19.7	18.9	17.5	17.3
Dresinate DS-60W-80F	47.8	47.2	45.3	43.6	42.8
Dust Control Oil 1/4 gsy	528.3	526.1	525.9	523.6	523.0
Petroset SB	59.3	58.5	57.3	56.8	56.1
Norlig 41 + F-125	134.3	133.1	132.6	131.2	130.6
Coherex	132.8	135.5	132.8	129.3	128.5
Surfaseal 1:10	40.3	40.4	39.6	38.2	38.5
Surfaseal 1:20	23.5	23.4	22.9	22.5	23.0
Paracol 1461	49.8	49.9	48.8	48.5	48.1

TABLE 6 (Continued)

Date Accum. Rain Chemical	2/1/75 10.45 in.	2/22/75 10.51 in.	3/15/75 11.35 in.	3/31/75 11.47 in.	4/12/75 12.00 in.
Water (Control)	5.1	5.3	4.9	5.4	5.0
Dust Stop	7.7	7.6	7.4	6.8	6.7
Terrakrete #2	34.1	33.6	32.4	32.4	32.1
Aerospray 70	38.1	38.3	37.6	37.3	36.9
Dust Control Oil 1/10 gsy	210.1	209.7	206.7	204.2	202.8
Foramine 99-194	16.6	16.4	14.8	15.1	14.2
Dresinate DS-60W-80F	39.8	38.0	35.6	34.0	32.7
Dust Control Oil 1/4 gsy	519.9	520.8	514.7	513.9	511.3
Petroset SB	54.5	43.6	42.8	42.7	41.6
Norlig 41 + F-125	128.7	127.6	125.4	125.0	124.5
Coherex	125.2	121.0	117.6	114.2	113.0
Surfaseal 1:10	37.4	37.2	36.4	36.1	35.3
Surfaseal 1:20	22.4	22.1	21.7	21.2	20.7
Paracol 1461	47.3	46.8	43.9	44.3	43.2

TABLE 6 (Continued)

Date Accum. Rain Chemical	4/26/75 12.07 in.	5/10/75 12.07 in.	5/23/75 12.07 in.	6/6/75 12.07 in.	6/20/75 12.07 in.
Water (Control)	5.2	5.4	5.2	5.5	5.0
Dust Stop	6.4	6.6	6.3	6.7	6.8
Terrakrete #2	31.5	31.6	31.2	30.8	30.6
Aerospray 70	36.7	36.2	35.8	35.9	35.7
Dust Control Oil 1/10 gsy	200.7	198.5	195.7	193.2	192.1
Foramine 99-194	13.8	13.6	12.8	12.1	11.6
Dresinate DS-60W-80F	31.6	30.2	28.1	27.9	25.7
Dust Control Oil 1/4 gsy	510.0	509.3	506.3	503.4	500.9
Petroset SB	41.2	40.3	39.8	38.5	38.1
Norlig 41 + F-125	123.8	123.5	121.9	120.5	119.4
Coherex	110.5	109.0	108.1	107.3	106.2
Surfaseal 1:10	35.4	34.9	34.7	34.3	34.3
Surfaseal 1:20	20.4	20.5	19.6	19.6	19.2
Paracol 1461	42.6	42.5	42.1	41.5	41.1

TABLE 6 (Concluded)

Date Accum. Rain Chemical	7/7/75 12.93 in.	7/28/75 15.21 in.	Percentage Reduction of Extraction Residue
Water (Control	5.2	5.1	-
Dust Stop	6.4	6.6	63
Terrakrete #2	29.3	28.6	33
Aerospray 70	34.8	33.9	31
Dust Control Oil 1/10 gsy	118.2	182.6	25
Foramine 99-194	10.2	9.3	70
Dresinate DS-60W-80F	23.3	19.1	68
Dust Control Oil	496.3	491.8	16
Petroset SB	36.6	33.1	54
Norlig 41 + F-125	117.8	113.1	28
Coherex	101.1	94.3	46
Surfaseal 1:10	33.8	33.1	38
Surfaseal 1:20	18.7	18.3	41
Paracol 1461	40.2	38.2	36

stabilization for dust control may not all be soluble and thus extractable by benzene. However, without the availability of the exact formulations of each chemical (trade secrets), an exact treatment and evaluation of these residues would be almost impossible.

4. In general, however, the amounts of extraction residues obtained for each chemical treatment continued to decrease with time, indicating various rates of leaching out of the soil under effects of rainfall and other environmental conditions.
5. The gradual reduction in the extraction residues with time, appear to be related to the increase in dust collection obtained with the Hi-Vol.
6. The percentage reduction in extractable residues during the 14-month monitoring period ranged between 16% and 70% with an average of about 42% reduction.

ADOT Yard Site

Extraction test specimens were taken at the ADOT Yard site for a period of about 12 months, at approximately 2-week intervals between October 12, 1974 and September 29, 1975. The test results obtained from the extraction specimens at the Yard site, presented as the extraction residue amounts in gm/m^2, are given in Table 7. The accumulated rainfall at the site since the chemicals were applied is also given. The results given in Table 7 are very similar to those given in Table 6 and indicate the following:

1. There exists a wide range of extraction residues among the chemical treatments used in the study. The range varied between about 15 and 600 gm/m^2.

TABLE 7

EXTRACTION TEST RESIDUE (gm/m^2)
ADOT YARD SITE

Chemical \ Date / Accum. Rain	10/12/74 0.86 in.	11/2/74 2.09 in.	11/16/74 2.77 in.	11/30/74 2.77 in.	12/19/74 2.91 in.
Water + Herbicide	6.0	5.6	5.2	5.0	4.3
Untreated	4.3	4.7	4.4	4.3	4.2
Dust Stop	14.6	13.2	12.3	12.1	11.8
Terrakrete #2	43.6	41.7	41.0	40.8	39.3
Aerospray 70	52.9	50.7	49.4	49.5	48.4
Dust Control Oil 1/4 gsy	598.7	572.4	565.2	563.0	557.3
Foramine 99-194	34.7	32.8	30.6	30.8	29.8
Dresinate DS-60W-80F	63.9	59.2	56.9	56.3	54.8
Dust Control Oil 1/10 gsy	253.7	246.9	241.5	236.3	230.7
Petroset SB	67.3	62.4	60.4	59.3	58.6
Norlig 41 + F-125	142.8	138.1	132.4	131.6	128.3
Coherex	186.1	174.7	168.4	163.4	160.1
Surfaseal 1:10	52.1	51.3	49.1	49.7	48.3
Surfaseal 1:20	28.5	27.4	26.1	26.3	25.6
Paracol 1461	55.9	54.6	53.4	53.2	52.5

TABLE 7 (Continued)

Date Accum. Rain Chemical	1/7/75 3.11 in.	1/18/75 3.11 in.	2/1/75 3.64 in.	2/15/75 3.75 in.	3/15/75 4.54 in.
Water + Herbicide	4.6	4.5	4.7	4.8	4.9
Untreated	4.7	4.2	4.4	4.6	4.5
Dust Stop	11.5	10.4	9.6	9.4	8.9
Terrakrete #2	37.8	39.1	35.2	34.6	33.2
Aerospray 70	48.1	47.3	45.2	44.7	41.3
Dust Control Oil 1/4 gsy	551.2	547.1	541.6	542.6	536.7
Foramine 99-194	28.6	27.0	26.2	23.1	21.8
Dresinate DS-60W-80F	54.2	53.7	51.4	51.7	48.3
Dust Control Oil 1/10 gsy	227.1	225.7	221.2	219.8	210.8
Petroset SB	55.8	56.1	53.5	51.8	47.3
Norlig 41 + F-125	127.7	126.5	123.6	121.8	118.2
Coherex	156.8	155.3	147.2	142.6	138.4
Surfaseal 1:10	46.8	46.1	45.2	44.3	43.1
Surfaseal 1:20	25.2	24.6	23.7	23.2	22.1
Paracol 1461	51.7	51.9	50.3	49.6	49.8

TABLE 7 (Continued)

Date Accum. Rain Chemical	3/31/75 4.66 in.	4/12/75 5.19 in.	4/26/75 5.20 in.	5/10/75 5.26 in.	5/23/75 5.26 in.
Water + Herbicide	4.6	4.5	4.0	4.2	4.2
Untreated	4.2	4.5	4.1	4.4	4.6
Dust Stop	8.3	7.5	7.9	7.8	7.7
Terrakrete #2	35.8	33.8	32.1	32.5	31.6
Aerospray 70	41.6	40.9	41.1	38.8	37.9
Dust Control Oil 1/4 gsy	535.2	531.7	528.9	526.6	522.1
Foramine 99-194	20.2	18.9	18.1	17.4	16.2
Dresinate DS-60W-80F	47.2	45.3	43.9	39.6	35.7
Dust Control Oil 1/10 gsy	205.3	199.1	200.7	195.8	193.0
Petroset SB	46.1	43.4	43.9	41.8	40.8
Norlig 41 + F-125	117.3	115.5	114.9	114.7	115.2
Coherex	136.6	128.1	130.8	122.6	118.7
Surfaseal 1:10	42.5	41.3	41.6	40.8	40.6
Surfaseal 1:20	21.5	21.5	21.2	20.8	20.7
Paracol 1461	48.1	47.2	47.2	46.8	46.1

TABLE 7 (continued)

Date Accum. Rain Chemical	6/6/75 5.26 in.	6/20/75 5.26 in.	7/9/75 6.1 in.	7/28/75 8.38 in.	8/11/75 8.75 in.
Water + Herbicide	4.1	4.6	4.3	4.9	4.4
Untreated	4.5	4.4	4.0	4.3	4.6
Dust Stop	6.4	6.8	6.2	5.8	5.9
Terrakrete #2	30.5	29.8	29.1	28.7	26.1
Aerospray 70	36.4	36.2	35.3	34.1	33.8
Dust Control Oil 1/4 gsy	519.9	522.6	518.2	508.1	501.5
Foramine 99-194	15.8	15.2	13.8	12.1	11.5
Dresinate DS-60W-80F	32.1	30.9	28.1	25.2	23.8
Dust Control Oil 1/10 gsy	191.8	190.3	182.9	178.1	175.2
Petroset SB	40.6	39.6	38.9	37.2	36.2
Norlig 41 + F-125	113.6	113.8	110.2	106.1	105.4
Coherex	115.2	110.7	101.3	93.1	87.2
Surfaseal 1:10	40.2	38.9	38.2	36.7	35.6
Surfaseal 1:20	20.2	19.7	19.1	18.7	18.2
Paracol 1461	45.2	44.6	43.8	42.4	41.9

TABLE 7 (Concluded)

Date Accum. Rain Chemical	8/25/75 9.01 in.	9/11/75 9.77 in.	9/29/75 9.83 in.	Percentage Reduction of Extraction Residue
Water + Herbicide	4.6	4.8	4.4	-
Untreated	4.3	4.2	4.1	-
Dust Stop	5.7	5.7	5.5	62
Terrakrete #2	27.5	25.8	26.3	41
Aerospray 70	33.7	31.8	30.7	42
Dust Control Oil 1/4 gsy	496.1	488.8	485.1	20
Foramine 99-194	10.2	9.8	8.8	75
Dresinate DS-60W-80F	21.3	19.2	16.1	75
Dust Control Oil 1/10 gsy	171.6	167.2	162.8	36
Petroset SB	35.6	35.0	34.7	48
Norlig 41 + F-125	140.1	102.8	102.2	28
Coherex	81.2	78.2	73.1	61
Surfaseal 1:10	35.1	34.8	35.2	33
Surfaseal 1:20	17.9	17.6	17.1	40
Paracol 1461	41.3	40.7	40.6	27

2. The addition of the weed control agent did not significantly increase the extraction residue. The maximum measured change was about 1.7 gm/m^2 for the water-sprayed plot.
3. The amount of extracted residues is not directly related to the degree of dust control afforded by the chemical.
4. In general, the amount of extracted residues continued to decrease with time. This reduction ranged between 20% and 75% with an average of about 45%.

Discussion of Test Results

1. The results given in Tables 6 and 7 are quite similar and indicate agreement between the data collected at the two separate sites.
2. The addition of "Princep-80W" as a weed control agent had no effect on the results obtained, other than preventing vegetation growth.
3. Since the numerical amount of the extracted residues for the best performing chemicals showed such a wide variation, it is possible that the elements (organic or otherwise) that are responsible for the soil stabilization may not all be soluble in benzene.
4. A comparison of the degree of dust control, based on the Hi-Vol test, and the percent reduction (leaching) of the extracted residues for the ADOT Yard site is given in Table 8. No direct correlation is apparent between the two criteria, except that the five chemicals exhibiting the lowest degree of control also suffered the largest percent-reductions in the extracted residues.

TABLE 8

COMPARISON OF HI-VOL AND EXTRACTION TEST RESULTS, ADOT YARD SITE

Hi-Vol Rating	Chemical	Hi-Vol Control %	Residue Reduction %
1	Terrakrete #2	97.7	41
2	Surfaseal 1:10	96.7	33
3	Dust Control Oil, 1/4 gsy	96.7	20
4	Surfaseal 1:20	94.8	40
5	Dust Control Oil, 1/10 gsy	91.7	36
6	Aerospray 70	91.6	42
7	Norlig 41 + F-125	90.7	28
8	Paracol 1461	88.3	27
9	Dust Stop	64.0	62
10	Petroset SB	51.8	48
11	Coherex	46.7	61
12	Dresinate DS-60W-80F	35.8	75
13	Foramine 99-194	11.8	75

Visual Inspection and Evaluation

The conditions of the treated surfaces at the two sites were monitored in the field with time. Field observations included color change, firmness of crust, vegetation growth and presence of surface cracks. The results of these field observations, particularly the final conditions of the treated plots, are included in Table 3 and Table 5 for the AES Farm site and the ADOT Yard site, respectively. These results are in general accordance with the quantitative data obtained from the Hi-Vol and the extraction test data.

CHAPTER 5

FIELD APPLICATIONS - ROAD TEST SITE

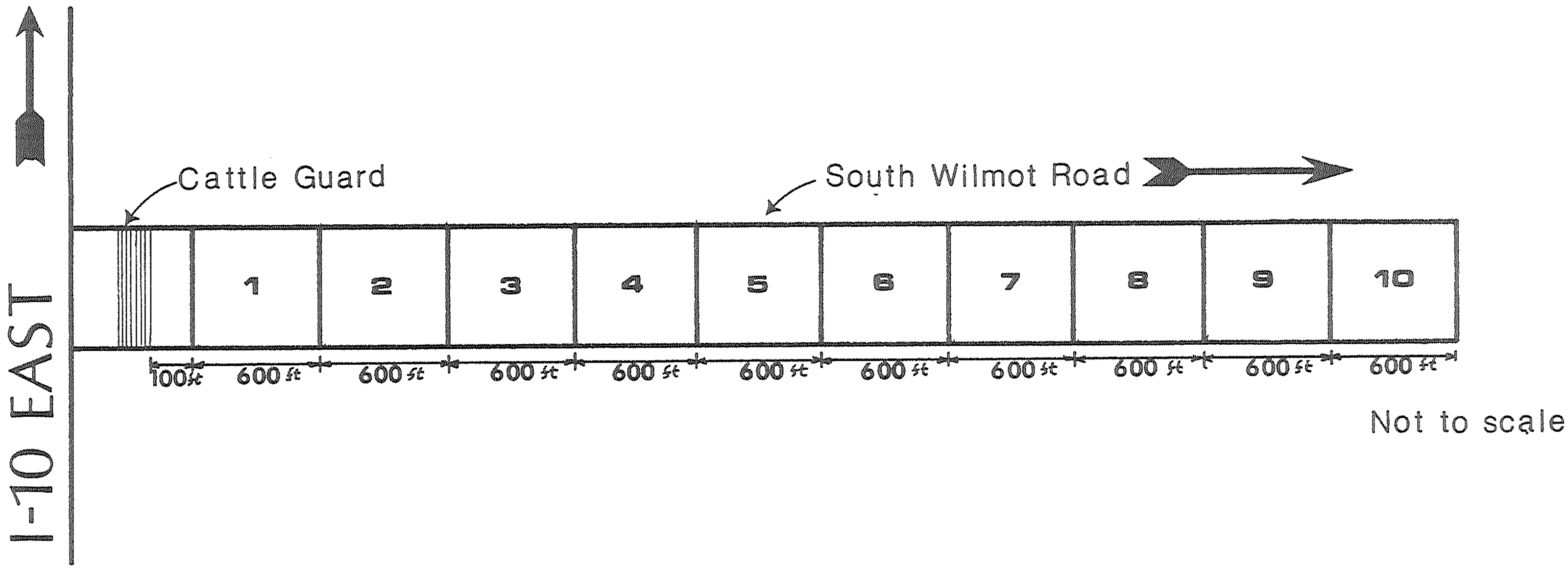
Near the completion of the laboratory testing phase of this project an unpaved road was allocated for our field evaluation by the Pima County Highway Department. The South Wilmot Road (South of I-10) was selected from a few choices given to us. The selection was made due to the reasonable traffic volume (130-150 vpd) on the road and particularly due to the lack of residential housing nearby which reduced the possibility of damage to the field monitoring instruments. The County Engineer also agreed to provide equipment and personnel to work with us for the field application.

The road test site on South Wilmot Road was selected just south of I-10. The first test section starts at approximately 100 feet (30.48 m) south of the cattle guard across the road. Ten sections 600-feet long and 28-feet wide (183 m long and 8.5 m wide) were marked along the road and are referred to as sections no. 1 through 10 going southward, as outlined in Figure 9. Properties of surface soils at the road site are given in Table 1.

Spray-On Applications

Site Preparation

For the spray applications, the surface of the road was usually prepared by surface blading (no ripping) leaving a nominally loosened surface



SPRAY TREATMENT Section

1 DUST CONTROL OIL

2 AEROSPRAY 70

3 WATER (CONTROL)

4 FORAMINE 99-194

5 DUST BOND AND F 125

6 CURASOL-AE

MIXED-IN-DEPHT TREATMENT Section

7 DUST BOND AND F 125

8 REDICOTE-E 52 EMULSION

9 WATER (CONTROL)

10 DUST CONTROL OIL

FIGURE 9- WILMOT ROAD TEST LAYOUT

layer. The chemical solution was prepared in a boot truck and sprayed on the surface through the spray bar. It is pointed out that the boot truck was equipped with a circulating pump that continued to mix the chemicals during application. After spraying, the surface was usually rolled using a rubber tire roller.

Chemicals Applied

As pointed out in the Interim Report, Part II, five chemicals were decided upon for uses in the field application for traffic erosion, using the spray-on application. In addition water treatment was used for one control section. Figure 9 includes the outline of the sections allocated for the chemical treatments. Each one of these chemicals is briefly discussed below. For each chemical the outline includes its major constituents, the dilution ratio, the rate of application and the cost of application per square yard for the chemical only. A brief description of the field application is also given. The number given after the chemical name refers to the number assigned to each chemical during the laboratory testing program.

1. Water (0): Section number 3 was sprayed with 1/2 gsy (2.26 liters/m^2) of water and rolled.
2. Aerospray-70 (7): Its major constituent is a polyvinyl acetate resin. The laboratory dilution ratio is 1 to 10 in water, and the application rate is 1.9 gsy (8.6 liters/m^2). The cost of this chemical application is 43.2 cents and 47.17 cents per square yard (51.66 and 56.41 ¢/m^2), F.O.B. Torrence, California and F.O.B. Tucson, Arizona, respectively.

For the field application, the boot truck was filled with 800 gallons (3 m^3) of water, 270 gallons (1.0 m^3) of chemical were added using a transfer pump, then an additional 800 gallons (3 m^3) of water were added. The solution was then sprayed at 1.0 gsy (4.52 liters/m^2) on the surface of the road using four passes at 1/4 gsy (1.13 liters/m^2) each. This rate of application was decided upon since larger rates caused heavy flooding of the surface. The surface was rolled immediately without noticeable tracking.

This field application is thus a dilution of 1:6 in water, with the solution rate of application at 1.0 gsy (4.52 liters/m^2). The amount of chemical per square yard in the field application is about 84% of that given in the laboratory test. Thus the chemical cost of the actual field application is 36.3 cents and 39.6 cents per square yard (43.4 and 47.4 ¢/m^2), F.O.B. supplier and F.O.B. Tucson, respectively.

3. Curasol AE (9b): This is identified as a polymer dispersion. The laboratory dilution is 1 to 5 in water applied at 1.0 gsy (4.52 liters/m^2). The cost of this chemical application is 43.3 cents and 45.8 cents per square yard (51.8 and 54.8 ¢/m^2), F.O.B. Los Angeles, California and F.O.B. Tucson, Arizona, respectively.

   For the field application, the boot truck was filled with 800 gallons (3 m^3) of water, 270 gallons (1 m^3) of chemical were added using a transfer pump, then an additional 800 gallons (3 m^3) of water were added. The solution was then sprayed at 1.0 gsy (4.52 liters/m^2) on the road surface using four passes at 1/4 gsy (1.13 liters/m^2) each. The surface was rolled immediately without noticeable tracking.

This field application is thus a dilution of 1 to 6 in water instead of 1 to 5 as in the laboratory test. Accordingly, the amount of chemical is about 87% of that given in the laboratory test. The chemical cost of the actual field application is 37.67 cents and 39.84 cents per square yard (45.05 and 47.65 ¢/m^2), F.O.B. supplier and F.O.B. Tucson, respectively.

4. Dust Bond 100 (18b): This is a mixture of lignin sulfonate and other chemicals. The laboratory rate of application is at 1.0 gsy (4.52 liters/m^2) undiluted. This chemical application costs 36 cents per square yard (43.05 ¢/m^2), F.O.B. Tucson and supplier. Since Dust Bond 100 was used to represent the group of lignin sulfonate products as waterproofed with Formula 125, ten gallons of F-125 were also used in the field to achieve the same rate of F-125 application given in chemical No. 46 (Norlig-41 and F-125).

For the field application, the boot truck was filled with about 1,900 gallons (7.1 m^3) of Dust Bond. The chemical was sprayed on the road surface at about 1.0 gsy (4.52 liters/m^2), until there was about 200 gallons (0.75 m^3) left. Two hundred gallons (0.75 m^3) of water were then added along with ten gallons (38 liters) of Formula 125, and the mix was spread evenly on the road surface. The surface was rolled about one hour after spraying, due to high surface moisture, for about half an hour, then left until the following morning since the surface was still quite wet for rolling. The following morning, the rolling continued until sufficient compaction was achieved.

The cost of the field chemical application (Dust Bond 100 + Formula 125) is 41.3 cents per square yard (49.4 ¢/m^2) F.O.B. supplier in Tucson, Arizona.

5. Dust Control Oil (37): This is a mixture of petroleum resin and a light hydrocarbon solvent. The laboratory rate of application is 0.6 gsy (2.71 liters/m^2) undiluted. This chemical application costs 9.0 cents and 25.8 cents per square yard (10.76 and 30.86 ¢/m^2), F.O.B. Richmond, California and F.O.B. Tucson, Arizona, respectively.

   For the field application, the chemical was sprayed on the road surface at 1/2 gsy (2.26 liters/m^2) and rolled immediately without any tracking observed. The cost of this actual field application is 7.5 cents and 21.5 cents per square yard (8.97 and 25.71 ¢/m^2), F.O.B. supplier, and F.O.B. Tucson, Arizona, respectively.

6. Foramine 99-194 (41a): This is a urea-formaldehyde resin in a water solution. Laboratory application calls for 4.1 lbs of the chemical per square yard (2.22 Kg/m^2) with enough water to make a sprayable solution. The cost of this chemical application is 34.0 cents and 50.57 cents per square yard (40.66 and 60.48 ¢/m^2), F.O.B. Tacoma, Washington, and F.O.B. Tucson, Arizona, respectively.

For the field application approximately 720 gallons (2.7 m^3) of the chemical were transferred to the boot truck in addition to about 1,150 gallons (4.3 m^3) of water. The solution was sprayed at 1.0 gsy (4.52 liters/m^2) on the road surface. It is pointed out that the chemical appeared to have hardened somewhat in the drums due to the 103^{0}F (40^{0}C) temperature that lasted three days before the field application. Attempts to roll the surface after application were unsuccessul due to severe tracking. It was about two hours later when the section was rolled with tracking still observed. The road condition after rolling was not very good. The cost of the field application is the same as for the laboratory test, given above.

It is pointed out that after every application the boot truck was rinsed and flushed clean with water before starting the next chemical solution. After application of the Dust Control Oil, the truck was flushed out with gasoline. The chemicals were applied in the field between May 28 and May 31, 1974.

Mixed-in Applications

Four sections of the road (7 through 10) were used for the mixing application of chemicals. Three chemicals and water (control) were used.

Site Preparation

The road surface was given a light water spray and then the surface was ripped, using the ripper attached to the grader, to a depth of about three inches (7.62 cm). It was decided to aim for a three-inch (7.62 cm) stabilized, mixed and compacted mat due to the unavailability of a Seaman mixer and based on previous field results reported by Hoover (1971). In a previous study Hoover (1971) reported difficulties in mixing and compacting a ripped four-inch (10.16 cm) thick layer and recommended future use of three-inch (7.62 cm) thickness. After the road surface was ripped up, additional water was sprayed to reduce surface tension effects, then a portion of the required chemical application was sprayed on the surface. The loosened surface soil was then bladed to the sides of the roads forming two windrows. Each windrow was then spread back on the road surface, sprayed with more chemical and water if necessary and then bladed to form a windrow in the middle of the road. When all the required chemical and enough water (to reach optimum moisture in the field) were added a continuous operation of surface mixing by the blade was done. After complete mixing two side windrows were formed. The mixed soil was then spread on the surface and compacted in two lifts, forming a slight crown near the center.

Each of the chemicals used is briefly discussed below. For each chemical the outline includes its major constituents, the dilution ratio, rate of application, and the cost of application (chemical only) for a three-inch (7.62 cm) mat. The number given after the chemical name refers to the number assigned to each chemical during the laboratory testing program.

1. Water (0): Water spray was given as discussed above, with final moisture content measured at 9.5 percent. Field density reached was about 120 pcf (1.92 gm/cm^3). No tracking during compaction was observed.
2. Redicote E-52 (6): This is a cationic CSS-1h asphalt emulsion.

Laboratory application calls for an 8.4 percent emulsion by dry weight of the soil compacted with enough water to reach optimum moisture content.

For the field application 4500 gallons (16.9 m^3) were used for the three-inch (7.62 cm) compacted mat. At 120 pcf (1.92 gm/cm^3) dry density, this gives 7.44 percent emulsion and 2.41 gsy (10.89 $liters/m^2$) for a three-inch (7.62 cm) mat. The cost of this field application is 53 cents per square yard (63.39 ¢/m^2), F.O.B. supplier in Tucson, Arizona.

3. Dust Bond 100 (18): This is a mixture of lignin sulfonate and other chemicals. The laboratory rate of application is at 1.0 gsy (4.52 $liters/m^2$) undiluted, for a two-inch (5.08 cm) compacted mat. About 2000 gallons (7.5 m^3) of the chemical were sprayed at about 1 gsy (4.52 $liters/m^2$) along with ten gallons (38 liters) of Formula 125, for a compacted three-inch (7.62 cm) mat. This rate of field application costs 41.3 cents per square yard (49.49 ¢/m^2), F.O.B. supplier in Tucson, Arizona.

4. Dust Control Oil (37): This chemical did not pass the laboratory test requirements, but was used as the supplier donated the chemical for field use.

The field application rate was at 1/2 gsy (2.26 $liters/m^2$) undiluted for a three-inch (7.62 cm) compacted mat. The cost of this chemical application is 7.5 cents and 21.5 cents per square yard (8.97 and 22.7 ¢/m^2), F.O.B. Richmond, California and Tucson, Arizona respectively. Two days after the field application, the first 150 feet (30.48 meters) of the treated section (No. 10) was sprayed with a surface application of 1/10 gsy (0.45 liters/m^2) of Dust Control Oil. This first section is identified as section (10a), while the rest of the Dust Control Oil section as (10b).

As with the spray-on application the boot truck was rinsed and flushed clean before starting the next chemical. A separate boot truck was used for the Redicote E-52 emulsion. The chemicals were applied in the field between May 28 and May 31, 1974.

CHAPTER 6

FIELD MONITORING TESTS - ROAD TEST SITE

It is pointed out that the field monitoring techniques used to evaluate the chemical treatments applied at the road test site were developed and/or modified by the principal investigator, due to the lack of well defined and widely accepted standardized tests that can be used for such monitoring.

Sampling for Wind Blown Dust (Hi-Vol)

This test procedure is identical to that Hi-Vol dust collecting test discussed previously for the dust control sites. The test was conducted at each section of the road test site at bi-weekly intervals whenever the weather permitted.

Dust Collectors Across the Road Centerline

Dust collectors were installed transverse to the road centerline at the middle of each section. The dust collectors were plastic cups 3-1/2 inches (8.9 cm) diameter at the top, 2-3/4 inches (7.0 cm) diameter at the bottom, and 3-1/2 inches (8.9 cm) high. The cups were taped to the top of 2-inch (5.08 cm) wide plywood sticks, with their top approximately 3-feet (0.91 m) above the ground. The containers were half-filled with distilled water and covered at the top with a wire screen with square openings of 2 millimeter size. The screen was taped to the side of the cup to prevent ants and other insects from crawling into the cup, as occurred when only a rubber band was used at first.

The cups were placed at a spacing of 20 feet (6.1 m) for a distance of 140 feet (42.67 m) and at a 50 foot (15.24 m) spacing for an additional 100 feet (30.48 m) at both sides of the road. The first cup was placed at 24 feet (7.3 m) from the centerline of the road, while the last cup was at 264 feet (80.5 m) from the centerline. Later on an additional cup was placed at the edge of the road, 14 feet (4.27 m) from the centerline. The cups were left in place for a 21-day period and were periodically checked to make sure there was sufficient water in them. This test was considered to be relatively simple yet conforms, as nearly as possible, to ASTM designation D 1739 for collection and analysis of dust fall. The distance adopted for dust collection across the road, 240 feet (73.15 m) on both sides, was based on the results of similar testing reported by Hoover (1973), where the dust collected showed a very rapid drop-off from the road shoulder out to 30-40 feet (9.14 - 12.19 m) followed by a more gradual drop out to about 150 feet (45.72 m). Beyond 150 feet (45.72 m) a nearly constant low deposition rate was reported by Hoover (1973).

At the end of the collection period, the cups were sealed and brought to the laboratory. Details of the laboratory filtration and determination of non-volatile solids (dust particles) are given in Appendix A. It is pointed out that this test was conducted three times during the entire monitoring period. Figure 10 shows the dust collectors set-up in lines transverse to the road centerline, and Figure 11 shows a close-up of a dust collector cup.

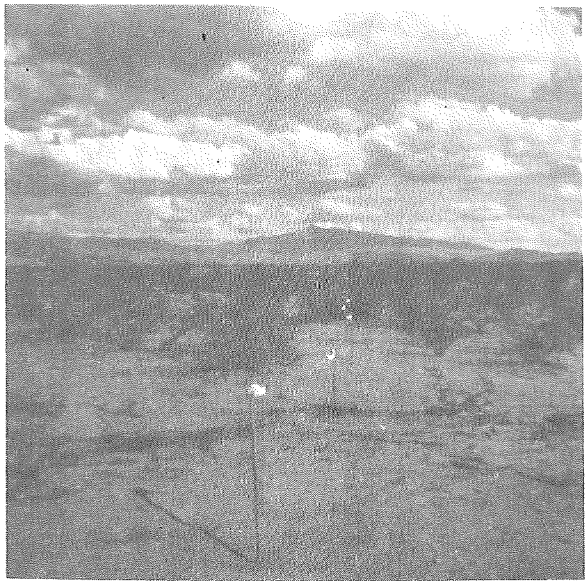


FIGURE 10 Dust Collectors Set-up in the Road

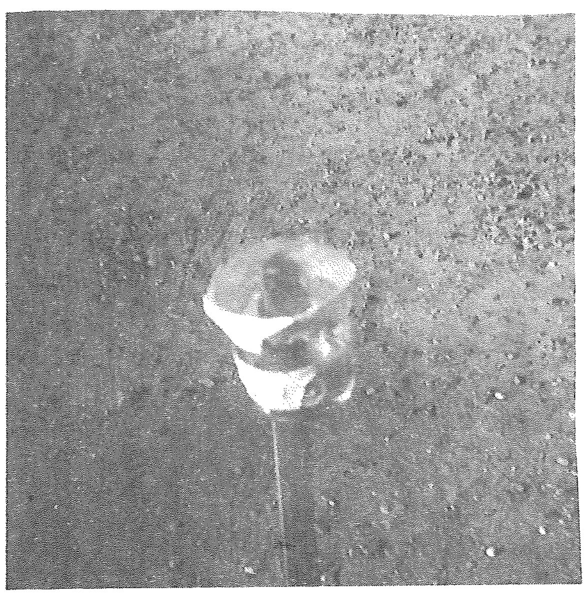


FIGURE 11 Close-up of a Dust Collector Cup

Adhesive-Sheet Dust Collection

For the first few months of the field monitoring, attempts were made to collect dust on sheets of adhesive paper to see if they can replace and/or supplement the cup-collection method.

Along the cup collectors across the road centerline, adhesive sheets 4-1/2 inch (11.43 cm) square, were placed flat with the adhesive side facing up, and pinned on top of plywood sticks similar to those mentioned before. This was done for one section of the road to evaluate the feasibility of this method.

In addition, the same size of adhesive sheets were attached to a 2 inch by 4 inch (5.08 cm by 10.16 cm) wood beam, 7 feet (2.13 m) long. The beam was clamped to the bed of a pick-up truck making the distance between the adhesive sheet (facing the rear of the pick-up truck) at a 9 foot (2.74 m) distance from the rear wheels. The pick-up truck was then driven at 30 mph (48 Km/hr), one section at a time, and the weight of dust collected on the adhesive sheet was measured.

These two attempts failed to provide a good method for dust collection and showed this technique to be not feasible. The adhesive sheets left across the road, lost their adhesive quality when exposed to the atmosphere and curled up within a few days. The sheets attached to the truck seemed to lose weight (moisture) when the adhesive side was exposed, and very erratic results including negative dust collection resulted. Accordingly, after two months of trials, this approach was discontinued.

Dust Collectors Along the Road

For this test the same type of collection cups were used and placed on the edge of the road (on both sides), half-filled with water. A pick-up truck was then driven continuously along the entire length of the road test sections, in both directions, at a constant speed of 30 mph (48 Km/hr). The cups were then picked up, sealed and returned to the laboratory where the amount of dust collected was determined as discussed above. This test was conducted on a bi-weekly basis. Figure 12 shows the dust collector cup at the edge of the road while the driven pick-up truck stirred up dust along the water-sprayed (contol) section. Due to the small amount of dust generally collected, except for the control sections, this test was discontinued after a few months.

Visual Inspection and Evaluation

In addition to the quantitative evaluation techniques given above, a qualitative evaluation was made periodically on the condition of each test section. This evaluation included condition of the road surface, degree of dust control during traffic, riding quality, ruts, potholes, and surface cracking.

FIGURE 12 Dust Collector Cup at Road Edge

CHAPTER 7

FIELD TESTING DATA AND RESULTS - ROAD TEST SITE

In this chapter the collected field testing data at South Wilmot Road test site are presented and discussed. For each evaluation method, the data collected at the spray-on application sections and the mixed-in application sections are presented and analysed together; and a comparative evaluation for the chemical treatments is given.

As pointed out in the quarterly progress reports,the Pima County Maintenance crew, without notifying the principal investigator, graded the drainage ditches alongside Wilmot Road after the heavy rainfall encountered during September 1974. This was done sometime in September and the crew spread the loose soil back on top of the road, apparently not knowing that this section of the road was being used as a test section. This loose soil was reasonably washed off by the continued heavy rainfall by the end of September 1974. The principal investigator contacted the County Engineer and asked that no further grading be done on the road test section without prior notification. Apparently this message never reached the maintenance group, as upon arrival at the site on November 16, 1974 for the bi-weekly testing it was apparent that the maintenance crew had once again graded the drainage ditches and had caused reasonable disturbance to the treated road surface by actually blading the surface. Again the County Engineer was requested to halt any further grading at the test section. However, beyond January 1975, while personnel changes occurred at the County Engineer's office and the principal investigator was on a sabbatic leave abroad, further surface blading of the road surface was done at various times as shown later on.

Obviously such disturbance to the treated road surface have caused significant changes in the surface treatment, added loose soil particles to the surface, and destroyed the potential continuity in monitoring the behavior of the treated surfaces under traffic effects. Beyond November 1974, therefore, the results obtained at the road test site have to be viewed with this situation in mind. In addition, evaluation of the chemical treatments, based on personal observations in the field rather than on numerical collected data, became quite important.

Hi-Vol Dust Collection Data

Spray-on Applications

Hi-Vol dust collection tests were conducted at approximately 2-week intervals between June 12, 1974 and September 29, 1975. The collected Hi-Vol dust particulates in $\mu g/m^3$ at the road sections are given in Table 9. The accumulated rainfall at the site since the chemicals were applied is also given, along with the degree of wetness of the surface soils as observed at the time of the test. As shown on Table 9, the road surface was graded with a blade four times during the monitoring period. However, no significant disturbance to the test sections was made between June 12, 1974 and November 5, 1974; a period of about 5-months.

Discussion of Test Results. The results given in Table 9 indicate that:

TABLE 9

COLLECTED HI-VOL DUST PARTICULATES ($\mu g/m^3$)

Type	Date / Accum. Rain / Chemical	6/12/74 0.0"(D)	7/6/74 0.17"(D)	7/23/74 1.54"(M)	8/7/74 3.71"(M)	8/24/74 3.83"(M)	9/7/74 5.67(W)
Spray-on Application	Water (Control)	63367	59147	14559	15250	13356	5696
	Dust Control Oil	852	1352	283	349	396	537
	Aerospray 70	651	1481	341	945	1840	819
	Foramine 99-194	11554	16918	7646	5904	8773	1918
	Dust Bond 100 + F-125	1614	1297	741	520	425	427
	Curasol AE	694	1793	1016	1419	1155	526
Mixed-in Application	Water (Control)	31834	41333	12265	11023	12938	6455
	Dust Bond 100 + F-125	1048	1897	660	594	756	526
	Redicote E52	421	624	212	113	198	152
	Dust Control Oil and Spray	616	681	235	228	325	361
	Dust Control Oil	587	835	511	207	375	149

(D) = Dry (M) = Moist (W) = Wet

TABLE 9 (Continued)

Type	Date / Accum. Rain / Chemical	9/25/74 6.75"(W)	10/18/74 7.67"(D)	11/5/74 8.9"(D)	11/16/74* 9.58"(D)	11/30/74 9.58"(D)	12/19/74 9.72"(D)
Spray-on Application	Water (Control)	4233	41922	48650	75067	67455	56819
	Dust Control Oil	300	1311	1367	20311	21597	16763
	Aerospray 70	934	4932	3696	19088	13272	13576
	Foramine 99-194	1054	16007	26289	37971	28537	28897
	Dust Bond 100 + F-125	526	5286	6127	19307	13349	21250
	Curasol AE	904	4191	4662	26572	26445	23477
Mixed-in Application	Water (Control)	4141	26982	35321	46051	20170	28325
	Dust Bond 100 + F-125	698	1629	1583	27435	18572	19505
	Redicote E52	85	1246	1017	2530	1894	1597
	Dust Control Oil and Spray	579	3618	7731	23943	19024	18233
	Dust Control Oil	206	5111	6201	30318	24523	19537

(D) = Dry (W) = Wet

* Site graded prior to this reading

TABLE 9 (Continued)

Type	Date / Accum. Rain / Chemical	1/7/75 9.92"(D)	1/18/75* 9.92"(D)	2/1/75 10.45"(D)	2/22/75 11.35"(D)	3/15/75 11.35"(D)	3/31/75 11.47"(D)
Spray-on Application	Water (Control)	60968	72657	4706	60297	58749	53632
	Dust Control Oil	12275	27809	1130	14325	15552	13325
	Aerospray 70	13915	19845	1625	17343	14410	18254
	Foramine 99-194	32155	39802	1890	26523	28120	23364
	Dust Bond 100 + F-125	21413	34657	1410	21455	21936	26671
	Curasol AE	25229	44240	1814	23632	24275	26501
Mixed-in Application	Water (Control)	30092	57102	1173	50855	52897	48282
	Dust Bond 100 + F-125	13187	28615	1980	12219	18051	18961
	Redicote E52	1639	1795	580	2148	848	1102
	Dust Control Oil and Spray	21873	28332	1201	19088	21455	23279
	Dust Control Oil	19505	40720	2010	24410	23166	27067

(D) = Dry (W) = Wet

* Site graded prior to this reading

TABLE 9 (Continued)

Type	Date Accum. Rain Chemical	4/12/75 12.0"(M)	4/26/75 12.07"(D)	5/10/75* 12.07"(D)	5/23/75 12.07"(D)	6/6/75 12.07"(D)	6/20/75 12.07"(D)
Spray-on Application	Water (Control)	32706	50388	82855	71095	53258	58321
	Dust Control Oil	4484	18685	28905	19696	14684	16291
	Aerospray 70	8212	20353	47420	22092	20678	24351
	Foramine 99-194	28010	32099	67109	46367	39074	42382
	Dust Bond 100 + F-125	13300	22939	50205	46395	36509	40885
	Curasol AE	13272	21993	56297	41604	44000	46213
Mixed-in Application	Water (Control)	21032	42473	70205	61385	47618	52391
	Dust Bond 100 + F-125	16000	18770	42615	34424	27392	26356
	Redicote E52	1272	2501	3605	3335	1682	3012
	Dust Control Oil and Spray	14035	23286	34360	19908	23689	25235
	Dust Control Oil	19236	27922	46473	45597	41908	39625

(D) = Dry   (M) = Moist

* Site graded prior to this reading

TABLE 9 (Concluded)

Type	Date / Accum. Rain / Chemical	7/7/75 12.93"(W)	7/28/75 15.21"(D)	8/11/75 15.58"(W)	8/25/75* 15.82"(D)	9/11/75 16.58"(D)	9/29/75 16.64"(D)
Spray-on Application	Water (Control)	5025	61659	4969	88700	75212	68815
	Dust Control Oil	2015	13685	1912	26361	20935	16541
	Aerospray 70	9310	27695	8932	42383	31777	29352
	Foramine 99-194	3835	40891	4815	69635	63221	62329
	Dust Bond 100 + F-125	2890	41424	3720	48212	41825	42699
	Curasol AE	2810	42651	3005	43623	45925	47301
Mixed-in Application	Water (Control)	3210	47201	3492	68212	61310	58521
	Dust Bond 100 + F-125	1006	23875	1261	41932	36515	38315
	Redicote E52	530	2310	496	3510	2812	3011
	Dust Control Oil and Spray	2328	24655	2911	38313	30111	31592
	Dust Control Oil	3125	41691	3619	52313	46219	44918

(D) = Dry (W) = Wet

* Site graded prior to this reading

1. During the initial 5-month period, prior to the surface blading of the treated sections, the applied spray-on chemical stabilizers afforded good means for controlling dust on this unpaved road. Except for Foramine 99-194, the degree of dust control for the other four treatments was above 90 percent, as shown in Table 10.
2. The performance ratings assigned to the chemicals based on their degree of dust control, as compared with the control section sprayed with water, after the initial 5-month period are shown in Table 10, along with general conditions of the treated surfaces at that time.
3. At the conclusion of the monitoring period, after 14 months, one chemical treatment, Dust Control Oil, still afforded a good degree of controlling dust on the road at 76 percent as shown in Table 11. The other treatments did not provide as good a performance, however, this may be partly attributed to the occasional blading that was done to the treated surfaces after the initial 5 months. The conditions of the treated surfaces after the 14-month monitoring period are also given in Table 11.
4. The degree of wetness of the treated and untreated surfaces (whether dry, moist, or wet) had a profound effect on the amount of dust stirred-up by traffic and wind on the road. The wetter the surface soils the lower were the amounts of dust collected from the road surface, as shown in Figure 13 which is a graphical representation of the dust collection

TABLE 10

PERFORMANCE RATINGS AND ROAD CONDITIONS AFTER 5 MONTHS
SPRAY-ON APPLICATIONS

Rating	Chemical	Percent Control	Description of Road Condition 11/5/74
1	Dust Control Oil	97.8	Black, very hard surface, some potholes near shoulders, minimal loose material, extremely light dust behind traffic
2	Curasol AE	92.6	Dark brown, medium hard surface, rutted with few potholes, loose coarse particles on surface, moderate dust behind traffic
3	Aerospray 70	92.2	Brown, medium hard surface, medium wear and ruts, few potholes, loose coarse particles on surface, moderate dust behind traffic
4	Dust Bond 100 + F-125	90.3	Brown, medium hard surface, moderate wear, few potholes, smooth surface, slippery when wet, moderate dust behind traffic
5	Foramine 99-194	58.5	Natural color, worn and rutted surface, large amount of loose particles, poor riding quality, heavy dust behind traffic
6	Water	0	Natural color, soft when wet, worn and rutted surface, large amount of loose particles, heavy dust cloud behind traffic

TABLE 11

PERFORMANCE RATINGS AND ROAD CONDITIONS AFTER 14 MONTHS
SPRAY-ON APPLICATIONS

Rating	Chemical	Percent Control	Description of Road Condition After Several Bladings 9/29/75
1	Dust Control Oil	76	Dark brown, hard surface, scattered potholes, moderate loose material but from outside the road, light dust behind traffic
2	Aerospray 70	57.3	Lt. brown, several ruts and potholes, large amount of loose particles, heavy dust behind traffic
3	Dust Bond 100 + F-125	38	Lt. brown, few patches of treated surface, several ruts, large amount of loose particles, heavy dust behind traffic
4	Curasol AE	31.3	Brown, several ruts and potholes, large amount of loose particles, very heavy dust behind traffic
5	Foramine 99-194	9.4	Natural color, similar to untreated (water) section
6	Water	0	Natural color, warn, numerous ruts and potholes, large amount of loose particles, heavy dust cloud behind traffic

data given in Table 9, for the section sprayed with Dust Control Oil and the control (water-spray) section.

5. Immediately after each time the surfaces were graded, a sudden rise in the amount of Hi-Vol collected dust occurred due to the increased amount of loose soil on the surface caused by the blading effects. In most instances, the amount of dust tended to decrease somewhat for a period of 2 to 4 weeks after the grading operations. These effects are also indicated in Figure 13.

6. The results given in Table 10 and Table 11 show that Dust Control Oil demonstrated the highest degree of dust control on the road surface both after the initial 5-month monitoring period and at the conclusion of the 14-month field observation period. It is pointed out that Dust Control Oil did not successfully pass the evaluation tests conducted in the laboratory, indicating that laboratory test results are not necessarily conclusive in predicting field performance of certain chemical stabilizers under effects of traffic.

7. As shown in Tables 10 and 11, Foramine 99-194 demonstrated the poorest degree of dust control on the road surface at both the short-term and long-term periods, even though this chemical had successfully passed the laboratory evaluation tests. This again points out the inconsistencies between laboratory and field performances of certain chemical stabilizers.

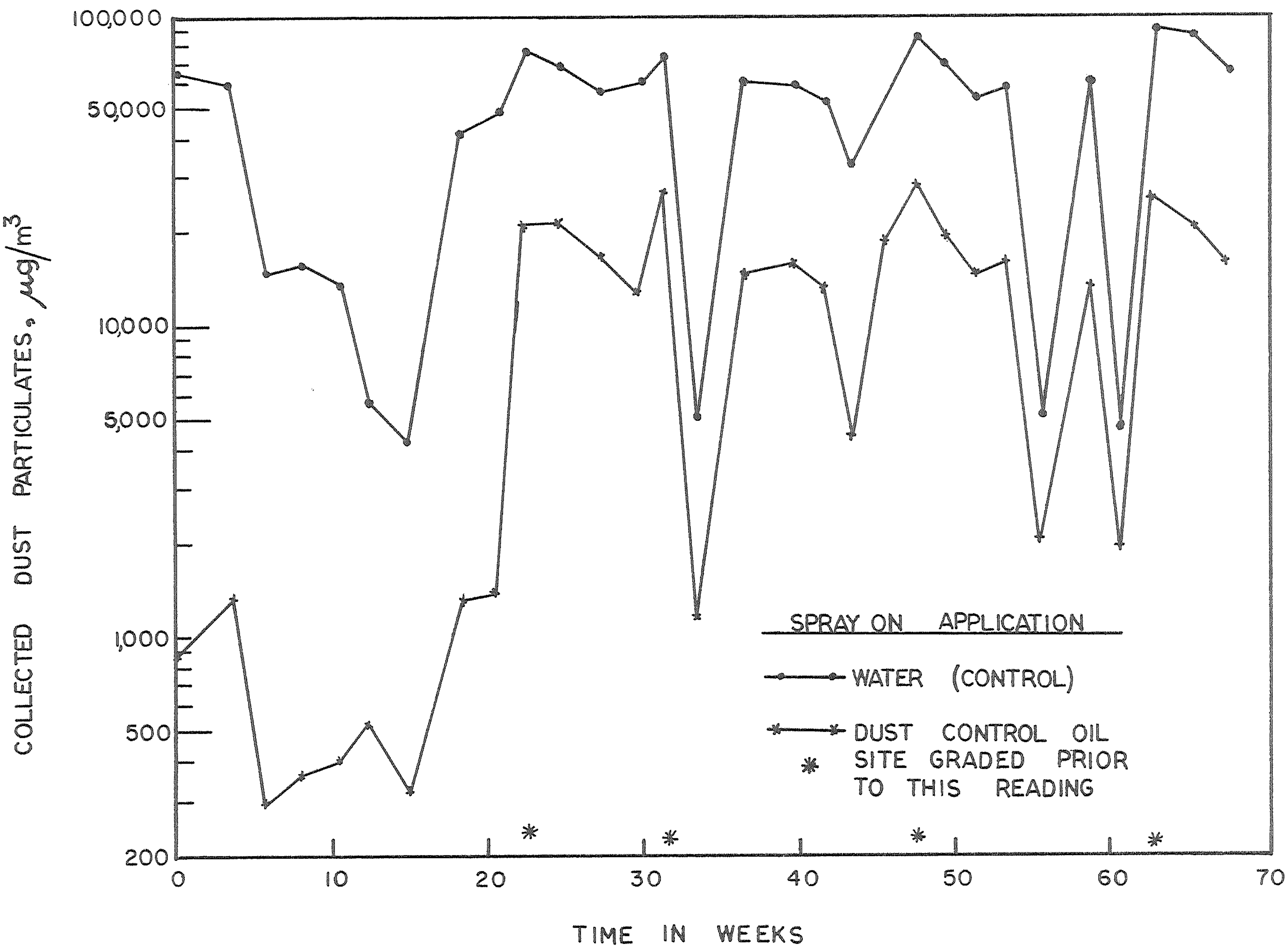


FIGURE 13. HI-VOL DUST PARTICULATES VS. TIME

Mixed-In Applications

Similar to the spray-on application sections, the Hi-Vol dust collection data obtained between June 12, 1974 and September 29, 1975 are given in Table 9. These mixed-in application sections were subjected to the same surface grading (blading) as the spray-on sections.

Discussion of Test Results. The results given in Table 9 indicate that:

1. The control section (water) for the mixed-in applications resulted in less dust collection as compared with the control section (water) for the spray-on applications.
2. During the initial 5-month period, prior to the surface blading of the treated sections, the mixed-in application of the chemical stabilizers afforded good means for controlling dust on the road.
3. The performance ratings assigned to the chemical treatments based on their degree of dust control, as compared with the control section where water was used, after the initial 5-month period are shown in Table 12, along with the general conditions of the road sections.
4. At the conclusion of the monitoring period, after 14 months, the Redicote E52 asphalt emulsion application continued to provide a high degree of dust control on the road (94.8 percent) shown in Table 13. This application appears to have an excellent promise for use on secondary roads to provide a good wearing surface and to effectively control dust behind traffic.

TABLE 12

PERFORMANCE RATINGS AND ROAD CONDITIONS AFTER 5 MONTHS
MIXED-IN APPLICATIONS

Rating	Chemical	Percent Control	Description of Road Condition 11/5/74
1	Redicote E52 Asphalt Emulsion	97.4	Black, very hard, asphalt like surface, v. little wear, smooth, no loose material, no dust behind traffic
2	Dust Bond 100 + F-125	96.1	Brown, hard surface, smooth, little wear, some loose material, very light dust behind traffic
3	Dust Control Oil	87.2	Black, hard at spots, few ruts and potholes, loose coarse material, moderate dust behind traffic
4	Dust Control Oil and Spray	84.1	Black, hard at spots, several ruts and potholes, loose coarse material, moderate dust behind traffic
5	Water	0	Natural color, rutted, several potholes, sunstantial loose material, heavy dust behind traffic

TABLE 13

PERFORMANCE RATINGS AND ROAD CONDITIONS AFTER 14 MONTHS
MIXED-IN APPLICATION

Rating	Chemical	Percent Control	Description of Road Condition After Several Bladings 9/29/75
1	Redicote E52 Asphalt Emulsion	94.8	Black, very hard, asphalt like surface, v.little wear, good riding quality, some loose coarse material, very little dust behind traffic
2	Dust Control Oil and Spray	46.0	Dark brown, hard surface at spots, several ruts and potholes, moderately high dust behind traffic
3	Dust Bond 100 + F-125	34.5	Brown, few hard spots, numerous ruts and potholes, heavy dust concentration behind traffic
4	Dust Control Oil	23.2	Dark brown, hard at few spots, numerous ruts and potholes, heavy dust cloud behind traffic
5	Water	0	Natural color, rutted, numerous potholes, substantial loose material, heavy dust cloud behind traffic

5. The other chemical treatments did not provide encouraging performances in controlling dust on the road. The conditions of the treated sections after the 14-month monitoring period are also given in Table 13.
6. As the degree of wetness of the road surfaces increased, the amount of dust collected significantly decreased as shown in Figure 14 which is a graphical representation of the dust collection data given in Table 9 for the mixed-in applications at the section treated with Redicote E52 asphalt emulsion and the water-control section.
7. After each time the surfaces were graded an increase of the Hi-Vol collected dust occurred, caused by the loose material bladed onto the road, as shown in Figure 14.

Dust Collector Data Across Road Centerline

Three sets of dust-fall data were collected at the test road during the field monitoring of the chemical treatments. Each set was collected for a period of 3 weeks; the first between June 15 and July 6, 1974; the second between October 12 and November 2, 1974; and the third between May 10 and May 31, 1975. Traffic counts were made during these periods. The average daily traffic on the road during the three test periods was 130 vehicles per day. The dust-fall collected in the cups on both sides of the road were averaged for every two cups at the same distance from the centerline, and these average values are reported herein. The cups on the east-side of the road generally had more dust-fall compared to those on the west-side. The difference ranged between 0 and 30 percent.

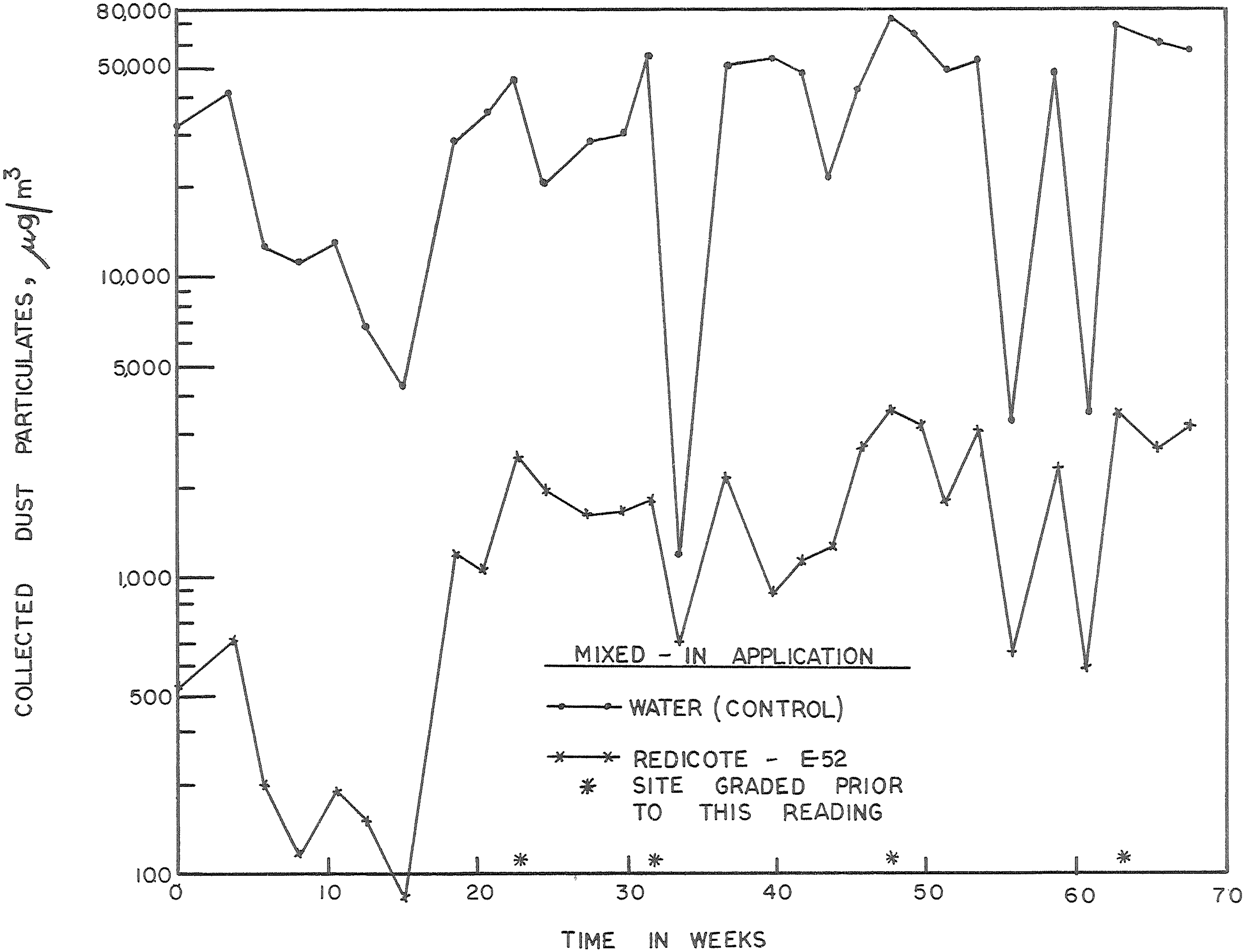


FIGURE 14. HI-VOL DUST PARTICULATES VS. TIME

The general trend for wind-blowing at the test road was from the west to the east which makes the leeward (east) side subject to higher dust concentrations. Previous studies, Handy et al (1975), indicated that the difference in the collected dust on either side of some roads can range from almost nil up to a factor of 7.

First Collection Data

The results of the field dust collection between June 15 and July 6, 1974, are given in Table 14 for the spray-on and mixed-in applications. This collection period started about two weeks after the field application of the chemicals. The amounts of dust collection are reported in kilograms per hectare per month (Kg/ha/mo). This unit has been used previously by other investigators in reporting dust collection amounts; Smith et al (1970), and Handy et al (1975). For conversion purposes, one lb/acre/day = 1.12 Kg/ha/day = 33.6 Kg/ha/mo.

The results given in Table 14 for the section sprayed with Dust Control Oil and the control (water spray) section are presented graphically in Figure 15 as a semi-logarithmic plot. When plotted on a linear scale, the resulting curve for the control section is almost asymptotic adjacent to the road. However, when plotted with the distance on a logarithmic scale, as in Figure 15, two straight lines result for the control section. Similar results have been previously reported for unpaved gravel roads, Handy et al (1975).

For the mixed-in application, the results given in Table 14 for the section treated with the Redicote E52 asphalt emulsion and the control (water) section are given in Figure 16, which is quite similar to Figure 15.

TABLE 14

COLLECTED DUST-FALL ACROSS ROAD CENTERLINE
(6/15/74 - 7/6/74)

		Average Dust Collected, Kg/ha/mo										
Distance from Centerline	Ft. M.	14 4.27	24 7.3	44 13.4	64 19.5	84 25.6	104 31.7	124 37.8	144 43.9	164 50.0	214 65.2	264 80.5
Spray-on Application	Dust Control Oil	135	86	62	60	53	48	41	36	38	32	29
	Aerospray 70	436	114	98	87	111	65	49	56	42	38	30
	Water (Control)	3760	1842	473	368	251	232	198	143	158	48	36
	Foramine 99-194	1254	376	172	131	112	98	72	70	48	39	28
	Dust Bond 100 + F-125	347	163	136	121	82	83	72	61	52	39	30
	Curasol AE	235	128	96	82	83	71	59	58	44	36	31
Mixed-in Application	Dust Bond 100 + F-125	306	258	201	172	143	128	112	78	66	35	29
	Redicote E52	172	87	73	58	50	52	48	45	40	32	28
	Water (Control)	3048	1532	373	295	251	209	168	150	126	41	33
	Dust Control Oil	405	242	137	129	141	99	87	68	55	36	27

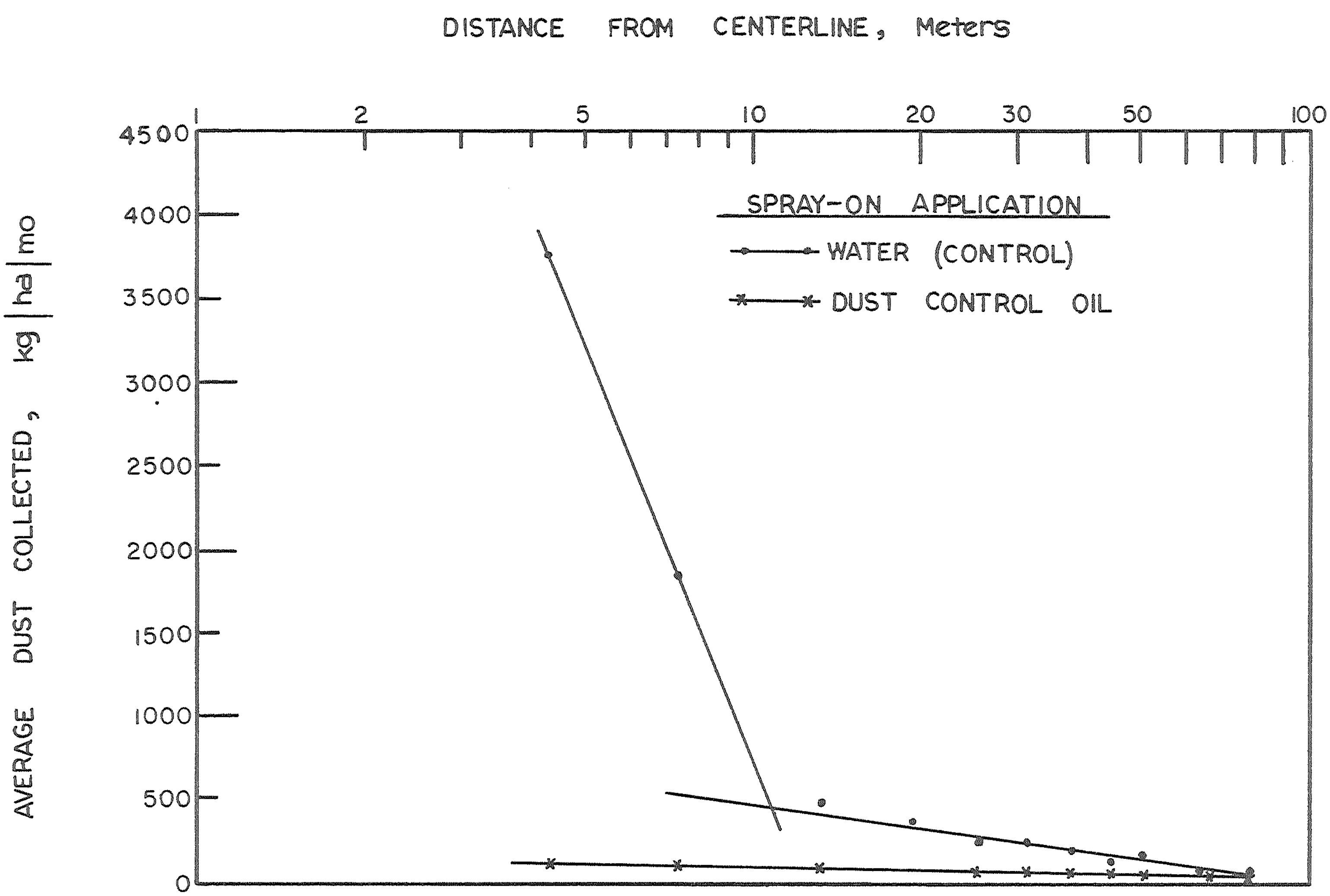


FIGURE 15 DUST COLLECTION VS. DISTANCE FROM CENTERLINE
(JUNE 15 – JULY 6, 1974)

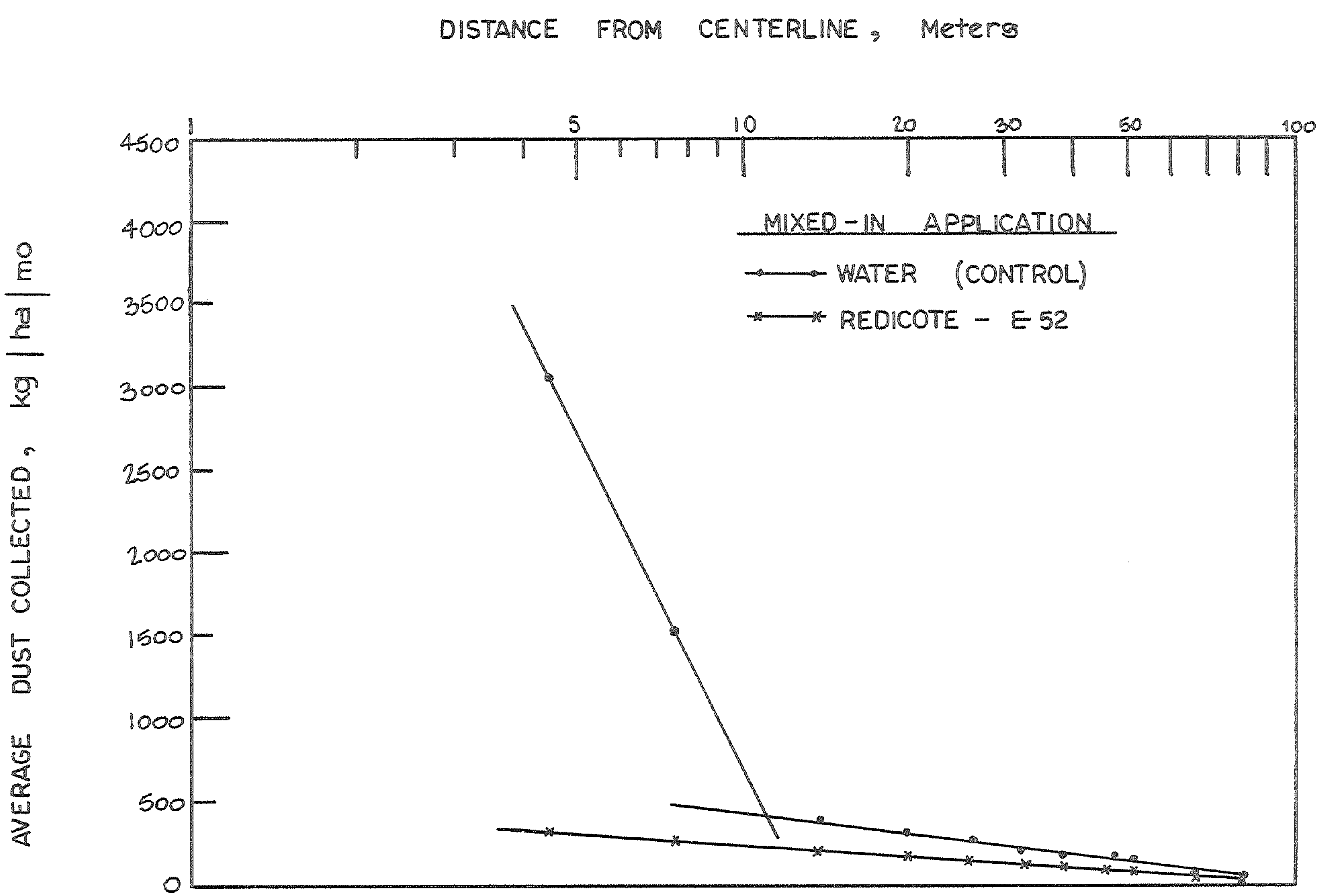


FIGURE 16. DUST COLLECTION VS. DISTANCE FROM CENTERLINE (JUNE 15 - JULY 6, 1974)

The results given in Table 14 and Figures 15 and 16 indicate that:

1. The closer the dust collector was to the road the more dust was collected for the given period.
2. The average dust collected at a distance of 264 feet (80.5 m) from the centerline at either side of the road ranged between 27 and 36 Kg/ha/mo, with an average of 30.1 Kg/ha/mo. This value agrees very closely with measurements (32.2, 32.7, 33.3 and 30.2 Kg/ha/mo) reported by Handy et al (1975) for the most distant containers along unpaved roads. This value of 30.1 Kg/ha/mo is, therefore, assumed to represent an atmospheric dust deposition during this collection period which can be subtracted from the collected amounts in order to compute the dust deposition due to traffic.
3. As shown in Figure 15 and 16, the intersections of the two linear relationships, for the control sections, lie at a distance of about 10 to 11 meters. Similar results were also found and reported on unpaved roads by Handy et al (1975) where the intersection occurred at about 10 to 12 meters from the centerline. These distances coincide rather closely with the usual right-of-way distances for secondary roads indicating that most of the dust-fall resulting from traffic on unpaved roads occur within the right-of-way area.
4. The relationship between the dust-fall amount versus log distance from the centerline for the treated sections vary significantly from those for the control sections. As shown in Figures 15 and 16 single linear relationships exist for the

section sprayed with Dust Control Oil, and the section mixed with the Redicote E52 asphalt emulsion. It is pointed out, however, that the amount of dust collected at the edge of the road for the section treated with Redicote E52 emulsion appears to be somewhat excessive due to the proximity of this section to the water control section next to it.

5. The proximity of water-control sections to the section sprayed with Aerospray 70 and to the section mixed with Dust Control Oil appears to have also caused an increase in the dust-fall collected at the edge of the road at these sections.

6. By integrating the areas under the semi-logarithmic plots similar to those given in Figures 15 and 16, the total amount of dust collected from the edge of the road (4.27 m from the centerline) to a distance 80.5 meters from the centerline can be calculated and maybe converted to units of kilogram per kilometer per month (Kg/km/mo). Correction for the amoumt collected due to atmospheric dust deposition (30.1 Kg/ha/mo during this collection period) can be made by a simple subtraction. In order to include the amount of dust generated at the road section itself (within the width of the road), it was assumed that the dust-fall readings at the edge of the road are similar to those across the road width. This assumption may tend to somewhat underestimate the amount of dust across the road width but it was chosen due to its consistency and simplicity. Another assumption for dust amount across the road width may have been made by extrapolating the linear relationship near the edge of the road upward, however, it was felt

that this may significantly overestimate the dust amount across the road width.

7. Table 15 presents a summary of the dust amounts due to traffic (after subtracting the atmospheric dust deposition) in Kg/km/mo for the 10 test sections at the road-test site, during the period between June 15 and July 6, 1974. The dust amounts given include the dust-fall across the road width, as discussed above and to a distance of 80.5 meters from the centerline of the road at both sides. From these data, the amount of dust resulting due to traffic of one vehicle per day given in kilogram per kilometer per year (Kg/km/yr) is also given in Table 15, along with the degree of dust control afforded by each chemical treatment as compared with the control sections that were treated with water.

8. The amount of dust at the water-spray section (8126 Kg/km/mo) was about 22 percent higher than the amount at the water-mixed section (6649 Kg/km/mo), indicating better dust control by the latter method of application.

9. These dust amounts at the water-control sections are in the same range of these reported for moderately dusty unpaved roads by Handy et al (1975).

10. For the spray-on application, Dust Control Oil provided the highest degree of dust control at 95.8% as compared with the water-spray control section. The Redicote E52 asphalt emulsion caused the highest degree of dust control at 93.7% as compared with the water-control section for the mixed-in application.

TABLE 15

SUMMARY OF DUST AMOUNT AND CONTROL, COLLECTION PERIOD JUNE 15-JULY 6, 1974

	Chemical	Dust Amount Kg/Km/Month 130 v.p.d.	Dust Amount Kg/Km/Year 1.0 v.p.d.	Dust Control %
Spray-on Application	Dust Control Oil	339	31.3	95.8
	Aerospray 70	944	87.1	88.4
	Water (Control)	8126	750	0.0
	Foramine 99-194	2373	219	70.8
	Dust Bond 100 + F-125	1028	94.9	87.3
	Curasol AE	703	64.9	91.3
Mixed-in Application	Dust Bond 100 + F-125	1414	130.5	78.7
	Redicote E52	417	38.5	93.7
	Water (Control)	6649	613.8	0.0
	Dust Control Oil	1280	118.2	80.7

11. During this period of dust collection (starting 2 weeks after field application) all the applications, both spray-on and mixed-in, afforded a good degree of dust control exceeding 70 percent.

Second Collection Data

The results of the field dust collection between October 12 and November 2, 1974 are given in Table 16 for the spray-on and mixed-in applications. This collection period started approximately 4-1/2 months after the field applications of the chemicals. The results given in Table 16 for the section sprayed with Dust Control Oil and the control (water-spray) section are presented on a semi-logarithmic plot in Figure 17. For the mixed-in application, the results given in Table 16 for the section treated with the Redicote E52 asphalt emulsion and the control (water) section are given in Figure 18.

Based on the results given in Table 16 and Figures 17 and 18, the following deductions are made:

1. The amount of dust collected continued to reduce as the location of the cup away from the centerline increased.
2. The average dust collected at a distance of 80.5 meters from the centerline ranged between 30 and 36 Kg/ha/mo with an average of 33 Kg/ha/mo. This value is slightly higher than that measured during the first collection period (30.1 Kg/ha/mo). This increase maybe attributed to the higher rainfall encountered during this collection period (1.38 inches vs. 0.17 inches). It has been shown previously by Smith et al (1970) that increased atmospheric dust-fall collection can be ex-

TABLE 16

COLLECTED DUST-FALL ACROSS ROAD CENTERLINE
(10/12/74 - 11/2/74)

Application	Distance from Centerline Ft. / M.	14 / 4.27	24 / 7.3	44 / 13.4	64 / 19.5	84 / 25.6	104 / 31.7	124 / 37.8	144 / 43.9	164 / 50.0	214 / 65.2	264 / 80.5
		Average Dust Collected, Kg/ha/mo										
Spray-on Application	Dust Control Oil	141	90	78	59	51	42	46	39	36	32	32
	Aerospray 70	456	251	137	122	73	81	80	55	48	39	34
	Water (Control)	3292	1405	354	261	250	183	168	151	106	60	33
	Foramine 99-194	1692	763	236	178	163	137	101	92	76	41	34
	Dust Bond 100 + F-125	353	204	101	83	71	62	50	51	39	32	30
	Curasol AE	269	173	146	113	92	78	75	53	45	38	32
Mixed-in Application	Dust Bond 100 + F-125	283	152	132	96	81	80	65	52	41	36	34
	Redicote E52	131	80	67	72	53	48	46	39	36	32	32
	Water (Control)	2942	1163	353	258	201	196	160	122	98	62	36
	Dust Control Oil	572	286	115	89	67	70	51	47	38	35	33

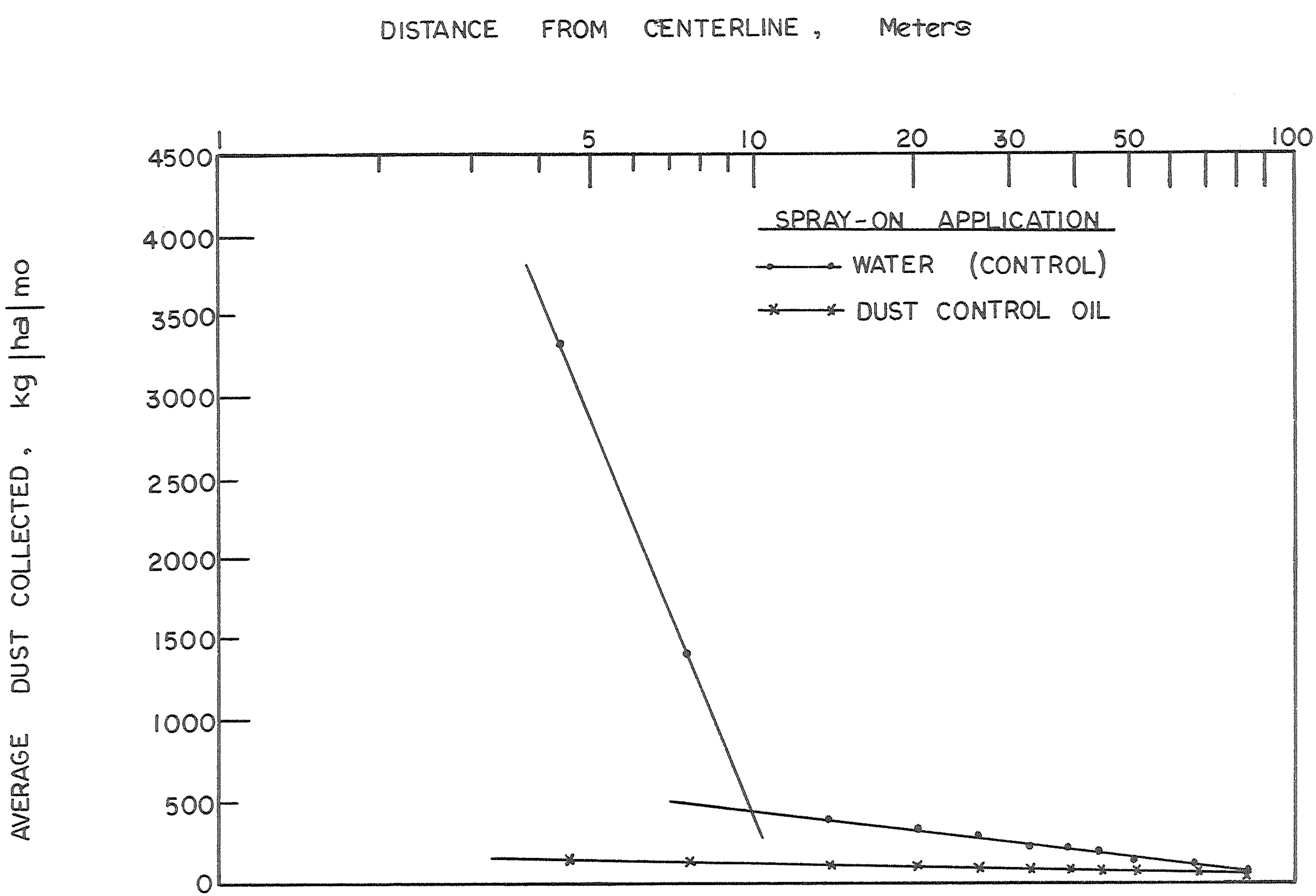


FIGURE 17. DUST COLLECTION VS. DISTANCE FROM CENTERLINE (OCTOBER 12 - NOVEMBER 2, 1974)

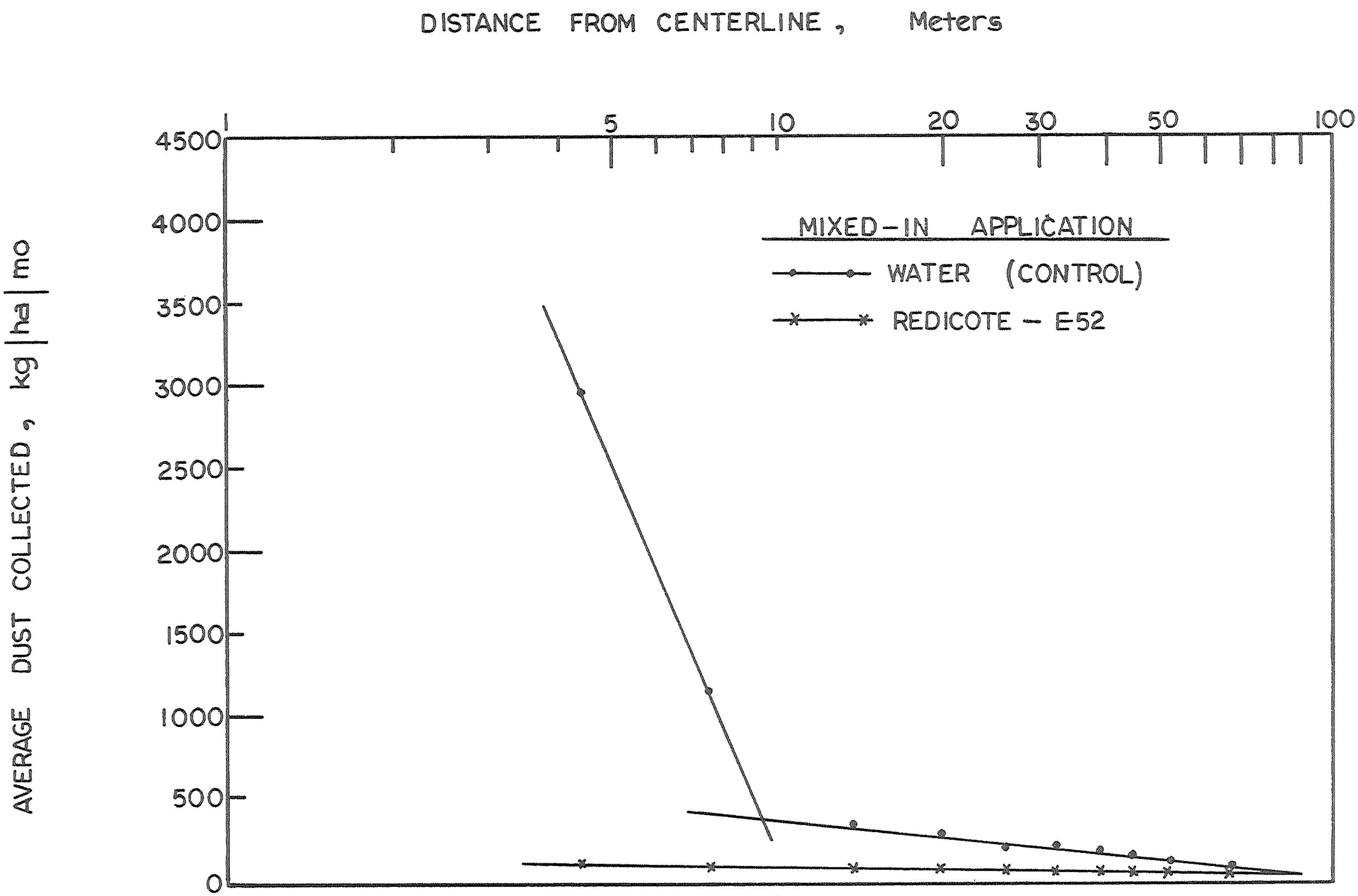


FIGURE 18. DUST COLLECTION VS. DISTANCE FROM CENTERLINE (OCTOBER 12 – NOVEMBER 2, 1974)

perienced during high rainfall periods due to the transportation of dust particulates to the earth in raindrops.

3. The intersections of the two linear relationships, for the control sections as shown in Figures 17 and 18, lie at a distance of about 9 to 10 meters. These are similar to those obtained from the first collection data and confirm that most of the dust-fall generated by traffic on unpaved roads occur within the right-of-way area.

4. The proximity of the water-control sections to the section sprayed with Aerospray 70,to the section mixed with Redicote E52 asphalt emulsion,and to the section mixed with Dust Control Oil, appears to have caused an increase in the dust-fall collected at the edge of the road at these sections.

5. Table 17 presents a summary of the dust amounts due to traffic (after correcting for atmospheric dust deposition) in Kg/km/mo for the 10 test sections at the road-test site, during the period between October 12 and November 2, 1974. Also given in Table 17 are the amounts of dust resulting due to traffic of one vehicle per day in Kg/km/yr, along with the degree of dust control afforded by each chemical treatment as compared with the control sections that were treated with water.

6. The amount of dust at the water-spray section (6687 Kg/km/mo) was about 12 percent higher than the amount at the water-mixed section (5961 Kg/km/mo). Both of these values are in the same range of those reported for moderately dusty unpaved roads by Handy et al (1975).

TABLE 17

SUMMARY OF DUST AMOUNT AND CONTROL,
COLLECTION PERIOD OCTOBER 12-NOVEMBER 2, 1974

	Chemical	Dust Amount Kg/Km/Month 130 v.p.d.	Dust Amount Kg/Km/Year 1.0 v.p.d.	Dust Control %
Spray-on Application	Dust Control Oil	321	29.7	95.2
	Aerospray 70	1167	107.7	82.6
	Water (Control)	6687	617.2	0.0
	Foramine 99-194	3568	329.4	46.6
	Dust Bond 100 + F-125	800	73.8	88.0
	Curasol AE	878	81.0	86.9
Mixed-in Application	Dust Bond 100 + F-125	801	73.9	86.6
	Redicote E52	313	28.9	94.7
	Water (Control)	5961	550.2	0.0
	Dust Control Oil	1165	107.5	80.5

7. Comparing the dust amounts given in Tables 15 and 17, the values consistently declined for the mixed-in applications in the second collection period versus the first period; the relationship was, however, mixed for the spray-on applications with three increasing and three decreasing in values.
8. For the spray-on application, Dust Control Oil continued to provide the highest degree of dust control at 95.2% as compared with the water-spray control section. The Redicote E52 asphalt emulsion also continued to afford the highest degree of dust control at 94.7% as compared with the water control section for the mixed-in application.
9. During this period of dust collection (starting 4-1/2 months after field application) all chemical treatments except for the spray-on application of Foramine 99-194 afforded a good degree of dust control exceeding 80 percent.

Third Collection Data

The results of the field dust collection between May 10 and May 31, 1975 are given in Table 18 for the spray-on and mixed-in applications. This collection period started almost one year after the field applications of the chemicals. It is pointed out that prior to this collection period, the road surface has been subjected to three surface blading operations as mentioned earlier. For all practical purposes, these surface blading operations have altered and disturbed the surface treatments to a very large degree. Accordingly, the data collected during this period should not be considered representative of the surface conditions had they been left undisturbed.

TABLE 18

COLLECTED DUST-FALL ACROSS ROAD CENTERLINE
(5/10/75 - 5/31/75)

		Average Dust Collected, Kg/ha/mo										
Distance from Centerline	Ft. M.	14 4.27	24 7.3	44 13.4	64 19.5	84 25.6	104 31.7	124 37.8	144 43.9	164 50.0	214 65.2	264 80.5
Spray-on Application	Dust Control Oil	1783	978	346	301	250	245	146	142	115	63	38
	Aerospray 70	2313	1252	461	338	298	202	200	161	108	69	41
	Water (Control)	4052	2321	637	547	383	378	301	249	186	87	48
	Foramine 99-194	3856	2092	601	482	365	317	251	199	178	80	43
	Dust Bond 100 + F-125	3415	1876	581	463	341	298	222	181	162	73	42
	Curasol AE	3741	2175	583	447	398	326	211	223	183	71	39
Mixed-in Application	Dust Bond 100 + F-125	2166	1172	453	341	289	223	181	158	106	70	39
	Redicote E52	653	378	151	118	103	88	81	70	63	52	38
	Water (Control)	4103	2286	673	526	401	362	283	215	162	72	43
	Dust Control Oil	3763	2031	609	446	362	271	198	183	146	78	41

The results given in Table 18 for the section sprayed with Dust Control Oil and the control (water-spray) section are presented on a semi-logarithmic plot in Figure 19. For the mixed-in application, the results given in Table 18 for the section treated with the Redicote E52 asphalt emulsion and the control (water) section are given in Figure 20.

Based on the results given in Table 18 and Figures 19 and 20, the following deductions are made:

1. The amounts of dust collected during this period were significantly higher than those accumulated during the previous two collection periods.
2. As previously noted, the amount of dust collected continued to reduce as the location of the cup away from the centerline increased.
3. The average dust collected at a distance of 80.5 meters from the centerline ranged between 38 and 48 Kg/ha/mo, with an average of 41.2 Kg/ha/mo. This value is significantly higher than the atmospheric depositions obtained during the previous two collection periods, and maybe attributed to the heavy dust storms encountered during this very dry period.
4. The intersection of the two linear relationships, for the control sections as shown in Figures 19 and 20, lie at a distance of about 11 to 12 meters. This distance is somewhat higher than in the previous data, which maybe attributed to the higher dust concentrations caused by traffic during this collection period that was carried farther across the road by the traffic generated wind.

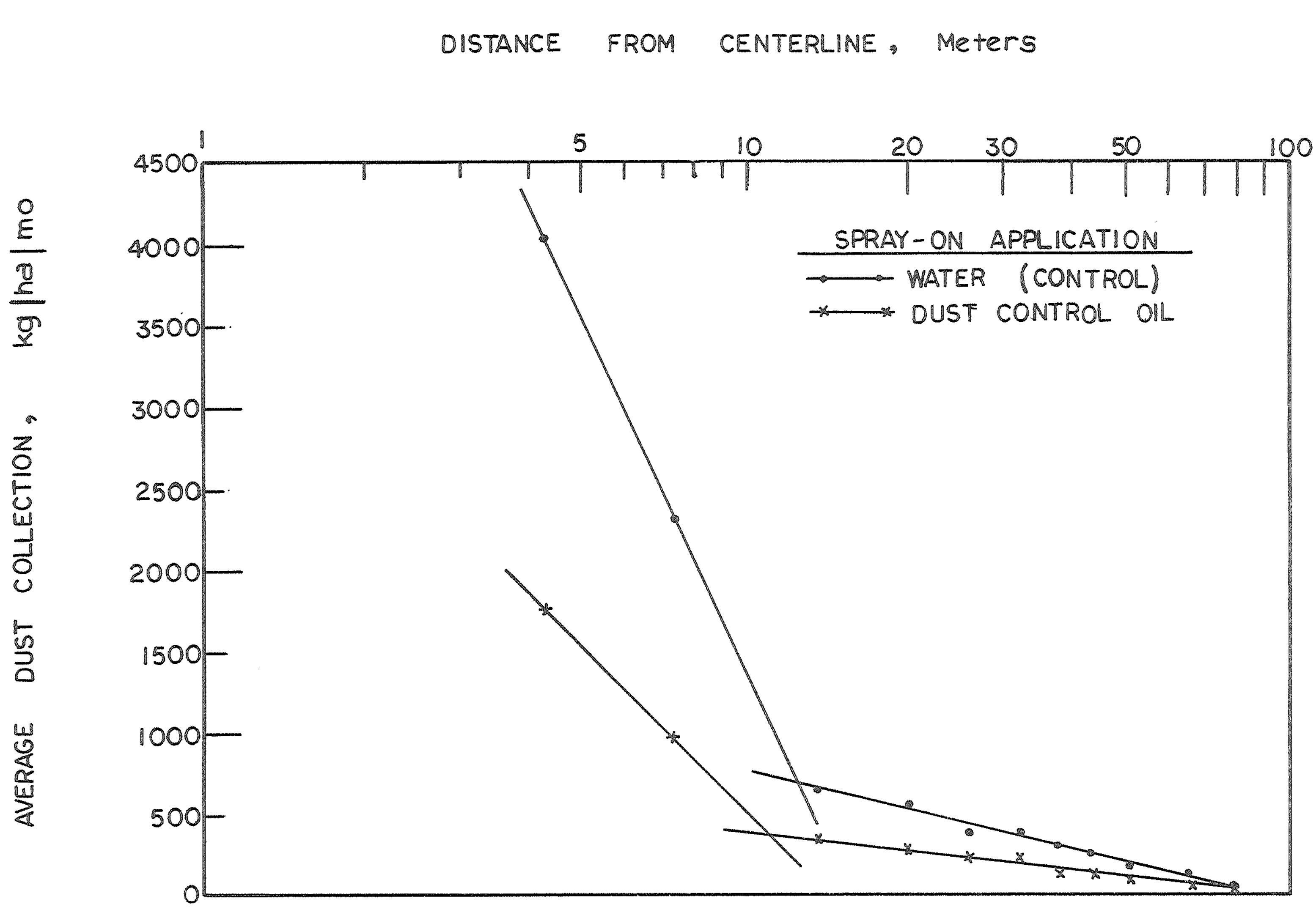


FIGURE 19. DUST COLLECTION VS. DISTANCE FROM CENTERLINE
(MAY 10 - MAY 31, 1975)

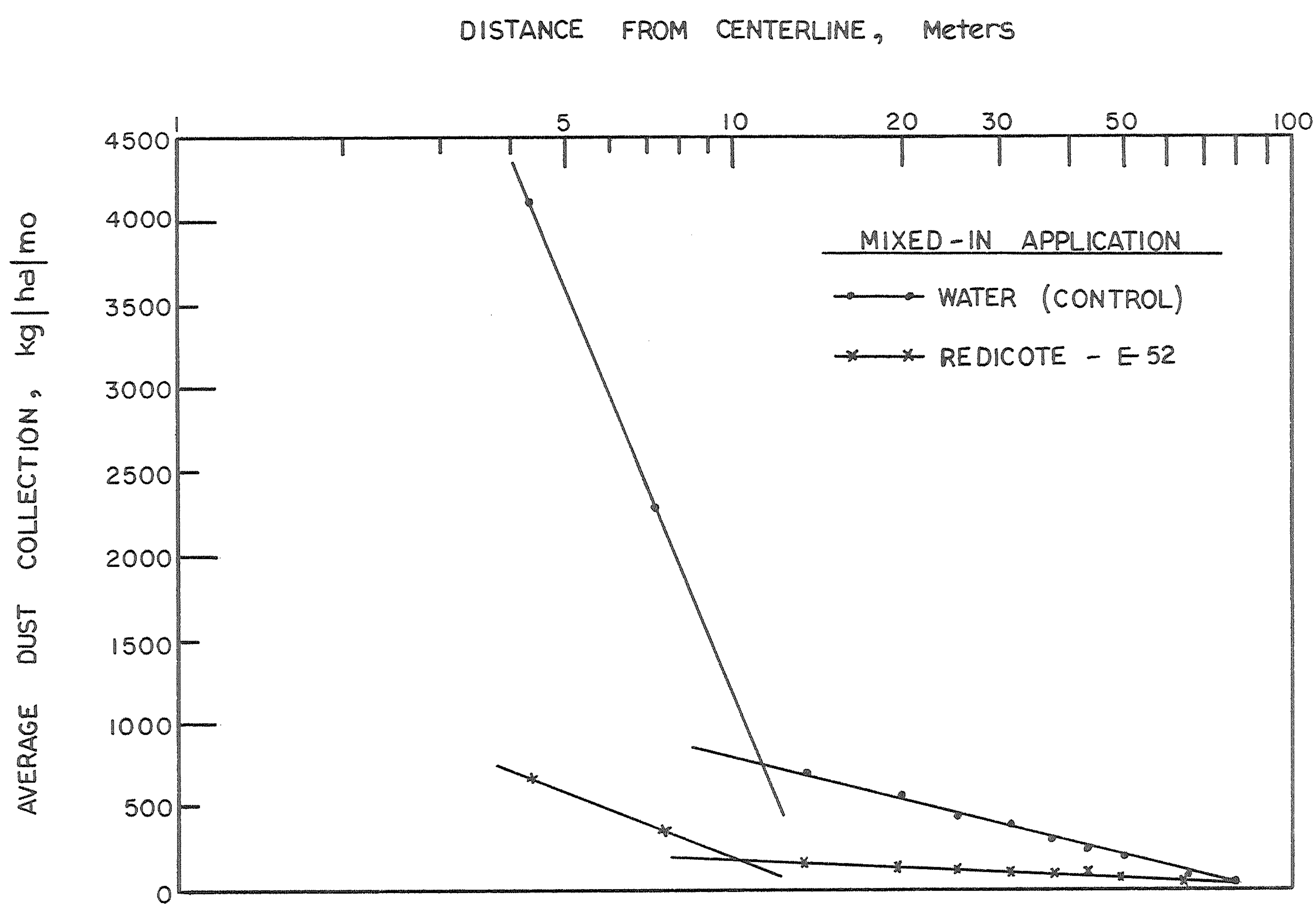


FIGURE 20. DUST COLLECTION VS. DISTANCE FROM CENTERLINE
(May 10 – May 31, 1975)

5. Table 19 presents a summary of the dust amounts due to traffic (after correcting for atmospheric dust deposition) in Kg/km/mo for the 10 test sections, during this collection period. Also given in Table 19 are the amounts of dust resulting due to traffic of one vehicle per day in Kg/km/yr; along with the degree of dust control afforded by each chemical treatment (after 3 blading operations) as compared with the control sections that were treated with water.
6. The amount of dust at the water-spray section (9038 Kg/km/mo) was about 8 percent lower than the amount at the water-mixed section (9803 Kg/km/mo); and both values are significantly higher than those calculated during the previous two collection periods.
7. Comparing the amounts of dust given in Tables 15, 17 and 19 for the three collection periods; it is apparent that a very significant increase in dust deposition, at all test sections, occurred during the third collection period after the road surface was repeatedly bladed.
8. For the spray-on application, Dust Control Oil continued to provide the best degree of dust control at 54.3% as compared with the water-spray control section. However, this degree of control was far less than those provided during the previous collection periods.
9. For the mixed-in application, the Redicote E52 asphalt emulsion also continued to provide the highest (by far) degree of dust control at 84.4% as compared with the water-control section. Figure 21 shows a close-up of the road surface at this section, 15 months after application.

TABLE 19

SUMMARY OF DUST AMOUNT AND CONTROL,
COLLECTION PERIOD MAY 10-MAY 31, 1974

	Chemical	Dust Amount Kg/Km/Month 130 v.p.d.	Dust Amount Kg/Km/Year 1.0 v.p.d.	Dust Control %
Spray-on Application	Dust Control Oil	4532	418.3	54.3
	Aerospray 70	5528	510.2	44.3
	Water (Control)	9923	915.9	0.0
	Foramine 99-194	9038	834.2	8.9
	Dust Bond 100 + F-125	8177	754.7	17.6
	Curasol AE	8986	829.4	9.4
Mixed-in Application	Dust Bond 100 + F-125	5418	500	44.7
	Redicote E52	1534	141.6	84.4
	Water (Control)	9803	904.8	0.0
	Dust Control Oil	8680	801.2	11.5

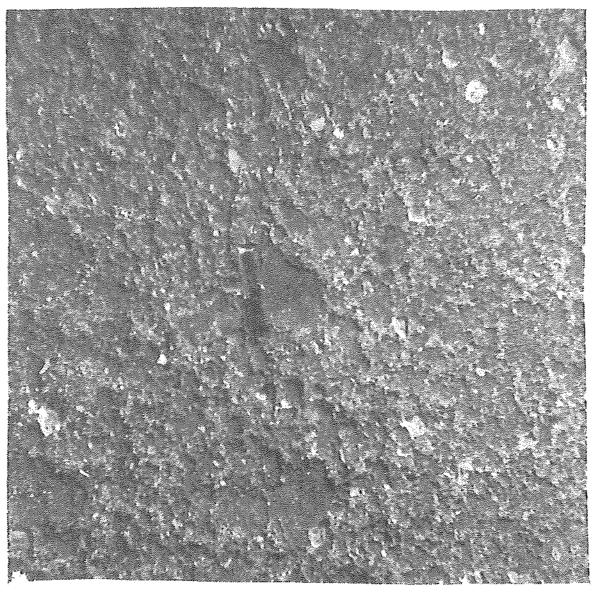


FIGURE 21 Close-up of Section Treated with Redicote E52 Asphalt Emulsion, Mixed-in Application

10. During this period of dust collection, starting almost one year after field application, the mixed-in application of Dust Bond 100 + Formula 125 proved to be better than the spray-on application of the same chemicals, even though the cost of chemical applied in both cases is identical. On the other hand, the spray-on application of Dust Control Oil proved to be better than the mixed-in application, for the same application cost.

Visual Inspection and Evaluation

The conditions of the treated test sections at the road test site were monitored in the field with time. Field observations included the condition of the road surfaces, degree of dusting behind traffic, riding quality, ruts, potholes, and surface cracking.

The results of these field observations at 5 months after application and at 14 months after applications were given in Tables 10 and 11, and Tables 12 and 13 for the spray-on applications and the mixed-in applications, respectively. These results are in general accordance with the quantitative data obtained from the Hi-Vol and the dust-fall dust collection tests.

CHAPTER 8

SUMMARY AND CONCLUSIONS

Dust Control Sites

1. Based on the field monitoring results, several chemical stabilizers that are available commercially proved to be highly successful in controlling dust due to wind effects. Degrees of dust control exceeding 88%, as compared with control sections, were achieved using chemical treatments costing between 4.3 cents and 10.9 cents per square yard (5.4 cents and 13.8 cents per square meter). These chemicals were: Terakrete #2, Surfaseal, Dust Control Oil, Aerospray 70, Norlig 41 + F-125, and Paracol 1461. These field applications are still providing such high degrees of control 15 months after they were applied.
2. The field monitoring technique, previously developed by the principal investigator, using the Hi-Vol and blower combination, appears to provide a good method for quantitatively assessing the degree of effectiveness of a chemical treatment in controlling dust.
3. The extraction test, using either benzene or water, does not provide a direct correlation between the amount of extracted residue and the potential dust control effected by the chemical.
4. Some of the chemical treatments that proved highly effective in the laboratory phase did not provide similar degrees of effectiveness in the field. However, other chemical treatments were highly effective under both conditions.

5. All chemicals used in the field did not harm the ability of the sprayed areas to support vegetation growth. Actually it was not until a weed control agent was used that vegetation growth was eliminated.
6. All the chemicals used can be applied very easily in the field using a small mobile sprayer.

Road Test Site

1. The spray-on application of several commercially available chemicals provided an excellent degree of dust behind traffic after they were subjected to 5 months of 130 v.p.d. traffic. The chemicals provided such excellent control at a cost between 21.5 cents and 47.2 cents per square yard (25.7 cents and 56.4 cents per square meter). These chemicals are: Dust Control Oil, Aerospray 70, Dust Bond 100 + F-125 and Curasol AE.
2. The mixed-in application of the chemicals used also provided excellent degrees of dust control after exposure to traffic for 5 months, at a cost of 21.5 cents to 53 cents per square yard for a 3-inch thick mat (25.7 cents to 63.4 cents per square meter for a 7.6 cm thick mat).
3. The field evaluation methods using the Hi-Vol dust collection, and the dust-fall collection (using cups), appear to provide a good estimate, numerically, for the effectiveness of the chemical treatments. The two evaluation techniques correlated reasonably well after 5 months of exposure of the treatments, with the Hi-Vol method giving a slight overestimate of the degree of control compared to the cup-collection method.

4. At the end of one year of exposure to traffic, only Dust Control Oil provided a reasonable degree of dust control behind traffic using the spray-on application.
5. The mixed-in application of the Redicote E52 asphalt emulsion continued to provide an excellent degree of dust control behind traffic along with a good wearing surface after 15 months of exposure. This treatment survived several surface blading operations without any noticeable damage.
6. Several chemicals that provided excellent resistance to simulated traffic erosive forces in the laboratory, did not survive the field exposure (e.g. Foramine 99-194). On the other hand, one chemical that did not pass the laboratory traffic simulation test provided good performance in the field (Dust Control Oil).
7. It is apparent that most of the dust-fall resulting from traffic on unpaved roads occur within the usual right-of-way of secondary roads (about 10 meters from the centerline).

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APPENDIX A

SOME DETAILS OF FIELD AND LABORATORY TEST PROCEDURES

Development of Hi-Vol Blower Dust Collection

This testing arrangement was initially developed by Sultan (1974d) based on actual field trials, and was modified for use in this project.

Inclination of Blower

With the steel support inclined at an angle of 50° with the horizontal as shown in Figure 3, the generated wind strikes the ground at an angle of 40° with the horizontal. This angle appeared to give the optimum dispersing of dust particles. Wind striking angles greater than 40° reduced the dispersing of the dust particles into the direction of the Hi-Vol; while angles flatter than 40° diminished the wind capability to stir up the dust.

Distance Between Hi-Vol and Blower

The distance between the tip of the blower and the tip of the Hi-Vol was set at 4.0 feet. Original design, Sultan (1974d),set the distance at 11.0 feet. However, using the later distance indicated still noticeable effects from small cross-winds and, therefore, the smaller distance was adopted for this project.

Time Duration of the Test

For an untreated dusty surface, the most part of the collected dust would be obtained within the first five minutes of the test. Sultan (1974d)presented the results of a test conducted for up to 60 minutes of collection time on an untreated area. Within the first five minutes approximately 83 percent of the total dust amount was collected.

Calculation of Dust Amount

The difference between the original weight of the filter paper (W_o) and its final weight after the dust collection (W_f) gives the weight of the collected dust in grams.

$$\text{Dust collection in } \mu g/m^3 = \frac{W_f - W_o}{7.075} \times 10^6$$

Extraction Test Procedure

A benzene extraction was performed on surface oil specimens collected periodically in order to determine the amount of benzene soluble organic matter present including petroleum resin.

The following steps were followed:

1. Place the specimens in the extraction Thimble and place the latter inside the distilling flask (Public Health Service 1962, p. 213).
2. One hundred and fifty milliliters of reagent-grade, thiophene-free benzene were added to each sample. For the Norlig and F-125 chemical mixture, benzene was replaced by distilled water as discussed in the report.
3. Place entire unit on a heater. Turn heater to calibration 70 and turn on the circulating cooling water.
4. The reflux process was carried out until the filtrate was reasonably clear; approximately four hours. Figure A-1 shows the extraction assembly.
5. Shut off the heater and allow the entire system to cool off.
6. Filter the flask contents through glass-fiber filter paper, into a pre-weighed beaker. Rinse the extraction flask with a small amount of chloroform and pour also in the beaker.

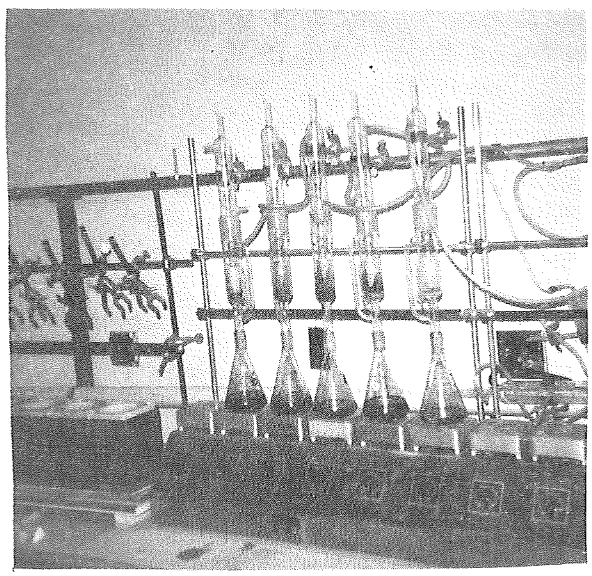

FIGURE A-1 Extraction Test Assembly

7. The benzene plus chloroform was evaporated to dryness on a hot plate.
8. Weigh beaker after cooling to nearest milligram.
9. The difference in beaker weights was considered to represent the weight of the residual organic.
10. Calculations:

$$\frac{\text{Wt. of Residue (W gms)}}{5.96 \text{ in.}^2} \times \frac{(36)^2 \text{in.}^2}{\text{yd}^2} \times \frac{1.19 \text{ yd}^2}{\text{m}^2} =$$

$$258 \text{ W gm/m}^2$$

* 5.96 in^2 = area of soil specimen (area of can)

Non-Volatile Solid Determination From Dust Collection Cups

This test was performed on the contents of the dust collection cups after being returned to the laboratory, to determine the amount of collected dust-fall during the test period.

The following steps were followed:

1. Each collection cup was opened and any insects, seeds, or other large contaminates were removed using a fine-pointed tweezer. Three drops of hydrochloric acid were added to each cup to help dissolve organic matters.
2. A box of glass-fiber filters (100 sheets, 5.5 cm. diameter) were placed in an oven (103°C) for 24 hours. After drying, the filter box was placed in a desiccator until needed for use.
3. Prior to use, the filters were removed from the box using the fine-pointed tweezer and each one was weighed to the nearest

0.0001 gm. After weighing, the filters were placed on numbered stainless steel racks (21 filters capacity).

4. As needed for each cup, one filter paper was removed from the racks and placed on the millipore filtering apparatus. Dust samples were then washed from the cups into the filters and the contents were vacuum-filtered.
5. After filtering, the filter sheets were removed from the millipore apparatus and placed back (filter residue side up) on the stainless steel racks. The filters were allowed to air-dry for a few hours after which each filter was separated from the steel rack for a few seconds. This process prevented the filters from sticking to the rack when dried at 550°C. later on.
6. The steel rack with filters was then placed in a muffle furnace for a period of 20 minutes at 550°C. temperature. The rack and filters were then removed from the furnace and cooled for a few minutes. This cooling period did not exceed five minutes or filters might pick up moisture. The filters were then weighed to nearest 0.0001 gm.
7. The difference between initial weight and final weight of each filter represented the non-volatile weight of the dust solids.
8. A correction was usually made for this difference in weight, which accounts for the moisture loss from the filters when dried at 550°C.
9. The amount of dust were reported in grams per cup and these were converted into kilograms per hectacre per month(Kg/ha/mo) according to the following conversion:

   1 gm/cup = 2301.675 Kg/ha/mo.

10. After plotting the dust distribution transverse to the road centerline (dust in Kg/ha/mo vs. log distance from centerline in meters), the area under the curve were converted into Kg/km/mo by multiplying it by $\frac{1000}{10,000} \times 2 = \frac{1}{5}$.

11. Considering the above dust amount to be generated due to traffic volume of 130 v.p.d., according to average traffic counts, the dust amount reported above in Kg/km/mo were converted to Kg/km/year due to traffic of one vehicle per day by multiplying the former value by $\frac{12}{130} = 0.0923$.

APPENDIX B

CHEMICALS DONATED BY SUPPLIERS

Chemicals Donated for Field Use

The following is a tabulation of the chemicals donated for the field testing phase of this study. Other chemicals have been donated for the laboratory phase of the project. In addition, supplementary amounts were purchased for use in the field program.

	Chemical	Amount	Donated By
a)	Redicote E52 (6)	4500 gallons	Arizona Refining Company and Armak
b)	Aerospray 72 (7)	20 gallons	American Cyanamid Co.
c)	Surfaseal (13)	10 gallons	Groutech Services, Inc.
d)	Dust Bond 100 (18)	1000 gallons	Ohm Research Products
e)	Petroset SB (20)	20 gallons	Phillips Petroleum Co.
f)	Coherex (21)	50 gallons	General Control Co.
g)	Dresinate 60W (25)	20 gallons	Hercules Incorporated
h)	Paracol 1461 (26)	20 gallons	Hercules Incorporated
i)	Terrakrete #2 (27)	20 gallons	Terrakrete
j)	Dust Control Oil (37)	2150 gallons	Standard Oil Company
k)	Dust Stop (38)	10 gallons	Standard Brand Chemicals
l)	Foramine 99-194 (41)	10 gallons	Reichhold Chemicals, Inc.
m)	Norlig 41 (46)	55 gallons	Pima County Highway Dept.

APPENDIX C

SUMMARY STATEMENT ON RESEARCH IMPLEMENTATION

SUMMARY STATEMENT ON RESEARCH IMPLEMENTATION

Based on the results of this laboratory and field investigation in using chemical stabilizers for dust and erosion control, the following statement points out the practical applications of these findings and some recommended future work.

Practical Applications of Research Findings

1. It is recommended that a spray-on application be utilized to control dust stirred-up by wind action along the windward sides of problem areas along the Arizona highway system. The field study indicated that chemical treatments costing between 4.3 cents and 10.9 cents per square yard (5.4 cents and 13.8 cents per square meter) were quite successful in suppressing dust on vacant, untrafficable areas for periods in excess of 16 months (end of project). The dust generating areas along Interstate 10 between Eloy and Toltec should be considered an early target for this type of application. Several major chain accidents have occurred there and a spray-on application at the problem areas should be considered a must prior to the windy summer season.
2. Similar spray-on applications should be considered on embankment slopes where wind and rain erosion have caused deep erosion gullies. This erosion problem can endanger the safety of bridges and their abutments, road and railroad embankments

and drainage canals and culverts. In addition, it creates unsightly scenery, destroying the natural beauty of the landscape. Recently, some mud flows occurred after heavy rainfall due to the instability of such eroded slopes.

3. The problem of potential erodibility of unprotected shoulders can be alleviated by chemical spray-on or mixed-in treatment of the subgrade material. Such treatments would result in reduction of maintenance costs, proper surface drainage of roadway, less dusty shoulders, and more stable-safe lay-by areas.
4. The problems of the dust generated behind traffic on unpaved secondary roads can be significantly reduced based on the results of this study. The use of a 3-inch mat of compacted subgrade mixed with a Redicote E52 cationic asphalt emulsion provided an excellent wearing surface and eliminated the dust problem at South Wilmot Road for 15 months (at the end of the project). It is anticipated that this treatment, at 53 cents per square yard (63.4 cents per square meter), can provide similar protection for about 3 years.

Recommendations for Further Research

1. It is recommended that periodic monitoring of the field applications for dust control at the ADOT Yard site be made for a period of 2 more years. Bi-monthly monitoring would be sufficient including Hi-Vol and extraction tests.
2. It is recommended that a concentrated effort be made to point out the best chemical stabilizers capable of protecting compacted subgrades and embankments against rain erosive force.

This project, even though it was not required, evaluated the rain-erosion protection of the chemicals as a durability measure. However, the type of tests made did not provide an evaluation of the run-off sheet erosion effects due to the geometry and size of the specimens used. Therefore, a testing program to identify positive chemical treatments for rain erosion control of compacted soil would provide solutions for the protection of unpaved shoulders, road and railroad embankments, drainage canals, and culverts. The recommended research project should utilize a limited number of chemicals based on our current knowledge (10 maximum), however, a wide variety of soil types should be tested ranging from dune sands to heavy and swelling clays. Both spray-on and mixed-in treatments should be investigated. A field application of the successful treatments should also be made and monitored for at least one year.