Rainfall Simulation on Disturbed Lands Treated with Dust Suppressants : Hydrologic Impacts

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Abstract
Disturbed land surfaces are a major source of fine particulate matter in the air. Dust suppressants are applied to these surfaces to minimize the suspension of the particulate matter. The application of dust suppressants affects the runoff characteristics of these lands as well as the water quality of the runoff. A rainfall simulator has been designed to create rainfall, and to study the hydrological impacts. Results of the study indicate that different dust suppressants have different magnitudes of hydrologic impacts.

1. Introduction

This research project focuses on the application of dust suppressants and palliatives to disturbed lands in Southern Nevada. The U.S. Environmental Protection Agency (EPA) has established air quality standards for fine particulate matter (PM-10) which are generated from unpaved roads and parking lots, vacant lots that have been graded, and construction sites. To minimize the generation of dust from these surfaces, EPA has recommended the use of dust suppressants and soil stabilizers. However, the potential environmental impacts of the use of dust suppressants have not been widely performed (e.g., RTAC, 1987; Addo and Sanders, 1995; Bolander and Yamada, 1999). In this study, both the hydrological and water quality impacts are studied using a rainfall simulator on plots where dust suppressants have been applied. Southern Nevada experiences low rainfall amounts, so it was necessary to design and build a low intensity rainfall simulator.

There are a large number of dust suppressants with different compositions available from private industry. This study focuses on the main categories of dust suppressants: Water Absorbing (e.g., Magnesium Chloride, Calcium Chloride); Organic Petroleum (e.g., asphalt emulsion); Organic Non-Petroleum (e.g., ligninsulfunate, vegetable oils); Acrylic Polymers (e.g., Soil Sement); and Fiber Mulches. Table 1 lists the different dust suppressants used in this study.

The overall goal of this research is to provide a scientific basis for evaluating the water quality impacts of the major categories of dust suppressants. Over a period of 12 months, experiments were performed on plots treated with dust suppressants. Simulated rainfall was applied to the plots and runoff was collected and analyzed for water quality impacts. The results of the chemical study are ongoing and presented in a complimentary paper. The results will provide guidance for proposed regulations on the application of dust suppressants to disturbed lands.

Table 1: List of dust suppressants used in study.

Trade Name	Manufacturer	Type
Poly Bond	Soil Tech	Acrylic Polymer
Soil Sement	Midwest Industrial Supply	Acrylic Polymer
Enviro Tac	Environmental Product & Applications Inc.	Acrylic Polymer
EK35	Midwest Industrial Supply	Acrylic Polymer
Plas Bond	Soil Solutions	Fiber Mulches
Dust Gard	Dustchem	Water Absorbing
Road Pro	Midwest Industrial Supply	Petroleum-based
Coherex	Golden Bear Oil	Petroleum-based
Road Oyl	Soil Stabilization Products	Organic Non-petroleum
Dustac	Georgia Pacific	Liginsulfonate
Topein	Topein Emulsions	Liginsulfonate

2. Rainfall Simulation System

In the past, rainfall simulators have been designed for high intensity events (> 25 mm/hr); however, there is a lack of studies on the simulation of low rainfall intensities. This research presents a system capable of performing rainfall simulations over large areas with intensities as low as 15.5 mm/hr (0.65in/hr) and a coefficient of variation greater than 0.80. A runoff collection system was designed to collect the runoff occurring from plots treated with dust suppressants.

2.1. Description Of The System

The system consists of three towers that form a triangle. The simulation area is inside the triangles to ensure adequate coverage and minimization of wind effects. Each tower consists of three aluminum legs that are approximately 2.4 meters high and support a 1/4 GG - SS 10 nozzle, manufactured by Spraying Systems Corporation, Inc. A pressure gauge is incorporated in each tower to monitor the flow. A domestic water supply is treated in a Reserve Osmosis (RO) and stored in a reservoir. During the experiments, the water is pumped from the reservoir through a main hose and distributed to each rainfall tower. A flow control valve and pressure gauge are used prior to the distribution to the individual towers. A layout of the rainfall simulator is shown in Figure 1.

This configuration is capable of simulating a wide range of rainfall intensities over small and large areas. The rainfall intensity can be as low as 15.5 mm/hr. Two additional towers are used at the far end to counter any wind effects. Desired intensities can be achieved with the two additional towers in place for wind speeds of up to 10 km/hr. A schematic of an individual tower is shown in Figure 2.

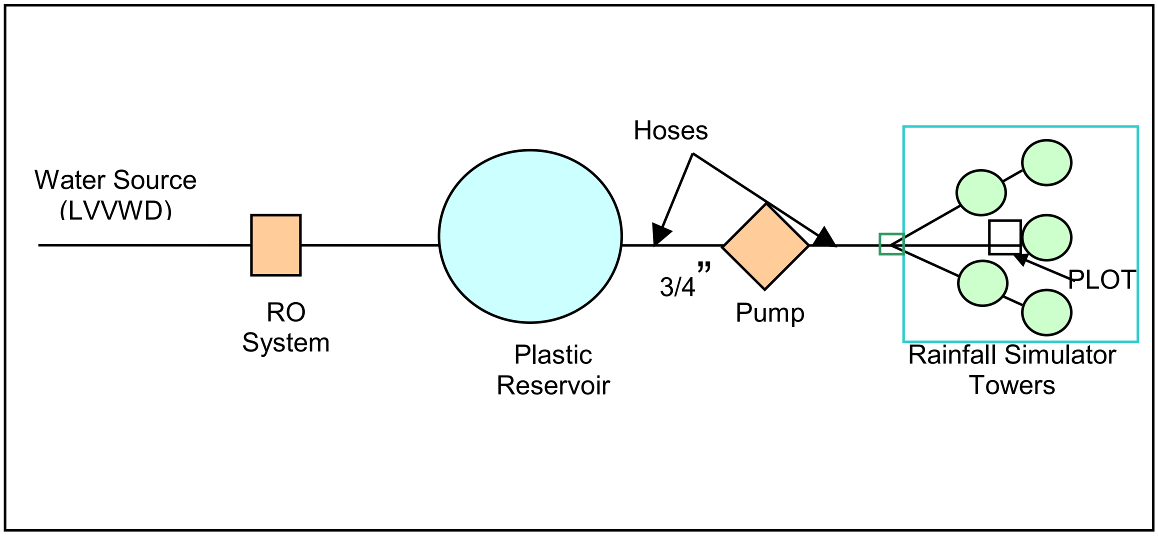

Figure 1: Layout of the rainfall simulator system

The RO system is necessary to remove any hardness in the water that may lead to clogging of the nozzles. Any damage to the nozzle may lead to a non-uniform distribution of rainfall over the virtual triangle. The RO system also removes any chemicals in the domestic water supply. Thus, the water used in the experiments is free from any contaminants. The clean water is essential for isolating the contamination levels caused by the runoff from the plot where dust suppressants have been applied. Any impurities mixed in the rainfall would have lead to distorted figures of contamination from the plots.

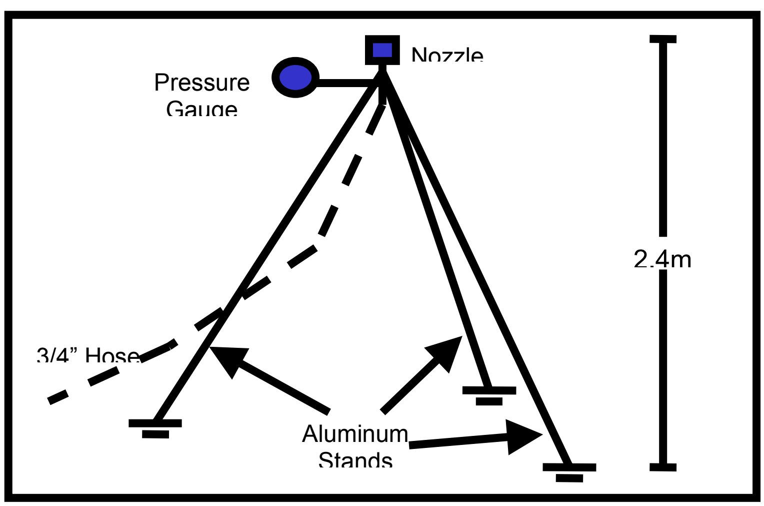

Figure 2: Schematic diagram of the rainfall simulation tower.

2.2. Intensity, Pressure And Distance

Varying the pressure in the hoses as well as varying the distance between the towers achieves various rainfall intensities. A distance of 3 or 4 meters was selected based on tests with varying distances between the towers. The intensities in the virtual triangle were most uniform at these distances. The results for a 4 meter distance between the towers are shown in Figure 3.

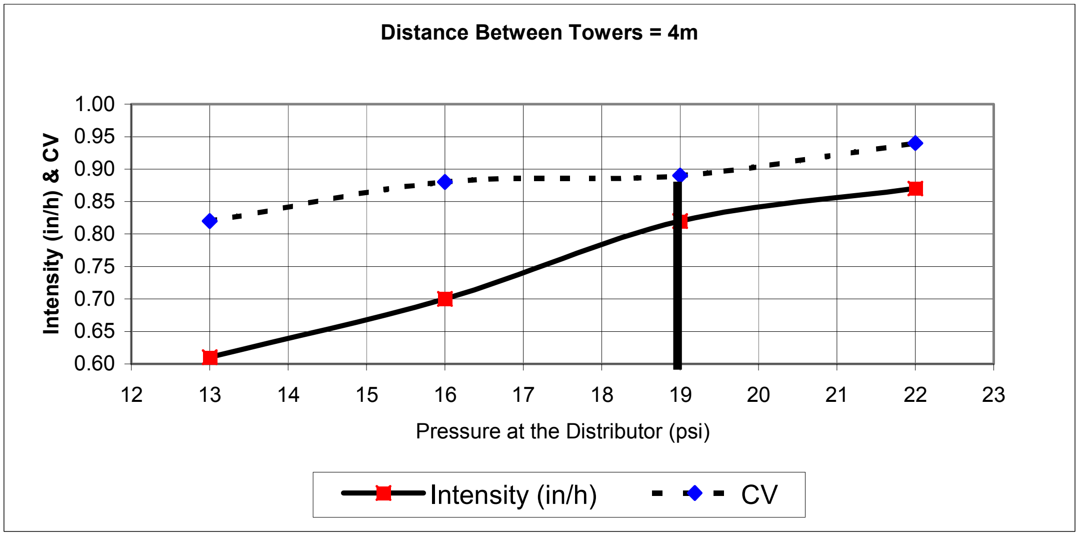

Figure 3: Intensity, Pressure and Coefficient of variation at 4 meters.

The rainfall simulation was applied to a plot area of approximately 2 meters (6 ft) x 2 meters (6 ft). A pressure of 19 psi and a distance of 4 meters between the towers results in a 5 yr 1 hr storm for the Las Vegas area — a rainfall intensity of 23 mm/hr (0.89 in/hr). The area of study is located within the virtual triangle created by the towers. The coefficient of variation, reflecting the spatial distribution of rainfall in the study area, is greater than 0.80. The field use of the rainfall simulation system is shown in Figure 4.

Figure 4: Field application of the rainfall simulation system.

2.3. Runoff Collection System

The runoff generated during the rainfall simulation is collected to test the water quality as well as the hydrologic impacts. A collection system was designed and constructed with a 1½” semicircular PVC pipe that reduces to a 1” diameter at the outlet. The runoff generated from the plot flows over a plastic sheet that conveys the runoff to the PVC pipe. The runoff then flows through the pipe and a reducer at the outlet discharges into a collection bottle. The discharge unit is designed so in case of blockage in the main discharge, due to accumulation of soil, an alternative discharge can be opened.

3. Hydrologic Impacts

The application of the dust suppressants impacts the hydrologic characteristics of the land surface that it is applied to. This includes changes in infiltration properties, runoff coefficients, runoff rates, and runoff timing. In this study, the changes in the runoff coefficient and runoff rates were determined.

3.1. Runoff Coefficients

Rainfall simulation was performed on all plots and the rainfall intensities were measured at nine points within each plot. The average rainfall intensity was calculated based on the nine measurements. Volumetric runoff was measured and the runoff coefficients were calculated using the relationship of rainfall/runoff. The large variation in the runoff coefficients is due mainly to the different properties of the dust suppressants. For instance, the petroleum-based products (Plots 1B and 11C) tend to produce an impermeable surface and a higher runoff coefficient as shown in Table 2. The experiments were designed to have surfaces that had similar properties; however, there may be some minor variations in the plots characteristics that could impact the runoff coefficients. The runoff coefficients for different dust suppressants are show in Table 2.

Table 2: Runoff coefficients for the different dust suppressants

DUST SUPPRESSANT	PLOT No.	Rainfall Depth (cm)	RAINFALL (ml)	FLOW (ml)	Runoff coefficient
ROAD PRO	1B	1.58	76123	23200	0.30
ROAD OYL	2B	1.99	91746	13050	0.14
ENVIRO TAC	3B	1.84	85270	44000	0.51
TOPEIN	4A	2.41	110323	11650	0.11
DUSTAC	5A	1.91	99330	26540	0.27
SOIL SEMENT	7A	2.05	96045	23200	0.24
EK – 35	8A	1.70	91379	30100	0.33
PLAS BOND	9A	3.76	160670	18250	0.11
POLY BOND	10A	1.67	74451	2700	0.04
COHEREX	11C	1.84	111546	46200	0.41

Runoff coefficients are well documented for different land surfaces. These coefficients are used for design purposes by engineers. Typical runoff coefficients for undeveloped desert areas are on the order of 0.20 – 0.25 (McCuen, 1998; DRCOG, 1969). The results in Table 2 indicate that the dust suppressants both increase and decrease the runoff coefficients. The results for the control plot (with no dust suppressant) are not yet available. Thus, further comparisons to the existing runoff coefficient for this land surface cannot be made at this time.

3.2. Magnitude and Timing of Runoff

The magnitude and timing of runoff from the individual plots was highly variable. Figure 5 compares the cumulative volume of runoff versus time for the different categories of dust suppressants (Table 1). For all plots, the rate of runoff increased with time; however, the initiation of runoff was much different for each plot. For example, the plot treated with the acrylic polymer (Enviro Tac, Figure 5b) had runoff starting at approximately 13 minutes after the start of the rainfall. In contrast, the plot treated with the Fiber Mulch (Plas Bond, Figure 5e) did not initiate runoff until 80 minutes after the start of rainfall. This plot also had the lowest runoff volume and the simulation lasted for two hours to get the minimum volume of runoff required (≈ 10 liters) for water quality tests.

There is a large variation in hydrologic impacts on surfaces treated with acrylic polymers. Comparing two acrylic polymers in Figures 5b and 5d, the volume of runoff in Figure 5b was nearly double that in Figure 5d. The acrylic polymers can change the hydrologic properties of a surface similar to that of a plot treated with a petroleum-based dust suppressant (See Figures 5b and 5f).

4. Conclusion

The preliminary results of dust suppressants applied to a disturbed land surface indicate changes in hydrologic properties. Water quality tests are ongoing and will be incorporated with these results to provide guidance on the use of dust suppressants. Noteworthy observations of hydrologic changes are:

- The runoff coefficients from plots treated with dust suppressants are highly variable and depends on the type of dust suppressant.
- All plots had similar physical characteristics (e.g., soil type, slope), thus the runoff generated was independent of the inherent plot characteristics.
- The runoff volume, timing of initial runoff, and rate of runoff varied for most plots.
- One acrylic polymer created a surface similar to that created by a petroleum-based product.
- Additional studies are planned to verify these preliminary results and to investigate the changes of surface properties of the plots over time.

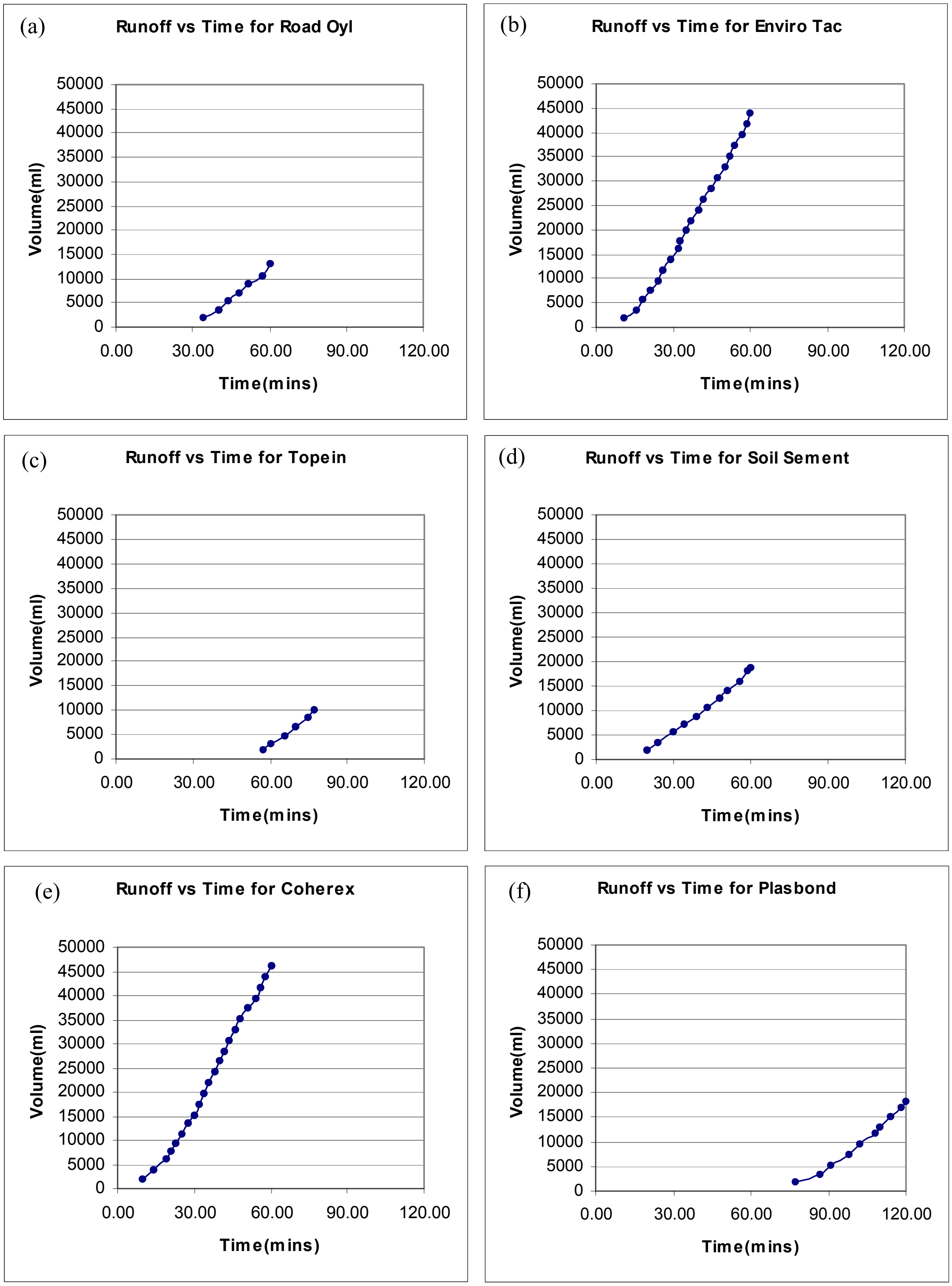

Figure 5: Cumulative runoff volume (ml) versus time for (a) Road Oyl, (b) Enviro Tac, (c) Topein, (d) Soil Sement, (e) Plas Bond, (f) Coherex.

5. Acknowledgements

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