

Development of Vacant Land Emission PM-10 factors in the Las Vegas Valley

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ABSTRACT

A portable open-floored wind tunnel and TSI Dust-Trak® PM-10 monitor were used to develop PM-10 emission factors from three categories of vacant lands in the Las Vegas Valley.

1. Stable native desert, undisturbed by human activity
2. Unstable or potentially unstable lands, disturbed by human activity
3. Stabilized lands, previously disturbed by human activity and then treated with commercial dust suppressants

Emission factors for stable and unstable vacant lands were developed from a 78-site field study conducted in the Las Vegas Valley in the summer of 1995. Emission factors for stabilized lands were developed from a year-long intensive study of the performance of nine different commercially available dust suppressants applied to a very dusty site on the eastern side of the Las Vegas Valley that was conducted from August 1, 1998 to July 31, 1999.

PM-10 emission factors in units of English tons PM-10/acre/hour were developed from wind tunnel runs. TSI readings were taken every second, and integrated to determine average values over the duration of the run. Initial “spikes” in observed PM-10 occurring in the first ½ to 2 minutes of each run were separated from the rest of the data and computed separately. Approximate geometric mean spike-corrected values were, for stabilized lands, 2×10^{-4} ton/acre/hour, stable lands 2×10^{-3} ton/acre/hour, and unstable lands 5×10^{-3} ton/acre/hour. There was significant scatter in observed data, with within-category variability ranging over 1-2 orders of magnitude.

INTRODUCTION

The metropolitan area of Clark County, Nevada, has been in non-attainment for PM-10 for most of the last decade. As part of preparations for submission of a new State Implementation Plan (SIP) for PM-10, the Clark County Health District and Clark County Department of Comprehensive Planning hired the University of Nevada, Las Vegas to develop local emission factors for windblown dust from vacant land surfaces. In 1995, UNLV constructed and operated a portable wind tunnel to evaluate PM-10 emissions from vacant lands within the metropolitan area. In 1998-1999, UNLV undertook a year-long study of the performance of nine commercially available dust suppressants. As part of this study, PM-10 emissions were measured from the treated surfaces. In 1999-2000, UNLV was requested to compile its emissions factor data from the 1995 and 1998-1999 studies and develop a comprehensive set of PM-10 emissions factors for unstable, stable and stabilized lands that could be used in design year, and design day estimates of valley-wide PM-10 emissions. This paper summarizes the experimental methods and

data processing that generated the emission factors, and presents the emissions factors in graphical format.

METHODS

Site Selection and Classification

Wind tunnel sites for the 1995 study were selected to provide uniform coverage in the urban core of Las Vegas. In the 1995 study, major cross streets and compass direction relative to the nearest intersection (i.e. North-east corner of Mountain Vista and Gold Dust) were recorded, and uncorrected global positioning system (GPS) coordinates were determined by a Magellan hand-held Global Positioning System unit, generally accurate to +/- 2 seconds of latitude and longitude (+/- 3 hundredths of a minute, approximately +/- 50 meters). When near the intersections of major north-south and east-west streets, the compass location relative to the intersection (example, north-east corner of Sahara and Walnut for WT006) was usually recorded. To determine major soil group, site GPS coordinates were manually mapped onto an enlarged version of the major soil group map from the 1985 Speck and McKay US Agricultural Research Service soil survey.

Photographs of the site were taken, including an area photograph (nearest landmarks) and a close-up of the soil surface under the working section of the tunnel. Two digit numeric site codes were assigned to each tested location. A total of 85 sites were tested in a three-month period from May 31, 1995 until September 1, 1995. In 1995, site stability was determined by presence or absence of intact crust, by proportion of vegetation present (using an average from two 50-foot transects, counting vegetation every foot), and by evidence of human disturbance (tire tracks, trash, litter, evidence of recent earthmoving). Since the 1995 study was completed, new procedures for determination of stability of vacant lands have been proposed and adopted by ordinances or rules in Maricopa County, Arizona and by Clark County, Nevada. In late 1999, Clark County requested that the stability of the 1995 wind tunnel sites be re-evaluated using 1995 close up (generally from a distance of 2 feet) site photographs (most of which showed sheltering elements, rocks and cobbles) and the proposed Maricopa/Clark County rules. The 1995 site photos were evaluated by the 1999 UNLV field crew (which had been performing field stability classifications under the proposed Maricopa County rules) as to whether or not they would pass ball drop and threshold friction velocity (TFV) tests. The result of this re-estimation using the Maricopa/Clark County rules converted three 1995 "unstable" site designations to "stable," at Wind tunnel sites, WT058, WT059 and WT060. All other 1995 site stability designations were unchanged.

The 1998-1999 dust suppressant study was conducted in the long-abandoned sludge beds at the City of Las Vegas Water Pollution Control Facility, located on the eastern side of the Las Vegas Valley. Three sludge beds were used for the application of nine different commercially available dust suppressants. Sludge bed surfaces were scoured with a road grader to remove vegetation and break up the surface crust. The crust reformed after a rainfall event, and was broken up again by the tires of a 1-ton Ford pickup truck immediately prior to application of the dust suppressants. Suppressants were applied on adjacent 50 foot x 150 foot sections at rates recommended by vendors for stabilization of untrafficked vacant lands. Baseline PM-10 emissions were measured immediately prior to application of dust suppressants, measured again after application of suppressants, and measured at approximately monthly intervals after application for a period of 4-5 months.

Description of Wind Tunnel

The UNLV-CCHD wind tunnel used in the 1995 field study and the 1998-99 dust suppressant study is a modification of the draw-through design developed by Duane Ono at Great Basin Unified Air

Pollution Control District, Bishop, California. Modifications in the UNLV tunnel include a 6 inch diameter working section instead of 4 inch section, addition of a TSI Dust-Trak^(r) PM-10 monitor in the riser section, use of heavy gauge plastic flaps and soil or draft tubes to seal the tunnel to the surface instead of sharp metal runners, and use of a rear air bypass to control averaging flow instead of a venturi and an electronic motor speed controller. Major components of the tunnel are shown schematically in Figure 1. Wind tunnel processes are diagrammed in Figure 2.

The working section of the tunnel is 6.00 inches wide x 6.00 inches high x 60 inches long. Additionally, not shown in the figure, there is a 60-inch long flow-conditioning section installed ahead of the working section of tunnel with a honeycomb flow diffuser at the front end, giving incoming air 10 diameters to develop a turbulent profile before it passes into the tunnel working section.

The working section is sealed to the soil surface with 3-inch wide heavy gauge flexible PVC flaps. In 1995, the flaps were sealed to the surface with soil and rock excavated from the site being tested. In 1998-1999, to allow measurement of much lower fluxes on stabilized surfaces treated with dust suppressants, the flaps were sealed to the surface with closed cell foam and 2-inch diameter 6 foot long cloth draft tubes filled with sand.

A Dwyer 90-degree pitot tube (labeled “profiling pitot tube” in Figure 1) is located in the working section, attached to a height adjusting system that allows the tube to be set at a logarithmic series of elevations above the soil surface. The pitot tube is connected in parallel to two Magnehelic(r) pressure gauges, one reading from 0.00 to 0.20 inches of water, and the other reading from 0.00 to 1.00 inches of water.

As air passes through the working section of the tunnel, it entrains particulates from the soil surface (Figure 2), and the particulates are conveyed in the air flow through the working section to the divergence section. The expansion section contains a front bypass air inlet, located on the top of the section. The size of the front bypass opening is controlled by a sliding damper. The purpose of this front bypass air inlet is to control the volumetric flow rate of air in the working section, and thus control the erosion velocity. Air flow rate in the working section is lowest when the damper is wide open, and highest when the damper is closed. In field work the damper is adjusted to give a specified centerline pitot tube reading for a particular erosion run.

The expansion section is connected to a rectangular metallic box called the elutriation chamber (Figure 1). As air flow enters the elutriation chamber and slows down, the chamber captures particles with diameters greater than 70 microns physical diameter (Figure 2). A door at the back of the elutriation chamber allows it to be cleaned after each wind tunnel run.

Air flow leaves the elutriation chamber through a 6-inch diameter PVC pipe section, called the riser (Figure 1). Air velocity in the riser is generally sufficient to suspend soil particles with physical diameters less than 70 microns (Figure 2). As air proceeds up the riser, a small sample is pulled off by the TSI Dust-Trak PM-10 monitor. The Dust-Trak(r) measures PM-10 concentrations in the range 0.000 to 19.99 mg/m³. The instrument uses attenuation of a laser diode light beam to estimate PM-10 concentration. Air is drawn into the unit at a fixed rate of 1.70 liters per minute by a positive displacement pump, and passes through a built-in cyclonic separator (50% aerodynamic cut size, 10 microns) before proceeding into a chamber where the suspended particle stream breaks the light beam. The units are factory calibrated against a standard dust suspension. The manufacturer (TSI) recommends annual servicing and recalibration. UNLV’s first unit (Unit A) was acquired in the Spring of 1995, and was used during the summer 1995 study with its original factory calibration. Prior to the start of the

1998-1999 wind tunnel study, Unit A was shipped to the factory for calibration. A second TSI Dust-Trak^(r), Unit B, acquired in 1999, was employed at the end of the 1998-1999 study, when Unit A was returned to the factory for calibration.

After passing the TSI sampling port, particle-laden air in the riser makes a 90-degree turn and passes by the sampling orifice of the cyclone, filter, venturi and fan system (Figure 1). The venturi, fan motor and filter housing, from a standard General Metal Works PM-10 atmospheric sampler, is equipped with a venturi orifice designed to choke air flow through sonic velocity, and thus make air flow independent of temperature and pressure. Design flow rate is 40 cubic feet per minute. The cyclone was built by UNLV to have a 50% physical cut size of 6.5 microns for approximately spherical particulates of density approximately 2.5 grams/cm³. This physical diameter corresponds to an aerodynamic diameter of 10 microns for particles of density 1.0 gram/cm³ for particles settling in Stokesian flow. After passing through the cyclone, air is drawn through a glass fiber filter for particle trapping before exhaust to the atmosphere (Figure 2).

After passing the cyclone orifice, the remaining flow proceeds through a reducing coupling into a 4-inch diameter flexible tube, and then enters the velocity box (Figure 1). The velocity box is a 6-foot long 4-inch diameter PVC pipe that is used for measurement of the total volumetric flow rate in the wind tunnel. A Dwyer averaging pitot tube is located 40 inches (10 diameters) downstream of the entrance to the velocity box. Pressure drop across this pitot tube is measured by a Dwyer solid-state pressure logger with a range of 0.00-9.99 inches of water, a resolution of 0.01 inches of water, and an accuracy of 2%.

After passing the averaging pitot tube, flow enters the rear-bypass air inlet (Figures 1 and 2). The rear by-pass air inlet is adjusted to give a specified pressure drop in the averaging pitot tube, so that the flow sampling at the TSI and the cyclone is nearly isokinetic. Typical pressure drop values were usually in the range of 3.00-3.30 inches of water. After leaving the rear bypass, air is drawn into the fan section and exhausted from the system (Figures 1 and 2). The Dayton 10 5/8" diameter fan is powered by a 1 horsepower Dayton electric motor, turning approximately 3000 rpm. At field sites, the electric motor is powered by a 5 horsepower portable AC generator.

Operation of Wind Tunnel

1995 Field Study methods

The wind tunnel was transported disassembled in the back of a medium size (Dodge Dakota) pick-up truck, and assembled at each site. A flat area at least 15 feet long x 5 feet wide was needed for assembly of four rigidly-connected units, the tunnel flow conditioning section, tunnel working section, elutriation chamber, and support stand for the cyclone-filter combination. Other components, attached with flexible PVC, could be arranged in a variety of locations behind the rigidly connected units. Soil was excavated from locations outside of the tunnel working section with hand trowels and shovels and deposited in a 2-3 inch thick layer on the flexible plastic flaps to form a seal to the surface.

After assembly, the ambient barometric pressure, atmospheric temperature and relative humidity were recorded, and the pressure gauges were zeroed. The rear bypass air inlet was set to measure a pressure drop of 3.20 inches of water to give a riser section flow velocity that was nearly isokinetic with the flow velocities of the cyclone and TSI Dust-Trak^(r) sampling ports.

The TSI Dust-Trak^(r) was turned on and set to measure instantaneous PM-10 concentration, with no logging of data to memory. The tunnel fans were turned on and the damper on the front bypass air inlet was closed until a "spike" of PM-10 exceeding 1 mg/m³ was observed on the TSI display. Damper position was fixed at this point, and the velocity profile over the soil surface was determined by the

profiling pitot tube. The tunnel fans were then turned off and the front bypass air inlet was opened all the way.

Barometric pressure, air temperature, and profiling pitot pressure drop data were entered into a Quick-BASIC^(r) computer program on a laptop computer to determine the aerodynamic roughness and a corresponding set of pitot tube centerline pressure drops that would correspond to a range of three or four 10-meter erosion velocities.

For the first wind tunnel run, the TSI Dust-Trak(r) was then set to datalogging mode, the tunnel fans were turned on, and the bypass damper was closed until the indicated pressure drop from the pitot tube reached the first designated 10-meter erosion velocity. At this point, the Dust-Trak was set to begin recording one PM-10 concentration each second for 10 minutes.

The TSI display would blank at the end of the 10-minute period, and the tunnel fans were turned off. Dust captured in the elutriation chamber and cyclone was brushed into new, preweighed zip-lock plastic bags, and the glass fiber filter was changed. The tunnel was reassembled, and the sampling repeated in exactly the same location, at a higher indicated wind speed. In the 1995 study, for the first 49 wind tunnel sites (WT001 through WT049), the goal was to conduct three sampling runs per location at progressively higher wind-speeds. For sites WT050 through WT078, this was changed to four runs per location at the request of Clark County Health District.

Samples collected in the elutriation chamber were brushed into clean, plastic bags at the end of each run and returned to the laboratory for weighing. Weight changes were determined in a Sargent-Welch electronic analytical balance with resolution of +/- 0.1 milligram (mg). These data are available, and were reported in the UNLV M.S. thesis by Joe Alvin Haun, but are not reported in this paper.

Samples collected in the cyclone were brushed into clean, plastic bags at the end of each run and returned to the laboratory for weighing. Weight changes were determined in a Sargent-Welch electronic analytical balance with resolution of +/- 0.1 milligram (mg). These data are available, and were reported in the UNLV M.S. thesis by Joe Alvin Haun, but are not reported in this paper.

Glass fiber filters were pre-conditioned in a constant relative humidity chamber, weighed, sealed flat in large plastic ziplock bags, handled with latex gloves when installed and removed from the PM-10 filter mount in the field. After sampling, they were returned to the lab and reconditioned to the same relative humidity and temperature, and then reweighed. Filter weights were determined to +/- 0.1 milligram in a Sargent-Welch electronic balance. Experience in both the 1995 and 1998-99 wind tunnel studies showed that, unless an unusually high PM-10 concentration was eroded from the soil surface, 10 minute wind tunnel sampling runs were of insufficient duration to obtain a detectable weight change on the glass fiber filters. For this reason, TSI Dust-Trak PM-10 data are the only values reported in this paper. PM-10 filter data are available, and were reported in the UNLV M.S. thesis by Joe Alvin Haun.

Computation of Emission Factors

PM-10 mass balances and air flow balances from Figure 2 were used to develop an equation that estimates PM-10 flux rate from the soil surface in terms of known or measured quantities. The term "mdot" in Figure 2 refers to a time rate of change of mass.

The key relationship that derived from the mass balance is:

$$\text{Equation (1) } \text{flux}_{\text{soil}} = [(Q_{\text{avg}} + Q_{\text{cyc}}) \times (C_{\text{rise}} - C_{\text{bak}})] / [\text{Floor area}]$$

where:

fluxsoil = mass rate per unit area of PM-10 eroded from the soil surface in units of mass/area/time, generally milligrams per square meter per minute and tons per acre per hour.
Qavg = flow rate measured by the averaging pitot tube in the velocity box
Qcyc = known flow rate passing through the venturi in the cyclone-filter set
Crise = PM-10 concentration measured by the TSI Dust-Trak^(r) in the tunnel riser
Cbak = PM-10 atmospheric background concentration, typically assumed to be 20 or 30 $\mu\text{g}/\text{m}^3$ (0.020 or 0.030 mg/m^3)

Floor area = exposed area under the working section of the tunnel, 2.500 ft^2

Measured, known or assumed quantities from each wind tunnel run are substituted into Equation 1 to compute the wind tunnel flux. For example, using data from WT002, run 1, with an average PM-10 concentration of 0.157 mg/m^3 , and a flow rate of 431.1 ft^3/min , the calculated result is:

$$\text{PM-10 flux} = [(0.157 \text{ mg}/\text{m}^3) - (0.030 \text{ mg}/\text{m}^3)] \times [(431.1 \text{ ft}^3/\text{min}) + (40 \text{ ft}^3/\text{min})] / (2.500 \text{ ft}^2) = 23.93 \text{ (mg-ft)}/ (\text{m}^3\text{-min}) \times (0.305 \text{ meter/foot}) = \underline{7.30 \text{ mg} / (\text{m}^2\text{-min})}.$$

Fluxes were converted from $\text{mg}/\text{m}^2/\text{min}$ to ton/acre/hour. The conversion factor from $\text{mg}/\text{m}^2/\text{min}$ to ton/acre/hour is $2.206 \times 10^{-6} \text{ lb}/\text{mg} \times 0.0005 \text{ ton}/\text{lb} \times 4047 \text{ m}^2/\text{acre} \times 60 \text{ min}/\text{hour} = 2.68 \times 10^{-4} \text{ (ton/acre/hr)}/ (\text{mg}/\text{m}^2/\text{min})$. For WT002, run 1, the flux then converts to:
 $7.30 \text{ (mg} / \text{m}^2/\text{min}) \times 2.68 \times 10^{-4} \text{ (ton/acre/hr)}/ (\text{mg}/\text{m}^2/\text{min}) = \underline{1.95 \times 10^{-3} \text{ ton/acre/hour}}$.

Spike processing

Figure 3 shows a typical TSI Dust-Trak^(r) data file for a wind-tunnel run. Most stable and unstable sites exhibited an initial “spike” in PM-10 concentration in the first one to two minutes of tunnel operation. We attributed this spike to a reservoir of loose PM-10 on the soil surface that was rapidly entrained by the wind and swept away. Afterward, lower PM-10 emissions rates occur as a result of steady-state erosion, brought on by impacts of saltating and suspended particles on the soil surface. When converting 10-minute runs to results for 1 hour, retaining the spike in the record would produce a disproportionately high estimate of flux in ton/acre/hour. TSI Dust-Track traces were processed using programs to estimate the proportion of signal attributable to the spike, and remove the spikes from the data. The remaining signal was used to estimate steady spike-corrected PM-10 emissions in ton/acre. The spike data were processed separately to estimate spike masses in ton/acre. Spike masses in mg/ft^2 were computed by multiplying total PM-10 mass for each run (in milligrams) by the proportion of the signal due to the spike, and dividing by the tunnel floor area (2.500 ft^2). This value was then converted to ton/acre. In modeling PM-10 emissions during a multi-hour wind event, the total emissions would be computed as

$$\text{Equation 2} \quad \text{Emissions} = \{ \text{land area, acres} \} \times \{ [\text{spike value, ton/acre}] + [(\text{hours of wind})(\text{emissions factor, ton/acre/hour})] \}$$

Details of the spike processing methodology can be found in the UNLV Final Report to Clark County (James, et al, 2001)

1998-1999 variations from 1995 field methods

Surface Seals

In the 1995 study, soil was excavated from locations outside of the tunnel working section with hand trowels and shovels and deposited in a 2-3 inch thick layer on the flexible plastic flaps to form a seal to the surface. In the 1998-1999 dust suppressant study, this approach was not found to work on the dust-suppressant-treated surfaces, as good surface seals could not be made with some of the crusted suppressant material, and cleaner sampling techniques were required. Instead, the tunnel flaps were placed on pad of flexible closed cell foam, and weighed down with 6-foot long, 3-inch diameter cloth tubes filled with sand.

Determination of aerodynamic roughness and velocity profile

During the 1995 study, PM-10 eroded in during first three minutes of low-velocity operation of the tunnel, was assumed to be small relative to the reservoir on the surface, and other than observing the first exceedance over 1 mg/m³, was not recorded by the TSI Dust-Trak^(r). During the 1998-1999 dust suppressant study, it became apparent that the PM-10 reservoir on dust suppressant-treated surfaces was very limited, and the first three minutes operation during velocity profile determination was significantly depleting the reservoir. A revised sampling procedure was developed as a result of this realization.

The TSI Dust-Trak^(r) was set to record PM-10 concentrations for a fixed period of five (5) minutes during the velocity profile determination. The tunnel was set to operate at a fixed centerline profiling pitot pressure drop during this initial 5-minute run. During this initial run, the velocity profile was measured and the fans and TSI were shut off exactly 5 minutes after they were started. The aerodynamic roughness and corresponding wind velocity at 10 meters were then calculated with the Quick-BASIC^(r) computer program. Then tunnel fans were then restarted, and tunnel was operated at exactly the same damper opening as in the 5 minute run, while the TSI logged PM-10 for 10 minutes. At the conclusion of the 10 minute run, the elutriation chamber and cyclone contents were swept into plastic bags, and the glass fiber filter was changed.

Fluxes obtained during the 1998-1999 sampling were then computed as a weighted average of the 5 minute (weight 1/3) and 10 minute (weight 2/3) runs.

Flux (emission factor) calculations

As discussed above, the wind tunnel was operated only one time in each place during the 1998-1999 dust suppressant testing study. In contrast, during the 1995 wind tunnel field study, the wind tunnel was operated for three or four times in each place at progressively increasing wind speeds, and cumulative fluxes were computed (see Sections 3 and 4 of this report for the computational methodology).

As a result, the flux values from Stabilized surfaces treated with dust suppressants are not cumulative, and the 1995 flux values from Unstable and Stable surfaces are reported as cumulative results. There should be little effect of this difference in data processing at lower wind speeds (< 30 mph), where most of the 1995 fluxes are reported for run 1, and are, not cumulative.

Site sampling protocols

Since the dust suppressant-treated surfaces generally had very low reservoirs of PM-10, it was found after a few tests that multiple runs in one location at progressively higher wind speeds did not produce additional PM-10. The first 15 minutes of operation (5 minute run + 10 minute run) significantly depleted the treated surfaces of PM-10. As result, the tunnel was operated for only one run (a "run" being the 5 minute velocity profile determination followed by the 10 minute erosion experiment) in each location. The tunnel was moved to a different location for a subsequent run.

Table 1 summarizes differences between the 1995 field study and the 1998-1999 dust suppressant study.

Geometric mean values of the spike-corrected fluxes and corresponding spikes were computed for 5 mph wind speed categories (for example: 15-20 mph, 20-25 mph), for each of the major soil groups, and also averaged over all soil groups. Data are plotted in Figures 4-9 at the midpoints of the 5 mph wind speed ranges.

Results and Discussion

Figure 4 summarizes spike-corrected cumulative flux results for stable (undisturbed) vacant lands, averaged over different soil groups in the Las Vegas Valley. Mean fluxes tended to range from

2.0 to 3.0×10^{-3} ton/acre/hour for average velocities under 35 mph. The large standard deviations indicate considerable scatter in the dataset, as measurements were made over a range of soil types.

Figure 5 summarizes spike-corrected cumulative flux results for unstable (disturbed) vacant lands, averaged over different soil groups in the Las Vegas Valley. Mean fluxes tended to range from 5.0 to 7.0×10^{-3} ton/acre/hour for average velocities under 35 mph. Standard deviations were larger than for stabilized surfaces, with 16th percentile and 84th percentile values separated by an order of magnitude or more.

Figure 6 summarizes spike values for stable vacant lands, averaged over different soil groups in the Las Vegas Valley. Stable surface spikes were about 5.0×10^{-4} ton/acre for average velocities under 35 mph.

Figure 7 summarizes spike values for unstable vacant lands, averaged over different soil groups. Geometric mean unstable surface spikes ranged from about 1.0 to 2.0×10^{-3} ton/acre for average velocities under 35 mph.

Figure 8 summarizes spike-corrected non-cumulative flux results for stabilized (dust suppressant treated) surfaces, averaged over 7 different surface treatments. Geometric mean fluxes ranged from 3.0 to 1.0×10^{-4} ton/acre/hour in the 15-20, 20-25 and 25-30 wind speed categories. Standard deviations were again large.

Figure 9 summarizes spike values for stabilized (dust suppressant-treated) surfaces, averaged over 7 different surface treatments. Geometric mean spike values were about 5.0×10^{-6} ton/acre.

Comparison of Figures 4 and 5 shows that, on average, unstable land surfaces in the Las Vegas Valley had, for the period of record studied, PM-10 emission factors that were typically two to three times as high as stable surfaces. Comparison of Figures 5 and 8 shows that treatment of unstable surfaces with dust suppressants may reduce wind-born steady PM-10 emissions factors by about a factor of 20, and may reduce PM-10 “spikes” by as much as three orders of magnitude.

Conclusions

The 1995 and 1998-1999 wind tunnel studies showed that disturbance of desert surfaces generally increases wind-borne PM-10 emissions compared to undisturbed (stable) lands, and that topical application of dust suppressants to disturbed vacant lands generally decreases wind-borne PM-10 emissions over the effective life of the suppressants. Geometric mean emissions computed over a range of soil types were, for stabilized lands, 2×10^{-4} ton/acre/hour, stable lands 2×10^{-3} ton/acre/hour, and unstable lands 5×10^{-3} ton/acre/hour. Although there is significant scatter in observed data, with within-category variability ranging over 1-2 orders of magnitude, the results indicate that reduction in disturbance of vacant lands, and treatment of previously disturbed vacant lands with dust suppressants can markedly reduce wind-borne PM-10 emissions.

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Acknowledgments

The financial support and project management from the Clark County Health District and Clark County Comprehensive Planning is gratefully acknowledged. Special thanks to Michael Naylor, Will Cates and Carrie MacDougall for their continued support and input through the years. Duane Ono of Great Basin Unified Air Pollution Control District, Chatten Cowherd of Midwest Research Institute and Jack Gillies of Desert Research Institute were instrumental in helping us with access to operating wind tunnels, wind tunnel plans, and advice on sealing to soil surfaces.

Disclaimer

Any errors or omissions are the sole responsibility of the principal author, David E. James.

Figure 1 - Wind Tunnel Component Diagram

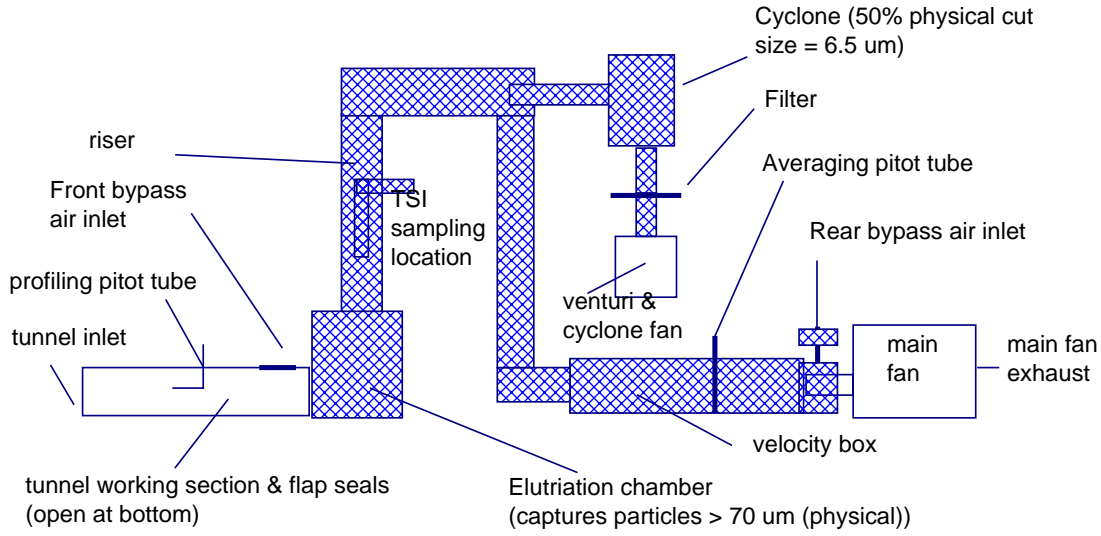


Figure 2: Wind Tunnel PM-10 Mass Balance
arrows indicate PM-10 mass fluxes

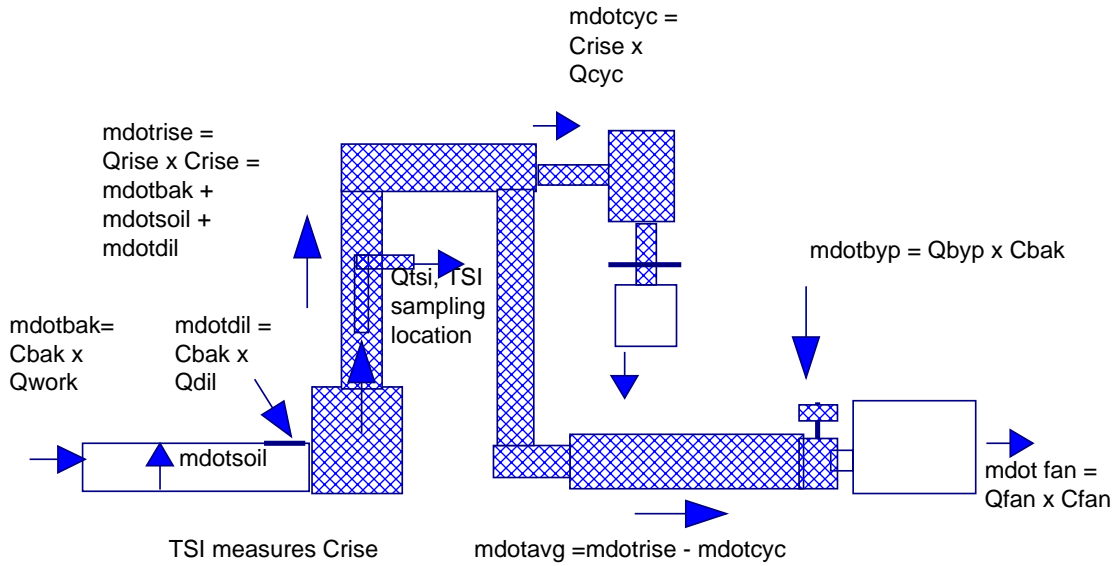


Figure 3. Example of initial spike in data. WT056 (unstable site) - Run1 - 7/28/1995

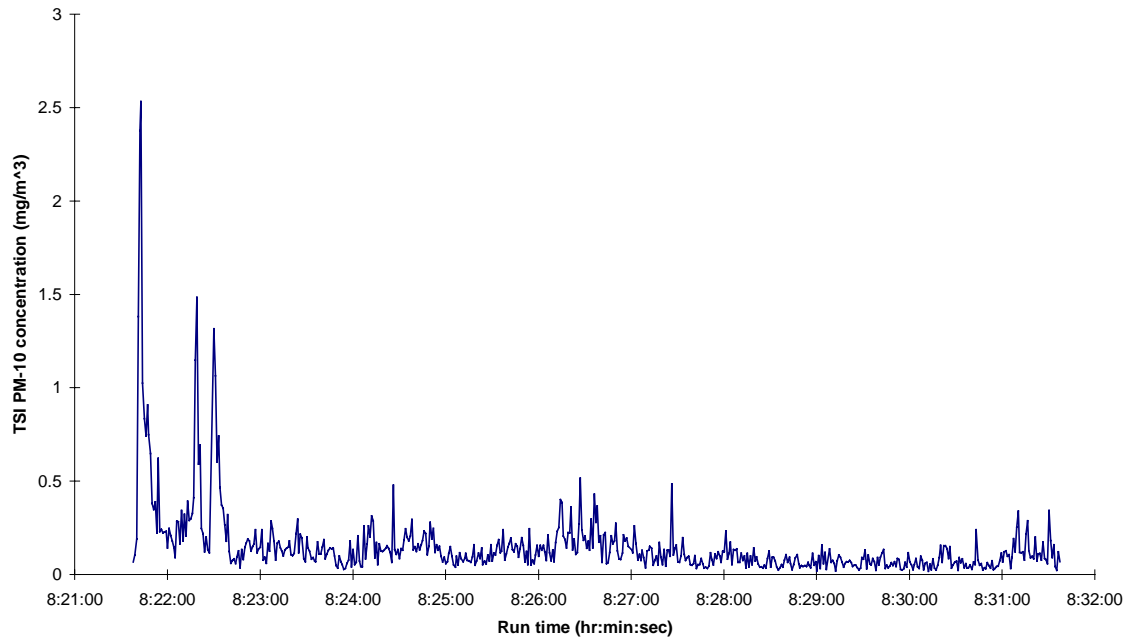


Table 1. Summary of methods changes from 1995 field study to 1998-1999 dust suppressant study

Feature	1995 field study	1998-1999 study
Surface seals	Site soil directly on flaps	open cell foam under flaps sand filled tubes over flaps
Aero roughness Velocity profile	3 minute, not logged by TSI	5 minutes, logged by TSI used in flux calculations
PM-10 spike velocity	damper closed until spike observed	too little PM-10 not performed
Repeat runs in one place	Yes, three or four	No, only one per test location
Emission factors	Computed directly from 10 minute runs	Weighted average of 5 and 10 minute runs
Emission factors	Cumulative at higher wind speeds, accounting for earlier runs in same place. Many runs > 30 mph	Not cumulative Few runs > 30 mph

Figure 4: Stable (undisturbed) flux, All soils, geometric mean +/- 1 standard deviation

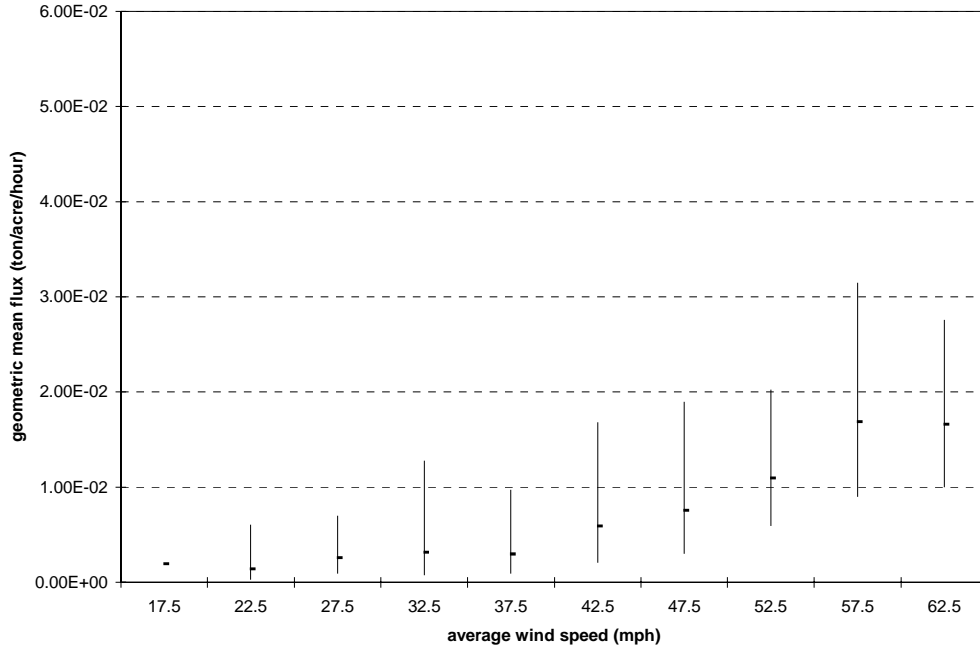


Figure 5: Unstable (disturbed) flux, All soils, geometric mean +/- 1 standard deviation

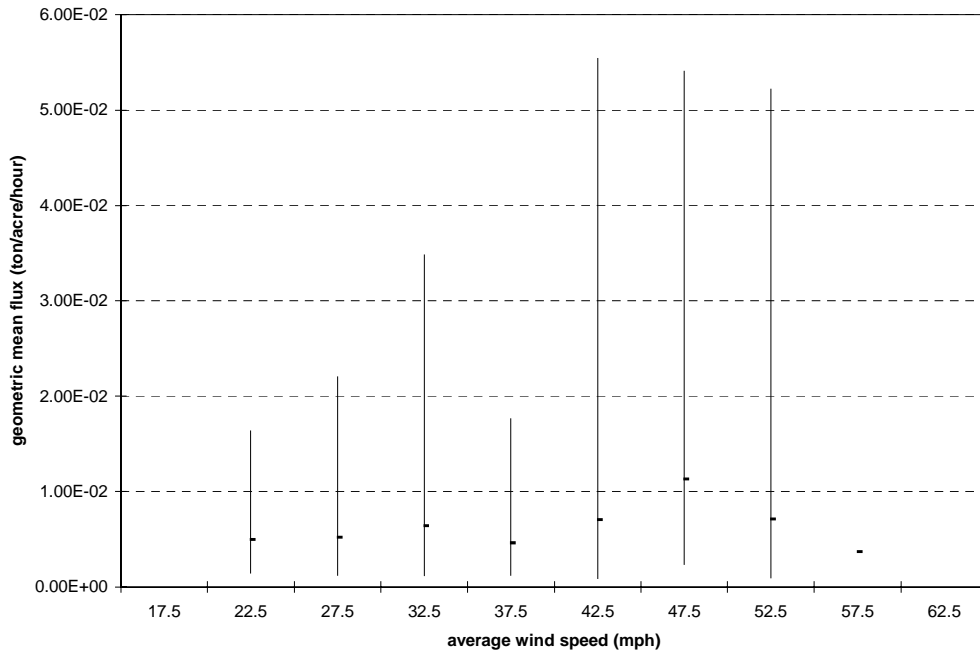


Figure 6: Stable (undisturbed) spike, All soils, geometric mean +/- 1 standard deviation

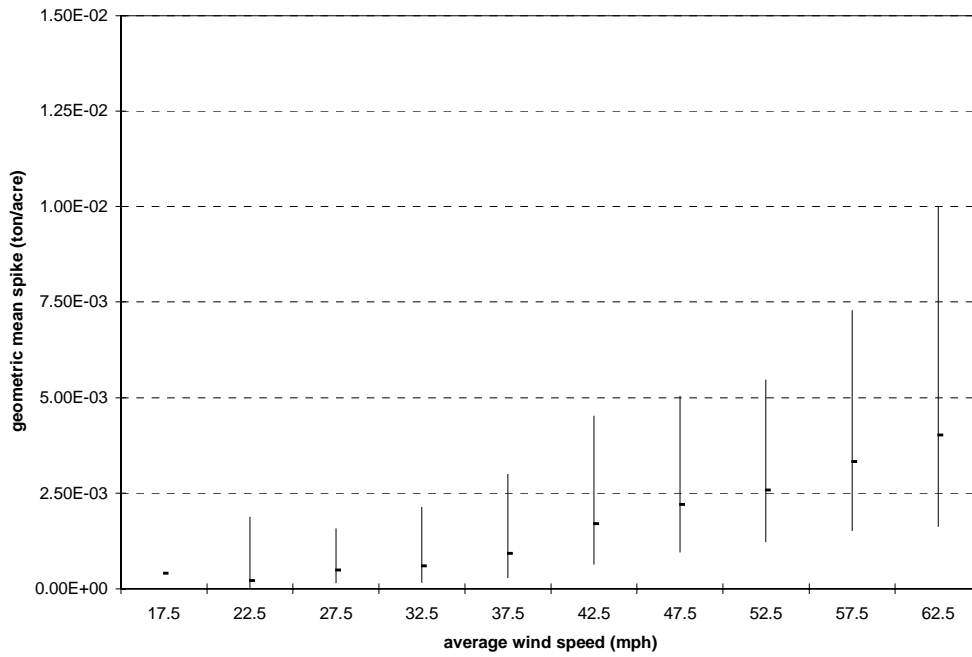


Figure 7: Unstable (disturbed) spike, All soils, geometric mean +/- 1 standard deviation

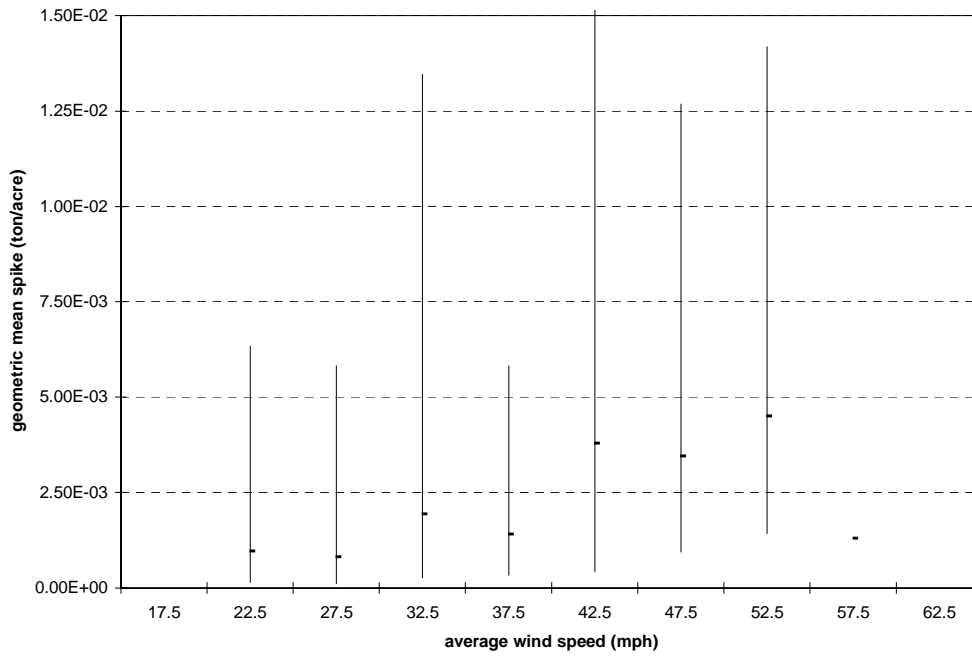


Figure 8: Stabilized (dust suppressant treated) flux. Geometric mean +/- 1 standard deviation

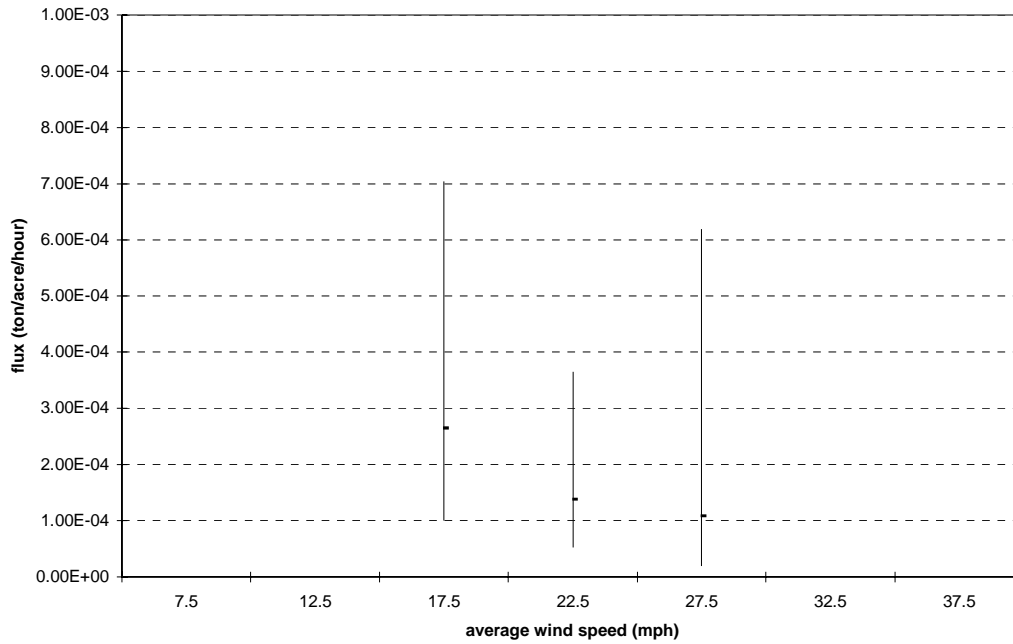
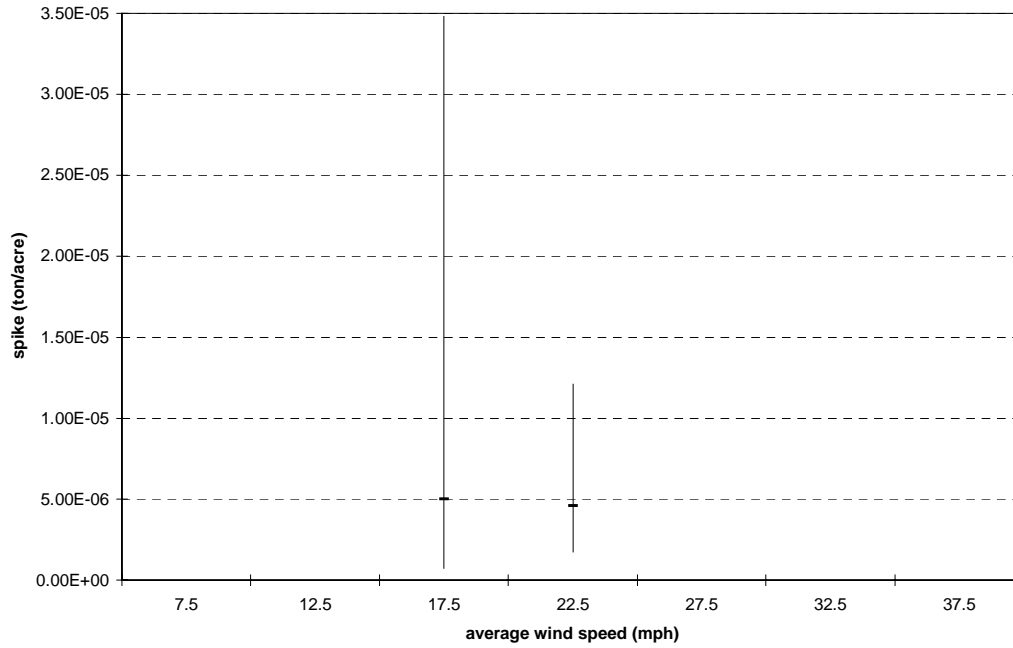


Figure 9: Stabilized (dust suppressant treated) spike. Geometric mean +/- 1 standard deviation



Key Words

Clark County, Dust Suppressant, Emission Factor, PM-10, Vacant Lands, Wind Erosion