An Index of PM_{10} Potential Emission from Soil

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Introduction

Concentrations of particulate matter with an aerodynamic diameter less than 10 micrometers (PM_{10}) exceed federal standards at a number of air basins in the western United States. In some of them, geological material - soil dust- is a major fraction of the total PM_{10}. During the Valley Air Quality Study in 1988-89, for example, Chow, et al. (1992) found that geological material accounted for 63% of PM_{10}, on average, in California's San Joaquin Valley. The percentage varied throughout the year, but agricultural activities were thought to be a major source during the fall months. In western Texas and eastern Washington, soil erosion by wind is a major source of PM_{10} (Stetler, et al., 1994). The PM_{10} standard has been exceeded at Spokane during high wind events, with soil dust comprising the major portion of the particulate matter. Fugitive resuspended dust emissions from vehicular travel on paved and unpaved roads also contribute to PM_{10} in many locations.

The predictive equations for emission factors for soil sources published by the United States Environmental Protection Agency are based on the dry "silt content" of the soil, defined as the fraction of soil, including aggregated soil particles, that is less than 75 micrometers in physical diameter. However, the predictive equations were derived empirically; they were not based on a systematic study of the ability of soil to release particles to the atmosphere. The Air Quality Group at UC Davis has examined the ability of soils with different dry silt content to emit PM_{10}. To describe this ability, we have developed a laboratory procedure that defines a PM_{10} "dustiness index".

The concept of a dustiness index has been explored by other researchers, including the British Occupation Hygiene Society Technology Committee working Party on Dustiness Estimation (BOHS, 1988), Heitbrink (1990), Chung and Burdett (1994), Heitbrink, et al. (1990), and Hjemsted and Schneider (1996). Three common principles of dust generation are common to the tests evaluated; a single drop of material into an enclosed chamber, a rotating drum to allow multiple drops of material, and fluidization by passing air through the material in a vertical tube. All methods produce a dustiness index that relates the mass of dust produced to the mass of soil that produced it. The BOHS working party evaluated the operating principles of the single drop method in detail (BOHS, 1988) by varying the mass of material dropped, the drop height, and the method of dropping it (single drop or stream). They concluded that the dust yield is strongly influenced by the size of sample and the height of drop, and that reproducibility is greater when the sample is released as a stream. They also found differences in dustiness depending on the sample grain size distribution.

We have developed a method to measure a PM_{10} dust index using a fluidization technique to generate the dust. With this method, we have found that the ability of soil to release PM_{10} under controlled laboratory conditions depends in a complex manner on the soil type. Soils with the same dry silt content do not necessarily have equivalent potential to emit PM_{10}. An index of PM_{10} emissions may improve our ability to estimate PM_{10} emission from more easily measured parameters. In this paper, we explore the amount of PM_{10} the soil emits as well as the ability of different soils to emit PM_{10} as a function of time.

Experimental

The UC Davis dust resuspension chamber consists of a fluidizing bed to generate dust and a collection chamber to collect the sample (Carvacho, 1996). The fluidizing bed uses upward flowing air to churn the sample and suspend the smaller particles to be carried into the dust collection chamber. The dust collection chamber is a 90 liter box that contains a PM_{10} inlet attached to a modified IMPROVE sampler (Eldred, et al., 1990). With the IMPROVE sampler, we can collect four filter samples in sequence without pausing to change filters.

We are mainly concerned with soil particles that remain suspended in ambient air, so we dry and sieve the soil particles to obtain the fraction less than or equal to 75 µm in physical diameter. This is known as the dry "silt content" to wind erosion scientists (U.S. EPA, 1997 [AP-42]). It is not the same as the "silt" known to soil scientists.

Approximately 1g of dried, sieved soil is placed in the fluidizing bed dust generation chamber, which is sealed with a clamp. A measured volume of air (3.5 liters per minute for 15 seconds) is forced through the soil sample at the base of the fluidizing bed. This is sufficient to suspend dust particles smaller than ~50 µm aerodynamic diameter. These particles are carried out of the generation chamber and introduced into the collection chamber. The particles are collected on Teflon filters after passing through a Sierra Anderson PM_{10} inlet. The IMPROVE sampler operates at 16.7 liters per minute (Eldred, 1988). With the 90 liter volume of the collection chamber, the "half life" of a cloud of particles in the chamber is approximately 3.5 minutes.

For this test, we collected each 15 second "puff" of dust for 15 minutes onto a single Teflon membrane filter. Prior experiments have demonstrated that this time is sufficient to collect nearly all the PM_{10} particles puffed into the chamber (Carvacho, 1996). We repeated this procedure using the same sample of soil in the dust generation chamber until the soil sample was depleted of PM_{10} material.

We tested five different soils with four distinct soil textures using the above procedure. Table 1 shows the source locations and characteristics of each of the tested soils.

Table 1. Soil used in the PM_{10} index calculationFigure 1. Cumulative mass emitted as a function of time

Site	Code	County	Texture	Classification	Silt Content (%)
Fancher	F1	Merced	Loam	Wyman Loam Wsa	15.1
Paramount	P1	Kern	Sandy Loam	Twissleman	11.3
Paramount	P2	Kern	Clay Loam	Panoche Clay Loam	8.1
Newton Brothers	N1	Kings	Clay	Tulare Clay	10.5
Stone Land	S1	Fresno	Loam	Westhaven Loam	16.1

Results and Discussion

We normalize the mass of PM_{10} dust collected to the mass of soil that produced it for all of the tests reported here. The cumulative PM_{10} mass emitted per gram of soil placed in the fluidized bed can be modeled using an exponential relationship of the form

$$\textit{Cumulative mass} = a(1-e^{b*time}). \qquad (1)$$

The “a” parameter (the asymptote) in equation (1) is a measure of the total amount of PM_{10} emitted per gram of soil (the PM_{10} index), while the “b” parameter (the inverse of the time constant) is a measure of how fast the soil emits the PM_{10}. We plotted the cumulative measured PM_{10} mass for each soil and fit curves to the data to obtain the PM_{10} index and time constant. Figure 1 shows the measured cumulative mass as a function of time and the fitted curve, with PM_{10} index (the asymptote), for the Twissleman Sandy Loam soil.

The five soils tested exhibited different PM_{10} emission characteristics. The two loam soils had higher PM_{10} indexes than the other soils, and emitted PM_{10} more readily. This latter characteristic is shown by the low time constants for these two soils. The clay loam soil was the slowest to emit PM_{10}, while the clay and sandy loam soils were intermediate. The PM_{10} index is weakly related to the dry silt content, as shown in Figure 2.

Conclusions

The concept of a dustiness index has been reported by others (for example BOHS, 1988), but not often in the context of PM_{10} emission by soils. The PM_{10} index developed here may be a useful measure of the ability of the soil to emit PM_{10}. Additional measurements are needed to see whether the index varies systematically and predictably with soil type. These measurements are ongoing at UC Davis with a collection of soils from different areas of the San Joaquin Valley.

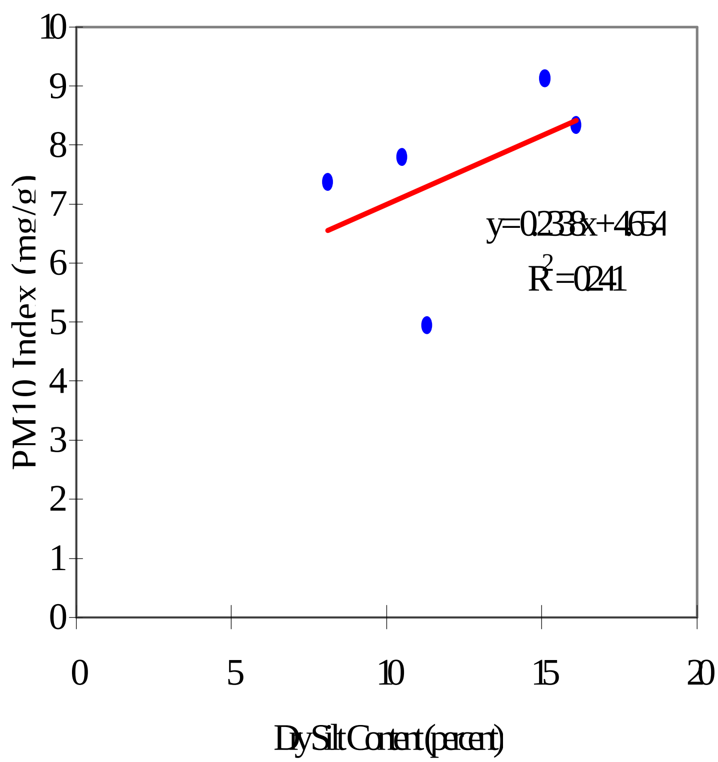

Figure 2. **PM_{10} index vs. dry silt content**

Table 2. Summary of PM_{10} index and time constantReferences

Site	Code	County	Texture	Dry Silt Content (percent)	PM 10 Index (mg/g)	Time Constant (minutes)
Fancher	F1	Merced	Loam	15.1	9.126	34.2
Paramount	P1	Kern	Sandy Loam	11.3	4.937	60.1
Paramount	P2	Kern	Clay Loam	8.1	7.366	106.3
Newton Brothers	N1	Kings	Clay	10.5	7.792	66.8
Stone Land	S1	Fresno	Loam	16.1	8.331	32.6

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