The PM-10 Production Potential of Soils in the Las Vegas Valley of Nevada

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Introduction

The Las Vegas Valley of Nevada was designated as a 'serious' PM-10 non-attainment area by the U.S. Environmental Protection Agency in 1993. (PM-10 is particulate matter less than 10 μm in aerodynamic diameter.) As one of the fastest-growing population areas in the U.S., there is a large demand for new construction that causes accompanying land disturbances. A recent study showed that about 90 % of the PM-10 emission was from fugitive dust sources, and that wind speeds above 7.5 m s^{-1} were often associated with large increases in airborne PM-10 (Chow and Watson, 1997). Moreover, there was substantial spatial variability in these geological source contributions over very short distances(< 1 km). Undisturbed desert areas produce low amounts of PM-10 (Chow and Watson, 1997), but wind tunnel studies show that the disturbed lands and construction sites are major sources of PM-10 (Haun, 1995).

To aid in characterizing the source variability and improving control practices, there is a need distinguish PM-10 production potential among the soils in the area. The objective of this study was to characterize the PM-10 and PM-2.5 production potential of some individual soils in the Las Vegas Valley after simulated disturbance.

Experimental Procedure and Methods

Soil survey maps prepared by the USDA Natural Resources Conservation Service identify 9 different soils in the Las Vegas Valley. Two of the soils have little impact on the PM-10 production. Samples of the top 50 mm of the remaining 7 soils were collected for laboratory analyses. One subsample from each soil was used for textural analyses of the soil. This procedure included dispersing the sample, sieving to remove rocks > 2 mm, and using the remainder to determine sand fraction (0.05 - 2.0 mm) and the clay fraction (<0.002 mm), according to the method of Gee and Bauder (1986).

Aggregate-size distribution for a subsample of each soil was determined by rotary sieving and finally, by micromesh sieving to determine the fractions of the smallest aggregates. Because soil particle density is about 2 g cm^{-3}, the geometric mean of the sieve fractions less than 10 and 5 μm was used as an estimate of loose PM-10. Another estimate, the ratio of loose PM-2.5 to PM-10, was obtained by measuring the aerodynamic diameters of the soil samples with an Aerosizer[1/].

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1/ Aerosizer model Mach II, manufactered by Amherst Process Instruments, Hadley, MA . Mention of equipment names are for information purposes and do not imply USDA endorsement.

The sampling and sieving procedures were designed to simulate an upper soil surface layer that is well-mixed by a disturbance process. Based on numerous wind tunnel tests of well-mixed soils, Chepil (1958) found that the average amount of soil, m(kg m^{-2}), that could be removed by wind alone at a friction velocity of 0.6 m s^{-1} (wind speed of 14 m s^{-1} at 10 m height) before the surface armored was about

$$m = 7.616\ e^{-7.627(1\ -\ EF)},\quad 0.3 < EF < 0.9 \qquad (1)$$

where EF is erodible fraction less than 0.84 mm diameter. In this study, the potential reservoir of PM-10 erodible by wind alone was estimated by multiplying the fraction of loose PM-10 in the EF by the potential mass, m, that could be removed.

The fractions of PM-2.5 and PM-10 created upon breakage of saltation-size aggregates (840 - 106 µm) to suspension-size (<106 µm) was determined by repeatedly impacting the soil fraction > 106 µm on a flat plate using a calibrated sand-blasting gun inside an aspirated chamber. The chamber was attached to a high volume particle sampler with multiple impact plates [2/] which trapped the PM-2.5 and PM-10 on filters.

Finally, the fractions of PM-2.5 and PM-10 created when clods/crust are abraded was determined by abrading clod/crust samples inside the chamber with the sand-blasting gun using washed sand (150-420 µm) as the abrader. Again, the PM-2.5 and PM-10 were collected in the high volume particle sampler.

Results and Discussion

Sources of PM-10 during wind erosion include emission of loose material, abrasion from clods/crusts and breakage of the saltation-size aggregates. However, on small areas the emission of loose material is the dominant process (Hagen et al., 1996). Estimates of the loose PM-10 reservoir available before the surface armors under a 14 m s^{-1} wind speed are illustrated in Fig. 1. A wide range of sand/clay ratios is represented by the samples, and there was a non-significant trend ($R^2 = 0.05$) of decreasing PM-10 with an increasing sand/clay ratio of the soils. The mean reservoir value of loose PM-10 was 9.7 g m^{-2} for the 25 soil samples. In comparison, James (1996) calculated from wind tunnel tests, that the base rate of PM-10 production for disturbed soils in the Las Vegas Valley was 4.9 g m^{-2} hr^{-1} at wind speeds of 13.4 to 16.4 m s^{-1}. He further estimated that the mean time to deplete the reservoir would be about 2 hours. Thus, James' estimate is in good agreement with the mean reservoir amounts estimated for disturbed soils in this study.

However, the results (Fig. 1) also show large range, with 64 % of the samples having an average PM-10 reservoir of less than 4.9 g m^{-2}. In contrast, 28 % of the samples had a reservoir of more than 10 g m^{-2}. The largest PM-10 reservoir values occurred in samples where the sand/clay ratio was less than 8. Hence, PM-10 emissions might be reduced most efficiently by identifying soils with low sand/clay ratios and high PM-10 emission potentials and then minimizing their disturbance or applying other erosion controls to them.

2/ Sierra-Anderson/GMW high volume air sampler model 1200, manufactured by Graseby-Anderson, Atlanta, GA.

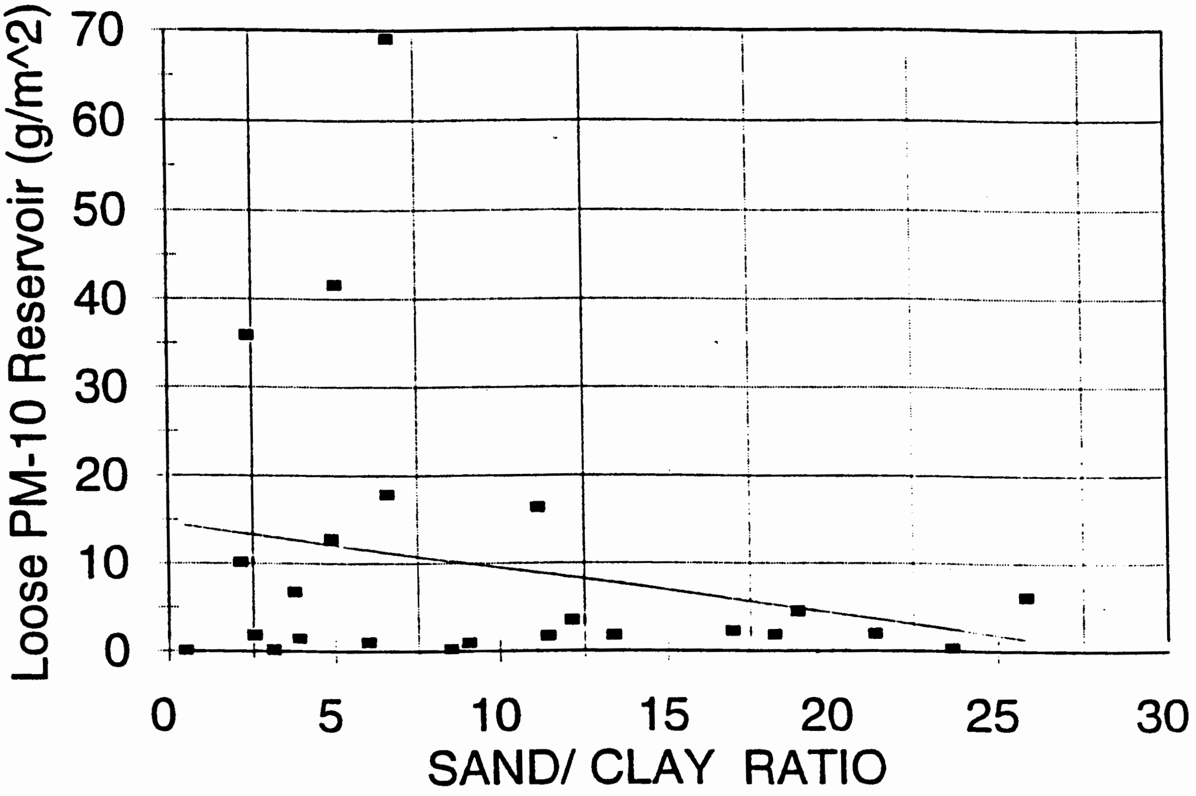

Fig.1. Reservoir of loose PM-10 removable by 14 m s^{-1} wind speed based on sieve analysis of 25 soil samples.

On large areas, breakage of saltation-size aggregates and abrasion of clods and crust also become significant sources of PM-10. However, in the Las Vegas soil samples the loose material had the largest variation, with a coefficient of variation of 166 followed by values of 101 and 49 for the abrasion rate and the breakage rates, respectively.

The mean ratios of PM-2.5/PM-10 ranged from about 0.03 to 0.1 among the three erosion processes studied (TABLE 1). The significant difference among the mean ratios, supports the concept that the processes should be investigated individually. There also was a trend of increasing PM-2.5/PM-10 ratios with increasing sand/clay ratios, except for the ratios of the loose particles which remained nearly constant.

The new 24-hour standard proposed by EPA for PM-2.5 is roughly 0.3 of the PM-10 air quality standard . However, the PM-2.5/PM-10 ratios from the various simulated erosion processes were all less than 0.3. Hence, during wind erosion events, meeting the PM-2.5 standard should not be more difficult than meeting the PM-10 standard for Las Vegas Valley soils. Of course, PM-2.5 emission from soil may still contribute to non-compliance problems, where significant other PM-2.5 sources are present.

.TABLE 1. Ratio of PM-2.5/PM-10 from various simulated wind erosion processes.

Simulated process	Number of soils	Test reps	Mean mass ratio PM-2.5/PM-10	Standard deviation
Saltation breakage	16	2	0.146 a *	0.051
Clod abrasion	5	2	0.094 b	0.037
Loose emission	16	1	0.029 c	0.003

* means followed by a different letter are different at the 0.05 probability level.

Conclusions

The amount of PM-10 available for emission during wind erosion events varies widely among disturbed Las Vegas Valley soils. Hence, reduction of PM-10 emissions could be facilitated by minimizing soil disturbance and applying controls on the most erosive soils. The PM-2.5 generated during simulated wind erosion processes was generally less than 0.3 of the PM-10. Thus, during wind erosion, the proposed new PM-2.5 air quality standard should not be more difficult to attain than the PM-10 standard.

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