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Clay and Carbonate Effect on Fine Dust Emissions Measured in a Rotating-Tube Dust Generation System

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Introduction

Dust emissions from wind erosion are a significant component of the atmospheric aerosol in regions of highly erodible soils (Gatz, 1995). Frequently, human activities and the force of the wind give rise to suspended dust in the atmosphere. Dust created in this way is called "fugitive dust" Because field evaluation of fugitive dust presents serious difficulties (Nickling and Gillies, 1989), considerable effort is now directed toward developing equipment and techniques to generate and analyze aerosol PM_{10} emissions in the laboratory. In this study, we used the Lubbock Dust Generation, Analysis and Sampling System (LDGASS) (Gill *et al*., 1999; Singh, 1994) developed by the USDA-ARS Wind Erosion and Water Conservation Research Unit in Lubbock, Texas. The LDGASS includes a dust generator module that applies kinetic energy to a dust source sample to simulate aerosol emissions by wind erosion. This system is capable of generating fugitive dust, measuring particle characteristics of the generated dust *in situ*, and collecting PM_{10} and $PM_{2.5}$ particulate aerosol samples. PM_{10} and $PM_{2.5}$ are particulate matter having aerodynamic diameters ≤ 10 and ≤ 2.5 μm, respectively. We will present an evaluation of the effect of soil clay and calcium carbonate ($CaCO_3$) content on aerosol PM_{10} and $PM_{2.5}$ production as determined by the LDGASS using two types of aerosol samplers for eight soils from the Southern High Plains near Lubbock, Texas.

Materials and Methods

The LDGASS consists of a dust aerosol generating tube, laser particle size analyzer, and dust settling chamber containing other dust aerosol monitoring and sampling devices (Figure 1). Source samples are placed in a 1-*m* long, 7 *cm* square tube (Figure 1-A). The tube is oscillated with the long axis perpendicular to the floor and inverted 27 times per minute, dropping the sample and generating dust by the impact. The dust is conveyed through a laser particle analysis system (Figure 1-E) and then to a settling chamber (Figure 1-F). In the settling chamber, the dust is sampled by a MiniVol sampler (Figure 1-I) to determine PM_{10} concentration, and DataRAM nephelometers (Figure 1-J) to monitor and sample *in situ* aerosol PM_{10} and $PM_{2.5}$.

Eight agricultural soils from the Southern High Plains near Lubbock, Texas, with combinations of carbonate and clay content were selected from a preliminary study. Two levels (low and high) of soil clay content and two levels (low and high) of soil $CaCO_3$ content were evaluated. Levels of clay content were < 20% for low and > 20% for high. For $CaCO_3$ content the low level was < 3% and the high level was > 3%. Selected soils series were: Amarillo "Amr" (low $CaCO_3$, low clay); Acuff "Acf1 & Acf2" and Olton "Olt" (low $CaCO_3$, high clay); Gomez

"Gmz" (high $CaCO_3$, low clay); and Drake "Drk1, Drk2 & Drk3" (high $CaCO_3$, high clay). Soils clay and carbonate content ranged from 12.7 to 32.6% and from 0.2 to 13.0%, respectively.

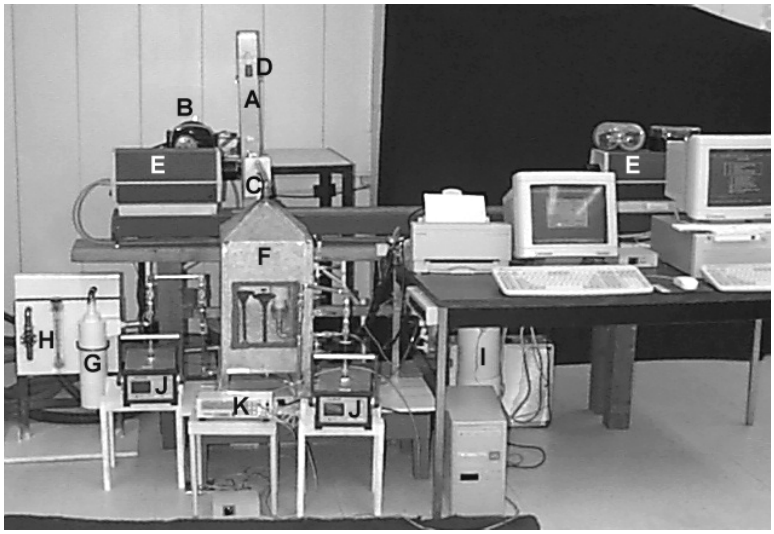

Figure 1. The Lubbock Dust Generation, Analysis and Sampling System (LDGASS).

A mass of 25 *g* of soil aggregates from 2 to 19 *mm* were placed in the dust generator tube and agitated for 30 *min* to create the aerosol. Five replications for each soil were made. An airflow of 200 *l/min* (generated by a vacuum) was used to transport the dust through the LDGASS.

Results and Discussion

For all soils, notable but proportional differences were observed in PM_{10} concentration (average in 30 *min*) as measured with a MiniVol and a DataRAM instruments (Figure 2), which showed a correlation coefficient (r) of 0.97. The average proportion of PM_{10} as measured with a DataRAM in relation to PM_{10} as measured with the MiniVol was 66%. Paired *t*-test results showed significant differences ($\alpha = 0.05$) among overall means for DataRAM and MiniVol as well as by soil means. Also $PM_{2.5}$ as measured by a DataRAM was proportional to PM_{10} as measured by a DataRAM and MiniVol in all soils (Figure 2). Correlation coefficients among $PM_{2.5}$ and PM_{10} as measured by DataRAM and MiniVol were 0.92 and 0.87, respectively. The overall average proportion of $PM_{2.5}$ in relation to PM_{10} as measured with DataRAM was 27%.

A general trend was observed for aerosol PM_{10} and $PM_{2.5}$ to increase as soil clay and $CaCO_3$ content increased. The effect of soil $CaCO_3$ content on aerosol PM_{10} (as measured with both DataRAM and MiniVol) and $PM_{2.5}$ (as measured with DataRAM) was significant as indicated in Table 1. Soil clay content, on the other hand, produced significant effect for PM_{10} data set for MiniVol but no significant effects for PM_{10} and $PM_{2.5}$ data sets from DataRAMs (Table 1).

As Table 1 indicates, differences among levels of soil $CaCO_3$ content produced greater differences in fine dust generation than those differences for levels of soil clay content. Gill *et al.* (1999) reported that a calcareous Drake soil produced more PM_{10} than an Amarillo soil of the same soil texture. They suggest that a lower binding energy in highly calcareous aggregates in the silt fraction of the Drake soil resulted in much less stable aggregates than those of the Amarillo soil, and that this fact might have favored their easier dissagregation into fine dust. Also, the increase in aerosol PM_{10} concentration with increases in soil clay content has been previously reported. Zobeck *et al.* (1999) observed a general increase in aerosol PM_{10} production as the clay content in agricultural soils of the Southern High Plains increased. Stetler *et al*. (1994) and Stetler and Saxton (1995) also have pointed out the higher potential of fine textured soils to generate dust when disturbed or eroded by wind.

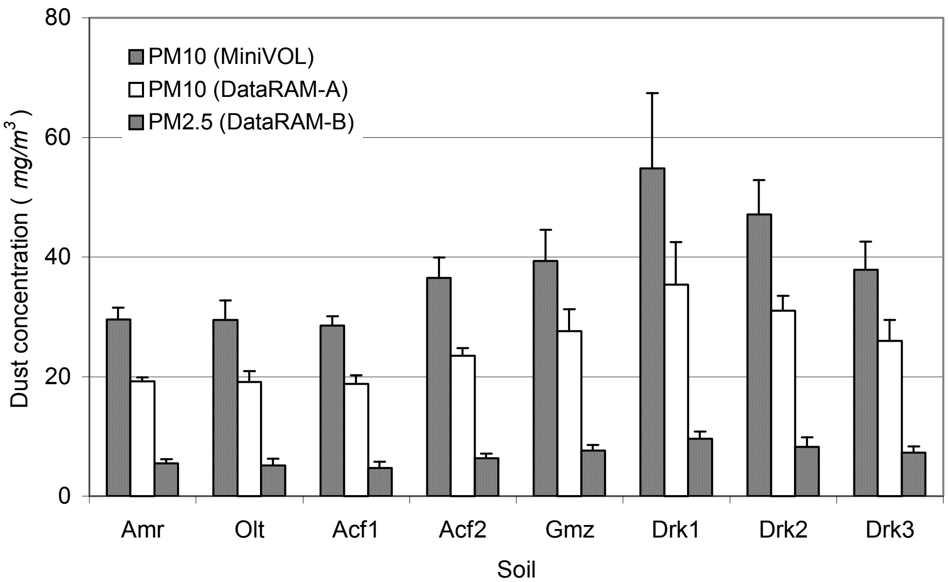

Figure 2. Aerosol PM_{10} and $PM_{2.5}$ concentrations as measured by the MiniVol and DataRAMs dust monitors.

Table 1. Means comparison of $CaCO_3$ and clay levels.

	Dust concentration (*mg/m*^{3})		
Level of factor	PM_{10} (MiniVol)	PM_{10} (DataRAM)	$PM_{2.5}$ (DataRAM)
High clay level	39.04 a	25.61 a	6.87 a
Low clay level	34.24 b	23.35 a	6.56 a
High $CaCO_3$ level	44.85 a	29.97 a	8.19 a
Low $CaCO_3$ level	31.01 b	20.12 b	5.42 b

Means with the same letter by columns within clay and $CaCO_3$ levels are not significantly different at $\alpha = 0.05$.

Conclusions

Significant differences were found among measurements of PM_{10} concentration made by DataRAM and MiniVol instruments. DataRAM PM_{10} measurements were on average 66% of measurements made by the MiniVol. Measurements between instruments, however, were proportional with a correlation coefficient of 0.97. $PM_{2.5}$ concentrations obtained with a DataRAM were also proportional to PM_{10} production. The overall average proportion of $PM_{2.5}$ in relation to PM_{10} as measured by a DataRAM was 27%. Correlation coefficients of 0.92 and 0.87 were found among $PM_{2.5}$ and PM_{10} as measured by a DataRAM and a MiniVol, respectively.

The increase of aerosol PM_{10} and $PM_{2.5}$ concentrations with the increase of soil $CaCO_3$ content was significant for the three datasets. The increase of particulate matter concentrations with the increase of soil clay content was significant for the PM_{10} data set from the MiniVol dust monitor, but was not significant for PM_{10} and $PM_{2.5}$ as measured with DataRAMs. Differences in soil $CaCO_3$ content produced greater differences in aerosol PM_{10} and $PM_{2.5}$ concentrations than the differences in soil clay content.

Disclaimer: Names of commercial products and/or their manufacturers are necessary to describe the equipment, processes and products in this study. Colegio de Postgraduados and USDA-ARS imply no approval of these products to the exclusion of others that may also be suitable.

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