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CONTROL OF OPEN FUGITIVE DUST SOURCES

FINAL REPORT

by

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4.0 STORAGE PILES

Inherent in operations that use minerals in aggregate form is the maintenance of outdoor storage piles. Storage piles are usually left uncovered, partially because of the need for frequent material transfer into or out of storage.

Dust emissions occur at several points in the storage cycle, during material loading onto the pile, during disturbances by strong wind currents, and during loadout from the pile. The movement of trucks and loading equipment in the storage pile area is also a substantial source of dust.

4.1 ESTIMATION OF EMISSIONS

The quantity of dust emissions from aggregate storage operations varies with the volume of aggregate passing through the storage cycle. Also, emissions depend on three correction parameters that characterize the condition of a particular storage pile: age of the pile, moisture content, proportion of aggregate fines, and friability of the material.

When freshly processed aggregate is loaded onto a storage pile, its potential for dust emissions is at a maximum. Fines are easily disaggregated and released to the atmosphere upon exposure to air currents from transfer operations or high winds. As the aggregate weathers, however, potential for dust emissions is greatly reduced. Moisture causes aggregation and cementation of fines to the surfaces of larger particles.

Field investigations have shown that emissions from certain aggregate storage operations vary in direct proportion to the percentage of silt (particles <75 μm in diameter) in the aggregate material.[1-3] The silt content is determined by measuring the proportion of dry aggregate material that passes through a 200-mesh screen, using ASTM-C-136 method. Table 4-1 summarizes measured silt and moisture values for industrial aggregate materials.

Total dust emissions from aggregate storage piles are contributions of several distinct source activities within the storage cycle:

TABLE 4-1. TYPICAL SILT AND MOISTURE CONTENT VALUES OF MATERIALS AT VARIOUS INDUSTRIES

Industry	Material	No. of test samples	Silt, percent		No. of test samples	Moisture, percent	
			Range	Mean		Range	Mean
Iron and steel production[a]	Pellet ore	10	1.4-13	4.9	8	0.64-3.5	2.1
	Lump ore	9	2.8-19	9.5	6	1.6-8.1	5.4
	Coal	7	2-7.7	5	6	2.8-11	4.8
	Slag	3	3-7.3	5.3	3	0.25-2.2	0.92
	Flue dust	2	14-23	18.0	0	NA	NA
	Coke breeze	1		5.4	1		6.4
	Blended ore	1		15.0	1		6.6
	Sinter	1		0.7	0	NA	NA
	Limestone	1		0.4	0	NA	NA
Stone quarrying and processing[b]	Crushed limestone	2	1.3-1.9	1.6	2	0.3-1.1	0.7
Taconite mining and processing[c]	Pellets	9	2.2-5.4	3.4	7	0.05-2.3	0.96
	Tailings	2	NA	11.0	1		0.35
Western surface coal mining[d]	Coal	15	3.4-16	6.2	7	2.8-20	6.9
	Overburden	15	3.8-15	7.5	0	NA	NA
	Exposed ground	3	5.1-21	15.0	3	0.8-6.4	3.4

[a]References 2 through 5. NA = not applicable.
[b]Reference 1.
[c]Reference 6.
[d]Reference 7.

1. Loading of aggregate onto storage piles (batch or continuous drop operations).

2. Equipment traffic in storage area.

3. Wind erosion of pile surfaces and ground areas around piles.

4. Loadout of aggregate for shipment or for return to the process stream (batch or continuous drop operations).

4.1.1 Materials Handling

Adding aggregate material to a storage pile or removing it usually involves dropping the material onto a receiving surface. Truck dumping on the pile or loading out from the pile to a truck with a front-end loader are examples of batch drop operations. Adding material to the pile by a conveyor stacker is an example of a continuous drop operation.

The following equation is recommended for estimating emissions from transfer operations (batch or continuous drop):

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (kg/Mg)}$$

(4-1)

$$E = k(0.0032)\frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (lb/ton)}$$

where: E = emission factor

k = particle size multiplier (dimensionless)

U = mean wind speed, m/s (mph)

M = material moisture content, percent

The particle size multiplier k varies with aerodynamic particle diameter as shown below:

Aerodynamic Particle Size Multiplier, k

<30 μm	<15 μm	<10 μm	<5 μm	<2.5 μm
0.74	0.48	0.35	0.20	0.11

Based on the criteria presented in AP-42, the above equation is rated A.

For emissions from equipment traffic (trucks, front-end loaders, dozers, etc.) traveling between or on piles, it is recommended that the equations for vehicle traffic on unpaved surfaces be used (see Section 3-0). For vehicle travel between storage piles, the silt value(s) for the areas among the piles (which may differ from the silt values for the stored materials) should be used.

4.1.2 Wind Erosion

Dust emissions may be generated by wind erosion of open aggregate storage piles and exposed areas within an industrial facility. These sources typically are characterized by nonhomogeneous surfaces impregnated with nonerodible elements (particles larger than approximately 1 cm in diameter). Field testing of coal piles and other exposed materials using a portable wind tunnel has shown that (a) threshold wind speeds exceed 5 m/s (11 mph) at 15 cm above the surface or 10 m/s (22 mph) at 7 m above the surface, and (b) particulate emission rates tend to decay rapidly (half life of a few minutes) during an erosion event. In other words, these aggregate material surfaces are characterized by finite availability of erodible material (mass/area) referred to as the erosion potential. Any natural crusting of the surface binds the erodible material, thereby reducing the erosion potential.

4.1.2.1 Emissions and Correction Parameters. If typical values for threshold wind speed at 15 cm are corrected to typical wind sensor height (7-10 m), the resulting values exceed the upper extremes of hourly mean wind speeds observed in most areas of the country. In other words, mean atmospheric wind speeds are not sufficient to sustain wind erosion from aggregate material surfaces. However, wind gusts may quickly deplete a substantial portion of the erosion potential. Because erosion potential has been found to increase rapidly with increasing wind speed, estimated emissions should be related to the gusts of highest magnitude.

The routinely measured meteorological variable which best reflects the magnitude of wind gusts is the fastest mile. This quantity represents the wind speed corresponding to the whole mile of wind movement which has passed by the 1-mi contact anemometer in the least amount of time. Daily measurements of the fastest mile are presented in the monthly Local Climatological Data (LCD) summaries. The LCD summaries can be obtained from the National Climatic Center, Asheville, North Carolina. The duration of the fastest mile, typically about 2 min (for a fastest mile of 30 mph), matches well with the half life of the erosion process, which ranges between 1 and 4 min. It should be noted, however, that peak winds can significantly exceed the daily fastest mile.

The wind speed profile in the surface boundary layer is found to follow a logarithmic distribution:

$$u(z) = \frac{u^*}{0.4} \ln\left(\frac{z}{z_0}\right) \quad (z > z_0) \tag{4-2}$$

where:
- u = wind speed, cm/s
- u^* = friction velocity, cm/s
- z = height above test surface, cm
- z_0 = roughness height, cm
- 0.4 = von Karman's constant, dimensionless

The friction velocity (u^*) is a measure of wind shear stress on the erodible surface, as determined from the slope of the logarithmic velocity profile. The roughness height (z_0) is a measure of the roughness of the exposed surface as determined from the y-intercept of the velocity profile, i.e., the height at which the wind speed is zero. These parameters are illustrated in Figure 4-1 for a roughness height of 0.1 cm.

Emissions generated by wind erosion are also dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action which results in the exposure of fresh surface material. On a storage pile, this would occur whenever aggregate material is either added to or removed from the old surface. A disturbance of an exposed area may also result from the turning of surface material to a depth exceeding the size of the largest pieces of material present.

4.1.2.2 Predictive Emission Factor Equation[8]. The emission factor for wind-generated particulate emissions from mixtures of erodible and nonerodible surface material subject to disturbance may be expressed in units of g/m^2-yr as follows:

$$\text{Emission factor} = k \sum_{i=1}^{N} P_i \tag{4-3}$$

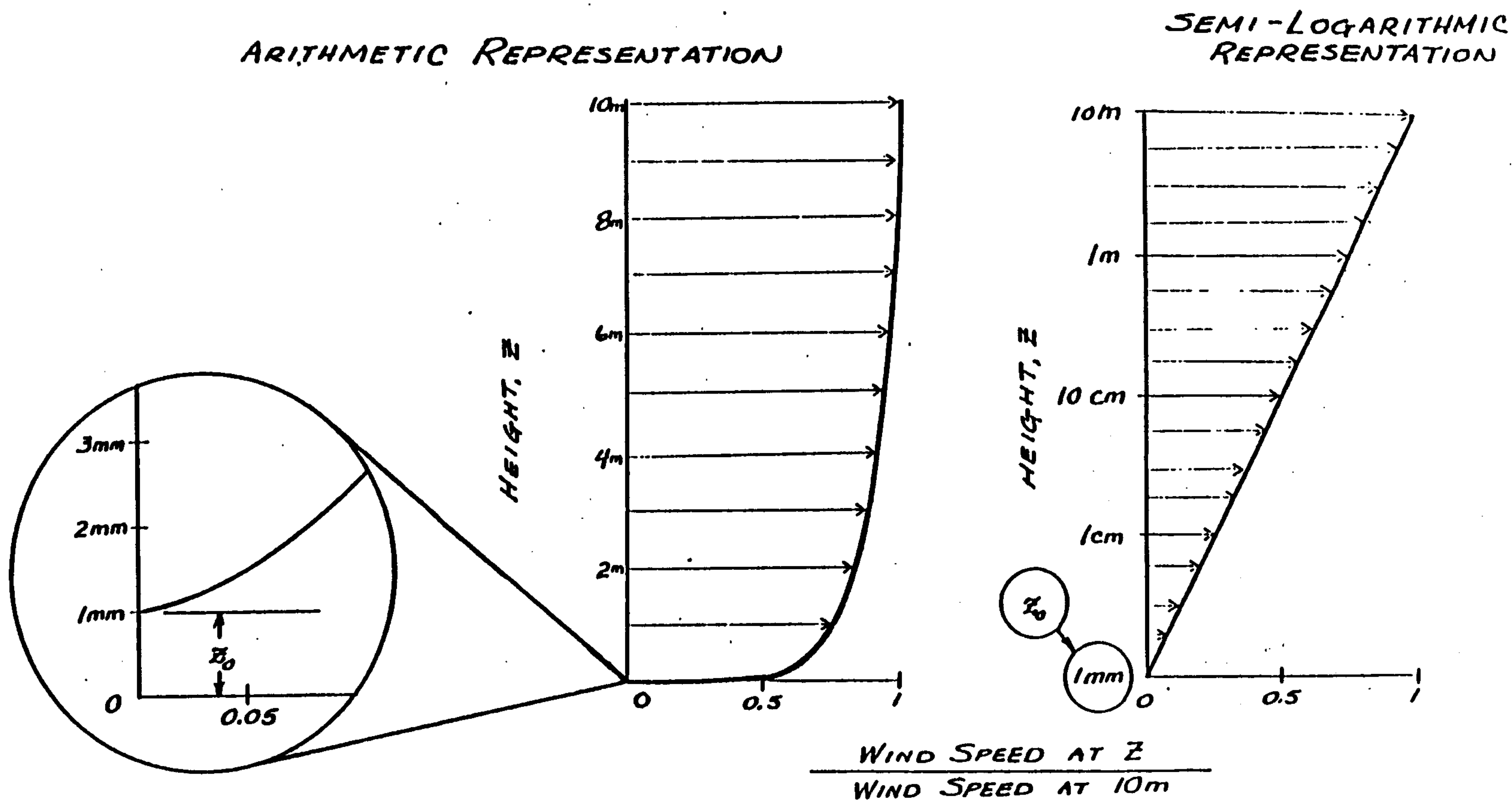


Figure 4-1. Illustration of logarithmic velocity profile.

where: k = particle size multiplier

N = number of disturbances per year

P_i = erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances, g/m^2

The particle size multiplier (k) for Equation 4-3 varies with aerodynamic particle size, as follows:

AERODYNAMIC PARTICLE SIZE MULTIPLIERS FOR EQUATION 4-3

<30 µm	<15 µm	<10 µm	<2.5 µm
1.0	0.6	0.5	0.2

This distribution of particle size within the <30 µm fraction is comparable to the distributions reported for other fugitive dust sources where wind speed is a factor. This is illustrated, for example, in the distributions for batch and continuous drop operations encompassing a number of test aggregate materials (see AP-42 Section 11.2.3).

In calculating emission factors, each area of an erodible surface that is subject to a different frequency of disturbance should be treated separately. For a surface disturbed daily, N = 365/yr, and for a surface disturbance once every 6 mo, N = 2/yr.

The erosion potential function for a dry, exposed surface has the following form:

$$P = 58\ (u^* - u_t^*)^2 + 25\ (u^* - u_t^*) \qquad (4\text{-}4)$$

$$P = 0 \text{ for } u^* \le u_t^*$$

where: u^* = friction velocity (m/s)

u_t^* = threshold friction velocity (m/s)

Table 4-2 presents the erosion potential function in matrix form. Because of the nonlinear form of the erosion potential function, each erosion event must be treated separately.

TABLE 4-2. EROSION POTENTIAL FUNCTION

u_*,		P (g/m^2)											
m/s	u_t^* =	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
0.2		0	0	0	0	0	0	0	0	0	0	0	0
0.4		7	0	0	0	0	0	0	0	0	0	0	0
0.6		19	7	0	0	0	0	0	0	0	0	0	0
0.8		36	19	7	0	0	0	0	0	0	0	0	0
1.0		57	36	19	7	0	0	0	0	0	0	0	0
1.2		83	57	36	19	7	0	0	0	0	0	0	0
1.4		114	83	57	36	19	7	0	0	0	0	0	0
1.6		149	114	83	57	36	19	7	0	0	0	0	0
1.8		188	149	114	83	57	36	19	7	0	0	0	0
2.0		233	188	149	114	83	57	36	19	7	0	0	0
2.2		282	233	188	149	114	83	57	36	19	7	0	0
2.4		336	282	233	188	149	114	83	57	36	19	7	0
2.6		394	336	282	233	188	149	114	83	57	36	19	7
2.8		457	394	336	282	233	188	149	114	83	57	36	19
3.0		525	457	394	336	282	233	188	149	114	83	57	36

Equations 4-3 and 4-4 apply only to dry, exposed materials with limited erosion potential. The resulting calculation is valid only for a time period as long or longer than the period between disturbances. Calculated emissions represent intermittent events and should not be input directly into dispersion models that assume steady state emission rates.

For uncrusted surfaces, the threshold friction velocity is best estimated from the dry aggregate structure of the soil. A simple hand sieving test of surface soil (adapted from a laboratory procedure published by W. S. Chepil[9]) can be used to determine the mode of the surface aggregate size distribution by inspection of relative sieve catch amounts, following the procedure specified in Section 6. The threshold friction velocity for erosion can be determined from the mode of the aggregate size distribution, as described by Gillette.[10] This conversion is also described in Section 6.

Threshold friction velocities for several surface types have been determined by field measurements with a portable wind tunnel.[10-13] These values are presented in Tables 4-3 and 4-4 for industrial aggregates and Arizona sites. Figure 4-2 depicts these data graphically.

The fastest mile of wind for the periods between disturbances may be obtained from the monthly LCD summaries for the nearest reporting weather station that is representative of the site in question.[14] These summaries report actual fastest mile values for each day of a given month. Because the erosion potential is a highly nonlinear function of the fastest mile, mean values of the fastest mile are inappropriate. The anemometer heights of reporting weather stations are found in Reference 15, and should be corrected to a 10 m reference height using Equation 4-2.

To convert the fastest mile of wind (u^+) from a reference anemometer height of 10 m to the equivalent friction velocity (u^*), the logarithmic wind speed profile may be used to yield the following equation:

$$u^* = 0.053\, u_{10}^+ \qquad (4\text{-}5)$$

where: u^* = friction velocity (m/s)

u_{10}^+ = fastest mile of reference anemometer for period between disturbances (m/s)

TABLE 4-3. THRESHOLD FRICTION VELOCITIES--INDUSTRIAL AGGREGATES

Material	Threshold friction velocity, m/s	Roughness height, cm	Threshold wind velocity at 10 m (m/s)		Ref.
			z_0 = actual	z_0 = 0.5 cm	
Overburden[a]	1.02	0.3	21	19	7
Scoria (roadbed material)[a]	1.33	0.3	27	25	7
Ground coal[a] (surrounding coal pile)	0.55	0.01	16	10	7
Uncrusted coal pile[a]	1.12	0.3	23	21	7
Scraper tracks on coal pile[a,b]	0.62	0.06	15	12	7
Fine coal dust on concrete pad[c]	0.54	0.2	11	10	12

[a]Western surface coal mine.
[b]Lightly crusted.
[c]Eastern power plant.

TABLE 4-4. THRESHOLD FRICTION VELOCITIES--ARIZONA SITES[13]

Location	Threshold friction velocity, m/sec	Roughness height, (cm)	Threshold wind velocity at 10 m, m/sec
Mesa - Agricultural site	0.57	0.0331	16
Glendale - Construction site	0.53	0.0301	15
Maricopa - Agricultural site	0.58	0.1255	14
Yuma - Disturbed desert	0.32	0.0731	8
Yuma - Agricultural site	0.58	0.0224	17
Algodones - Dune flats	0.62	0.0166	18
Yuma - Scrub desert	0.39	0.0163	11
Santa Cruz River, Tucson	0.18	0.0204	5
Tucson - Construction site	0.25	0.0181	7
Ajo - Mine tailings	0.23	0.0176	7
Hayden - Mine tailings	0.17	0.0141	5
Salt River, Mesa	0.22	0.0100	7
Casa Grande - Abandoned agricultural land	0.25	0.0067	8

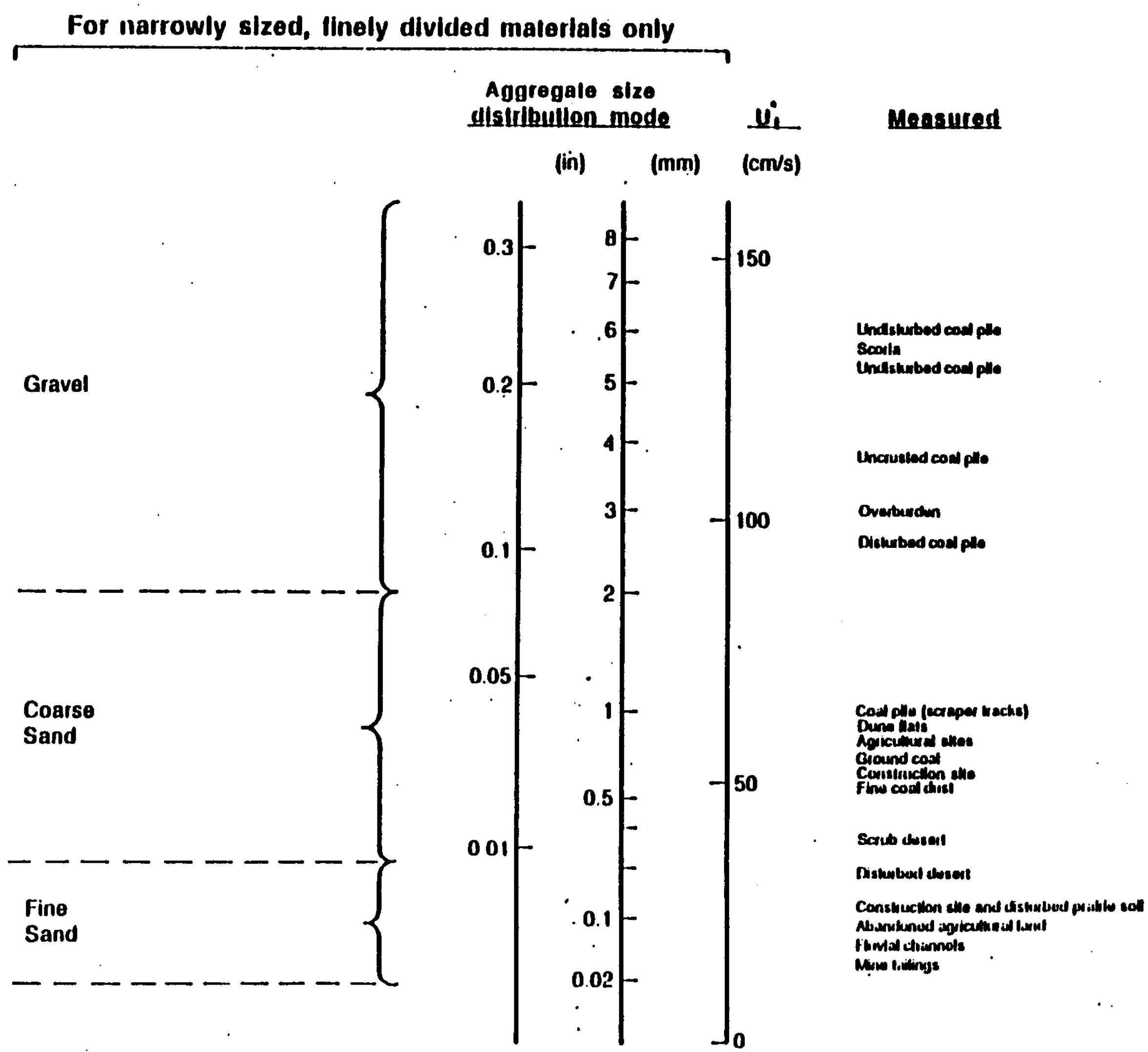


Figure 4-2. Scale of threshold friction velocities.

This assumes a typical roughness height of 0.5 cm for open terrain. Equation 4-5 is restricted to large relatively flat piles or exposed areas with little penetration into the surface wind layer.

If the pile significantly penetrates the surface wind layer (i.e., with a height-to-base ratio exceeding 0.2), it is necessary to divide the pile area into subareas representing different degrees of exposure to wind. The results of physical modeling show that the frontal face of an elevated pile is exposed to wind speeds of the same order as the approach wind speed at the top of the pile.

For two representative pile shapes (conical and oval with flat-top, 37 degree side slope), the ratios of surface wind speed (u_s) to approach wind speed (u_r) have been derived from wind tunnel studies.[11] The results are shown in Figure 4-3 corresponding to an actual pile height of 11 m, a reference (upwind) anemometer height of 10 m, and a pile surface roughness height (z_0) of 0.5 cm. The measured surface winds correspond to a height of 25 cm above the surface. The area fraction within each contour pair is specified in Table 4-5.

The profiles of u_s/u_r in Figure 4-3 can be used to estimate the surface friction velocity distribution around similarly shaped piles, using the following procedure:

1. Correct the fastest mile value (u^+) for the period of interest from the anemometer height (z) to a reference neight of 10 m (u^+_{10}) using a variation of Equation 4-2, as follows:

$$u^+_{10} = u^+ \frac{\ln (10/0.005)}{\ln (z/0.005)} \qquad (4\text{-}6)$$

   where a typical roughness height of 0.5 cm (0.005 m) has been assumed. If a site specific roughness height is available, it should be used.

2. Use the appropriate part of Figure 4-3 based on the pile shape and orientation to the fastest mile of wind, to obtain the corresponding surface wind speed distribution (u^+_s), i.e.,

$$(4\text{-}7) \qquad u^+_s = \left(\frac{u_s}{u_r}\right) u^+_{10}$$

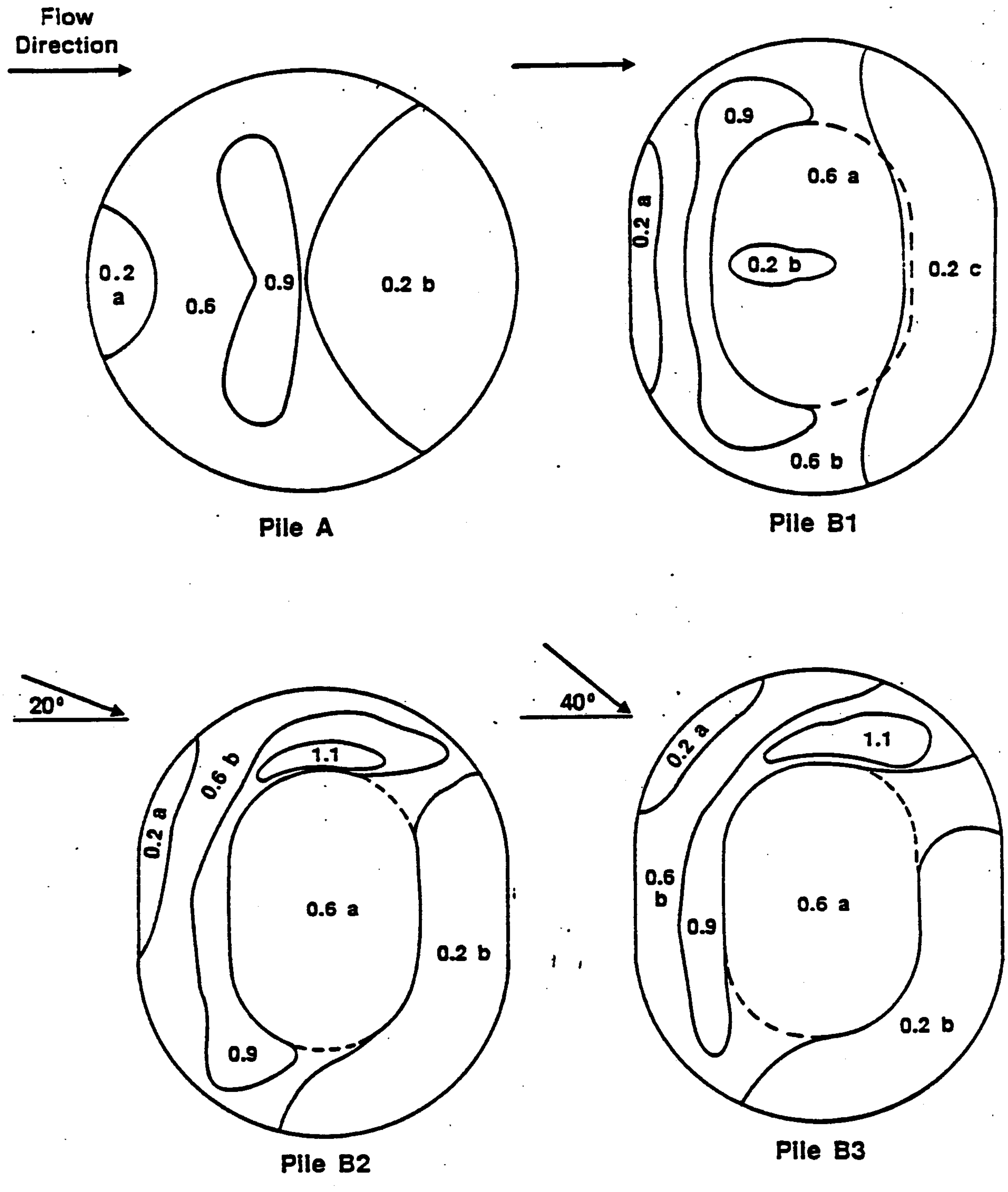


Figure 4-3. Contours of normalized surface wind speeds, u_s/u_r.

TABLE 4-5. SUBAREA DISTRIBUTION FOR REGIMES OF u_s/u_r

Pile subarea	Percent of pile surface area (Figure 4-3)			
	Pile A	Pile B1	Pile B2	Pile B3
0.2a	5	5	3	3
0.2b	35	2	28	25
0.2c	-	29	-	-
0.6a	48	26	29	28
0.6b	-	24	22	26
0.9	12	14	15	14
1.1	-	-	3	4

3. For any subarea of the pile surface having a narrow range of surface wind speed, use a variation of Equation 4-2 to calculate the equivalent friction velocity (u*), as follows:

$$u^* = \frac{0.4\ u_s^+}{\ln \frac{25}{0.5}} = 0.10\ u_s^+ \qquad (4\text{-}8)$$

From this point on, the procedure is identical to that used for a flat pile, as described above.

Implementation of the above procedure is carried out in the following steps:

1. Determine threshold friction velocity for erodible material of interest (see Tables 4-3 and 4-4 or Figure 4-2 or determine from mode of aggregate size distribution).

2. Divide the exposed surface area into subareas of constant frequency of disturbance (N).

3. Tabulate fastest mile values (u^+) for each frequency of disturbance and correct them to 10 m (u_{10}^+) using Equation 4-6.

4. Convert fastest mile values (u_{10}^+) to equivalent friction velocities (u*), taking into account (a) the uniform wind exposure of nonelevated surfaces, using Equation 4-5, or (b) the nonuniform wind exposure of elevated surfaces (piles), using Equations 4-7 and 4-8.

5. For elevated surfaces (piles), subdivide areas of constant N into subareas of constant u* (i.e., within the isopleth values of u_s/u_r in Figure 4-3 and Table 4-5) and determine the size of each subarea.

6. Treating each subarea (of constant N and u*) as a separate source, calculate the erosion potential (P_i) for each period between disturbances using Equation 4-4 and the emission factor using Equation 4-3.

7. Multiply the resulting emission factor for each subarea by the size of the subarea, and add the emission contributions of all subareas. Note that the highest 24-h emissions would be expected to occur on the windiest day of the year. Maximum emissions are calculated assuming a single wind event with the highest fastest mile value for the annual period.

The recommended emission factor equation presented above assumes that all of the erosion potential corresponding to the fastest mile of wind is lost during the period between disturbances. Because the fastest mile event typically lasts only about 2 min, which corresponds roughly to the half-life for the decay of actual erosion potential, it could be argued that the emission factor overestimates particulate emissions. However, there are other aspects of the wind erosion process which offset this apparent conservatism:

1. The fastest mile event contains peak winds which substantially exceed the mean value for the event.

2. Whenever the fastest mile event occurs, there are usually a number of periods of slightly lower mean wind speed which contain peak gusts of the same order as the fastest mile wind speed.

Of greater concern is the likelihood of overprediction of wind erosion emissions in the case of surfaces disturbed infrequently in comparison to the rate of crust formation.

4.1.3 <u>Wind Emissions From Continuously Active Piles</u>

For emissions from wind erosion of active storage piles, the following total suspended particulate (TSP) emission factor equation is recommended:

$$E = 1.9 \left(\frac{s}{1.5}\right) \left(\frac{365-p}{235}\right) \left(\frac{f}{15}\right) \text{ (kg/d/hectare)}$$

$$E = 1.7 \left(\frac{s}{1.5}\right) \left(\frac{365-p}{235}\right) \left(\frac{f}{15}\right) \text{ (lb/d/acre)} \qquad (4\text{-}9)$$

where: E = total suspended particulate emission factor

s = silt content of aggregate, percent

p = number of days with $\geq$0.25 mm (0.01 in.) of precipitation per year

f = percentage of time that the unobstructed wind speed exceeds 5.4 m/s (12 mph) at the mean pile height

The fraction of TSP which is PM_{10} is estimated at 0.5 and is consistent with the PM_{10}/TSP ratios for materials handling (Section 4.1.1) and wind erosion (Section 4.1.2). The coefficient in Equation (4-9) is taken from Reference 1, based on sampling of emissions from a sand and gravel storage pile area during periods when transfer and maintenance equipment was not operating. The factor from Reference 1, expressed in mass per unit area per day, is more reliable than the factor expressed in mass per unit mass of material placed in storage, for reasons stated in that report. Note that the coefficient has been halved to adjust for the estimate that the wind speed through the emission layer at the test site was one half of the value measured above the top of the piles. The other terms in this equation were added to correct for silt, precipitation, and frequency of high winds, as discussed in Reference 2. Equation (4-9) is rated in AP-42 as C for application in the sand and gravel industry and D for other industries (see Appendix A).

Worst case emissions from storage pile areas occur under dry windy conditions. Worst case emissions from materials handling (batch and continuous drop) operations may be calculated by substituting into Equation (4-9) appropriate values for aggregate material moisture content and for anticipated wind speeds during the worst case averaging period, usually 24 h. The treatment of dry conditions for vehicle traffic (Section 3.0) and for wind erosion (Equation 4-9), centering around parameter p, follows the methodology described in Section 3.0. Also, a separate set of nonclimatic correction parameters and source extent values corresponding to higher than normal storage pile activity may be justified for the worst case averaging period.

4.2 DEMONSTRATED CONTROL TECHNIQUES

The control techniques applicable to storage piles fall into distinct categories as related to materials handling operations (including traffic around piles) and wind erosion. In both cases, the control can be achieved by (a) source extent reduction, (b) source improvement related to work practices and transfer equipment (load-in and load-out operations), and (c) surface treatment. These control options are summarized in Table 4-6. The efficiency of these controls ties back to the emission factor relationships presented earlier in this section.

In most cases, good work practices which confine freshly exposed material provide substantial opportunities for emission reduction without the need for investment in a control application program. For example, pile activity, loading and unloading, can be confined to leeward (downwind) side of the pile. This statement also applies to areas around

TABLE 4-6. CONTROL TECHNIQUES FOR STORAGE PILES

Material handling	
Source extent reduction	Mass transfer reduction
Source improvement	Drop height reduction Wind sheltering Moisture retention
Surface treatment	Wet suppression
Wind erosion	
Source extent reduction	Disturbed area reduction Disturbance frequency reduction Spillage cleanup
Source improvement	Spillage reduction Disturbed area wind exposure reduction
Surface treatment	Wet suppression Chemical stabilization

the pile as well as the pile itself. In particular, spillage of material caused by pile load-out and maintenance equipment can add a large source component associated with traffic-entrained dust. Emission inventory calculations show, in fact, that the traffic dust component may easily dominate over emissions from transfer of material and wind erosion. The prevention of spillage and subsequent spreading of material by vehicle tracking is essential to cost-effective emission control. If spillage cannot be prevented because of the need for intense use of mobile equipment in the storage pile area, then regular cleanup should be employed as a necessary mitigative measure.

The evaluation of preventative methods which change the properties or exposure of transfer streams or surface material are discussed in the following section.

4.3 EVALUATION OF ALTERNATIVE CONTROL MEASURES

Preventive methods for control of windblown emissions from raw material storage piles include chemical stabilization, enclosures, and wetting. Physical stabilization by covering the exposed surface with less erodible aggregate material and/or vegetative stabilization are seldom practical control methods for raw material storage piles.

To test the effectiveness of chemical stabilization controls for wind erosion of storage piles and tailings piles, wind tunnel measurements have been performed. Although most of this work has been carried out in laboratory wind tunnels, portable wind tunnels have been used in the field on storage piles and tailings piles.[16,17] Laboratory wind tunnels have also been used with physical models to measure the effectiveness of wind screens in reducing surface wind velocity.[11]

4.3.1 Chemical Stabilization

A portable wind tunnel has been used to measure the control of coal pile wind erosion emissions by a 17 percent solution of Coherex® in water applied at an intensity of 3.4 L/m^2 (0.74 gal/yard^2), and a 2.8 percent solution of Dow Chemical M-167 Latex Binder in water applied at an average intensity of 6.8 L/m^2 (1.5 gal/yard^2).[16] The control efficiency of Coherex® applied at the above intensity to an undisturbed steam coal surface approximately 60 days before the test, under a wind of 15.0 m/s (33.8 mph) at 15.2 cm (6 in.) above the ground, was 89.6 percent for TP and approximately 62 percent for IP and FP. The control efficiency of the latex binder on a low volatility coking coal is shown in Figure 4-4.

Cost elements for chemical stabilization are presented in Table 4-7. The cost of a system for application of surface crusting chemicals to storage piles is $18,400 for the initial capital cost and $0.006 to $0.011/ft^2 for annual operating expenses based on April 1985 dollars.[18] Tables 4-8 and 4-9 provide recordkeeping forms for application of chemical dust suppressants.

4.3.2 Enclosures

Enclosures are an effective means by which to control fugitive particulate emissions from open dust sources. Enclosures can either fully or partially enclose the source. Included in the category of partial enclosures are porous wind screens or barriers. This particular type of enclosure is discussed in detail below.

With the exception of wind fences/barriers, a review of available literature reveals no quantitative information on the effectiveness of enclosures to control fugitive dust emissions from open sources. Types of passive enclosures traditionally used for open dust control include three-sided bunkers for the storage of bulk materials, storage silos for various types of aggregate material (in lieu of open piles), open-ended buildings, and similar structures. Practically any means that reduces wind entrainment of particles produced either through erosion of a dust-producing surface (e.g., storage silos) or by dispersion of a dust plume generated directly by a source (e.g., front-end loader in a three-sided enclosure) is generally effective in controlling fugitive particulate emissions. However, available data are not sufficient to quantify emission reductions.

Partial enclosures used for reducing windblown dust from large exposed areas and storage piles include porous wind fences and similar types of physical barriers (e.g., trees). The principle of the wind fence/barrier is to provide an area of reduced wind velocity which allows settling of the large particles (which cause saltation) and reduces the particle flux from the exposed surface on the leeward side of the fence/barrier. The control efficiency of wind fences is dependent on the physical dimensions of the fence relative to the source being

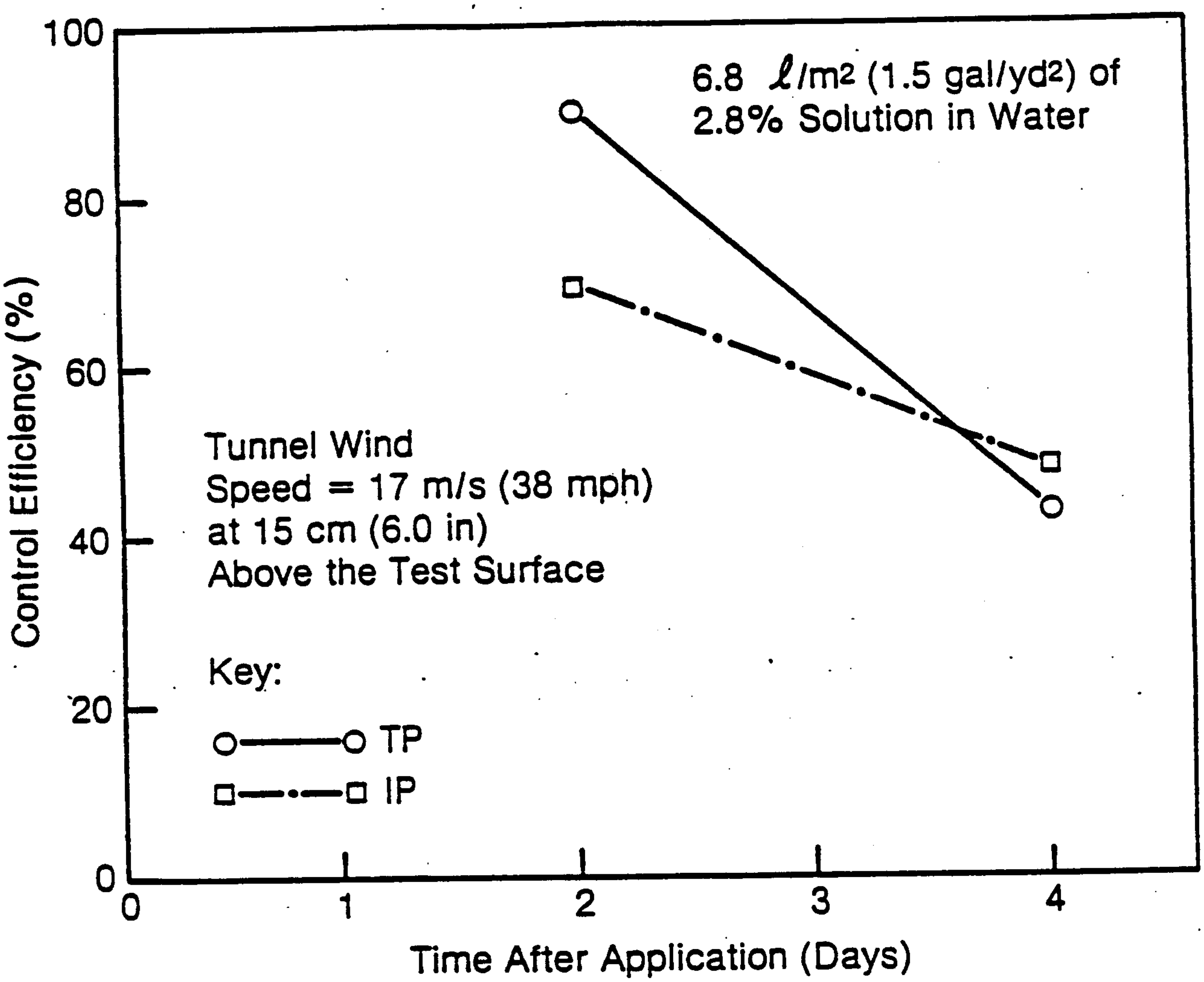


Figure 4-4. Decay in control efficiency of latex binder applied to coal storage piles.[15]

TABLE 4-7. CAPITAL AND O&M ITEMS FOR CHEMICAL STABILIZATION OF OPEN AREA SOURCES

Capital equipment

- Storage equipment
  - Tanks
  - Railcars
  - Pumps
  - Piping

- Application equipment
  - Trucks
  - Spray system
  - Piping (including winterizing)

O&M expenditures

- Utility or fuel costs
  - Water
  - Electricity
  - Gasoline or diesel fuel

- Supplies
  - Chemicals
  - Repair parts

- Labor
  - Application time
  - Road conditioning
  - System maintenance

TABLE 4-8. TYPICAL FORM FOR RECORDING CHEMICAL DUST SUPPRESSANT CONTROL PARAMETERS

Date	Time	Type of chemical	Dilution ratio	Application intensity, gal/yd^2	Area(s) treated	Equipment used	Operator initials	Comments

TABLE 4-9. TYPICAL FORM FOR RECORDING DELIVERY OF CHEMICAL DUST SUPPRESSANTS

Date	Time	Chemical delivered	Quantity delivered	Delivery agent	Facility destination[a]	Comments

[a]Denote whether suppressant will be applied immediately upon receipt or placed in storage.

controlled. In general, a porosity (i.e., percent open area) of 50 percent seems to be optimum for most applications. Wind fences/barriers can either be man-made structures or vegetative in nature.

A number of studies have attempted to determine the effectiveness of wind fences/barriers for the control of windblown dust under field conditions. Several of these studies have shown both a significant decrease in wind velocity as well as an increase in sand dune growth on the lee side of the fence.[19-22]

Various problems have been noted with the sampling methodology used in each of the field studies conducted to date. These problems tend to limit an accurate assessment of the overall degree of control achievable by wind fences/barriers for large open sources. Most of this work has either not thoroughly characterized the velocity profile behind the fence/barrier or adequately assessed the particle flux from the exposed surface.

A 1988 laboratory wind tunnel study of windbreak effectiveness for coal storage piles showed area-averaged wind speed reductions of ~50 to 70 percent for a 50 percent porosity windbreak with height equal to the pile height and length equal to the pile base. The windbreak was located three pile heights upwind from the base of the pile. This study also suggested "that fugitive dust emissions on the top of the pile may be controlled locally through the use of a windbreak at the top of the pile."

Based on the 1.3 power given in Equation (4-1), reductions of ~50 to 70 percent would correspond to ~60 to 80 percent control of material handling PM_{10} emissions. Estimation of wind erosion control requires source-specific evaluation because of the interrelation of u_t^* and u^* (for both controlled and uncontrolled conditions) in Equation (4-14).

This same laboratory study showed that a storage pile may itself serve as a wind break by reducing wind speed on the leeward face (Figure 4-3). The degree of wind sheltering and associated wind erosion emission reduction is dependent on the shape of the pile and on the approach angle of the wind to an elongated pile.

One of the real advantages of wind fences for the control of PM_{10} involves the low capital and operating costs.[21,23] These involve the following basic elements:

- Capital equipment:
  - Fence material and supports
  - Mounting hardware
- Operating and maintenance expenditures:
  - Replacement fence material and hardware
  - Maintenance labor

The following cost estimates (in 1980 dollars) were developed for wind screens applied to aggregate storage piles:[24]

- Artificial wind guards:
  - Initial capital cost = $12,000 to $61,000
- Vegetative wind breaks
  - Initial capital costs = $45 to $425 per tree

Due to the lack of quantitative data on costs associated with wind screens, it is recommended that local vendors be contacted to obtain more detailed data for capital and operating expenses. Also, since wind fences and screens are relatively "low tech" controls, it may be possible for the site operator to construct the necessary equipment using site personnel with less expense.

As with other options mentioned above, the main regulatory approach involved with wind fences and screens would involve recordkeeping by the site operator. Parameters to be specified in the dust control plan and routinely recorded are:

<u>General Information to be Specified in Plan</u>

1. Locations of all materials storage and handling operations to be controlled with wind fences referenced on a plot plan available to the site operator and regulatory personnel

2. Physical dimensions of each source to be controlled and configuration of each fence or screen to be installed

3. Physical characteristics of material to be handled or stored for each operation to be controlled by fence(s) or screen(s)

4. Applicable prevailing meteorological data (e.g., wind speed and direction) for site on an annual basis

<u>Specific Operational Records</u>

1. Date of installation of wind fence or screen and initials of installer

2. Location of installation relative to source and prevailing winds

3. Type of material being handled and stored and physical dimensions of source controlled

4. Date of removal of wind fence or screen and initials of personnel involved

<u>General Records to be Kept</u>

1. Fence or screen maintenance record

2. Log of meteorological conditions for each day of site operation

4.3.3 Wet Suppression Systems

Fugitive emissions from aggregate materials handling systems are frequently controlled by wet suppression systems. These systems use liquid sprays or foam to suppress the formation of airborne dust. The primary control mechanisms are those that prevent emissions through agglomerate formation by combining small dust particles with larger aggregate or with liquid droplets. The key factors that affect the degree of agglomeration and, hence, the performance of the system are the coverage of the material by the liquid and the ability of the liquid to "wet" small particles. This section addresses two types of wet suppression systems--liquid sprays which use water or water/surfactant mixtures as the wetting agent and systems which supply foams as the wetting agent.

Liquid spray wet suppression systems can be used to control dust emissions from materials handling at conveyor transfer points. The wetting agent can be water or a combination of water and a chemical surfactant. This surfactant, or surface active agent, reduces the surface tension of the water. As a result, the quantity of liquid needed to achieve good control is reduced. For systems using water only, addition of surfactant can reduce the quantity of water necessary to achieve a good control by a ratio of 4:1 or more.[25,26]

The design specifications for wet suppression systems are generally based on the experience of the design engineer rather than on established design equations or handbook calculations. Some general design guidelines that have been reported in the literature as successful are listed below:

1. A variety of nozzle types have been used on wet suppression systems, but recent data suggest that hollow cone nozzles produce the greatest control while minimizing clogging.[27]

2. Optimal droplet size for surface impaction and fine particle agglomeration is about 500 µm; finer droplets are affected by drift and surface tension and appear to be less effective.[28]

3. Application of water sprays to the underside of a conveyor belt improves the performance of wet suppression systems at belt-to-belt transfer points.[29]

Micron-sized foam application is an alternative to water spray systems. The primary advantage of foam systems is that they provide equivalent control at lower moisture addition rates than spray systems.[29] However, the foam system is more costly and requires the use of extra materials and equipment. The foam system also achieves control primarily through the wetting and agglomeration of fine particles. The following guidelines to achieve good particle agglomeration have been suggested:[30]

1. The foam can be made to contact the particulate material by any means. High velocity impact or other brute force means are not required.

2. The foam should be distributed throughout the product material. Inject the foam into free-falling material rather than cover the product with foam.

3. The amount applied should allow all of the foam to dissipate. The presence of foam with the product indicates that either too much foam has been used or it has not been adequately dispersed within the material.

Available data for both water spray and foam wet suppression systems are presented in Tables 4-10 and 4-11, respectively. The data primarily included estimates of control efficiency based on concentrations of total particulate or respirable dust in the workplace atmosphere. Some data on mass emissions reduction are also presented. The data should be viewed with caution in that test data ratings are generally low and only minimal data on process or control system parameters are presented.

The data in Tables 4-10 and 4-11 do indicate that a wide range of efficiencies can be obtained from wet suppression systems. For conveyor transfer stations, liquid spray systems had efficiencies ranging from 42 to 75 percent, while foam systems had efficiencies ranging from 0 to

TABLE 4-10 SUMMARY OF AVAILABLE CONTROL EFFICIENCY DATA FOR WATER SPRAYS

Ref. No.	Type of process	Type of material	Process design/ operating parameters	Control system parameters	Measurement technique[a]	No. of tests	Test data rating[b]	Control efficiency, percent[c]
25	Chain feeder to belt transfer	Coal	3 ft drop, 8 tons coal per load	8 sprays, 2.5 gal/min, above belt only	Personnel samplers, Type 1 test scheme	10	C	RP 56 TP 59
				8 sprays, 2.5 gal/min and one one spray on underside of belt	Personnel samplers, Type 1 test scheme	4	C	RP 81 TP 87
	Belt-to-belt transfer	Coal	Not specified	8 sprays, 2.5 gal/min above belt only[d]	Personnel samplers, Type 1 test scheme	10	C	RP 53
				8 sprays, 2.5 gal/min and one one spray on underside of belt[d]	Personnel samplers, Type 1 test scheme	4	C	RP 42
27	Grizzly transfer to the bucket elevator	Run of mill sand	Not specified	Liquid volume 757 mL	Personnel samplers, Type 1 test scheme	NA	C	RP 46
				Liquid volume 1,324 mL	Personnel samplers, Type 1 test scheme	NA	C	RP 58
				Liquid volume 1,324 mL[e]	Personnel samplers, Type 1 test scheme	NA	C	RP 54
				Liquid volume 1,324 mL[f]	Personnel samplers, Type 1 test scheme	NA	C	RP 54
28	Conveyor transport and transfer	Coal	2 belts 0.91 m and 1.07 m widths, ~500 m length	3 spray bars/belt, underside of tail pulley, 5-10 cc H_2O/s per bar, Delevan "Fanjet" sprays	Personnel samplers, Type 1 test scheme[g]	NA	D	RP-65-75

[a]RAM samples are from Realtime Aerosol Monitors, light scattering type instruments. Type 1 tests include measurements of a single source with and without control.
[b]Test rating scheme defined in Section 4.4.
[c]TP = Total particulate; RP = respirable particulate.
[d]Control applied at a point five transfers upstream.
[e]Water+1.5 percent surfactant.
[f]Water+2.5 percent surfactant.
[g]Individual test values not specified; no airflow data or QA/QC data.

TABLE 4-11. SUMMARY OF AVAILABLE CONTROL EFFICIENCY DATA FOR FOAM SUPPRESSION SYSTEMS

Ref. No.	Type of process	Type of material	Process design/ operating parameters	Control system parameters	Measurement technique[a]	No. of tests	Test data rating[b]	Control effi-ciency, percent[c]
27	Belt-to-belt transfer	30-mesh glass sand	Sand temp. ~120°F	Not specified	Personnel samplers, Type 1 test scheme	NA	C	RP 20[d]
	Belt-to-bin transfer	30-mesh glass sand	Sand temp. ~120°F	Not specified	Personnel samplers, Type 1 test scheme	NA	C	RP 33[d]
	Bulk loadout	30-mesh glass sand	Sand temp. ~120°F	Not specified	Personnel samplers, Type 1 test scheme	NA	C	RP 65[d]
	Screw-to-belt transfer	Cleaned run-of-mine sand	174 tons/h, sand temp. ~190°F	Moisture = 0.25 percent	Grav/RAM samplers, Type 1 scheme	4	C	RP 10[d]
	Bucket elevator discharge	Cleaned run-of-mind sand	179 tons/h, sand temp. ~190°F	Moisutre = 0.18 percent	RAM/personnel samplers, Type 1 test scheme	5	C	RP 8[d]
	Belt-to-belt transfer	Cleaned run-of-mine sand	193 tons/h, sand temp. ~190°F	Moisture = 0.18 percent	RAM/personnel samplers, Type 1 test scheme	8	C	RP 7[d]
	Feeder bar discharge	Cleaned run-of-mine sand	191 tons/h, sand temp. ~190°F	Moisutre = 0.19 percent	RAM/personnel samplers, Type 1 test scheme	6	C	RP 2[d]
	Grizzley transfer to bucket elevator	Dried run of mine sand	Not specified	Foam rate = 10.5 ft^3/ton sand Liquid rate = 0.38 gal/min	Personnel samplers, Type 1 test scheme	2	C	RP 97
				Foam rate = 8.2 ft^3/ton sand Liquid rate = 0.34 gal/min	Personnel samplers, Type 1 test scheme	1	C	RP 74
				Foam rate = 7.5 ft^3/ton sand Liquid rate = 0.20 gal/min	Personnel samplers. Type 1 test scheme	1	C	RP 68
25	Chain feeder to belt transfer	Coal	3-ft drop, 8 tons coal per load	50 psi H_2O, 2.5 percent reagent, four nozzles 15 to 20 ft^3 foam applied[d]	Personnel samplers, Type 1 test scheme	9	C	RP 96 IP 97
	Belt-to-belt transfer	Coal	Not specified	50 psi H_2O, 2.5 percent reagent, four nozzles 15 to 20 ft^3 foam applied[e]				RP 71

(continued)

TABLE 4-11. (continued)

Ref. No.	Type of process	Type of material	Process design/ operating parameters	Control system parameters	Measurement technique[a]	No. of tests	Test data rating[b]	Control efficiency, percent[c]
27	Grizzley	Dried run-of-mine sand	Not specified	Foam rate = 4.8 ft^3/ton sand Liquid rate = 0.18 gal/min	Personnel samplers, Type 1 test scheme	2	C	RP 0
				Foam rate = 2.6 ft^3/ton sand Liquid rate = 0.13 gal/min	Personnel samplers, Type 1 test scheme	NA	C	RP 0
				Liquid volume 1,420 mL	Personnel samplers, Type 1 test scheme	NA	C	RP 91
				Liquid volume 1,330 mL	Personnel samplers, Type 1 test scheme	NA	C	RP 73
				Liquid volume 764 mL	Personnel samplers, Type 1 test scheme	NA	C	RP 68

[a]RAM samples are from Realtime Aerosol Monitors, light scattering type instruments. Type 1 tests include measurements of a single source with and without control.
[b]Test rating scheme defined in Section 4.4.
[c]RP = respirable particulate.
[d]Efficiency based on concentrations only.

92 percent. The data are not sufficient to develop relationships between control or process parameters and control efficiencies. However, the following observations relative to the data in Tables 4-10 and 4-11 are noteworthy:

1. The quantity of foam applied to a system does have an impact on system performance. On grizzly transfer points, foam rates of 7.5 ft^3 to 10.5 ft^3 of foam per ton of sand produced increasing control efficiencies ranging from 68 to 98 percent.[31] Foam rates below 5 ft^3 per ton produced no measurable control.

2. Material temperature has an impact on foam performance. At one plant where sand was being transferred, control efficiencies ranged from 20 to 65 percent when 120°F sand was handled. When sand temperature was increased to 190°F, all control efficiencies were below 10 percent.[31]

3. Data at one plant suggest that underside belt sprays increase control efficiencies for respirable dust (56 to 81 percent).[29]

4. When spray systems and foam systems are used to apply equivalent moisture concentrations, foam systems appear to provide greater control.[31] On a grizzly feed to a crusher, equivalent foam and spray applications provided 68 percent and 46 percent control efficiency, respectively. Capital and O&M cost elements for wet suppression are shown in Table 4-12.

In estimating the wind erosion control effectiveness of wet suppression, it can be assumed that emissions are inversely proportional to the square of the surface moisture content. The emission/moisture dependence is embedded in the agricultural wind erosion equation as described in Section 7. It also appears in the observed relationship between the role of emissions from an unpaved road and the surface moisture content, as illustrated in Figure 3-3.

In addition, a relationship between surface moisture content and daily moisture addition has been developed from field studies of storage piles exposed to natural precipitation. The results of that research are illustrated in the example problem to be presented at the end of this section.

Costs associated with wet suppression systems include the following basic elements:

TABLE 4-12. WET SUPPRESSION SYSTEM CAPITAL AND O&M COST ELEMENTS

Capital equipment
• Water spray system
Supply pumps
Nozzles
Piping (including winterization)
Control system
Filtering units
• Water/surfactant and foam systems only
Air compressor
Mixing tank
Metering or proportioning unit
Surfactant storage area
O&M expenditures
• Utility costs
Water
Electricity
• Supplies
Surfactant
Screens
• Labor
Maintenance
Operation

- Capital equipment:
  - -- Spray nozzles or other distribution equipment
  - -- Supply pumps and plumbing (plus weatherization)
  - -- Water filters and flow control equipment
  - -- Tanker truck (if used)
- Operating and maintenance expenditures:
  - -- Water and chemicals
  - -- Replacement parts for nozzles, truck, etc.
  - -- Operating labor
  - -- Maintenance labor

Reference 6 estimates the following costs (in 1985 dollars):

- Regular watering of storage piles:
  - -- Initial capital cost = $18,400 per system
- Watering of exposed areas:
  - -- Initial capital cost = $1,053 per acre
  - -- Annual operating cost = $25 to 67 per acre

The costs associated with a stationary wet suppression system using chemical surfactants for the unloading of limestone from trucks at aggregate processing plants (in 1980 dollars) have been estimated at: capital = $72,000; annual = $26,000. Typical costs for wet suppression of materials transfer operations are listed in Table 4-13.

As with watering of unpaved surfaces, enforcement of a wet suppression control program would consist of two complementary approaches. The first would be record keeping to document that the program is being implemented and the other would be spot-checks and grab sampling. Both were discussed previously above.

Records must be kept that document the control plan and its implementation. Pertinent parameters to be specified in a plan and to be regularly recorded include:

General Informatio to be Specified in Plan

1. Locations of a ma ials storage and handling operations referenced on plot plan of the site available to the site operator and regulatory personnel

2. Materials deliv y o transport flow sheet which indicates the type of material, its ha lin and storage, size and composition of storage piles, etc.

TABLE 4-13. TYPICAL COSTS FOR WET SUPPRESSION OF MATERIAL TRANSFER POINTS

Source method	Initial cost, April 1985 dollars[b]	Unit operating cost, April 1985 dollars[b]
Railcar unloading station (foam spray)	48,700	NR
Railcar unloading station (charged fog)	168,000	NR
Conveyor transfer point (foam spray)	23,700	0.02 to 0.05/ton material treated
Conveyor transfer point (charged fog)	19,800	NR

[a]Reference 18. NR = not reported.
[b]January 1980 costs updated to April 1985 cost by Chemical Engineering Index. Factor = 1.315.
[c]Based on use of 16 large devices at $10,500 each.
[d]Based on use of three small devices at $6,600 each.

3. The method and application intensity of water, etc., to be applied to the various materials and frequency of application, if not continuous

4. Dilution ratio for chemicals added to water supply, if any

5. Complete specifications of equipment used to handle the various materials and for wet suppression

6. Source of water and chemical(s), if used

Specific Operational Records

1. Date of operation and operator's initials

2. Start and stop time of wet suppression equipment

3. Location of wet suppression equipment

4. Type of material being handled and number of loads (or other measure of throughput) loaded/unloaded between start and stop time (if material is being pushed, estimate the volume or weight)

5. Start and stop times for tank filling

General Records to be Kept

1. Equipment maintenance records

2. Meteorological log of general conditions

3. Records of equipment malfunctions and downtime

4.4 EXAMPLE DUST CONTROL PLAN--WATERING OF COAL STORAGE PILE

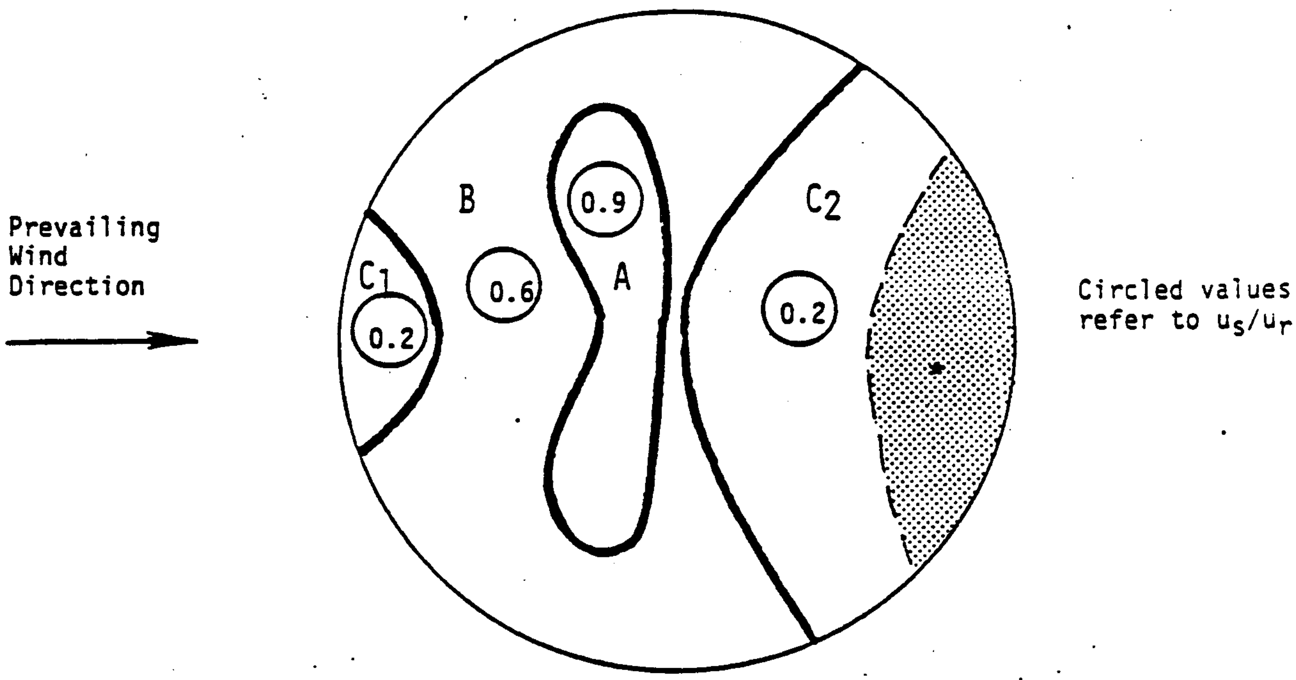
Description of Source

- Conically shaped pile (uncrusted coal)
- Pile height of 11 m; 29.2 m base diameter; 838 m^2 surface area
- Daily reclaiming of downwind face of pile; pile replenishment every 3 d affects entire pile surface (Figure 4-5)
- LCD as shown in Figure 4-6 for a typical month
- Coal surface moisture content of 1.5 percent

Calculation of Uncontrolled Emissions

Step 1: In the absence of field data for estimating the threshold friction velocity, a value of 1.12 m/s is obtained from Table 4-3.

Step 2: Except for a small area near the base of the pile (see Figure 4-5), the entire pile surface is disturbed every 3 d, corresponding to a value of N = 120/yr. It will be shown that the contribution of the area where daily activity occurs is negligible so that it does not need to be treated separately in the calculations.



* A portion of C_2 is disturbed daily by reclaiming activities.

Area ID	$\frac{u_s}{u_r}$	Pile Surface %	Pile Surface Area (m^2)
A	0.9	12	101
B	0.6	48	402
$C_1 + C_2$	0.2	40	335
			838

Figure 4-5. Example 1: Pile surface areas within each wind speed regime.

Local Climatological Data

MONTHLY SUMMARY

WIND					
			FASTEST MILE		
RESULTANT DIR.	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	SPEED M.P.H.	DIRECTION	DATE
13	14	15	16	17	22
30	5.3	6.9	9	36	1
01	10.5	10.6	14	01	2
10	2.4	6.0	10	02	3
13	11.0	11.4	16	13	4
12	11.3	11.9	15	11	5
20	11.1	19.0	23	30	6
29	19.6	19.8	30	30	7
29	10.9	11.2	17	30	8
22	3.0	8.1	15	13	9
14	14.6	15.1	23	12	10
29	22.3	23.3	31	29	11
17	7.9	13.5	23	17	12
21	7.7	15.5	13	18	13
10	4.5	9.6	22	13	14
10	6.7	8.8	13	11	15
01	13.7	13.8	21	36	16
33	11.2	11.5	15	34	17
27	4.3	5.8	12	31	18
32	9.3	10.2	14	35	19
24	7.5	7.8	18	24	20
22	10.3	10.6	15	20	21
32	17.1	17.3	25	32	22
29	2.4	8.5	14	13	23
07	5.9	8.8	15	02	24
34	11.3	11.7	17	32	25
31	12.1	12.2	16	32	26
30	8.3	8.5	16	26	27
30	8.2	8.3	13	32	28
33	5.0	6.6	10	32	29
34	3.1	5.2	9	31	30
29	4.9	5.5	8	25	31
FOR THE MONTH:					
30	3.3	11.1	31	29	
—	—	—	DATE:	11	

Figure 4-6. Daily fastest miles of wind for periods of interest.

Step 3: The calculation procedure involves determination of the fastest mile for each period of disturbance. Figure 4-6 shows a representative set of values (for a 1-mo period) that are assumed to be applicable to the geographic area of the pile location. The values have been separated into 3-d periods, and the highest value in each period is indicated. In this example, the anemometer height is 7 m, so that a height correction to 10 m is needed for the fastest mile values.

From Equation (4-6)

$$u_{10}^{+} = u_{7}^{+} \frac{\ln (10/0.005)}{\ln (7/0.005)}$$

$$u_{10}^{+} = 1.05\ u_{7}^{+}$$

Step 4: The next step is to convert the fastest mile value for each 3-d period into the equivalent friction velocities for each surface wind regime (i.e., u_s/u_r ratio) of the pile, using Equations 4-7 and 4-8. Figure 4-5 shows the surface wind speed pattern (expressed as a fraction of the approach wind speed at a height of 10 m). The surface areas lying within each wind speed regime are tabulated below the figure.

The calculated friction velocities are presented in Table 4-14. As indicated, only three of the periods contain a friction velocity which exceeds the threshold value of 1.12 m/s for an uncrusted coal pile. These three values all occur within the $u_s/u_r = 0.9$ regime of the pile surface.

Step 5: This step is not necessary because there is only one frequency of disturbance used in the calculations. It is clear that the small area of daily disturbance (which lies entirely within the $u_s/u_r =$ 0.2 regime) is never subject to wind speeds exceeding the threshold value.

Steps 6 and 7: The final set of calculations (shown in Table 4-15) involves the tabulation and summation of emissions for each disturbance period and for the affected subarea. The erosion potential (P) is calculated from Equation (4-4).

TABLE 4-14. EXAMPLE 1: CALCULATION OF FRICTION VELOCITIES

3-day period	u_7^+		u_{10}^+		u_s/u_r	$u^* = 0.1\ u_s^+$ (m/s)		
	mph	m/s	mph	m/s		0.2	0.6	0.9
1	14	6.3	15	6.6		0.13	0.40	0.59
2	29	13.0	31	13.7		0.27	0.82	1.23
3	30	13.4	32	14.1		0.28	0.84	1.27
4	31	13.9	33	14.6		0.29	0.88	1.31
5	22	9.8	23	10.3		0.21	0.62	0.93
6	21	9.4	22	9.9		0.20	0.59	0.89
7	16	7.2	17	7.6		0.15	0.46	0.68
8	25	11.2	26	11.8		0.24	0.71	1.06
9	17	7.6	18	8.0		0.16	0.48	0.72
10	13	5.8	14	6.1		0.12	0.37	0.55

TABLE 4-15. EXAMPLE 1: CALCULATION OF PM_{10} EMISSIONS[a]

3-Day period	u^*, m/s	$u^* - u_t^*$, m/s	P, g/m²	ID	Pile Surface Area, m²	kPA, g
2	1.23	0.11	3.45	A	101	170
3	1.27	0.15	5.06	A	101	260
4	1.31	0.19	6.84	A	101	350
			Total PM_{10} emissions = 780			

[a]Where $u_t^* = 1.12$ m/s for uncrusted coal and k = 0.5 for PM_{10}.

For example, the calculation for the second 3-d period is:

$$P_2 = 58(1.23-1.12)^2+25(1.23-1.12)$$

$$= 0.70+2.75 = 3.45 \text{ g/m}^2$$

The PM_{10} emissions generated by each event are found as the product of the PM_{10} multiplier (k = 0.5), the erosion potential (P), and the affected area of the pile (A).

As shown in Table 4-15, the results of these calculations indicate a monthly PM_{10} emission total of 780 g.

Target Control Efficiency: 60 percent

Method of Control: Daily watering of erodible surfaces of coal pile (2 gal/m²)

Demonstration of Control Program Adequacy: Wind-generated dust emissions are known to be strongly dependent (inverse square) on moisture content as described in Section 4.3.3. In addition, coal storage pile surface moisture, M, is correlated with weighted precipitation, P_w, as follows:[3]

$$M_c = 0.13\, P_w + 1.41 \qquad (4\text{-}10)$$

where: M = surface moisture content (percent)

$$P_w = \sum_{n=1}^{4\text{ d}} P_n \exp[-(n - 0.5)] \text{ (mm)}$$

P_n = daily precipitation or watering amount (mm) for the nth day in the past

For uniform daily water application, $P_w \sim P_n$.

Uncontrolled PM_{10} wind erosion emissions, E_u, from the storage pile were shown to be 780 g for the month. To achieve a control efficiency of 60 percent, calculate the controlled emissions, E_c, using the following relationship.

$$E_c = E_u (1 - 0.60)$$

$$= 312 \text{ g}$$

The inverse square relationship of wind emissions with surface moisture content can be written as follows:

$$E_c = \frac{(M_u)^2}{(M_c)^2} E_u$$

Solving for the controlled surface moisture content, M_c, using an uncontrolled moisture content, M_u = 1.5 percent, produces:

$$M_c = M_u \quad \frac{E_u}{E_c} = 2.4 \text{ percent}$$

To achieve this moisture content, use Equation 4-10 to determine the daily water application rate.

$$P_w = \frac{M_c - 1.41}{0.13}$$

$$= 7.4 \text{ mm}$$

Convert this daily watering amount to gal/m² of erodible pile surface to obtain a recommended daily water application rate of 1.95 gal H_2O/m^2.

The upper pile area where $U_s/U_r \geq 0.9$ is the only surface which needs to be controlled in the example month since this area has been shown to produce virtually all the emissions. In this instance, it is only necessary to water the pile surface impacted by winds producing U_s/U_r values ≥ 0.9. This area can be estimated from Figure 4-5 if the 0.9 subarea is rotated about the pile center to represent the possible 360 degree impact of winds on the pile.

The surface area to be controlled is equivalent to the area of a cone with base diameter of about 21.3 m. This upper cone has an area of 53 percent of the entire coal pile surface, e.g., about 450 m². Consequently, 900 gal of water applied daily to the 450 m² of erodible surface will achieve a control efficiency of 60 percent.

4.5 POTENTIAL REGULATORY FORMATS

There are several possible regulatory formats for control of dust emissions from storage piles. Opacity standards are suitable for a standard observed at the point of emissions, such as continuous drop from a stacker; however, they may not be legally applied at the property line.

For wet suppression and chemical stabilization, suitable recordkeeping forms, such as those provided above, would provided evidence of control plan implementation. In addition, simple measurements of moisture level in transferred material or of the crust strength of the chemically treated surface could be used to verify compliance. In addition, the loading as well as the texture of material deposited around the pile could be used to check whether good work practices are being employed relative to pile reclamation and maintenance operations. The suitability of these measurements of surrogate parameters for source emissions stems from the emission factor models which relate the parameters directly to emission rate.

4.6 REFERENCES FOR SECTION 4

1. Cowherd, C., Jr., et al. Development of Emission Factors for Fugitive Dust Sources. EPA-450/3-74-037. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. June 1974.

2. Bohn, R., et al. Fugitive Emissions from Integrated Iron and Steel Plants. EPA-600/2-78-050. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. March 1978.

3. Cowherd, C., Jr., et al. Iron and and Steel Plant Open Dust Source Fugitive Emission Evaluation. EPA-600/2-79-103. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. May 1979.

4. Bohn, R. Evaluation of Open Dust Sources in the Vicinity of Buffalo, New York. U. S. Environmental Protection Agency, New York, New York. March 1979.

5. Cowherd, C., Jr., and T. Cuscino, Jr. Fugitive Emissions Evaluation. Equitable Environmental Health, Inc., Elmhurst, Illinois. February 1977.

6. Cuscino, T., et al. Taconite Mining Fugitive Emissions Study. Minnesota Pollution Control Agency, Roseville, Minnesota. June 1979.

7. Axetell, K., and C. Cowherd, Jr. Improved Emission Factors for Fugitive Dust from Western Surface Coal Mining Sources. 2 Volumes. EPA Contract No. 68-03-2924, PEDCo Environmental, Inc., Kansas City, Missouri. July 1981.

8. Cowherd, C., Jr. "Background Document for AP-42 Section 11.2.7 on Industrial Wind Erosion." EPA Contract No. 68-02-4395, Midwest Research Institute. July 1988.

9. Chepil, W. S. "Improved Rotary Sieve for Measuring State and Stability of Dry Soil Structure." Soil Science Society of America Proceedings., 16:113-117. 1952.

10. Gillette, D. A., et al. "Threshold Velocities for Input of Soil Particles into the Air by Desert Soils." Journal of Geophysical Research, 54(C10):5621-5630.

11. Studer, B. J. B., and S. P. S. Arya. "Windbreak Effectiveness for Storage Pile Fugitive Dust Control: A Wind Tunnel Study." Journal of the Air Pollution Control Association. 38:135-143. 1988.

12. Muleski, G. E. "Coal Yard Wind Erosion Measurements. Final Report prepared for Industrial Client of Midwest Research Institute, Kansas City, Missouri. March 1985.

13. Nicking, W. G., and J. A. Gillies. "Evaluation of Aerosol Production potential of Type Surfaces in Arizona." Submitted to Engineering-Science. Arcadia, California, for EPA Contract No. 68-02-388. 1986.

14. Local Climatological Data. Monthly Summary Available for each U.S. Weather Station from the National Climatic Center. Asheville, North Carolina 28801.

15. Changery, M. J. National Wind Data Index Final Report. National Climatic Center, Asheville, North Carolina, HCO/T1041-01 UC-60. December 1978.

16. Cuscino, T., Jr., G. E. Muleski, and C. Cowherd, Jr. Iron and Steel Plant Open Source Fugitive Emission Control Evaluation. EPA-600/2-83-110, NTIS No. PB84-1110568. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. October 1983.

17. Bohn, R. R., and J. D. Johnson. Dust Control on Active Tailings Ponds. Contract No. J0218024. U.S. Bureau of Mines, Minneapolis, Minnesota. February 1983.

18. U. S. Environmental Protection Agency. Control Techniques for Particulate Emissions From Stationary Sources--Volume 1. EPA-450/3-81-005a. Emission Standards and Engineering Division, Research Triangle Park, N.C. September 1982.

19. Chepil, N. S., and N. P. Woodruff. "The Physics of Wind Erosion and Its Control." In Advances in Agronomy, Vol. 15, Academic Press, New York. 1963.

20. Carnes, D., and D. C. Drehmel. "The Control of Fugitive Emissions Using Windscreens." In Third Symposium on the Transfer and Utilization of Particulate Control Technology (March 1981), Volume IV, EPA-600/9-82-005d, NTIS No. PB83-149617. April 1982.

21. Larson, A. G. Evaluation of Field Test Results on Wind Screen Efficiency. Fifth EPA Symposium on Fugitive Emissions: Measurement and Control, Charleston, South Carolina. May 3-5, 1982.

22. Westec Services, Inc. Results of Test Plot Studies at Owens Dry Lake, Inyo County, California. San Diego, California. March 1984.

23. Radkey, R. L., and P. B. MacCready. A Study of the Use of Porous Wind Fences to Reduce Particulate Emissions at the Mohave Generating Station. AV-R-9563, AeroVironment, Inc., Pasadena, California. 1980.

24. Ohio Environmental Protection Agency. 1980. Reasonably Available Control Measures for Fugitive Dust Sources. Columbus, Ohio. September 1980.

25. U. S. Environmental Protection Agency. Non-Metallic Processing Plants, Background Information for Proposed Standards. EPA-450/3-83-001a, NTIS No. PB83-258103. Research Triangle Park, North Carolina. March 1983.

26. JACA Corporation. Control of Air Emissions from Process Operations in the Rock Crushing Industry. EPA-340/1-79-002. U. S. Environmental Protection Agency, Washington, D.C., p. 15. January 1979.

27. U.S. Bureau of Mines. Dust Knockdown Performance of Water Spray Nozzles. Technology News, No. 150. July 1982.

28. Courtney, W., and L. Cheng. Control of Respirable Dust by Improved Water Sprays. Published in Respirable Dust Control Proceedings, Bureau of Mines Technology Transfer Seminars, Bureau of Mines Information Circular 8753, p. 96. 1978.

29. Seibel, R. Dust Control at a Conveyor Transfer Point Using Foam and Water Sprays. Bureau of Mines, Technical Progress Report 97. May 1976.

30. Cole, H. Microfoam for the Control of Source and Fugitive Dust Emissions. Paper 81-55.2. Presented at the 74th Annual Meeting of the Air Pollution Control Association, Philadelphia, Pennsylvania. June 1981.

31. Volkwein, J. C., A. B. Cecala, and E. D. Thimons. Use of Foam for Dust Control in Minerals Processing. Bureau of Mines RI 8808. 1983.

5.0 CONSTRUCTION AND DEMOLITION ACTIVITIES

Construction and demolition activities are temporary but important sources of PM_{10} in urban areas. These activities involve a number of separate dust-generating operations which must be quantified to determine the total emissions from the site and thus its impact on ambient air quality. Also, the specific type of activities which are conducted onsite will depend of the nature of the construction or demolition project taking place.

In the case of construction, a project may involve the erection of a building(s), single- or multifamily homes, or the installation of a road right-of-way. Operations commonly found in these types of construction projects consist of: land clearing, drilling and blasting, excavation, cut-and-fill operations (i.e., earthmoving), materials storage and handling, and associated truck traffic on unpaved surfaces.

In addition, secondary impacts associated with construction sites involve mud/dirt carryout onto paved surfaces. The additional loading caused by carryout can substantially increase PM_{10} emissions on city streets over the life of the project.

With regard to demolition, a particular project may involve the razing and removal of an entire building(s), a major interior renovation of a structure, or a combination of the two. Dust-producing operations associated with demolition are: mechanical or explosive dismemberment; debris storage, handling, and transport operations; and truck traffic over unpaved surfaces onsite.

Like construction, demolition activities can also create mud/dirt carryout onto paved surfaces with its associated increase in emissions. Also, since building debris is usually being removed from the site, spillage from trucks can also be of concern in increasing the amount of surface loading deposited on the paved street(s) providing access to the site. The generic sources of PM_{10} involved in construction and demolition sites are shown in Table 5-1.[1]

TABLE 5-1. GENERIC OPEN DUST SOURCES ASSOCIATED WITH CONSTRUCTION AND DEMOLITION SITES

Construction Sites

- Pushing (land clearing and earthmoving)
- Drilling and blasting
- Batch drop operations (loader operation)
- Storage piles (soil and construction aggregates)
- Exposed areas
- Vehicle traffic on unpaved surfaces
- Mud/dirt carryout onto paved surfaces

Demolition Sites

- Explosive and mechanical dismemberment (blasting and wrecking ball operations)
- Pushing (dozer operation)
- Batch drop operations (loading debris into trucks)
- Storage piles (debris)
- Exposed areas
- Vehicular traffic on unpaved surfaces
- Mud/dirt/debris carryout onto paved surfaces

This section presents a discussion of available emission factors, demonstrated control techniques, alternative control measures, and possible formats for determining compliance for controlled construction and demolition sites. It must be cautioned, however, that the information presented is for generic sites and site-specific analyses will be necessary for compliance determination.

5.1 ESTIMATION OF EMISSIONS

5.1.1 Construction Emissions

At present, the only emission factor available in AP-42 is 1.2 tons/acre/month (related to particles <30 μm Stokes' diameter) for an entire construction site. No factor has been published for demolition in AP-42. However, PM_{10} emission factors have been developed for construction site preparation using test data from a study conducted in Minnesota for topsoil removal, earthmoving (cut-and-fill), and truck haulage operations.[2] For these operations, the PM_{10} emission factors based on the level of vehicle activity (i.e., vehicle kilometers traveled or VKT) occurring onsite are:[3]

- Topsoil removal: 5.7 kg/VKT for pan scrapers
- Earthmoving: 1.2 kg/VKT for pan scrapers
- Truck haulage: 2.8 kg/VKT for haul trucks

PM_{10} emissions due to materials handling and wind erosion of exposed areas can be calculated using the emission factors presented in Sections 4.0 and 6.0, respectively.

5.1.2 Demolition Emissions

For demolition sites, the operations involved in demolishing and removing structures from a site are:

- Mechanical or explosive dismemberment
- Debris loading
- Onsite truck traffic
- Pushing (dozing) operations

5.1.2.1 Dismemberment. Since no emission factor data are available for blasting or wrecking a building, the first operation is addressed through the use of the revised AP-42 materials handling equation:[3,4]

$$E_D = k(0.0016) \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \quad (5\text{-}1)$$

where E_D = PM_{10} emission factor in kg/Mg of material
k = particle size multiplier = 0.35 for PM_{10}
U = mean wind speed in m/s (default = 2.2 m/s)
M = material moisture content in percent (default = 2 percent)

and E_D = 0.00056 kg/Mg (with default parameters)

The above factor can be modified for waste tonnage related to structural floor space where 1 m^2 of floor space represents 0.45 Mg of waste material (0.046 ton/ft^2).[3] The revised emission factor related to structural floor space (using default parameters) can be obtained by:

$$E_D = 0.00056 \text{ kg/Mg} \cdot \frac{0.45 \text{ Mg}}{m^2}$$

$$= 0.00025 \text{ kg/m}^2$$

5.1.2.3 Debris Loading. The emission factor for debris loading is based on two tests of the filling of trucks with crushed limestone using a front-end loader which is part of the test basis for the batch drop equation in AP-42, § 11.2.3.[5] The resulting emission factor for debris loading is:[3]

$$E_L = k(0.029)\ \text{kg/Mg} \cdot \frac{0.45\ \text{Mg}}{\text{m}^2}$$

$$= 0.0046\ \text{kg/m}^2$$

where 0.029 kg/Mg is the average measured TSP emission factor and k is the particle size multiplier (0.35 for PM_{10}).

5.1.2.4 Onsite Truck Traffic. Emissions from onsite truck traffic is generated from the existing AP-42 unpaved road equation presented in Section 3.0 above.[5]

$$E = 1.7\ k\ \left(\frac{s}{12}\right)\left(\frac{S}{48}\right)\left(\frac{W}{2.7}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365 - p}{365}\right) \qquad (5\text{-}2)$$

where
E = PM_{10} emission factor in kg/vehicle kilometer traveled (VKT)
k = particle size multiplier = 0.36 for PM_{10} .
s = silt content in percent (default = 12 percent)
S = truck speed in km/h (default = 16 km/h)
W = truck weight in Mg (default = 20 Mg)
w = number of truck wheels (default = 10 wheels)
p = number of days with measurable precipitation (default = 0 days)

and E_T = 1.3 kg/VKT (with default values)

The above factor is converted from kg/VKT to kg/m² of structural floor space by:[3]

$$E_T = \frac{0.40\ \text{km}}{23\ \text{m}^3\ \text{waste}} \cdot \frac{1\ \text{m}^3\ \text{waste}}{4\ \text{m}^3\ \text{volume}} \cdot \frac{7.65\ \text{m}^3\ \text{volume}}{0.836\ \text{m}^2\ \text{floor space}} \cdot \frac{1.3\ \text{kg}}{\text{VKT}}$$

$$= 0.052\ \text{kg/m}^2$$

5.1.2.5 Pushing Operations. For pushing (bulldozer) operations, the AP-42 emission factor equation for overburden removal at Western surface coal mines can be used.[5] Although this equation actually relates to particulate <15 µmA, it would be expected that the PM_{10} emissions from such operations would be generally comparable. The AP-42 dozer equation is:

$$E_p = \frac{0.45\ (S)^{1.5}}{(M)^{1.4}} \tag{5-3}$$

where E_p = PM_{10} emission rate in kg/h

S = silt content of surface material in percent (default = 6.9 percent)

M = moisture content of surface material in percent (default = 7.9 percent)

and E_p = 0.45 kg/h (with default parameters)

Finally, PM_{10} emissions due to wind erosion of exposed areas can be calculated as discussed in Section 6.0. In general, these emissions are expected to be minor as compared to other sources.

5.1.3 Mud/Dirt Carryout Emissions

Finally, the increase in emissions on paved roads due to mud/dirt carryout have been developed based on surface loading measurements at eight sites.[6] Tables 5-2 and 5-3 provide these emission factors in terms of gm/vehicle pass which represent PM_{10} generated over and above the "background" for the paved road sampled. Table 5-2 expresses the emission factors according to the volume of traffic entering and leaving the site whereas Table 5-3 expresses the same data according to type of construction.

5.2 DEMONSTRATED CONTROL TECHNIQUES

As discussed above, similar generic open dust sources exist at both construction and demolition sites. Therefore, similar types of controls would also apply. In this section, a discussion is provided on the various techniques available for the control of open dust sources associated with construction and demolition. Detailed information on control efficiency, implementation cost, etc., will be presented in Section 5.3 below.

TABLE 5-2. EMISSIONS INCREASE (ΔE) BY SITE TRAFFIC VOLUME[a]

Particle size fraction[b]	Sites with >25 vehicle/d			Sites with <25 vehicle/d		
	Mean, $\bar{x}$	Standard deviation, σ	Range	Mean, $\bar{x}$	Standard deviation, σ	Range
<-30 μm	52	28	15-80	19	7.8	14-28
<10 μm	13	6.7	4.4-20	5.5	2.3	4.2-8.1
<2.5 μm	5.1	2.6	1.7-7.8	2.2	0.88	1.6-3.2

[a]ΔE expressed in g/vehicle pass.
[b]Aerodynamic diameter.

TABLE 5-3. EMISSIONS INCREASE (ΔE) BY CONSTRUCTION TYPE[a]

Particle size fraction[b]	Commercial			Residential		
	Mean, $\bar{x}$	Standard deviation, σ	Range	Mean, $\bar{x}$	Standard deviation, σ	Range
<-30 μm	65	39	15-110	39	22	10-72
<10 μm	16	9.3	4.2-25	10	5.4	2.8-19
<2.5 μm	6.3	3.6	1.6-9.7	3.9	2.1	1.1-7.3

[a]ΔE expressed in g/vehicle pass.
[b]Aerodynamic diameter.

5.2.1 Work Practice Controls

Work practice controls refer to those measures which reduce either emissions potential and/or source extent. These will be discussed below for both construction and demolition activities.

For construction activities, a number of work practice controls can be applied to reduce PM_{10} emissions from the site. These include paving of roads and access points early in the project, compaction or stabilization (chemical or vegetative) of disturbed soil, phasing of earthmoving activities to reduce source extent, and reduction of mud/dirt carryout onto paved streets. Each of these techniques is pretty much site-specific. However, subdivisions, for example, can be constructed in phases (or plats) whereby the amount of land disturbed is limited to only a selected number of home sites. Also, subdivision streets can be constructed and paved when the utilities are installed, thus reducing the duration of land disturbance.

Finally, increased surface loading on paved city streets due to mud/dirt carryout can be reduced to mitigate secondary site impacts. This may involve the installation of a truck wash at access points to remove mud/dirt from the vehicles prior to exiting the site or periodic cleaning of the street near site entrances. All of these techniques require preplanning for implementation without substantially interfering with the conduct of the project.

In the case of demolition sites, the work practice controls which can be employed are far more limited than is the case of construction. Normally, demolition is an intense activity conducted over a relatively short time frame. Therefore, measures to limit emissions potential or source extent are not usually possible. The only technique which seems feasible is the control of carryout onto paved city streets. This could be conducted by installing a truck wash and grizzly to remove mud and debris from the vehicles as they leave the site. Also the use of freeboard over the load will reduce blow-off dust from the truck beds. It should also be remembered that asbestos removal is also of concern at some sites which involve additional controls not normally necessary for most demolition activities.

As a final note, there are no quantitative control efficiency values for any of the above work practices. Estimates can be obtained by a site-specific analysis of alternative site preparation schemes based on the planned level of activity for the entire project using the emission factors provided in Section 5.1 above. For mud/dirt carryout, a quantitative value for control efficiency could be obtained if street surface loading data for uncontrolled (i.e., those which do not employ any measures to reduce carryout) and controlled sites were collected. Also, alternative methods for reducing mud/dirt carryout could be explored by a properly designed study of available techniques.

5.2.2 Traditional Control Technology

In addition to work practices, a number of open source controls are also available for reducing PM_{10} emissions from construction and demolition sites. These traditional controls are: watering of unpaved surfaces; wet suppression for materials storage, handling, and transfer operations; wind fences for control of windblown dust; and water injection and filters for drilling operations. Each will be discussed briefly with detailed information included in Section 5.3 below.

The use of water is probably the most widely used method to control open source emissions. However, very little quantitative data are available on the efficacy of wet suppression for the control of fugitive PM_{10}. This is especially true for materials storage and handling operations. Some limited data are available for watering of unpaved surfaces, but estimation of control efficiency (and thus a watering control plan) is difficult. Those data which are available are presented below.

It should be noted that wet suppression of unpaved surfaces using chemical dust palliatives has not been included in the list of available controls for construction/demolition. This is due to the fact that the temporary nature of these operations generally preclude their use. The same travel surface is not used for extended periods which is usually required for cost-effective application of chemical suppressants. The only possibility that might be considered is the use of hydroscopic salts which require only one application at the beginning of the project. Therefore, the use of chemical suppressants will not be discussed further in this section.

With regard to wind fences, only three studies have been identified for this particular control technique which attempt to quantify the degree of control achieved. Wind fences (and other types of barriers) are extremely cost effective in that they incur little or no operating and maintenance costs. For this reason wind fences are an attractive control alternative for windblown PM_{10} emissions.

Finally, both water injection and fabric filters have been used to control dust generation during drilling operations. Since this is a relatively minor source associated with construction operations, these controls do not offer significant emissions reductions. It should be noted, however, that drilling may be important at certain sites.

5.3 EVALUATION OF ALTERNATIVE CONTROL MEASURES

In this section, the various alternative control measures for fugitive PM_{10} at construction and demolition sites will be discussed in some detail. Included in this discussion will be the manner in which each technique controls emissions, methods for estimating control efficiency, an identification of cost elements to be considered, and available cost estimates for each in terms of capital and operating expenditures. Each control will be presented in the order shown previously in Section 5.2.

5.3.1 Watering of Unpaved Surfaces

5.3.1.1 Control Efficiency. Watering of unpaved roads is one form of wet dust suppression. This technique prevents (or suppresses) the fine particulate from leaving the surface and becoming airborne through the action of mechanical disturbance or wind. The water acts to bind the smaller particles to the larger material thus reducing emissions potential.

The control efficiency of watering of unpaved surfaces is a direct function of the amount of water applied per unit surface area (liters per square meter), the frequency of application (time between reapplication), the volume of traffic traveling over the surface between applications, and prevailing meteorological conditions (e.g., wind speed, temperature, etc.). As stated previously, a number of studies have been conducted with regard to the efficiency of watering to control dust, but few have quantified all parameters listed above.

The only specific control efficiency data which are available for construction and demolition involve the use of watering to control truck haulage emissions for a road construction project in Minnesota.[2] Using the geometric means of the important source characteristics (i.e., silt content, traffic volume, and surface moisture) and the regression equation developed from the downwind concentration data, a PM_{10} control efficiency of approximately 50 percent was obtained for a water application intensity of approximately 0.2 $gal/yd^2/hour$.

It should be noted that truck travel at road construction sites is only somewhat similar to travel on unpaved roads. The road bed surface is generally not as compacted as a well-constructed unpaved road. There are also subtle differences in surface composition. Care should be taken, therefore, in estimating control efficiency for noncompacted surfaces.

For more compacted unpaved surfaces found in construction and demolition sites, an empirical model for the performance of a watering as a control technique has been developed. The supporting data base consists of 14 tests performed in four states during five different summer and fall months. The model is:[1]

$$C = 100 - \frac{0.8\ p\ d\ t}{i} \qquad (5\text{-}4)$$

where C = average control efficiency, in percent

p = potential average hourly daytime evaporation rate in mm/h

d = average hourly daytime traffic rate in vehicles per hour

i = application intensity in L/m^2

t = time between applications in h

The term p in the above equation is determined using Figure 5-1 and the relationship:

$$p = \begin{cases} 0.0049\ e\ \text{(annual average)} & (5\text{-}5a) \\ 0.0065\ e\ \text{(worst case)} & (5\text{-}5b) \end{cases}$$

where p = potential average hourly daytime evaporation rate (mm/h)

e = mean annual pan evaporation (inches) from Figure 5-1

An alternative approach (which is potentially suitable for a regulatory format) is shown as Figure 5-2. This figure was presented earlier in Section 3.0.

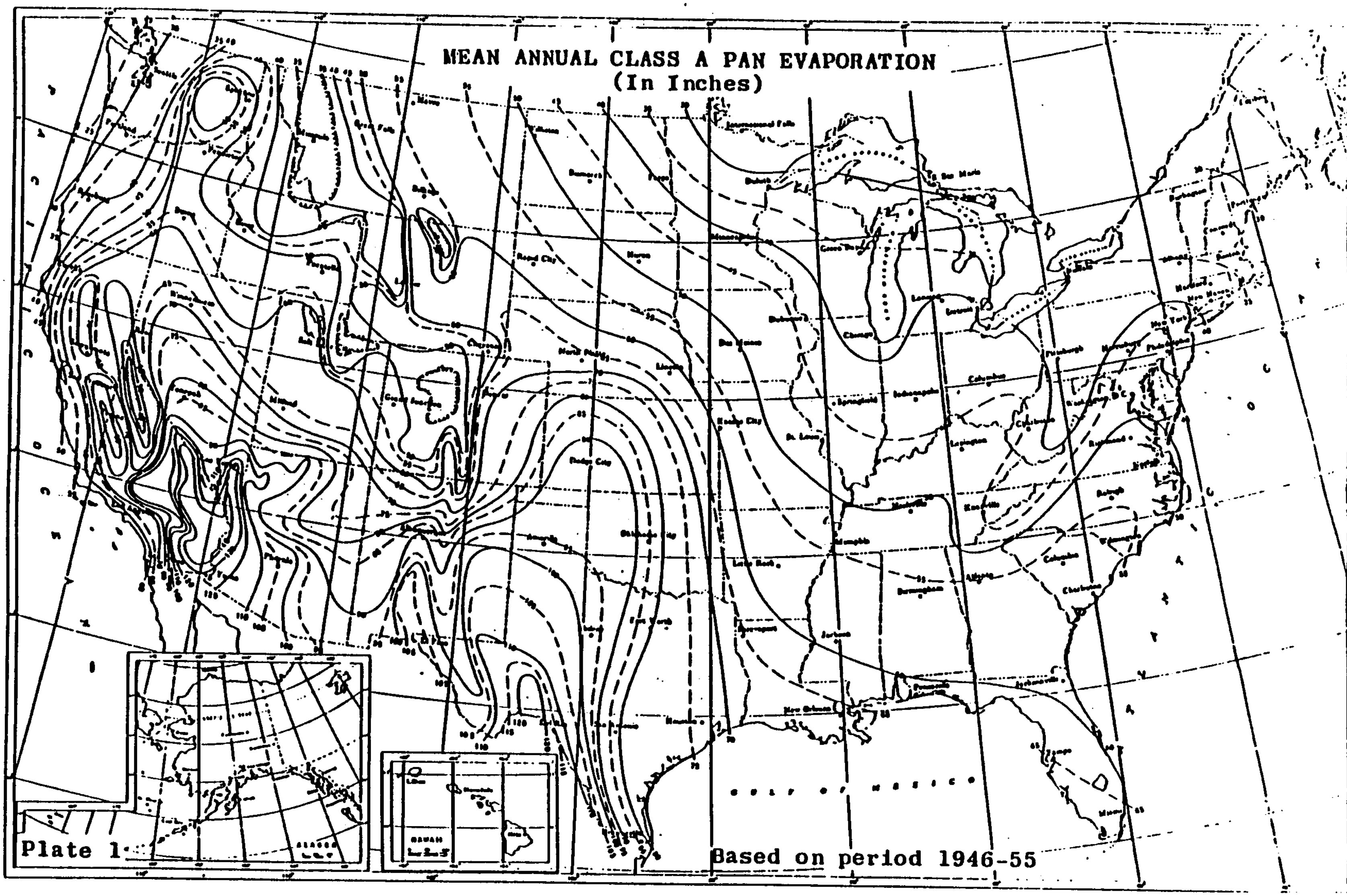


Figure 5-1. Mean evaporation for the United States.

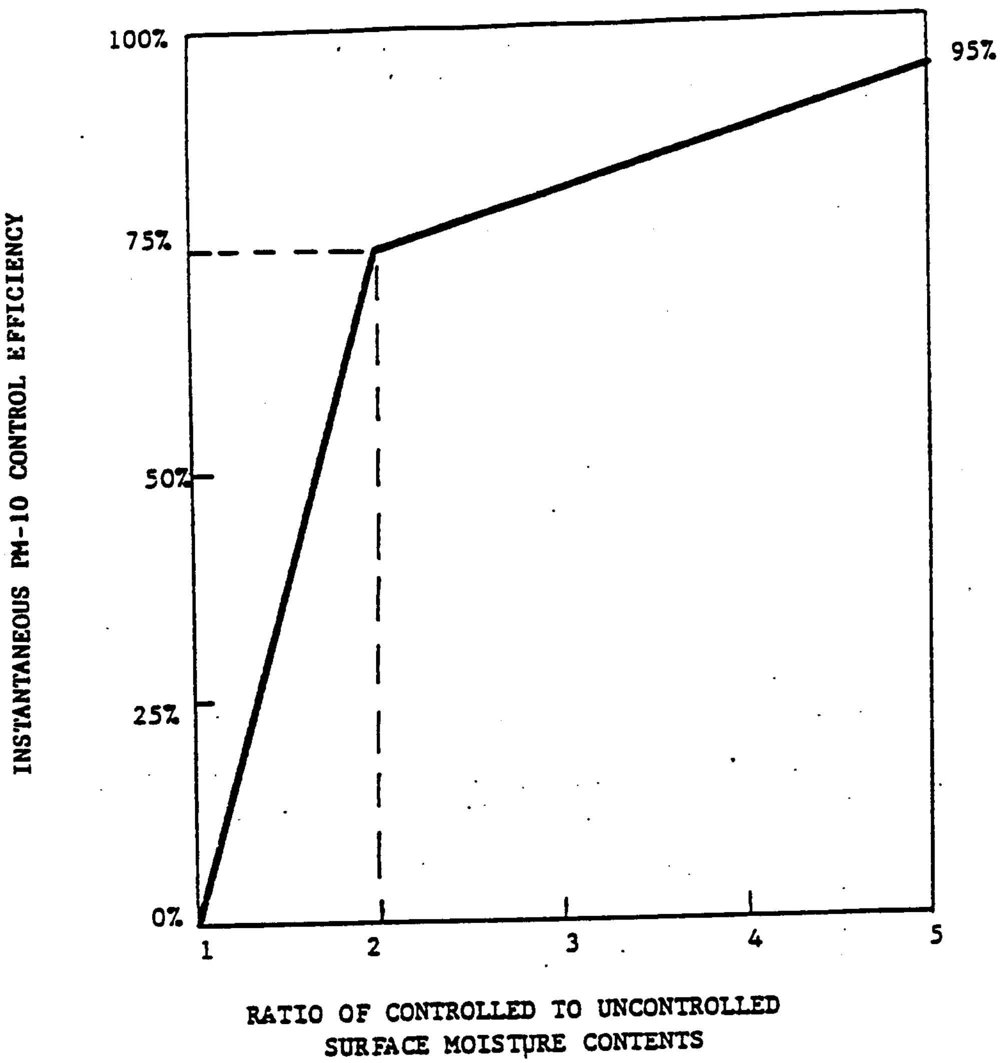


Figure 5-2. PM-10 control efficiency for watering unpaved roads.

Figure 5-2 shows that, between the average uncontrolled moisture content and a value of twice that, a small increase in moisture content results in a large increase in control efficiency. Beyond this point, control efficiency grows slowly with increased moisture content. Furthermore, this relationship is applicable to all size ranges considered:

$$c = \begin{cases} 75\,(M-1) & 1 \le M \le 2 \\ 62 + 6.7\,M & 2 \le M \le 5 \end{cases} \qquad (5\text{-}6)$$

where c = instantaneous control efficiency in percent

M = ratio of controlled to uncontrolled surface moisture contents

5.3.1.2 Control Costs. Costs for watering programs include the following elements:

- Capital: Purchase of truck or other device
- O&M: Fuel, water, truck maintenance, operator labor

Reference 6 estimates the following costs (1985 dollars):

Capital: $17,100/truck

O&M: $32,900/truck

The number of trucks required may be estimated by assuming that a single truck, applying water at 1 L/m^2, can treat roughly 4 acres of unpaved surface every hour.

5.3.1.3 Enforcement Issues. Enforcement of a watering program would ideally consist of two complementary approaches. The first facet would require the owner to maintain adequate records that would document to agency personnel's satisfaction that a regular program is in place. (See Appendix C for a suggested recordkeeping format.) The second approach would involve agency spot checks of controlled surfaces by taking material grab samples.

Records must be kept that document the frequency of water application to unpaved surfaces. Pertinent parameters to be specified in a control plan and rigorously recorded include:

General Information to be Specified.

1. All travel routes to be treated referenced on a plot plan available to both the site operator and regulatory personnel
2. Length and area of surfaces to be watered

3. Application intensity (gal/sq yd) and frequency (a minimum moisture content may be specified as an alternative)
4. Type of application vehicle, capacity of tank, and source of water

Specific Records to be Kept by Truck Operator

1. Date and time of treatment
2. Equipment used (this should be referred back to dust control plan specifications)
3. Operator's initials (a separate operators log may be kept and transferred later to permanent records by site operator)
4. Start and stop time, average speed, and number passes
5. Start and stop time for filling of water tank

Specific Records to be Kept by Site Operator

1. Equipment maintenance logs
2. Meteorological log of general conditions (e.g., sunny and warm vs. cloudy and cold)
3. Records of equipment breakdowns and downtime

An example permanent record form which may be used to record the above information is shown in Figure 5-3.

In addition to the above, some of the regulatory formats suggested in Section 5.4 require that records of surface samples or traffic counts also be kept. A suggested format for recording surface samples is shown in Figure 5-4. Traffic data may be recorded either manually or by automated counting devices.

5.3.2 Wet Suppression for Materials Storage and Handling

5.3.2.1 Control Efficiency. Wet suppression of materials storage and handling operations is similar to that used for unpaved surfaces. However, in addition to plain water this technique can also use water plus a chemical surfactant or micronized foam to control fugitive PM_{10}.

Surfactants added to the water supply allow particles to more easily penetrate the water droplet and increase the total number of droplets, thus increasing total surface area and contact potential. Foam is generated by adding a chemical (i.e., detergent-like substance) to a relatively small quantity of water which is then vigorously mixed to produce small bubble, high energy foam in the 100 to 200-μm size range.

Date	Time	Application intensity (gal/yd²)	Area(s) treated	Climatic parameters Amb. temp. (°F)	Climatic parameters Date/amt. of last rainfall	Equipment used	Operator initials	Comments

Figure 5-3. Typical form for recording watering program control parameters. (Sources: Unpaved surfaces, exposed areas, storage piles)

Sampling Data
Unpaved Roads

Date ____________
Recorded by: ____________

SAMPLING DATA

Sample No.	Time	Location*	Surface Area	Depth	Quantity of Sample

*Use code given on plant map for segment identification and indicate sample location on map.

Figure 5-4. Unpaved road sample log.

The foam uses very little liquid volume, and wnen applied to the surface of the bulk material, wets the fines more effectively than untreated water.

As with watering of unpaved surfaces, the control efficiency of wet suppression for materials storage and handling is dependent on the same basic application parameters. These include: the amount of water, water plus surfactant, or foam applied per unit mass or surface area of material handled (i.e., liters per metric ton or square meter); if not continuous, the time between reapplications; the amount of surfactant added to the water (i.e., dilution ratio), if any; the method of application including the number and types of spray nozzles used; and applicable meteorological conditions occurring onsite.

Wet suppression can be applied to material storage and handling operations by a variety of methods depending on the material and how it is being handled. For construction sites, soil and construction aggregates may be batch transferred to or from storage using loaders or by truck dumping. In these cases, water (with or without chemicals) could be applied with a water cannon or spray bar to the material prior to or during load-in or load-out. Foam may be a good alternative in such instances when the material is handled repeatably over the period of a day. Foam can be applied once in the handling process (e.g., as it is initially loaded into trucks) and the binding action of the bubbles will carry through subsequent handling operations.

For demolition sites, water, etc., can be applied with a cannon to wrecking operations as well as to building debris being moved (pushed) with dozers and transferred into trucks by end-loaders. Control of transfer operations can also be augmented using portable wind fences to provide a wind break to reduce dust generation and improve application of water to the load during transfer to haul trucks. Wind fences are discussed later in this discussion.

Available control efficiency data for wet dust suppression for materials handling and storage are practically nonexistent. However, certain limited information was compiled by Cowherd and Kinsey which can be used to estimate control efficiencies.[1]

For suppression using plain water, the most applicable efficiency information available is for feeder to belt transfer of coal in mining operations. Control efficiencies of 56 to 81 percent are reported for respirable particulate (particles <~ 3.5umA) at application intensities of 6.7 to 7.1 L/Mg (1.6 to 1.7 gal/ton), respectively. Assuming that respirable particulate is essentially equivalent to PM_{10}, the above control efficiencies would be representative of similar controls for construction/demolition. (The above application intensities were estimated assuming 5 min to discharge 7 Mg of coal and 1.4 L/min/spray nozzle.)

In the case of foam suppression, the most appropriate data available are for the transfer of sand from a grizzly. Using the respirable particulate control efficiencies at various foam application intensities (and assuming respirable particulate is equivalent to PM_{10}), the following equation was developed by simple linear regression of the data compiled by Cowherd and Kinsey:[1]

$$C = 8.51 + 7.96\ (A) \qquad (5\text{-}7)$$

where: C = PM_{10} control efficiency in percent

A = application intensity in ft^3 foam/ton of material

A coefficient of determination (r^2) of 99.97 percent was obtained for the above equation based on the three data sets used in its derivation.

An alternate approach (which is potentially suitable for regulatory formats) involves the use of the recently developed materials handling equation soon to be published in AP-42. This equation was presented as Equation 5-1 above. By determining the "uncontrolled" moisture content of the material and again after wet suppression, the control efficiency can be determined by:

$$CE = 100(E_U - E_C)/E_U \qquad (5\text{-}8)$$

where CE = PM_{10} control efficiency in percent

E_U = "uncontrolled" PM_{10} emission factor

E_C = "controlled" PM_{10} emission factor

The above calculations would necessitate the determination of the amount of water added to the material by laboratory analysis. This could be accomplished by taking grab samples of the material before and after application of the wet suppression technique being employed.

5.3.2.2 Control Costs. Costs associated with wet suppression systems include the following basic elements:

- Capital equipment:
  - -- Spray nozzles or other distribution equipment
  - -- Supply pumps and plumbing (plus weatherization)
  - -- Water filters and flow control equipment
  - -- Tanker truck (if used)
- Operating and maintenance expenditures:
  - -- Water and chemicals
  - -- Replacement parts for nozzles, truck, etc.
  - -- Operating labor
  - -- Maintenance labor

Reference 6 estimates the following costs (in 1985 dollars):

- Regular watering of storage piles:
  - -- Initial capital cost = $18,400 per system
- Watering of exposed areas:
  - -- Initial capital cost = $1,053 per acre
  - -- Annual operating cost = $25 to 67 per acre

The costs associated with a wet suppression system using chemical surfactants for the unloading of limestone from trucks at aggregate processing plants (in 1980 dollars) have been estimated at: capital = $72,000; annual = $26,000. These costs are based on a stationary system and may not be indicative of those used at construction and demolition sites.

5.3.2.3 Enforcement Issues. As with watering of unpaved surfaces, enforcement of a wet suppression control program would consist of two complementary approaches. The first would be record keeping to document that the program is being implemented and the other would be spot-checks and grab sampling. Both were discussed previously above.

Records must be kept that document the control plan and its implementation. Pertinent parameters to be specified in a plan and to be regularly recorded include:

General Information to be Specified in Plan

1. Locations of all materials storage and handling operations referenced on plot plan of the site available to the site operator and regulatory personnel
2. Materials delivery or transport flow sheet which indicates the type of material, its handling and storage, size and composition of storage piles, etc.
3. The method and application intensity of water, etc, to be applied to the various materials and frequency of application, if not continuous
4. Dilution ratio for chemicals added to water supply, if any
5. Complete specifications of equipment used to handle the various materials and for wet suppression
6. Source of water and chemical(s), if used

Specific Operational Records

1. Date of operation and operator's initials
2. Start and stop time of wet suppression equipment
3. Location of wet suppression equipment
4. Type of material being handled and number of loads (or other measure of throughput) loaded/unloaded between start and stop time (if material is being pushed, estimate the volume or weight)
5. Start and stop times for tank filling

General Records to be Kept

1. Equipment maintenance records
2. Meteorological log of general conditions
3. Records of equipment malfunctions and downtime

In addition to the above, some of the regulatory formats suggested in Section 5.4 below require that records of material samples be kept. A suggested format for this purpose is shown in Figure 5-5.

5.3.3 Portable Wind Screens or Fences

5.3.3.1 Control Efficiency. The principle of wind screens or fences is to provide a sheltered region behind the fenceline to allow gravitational settling of larger particles as well as a reduction in wind erosion potential. Wind screens or fences reduce the mechanical turbulence generated by ambient winds in an area the length of which is many times the physical height of the fence.

Storage Pile Data	Date ______ Recorded by ______

AGGREGATE CHARACTERISTICS

Type: Coal ☐; Coke ☐; Iron Ore ☐; Other ____________
Nominal Size: ______ in.
Weight Density: ______ tons/cu. yd.
Silt Content: ______ %

PILE CONFIGURATION

Total Volume: Ground Area ______ acres
Average Height ______ ft.

Configuration: ____________

Location within Plant Boundaries: ____________

SEASONAL FACTORS

	WINTER	SPRING	SUMMER	FALL	ANNUAL
Avg. Quantity On Hand (tons; cu. yd.)					
Avg. Quantity Put Through Storage (tons; cu. yd.)					
Avg. Duration of Storage (days)					

MATERIALS HANDLING EQUIPMENT

Stationary: ____________

Mobile: ____________

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Figure 5-5. Storage pile sampling sheet

As stated previously, wind fences and screens are applicable to a wide variety of fugitive dust sources. They can be used to control wind erosion emissions from storage piles or exposed areas as well as providing a sheltered area for materials handling operations to reduce entrainment during load-in/load-out, etc. Fences and screens can be portable and thus capable of being moved around the site, as needed.

The control efficiency of wind fences is dependent on the physical dimensions of the fence relative to the source being controlled. In general, a porosity (i.e., percent open area) of 50 percent seems to be optimum for most applications. Note that no data directly applicable to construction/demolition activities were found. According to a recent field study of small soil storage piles, a screen length of five times the pile diameter, a screen-to-pile distance of twice the pile height, and a screen height equal to the pile height was found best.[8] Various problems were noted with the sampling methodology used, however, and it is doubtful that the study adequately assessed the particle flux from the exposed surface. These problems tend to limit an accurate assessment of the overall degree of control achievable by wind fences/barriers for large open sources.

While not entirely applicable to construction/demolition activities, results of a laboratory wind tunnel study were used to estimate 60 percent to 80 percent control efficiencies for materials handling emissions.

5.3.3.2 Control Costs. As stated above, one of the real advantages of wind fences for the control of PM_{10} involves the low capital and operating costs. These involve the following basic elements:

- Capital equipment:
  - -- Fence material and supports
  - -- Mounting hardware
- Operating and maintenance expenditures:
  - -- Replacement fence material and hardware
  - -- Maintenance labor

The following cost estimates (in 1980 dollars) were developed for wind screens applied to aggregate storage piles:[10]

- Artificial wind guards:
  - -- Initial capital cost = $12,000 to 61,000

- Vegetative wind breaks:
  -- Initial capital cost = $45 to 425 per tree

Due to the lack of quantitative data on costs associated with wind screens, it is recommended that local vendors be contacted to obtain more detailed data for capital and operating expenses. Also, since wind fences and screens are relatively "low tech" controls, it may be possible for the site personnel to construct the necessary equipment with less expense.

5.3.3.3 <u>Enforcement Issues</u>. As with other options mentioned above, the main regulatory approach involved with wind fences and screens would involve recordkeeping by the site operator. Parameters to be specified in the dust control plan and routinely recorded are:

<u>General Information to be Specified in Plan</u>

1. Locations of all materials storage and handling operations to be controlled with wind fences referenced on a plot plan available to the site operator and regulatory personnel
2. Physical dimensions of each source to be controlled and configuration of each fence or screen to be installed
3. Physical characteristics of material to be handled or stored for each operation to be controlled by fence(s) or screen(s)
4. Applicable prevailing meteorological data (e.g., wind speed and direction) for site on an annual basis

<u>Specific Operational Records</u>

1. Date of installation of wind fence or screen and initials of installer
2. Location of installation relative to source and prevailing winds
3. Type of material being handled and stored and physical dimensions of source controlled
4. Date of removal of wind fence or screen and initials of personnel involved

<u>General Records to be Kept</u>

1. Fence or screen maintenance record
2. Log of meteorological conditions for each day of site operation

5.3.4 <u>Drilling Control Technology</u>

5.3.4.1 <u>Control Efficiency</u>. Another type of control to be discussed is the use of water injection or fabric filters for drilling operations.

Both of these controls are generally directly associated with the drilling equipment when it is purchased and is an integral part of the system.

As might be expected, water injection used on rock drills involves the application of water either into the hole being drilled by a piston pump or to a ring around the top of the hole to control dust generation. Also, dust ejector systems equipped with small fabric filters or water sprays use compressed air to eject dust particles from the hole into a tube for removal from the drilled area.

At present, there are no data available for the PM_{10} control efficiency associated with either system used to reduce emissions from drilling operations. It might be expected, however, that a fabric filter-based system should be more efficient than wet suppression in most cases.

5.3.4.2 Control Costs. Cost elements associated with drilling control systems are as follows:

- Capital equipment:
  - -- Spray nozzles, pumps, and distribution plumbing for wet suppression system
  - -- Air compressor, air lines, and filter components for dry ejection system
  - -- Water filters and flow control equipment, as required
  - -- Water tank, if needed
- Operating and maintenance expenditures:
  - -- Water and chemicals, if used
  - -- Replacement bags, etc. for dry systems
  - -- Replacement parts for nozzles, pumps, etc.
  - -- Operating labor
  - -- Maintenance labor

Jutze et al. estimate the following costs (in 1980 dollars) for drilling operations in aggregate processing facilities:[10]

- Water injection systems:
  - -- Initial capital cost = $4,700
- Dust ejection to fabric filter:
  - -- Initial capital cost = $14,600

Specific cost data should be obtained from manufacturers relative to the capital costs associated with the above systems to update the above. No information is available at present for O&M costs for such systems.

5.3.4.3 Enforcement Issues. As with the other methods discussed previously, the regulation of drilling emissions would involve at least some recordkeeping as part of the overall emissions control plan for the site. The parameters to be specified in the plan and subsequently recorded by onsite personnel include:

General Information to be Specified in Plan

1. Location of all drilling operations to be conducted referenced to a plot plan of the site available to the site operator and regulatory personnel
2. Schedule for all drilling operations to be conducted onsite, number of holes to drilled, equipment used and hours of operation
3. Complete specifications of drilling and dust control equipment for each rock drill to be used
4. Amount of water to be used per unit time for wet systems or airflows for dry systems
5. Source of water and chemical(s), if used, and tank(s) capacity(ies)

Specific Operational Records

1. Date of operation and operator's initials
2. Start and stop time of drilling and control equipment
3. Number of holes drilled between start and stop time
4. Start and stop time for tank filling

General Records to be Kept

1. Equipment maintenance records
2. Meteorological log of general conditions
3. Records of equipment malfunctions and downtime

Because of the relatively confined nature of drilling operations, regulatory formats different from those discussed previously may be possible. For example, opacity as a measure of performance could be a viable approach. This is discussed further in Section 5.4 below.

5.3.5 Control of Mud/Dirt Carryout

5.3.5.1 Control Efficiency. Mud and dirt carryout from construction and demolition sites often accounts for a temporary but substantial increase in paved road emissions in many areas. Elimination of carryout can thus significantly reduce increases in paved road emissions.

At present, the efficacy of various methods to prevent or reduce mud/dirt carryout have not been quantified. These techniques include both methods to remove material from truck underbodies and tires prior to leaving the site (e.g., a temporary grizzley with high pressure water sprays) as well as techniques to periodically remove mud/dirt carryout from paved streets at the access point(s). The following method has been developed, however, to conservatively estimate the reduction in mass emissions due to carryout using the data contained in Reference 6.

As noted earlier, quantification of control efficiencies for preventive measures is essentially impossible using the standard before/after measurement approach. The methodology described below results in conservatively high control estimates in terms of emissions prevention. That is, the control afforded cannot be easily described in terms of a percent reduction but rather is discussed in terms of mass emissions prevented. Furthermore, tracking of material onto a paved road results in substantial spatial variation in loading about the access point. This variation may complicate the modeling of emission reductions as well as their estimation.

For an individual access point from a paved road to a typical construction or demolition site, let N represent the number of vehicles entering or leaving the area on a daily basis. Let E be given by:

$$E = \begin{cases} 5.5 \text{ g/vehicle for } N \leq 25 \\ 13 \text{ g/vehicle for } N > 25 \end{cases}$$

where E is the unit PM_{10} emission increase in g/vehicle pass (see Section 5.1). Finally, if M represents the daily number of vehicle passes on the paved road, then the net daily emission reduction (g/day) is given by ExM, assuming complete prevention.

The emission reduction calculated above assumes that essentially all carryout from the unpaved area is either prevented or removed periodically from the paved surface and, as such, is viewed as an upper limit. In use, a regulatory agency may choose to assign an effective level of carryout control by using some fraction of the E values given above to calculate an emission reduction.

Finally, field measurements of the increased paved silt loadings around unpaved areas may also be used to gauge the effectiveness of control programs. A discussion of this is found in Section 2.4.

5.3.5.2 Control Costs. The individual cost elements associated with the prevention of mud/dirt carryout will vary with the method used. For traditional street cleaning, the costs elements discussed in Section 2.0 would apply to construction and demolition sites as well. In this case, however, only the amount of surface to be cleaned would be limited to the area(s) near access point(s). For an onsite grizzley/water spray system, the cost elements are as follows:

- Capital equipment:
  - -- Grizzley, catch basin, and clarifier (as needed)
  - -- Spray nozzles, pumps, and distribution plumbing
  - -- Water tank, filters, and flow controllers, as required
- Operating and maintenance expenditures:
  - -- Water and replacement nozzles, plumbing, etc.
  - -- Removal of wastewater or residues, as required
  - -- Operating labor
  - -- Maintenance labor

At present, no cost data are available for the prevention of mud/dirt carryout.

5.3.5.3 Enforcement Issues. As with some other techniques, two complimentary approaches can be used for enforcement of mud/dirt carryout control. These are recordkeeping and grab sampling. The later would include the sampling of the paved surface loading near access points to determine the level of prevention being achieved by the method(s) employed. Surface sampling is discussed in more detail above.

Adequate records must be kept to document the types and level of preventative measures being taken to control mud/dirt carryout from the site. Appropriate parameters to be specified in the control plan and rigorously recorded are:

General Information to be Specified

1. A detailed plot plan available to both the site operator and regulatory personnel showing site access points and impacted paved city streets.

2. Details on the control method to be applied at each access point including the amount and types of vehicles entering and exiting the site on a daily basis at each.
3. For mitigative control techniques (i.e., surface cleaning), a description and schedule for implementation of the control method to be employed (see Section 2.0 above).
4. For preventive control techniques (e.g., onsite grizzley), specifications on the type(s) of equipment to be used and operation and maintenance of the system.
5. Source of water, if used.

Specific Records to be Kept by Site Operator (Mitigative Controls)

1. Date of cleaning operation and operator's initials.
2. Other applicable cleaning parameters as specified in Section 2.0 above.

General Records to be Kept

1. Equipment maintenance records.
2. Meteorological log of general conditions.
3. Records of equipment malfunctions and downtime.

In addition to the above, some of the regulatory formats suggested in Section 5.4 require that records of material samples also be kept. A suggested format for this purpose has been shown previously in Section 2.4.

5.4 EXAMPLE DUST CONTROL PLAN

To illustrate the development of an appropriate dust control plan for construction and demolition sites, Figure 5-6 provides example calculations for the demolition of a 167,200 m^2 (200,000 ft^2) building located on a one acre site in an urban area. These calculations include the determination of uncontrolled PM_{10} emissions, methods used for control, and demonstration of the adequacy of the various methods to achieve a target control efficiency of 90 percent.

5.5 POTENTIAL REGULATORY FORMATS

In this section, regulatory formats will be discussed relative to the control of fugitive PM_{10} emissions at construction and demolition sites. This section discusses a permit system, recordkeeping, measures of control performance, and enforcement as well as an example rule which implements

- Source Description:
  167,200 m^2 (floor space) building on a one acre site
  1 access point to a paved city street (2,000 ADT)
  30 vehicles/day removing building debris
  30 days project duration

- Assumptions:
  No detailed data are available for debris removal activities
  No dozing will be performed onsite
  Negligible exposed areas
  8 h/day operation

- Calculation of Uncontrolled Emissions:
  From Section 5.1.2 the uncontrolled PM_{10} emissions from dismemberment, debris loading, and onsite traffic are calculated as:

$$E_{DLT} = (E_D + E_L + E_T) \text{ kg/m}^2 \times \text{m}^2 \text{ floor space}$$

$$= (0.00025 + 0.0046 + 0.052) \text{ kg/m}^2 \times 167{,}200 \text{ m}^2$$

$$= 9.5 \text{ Mg } PM_{10}$$

For mud/dirt carryout from haul trucks entering and leaving the site, the mean <u>increase</u> in paved road emissions is calculated using Table 5-2 for sites with greater than 25 vehicles/day:

$$E_{MD} = 13 \text{ g/vehicle pass} \times 2{,}000 \text{ vehicles/day} \times 30 \text{ days}$$

$$= 780 \text{ Mg } PM_{10} \text{ emissions}$$

Therefore, the total emissions over the duration of the project are:

$$E_T = E_{DLT} + E_{MD} = 9.5 \text{ Mg} + 780 \text{ Mg}$$

$$= 789.5 \text{ Mg total } PM_{10} \text{ emissions}$$

- Target Control Efficiency: 90%

- Methods of Control:

  -- Wet suppression of debris handling and transfer (6.7 L/Mg application intensity)
  -- Watering of unpaved travel surfaces (2 L/m^2/h application)
  -- Broom sweeping/flushing for removal of mud/dirt carryout

Figure 5-6. Example PM_{10} control plan for building demolition.

- Demonstration of Control Program Adequacy:

As stated in Section 5.3.2.1, an efficiency of 56% is typical for wet suppression of debris transfer. Thus, the controlled emissions would be:

$$E_{CL} = 0.0046 \text{ kg } PM_{10}/m^2 \times 167{,}200 \text{ m}^2 \times (1 - 0.56) = 0.34 \text{ Mg } PM_{10}$$

Using water for dust control from unpaved surfaces, Equations 5-4 and 5-5 as well as Figure 5-1 will allow calculation of controlled emissions (assuming the site is located in Los Angeles, California):

$$p = 0.0049 \text{ e} = 0.0049 \text{ (60 inches)} = 0.29 \text{ mm/h}$$

and

$$C = 100 - \frac{0.8 \text{ pdt}}{i}$$

$$= 100 - \frac{0.8(0.29)(30/8)(1)}{2}$$

$$= 99.6\%$$

Therefore, the controlled PM_{10} emissions for haul truck traffic would be:

$$E_{CT} = 0.052 \text{ kg/m}^2 \times 167{,}200 \text{ m}^2 \times (1 - 0.996)$$

$$= 0.035 \text{ Mg } PM_{10} \text{ from haul trucks}$$

Finally, for removal of mud/dirt carryout using a combination of broom sweeping and flushing, no prevention efficiency data are available. However, if it is assumed that the emissions increase on the paved road for this source is reduced by 90 percent, E_{CMD} = 78 Mg PM_{10} from mud/dirt carryout (see Section 5.3.5.1).

From the above calculations, the overall reduction in PM_{10} due to the various controls employed would be:

$$E_C = E_{CL} + E_{CT} + E_{CMD}$$

$$= 0.34 + 0.035 + 78$$

$$= 78 \text{ Mg } PM_{10} \text{ after control}$$

Figure 5-6. (continued)

Thus,

$$CE = \frac{E_T - E_{CT}}{E_T} \times 100\% = \frac{789.5 - 78}{789.5} \times 100 = 90.1\%$$

As shown, the target control efficiency of 90 percent has not only been achieved but exceeded.

Figure 5-6. (continued)

the permit system. Example regulatory formats are provided for the following sources associated with construction/demolition: unpaved roads, haul roads, disturbed soil, mud carryout. These example formats provide a starting point for development of construction rules in a specific area.

5.5.1 Permit System

The first regulatory approach involves the implementation and enforcement of a permit program for construction and demolition sites. This has been used to some extent in the Denver metropolitan area for large construction projects and offers promise as a general regulatory format.

A permit system would require the site owner or operator to file an application with the appropriate regulatory agency having jurisdiction. This permit application would include the specific dust control plan to be implemented at the site which would involve the individual elements discussed in Section 5.3.

The air permit for construction and demolition sites would be coupled to the standard building or demolition permit process whereby no permit to conduct such activity would be issued by the county or city until such time that the air permit is approved. To reduce the burden of processing large numbers of such permits, a de minimus level would be established whereby construction and demolition projects below a certain cut-off size would not require an air permit. This de minimus level would depend on local factors such as the amount of emissions reduction required to meet the applicable PM_{10} NAAQS. For the sake of further discussion, a de minimus level of <25 vehicles entering and leaving the site per day for construction was used to determine the emissions increase associated with mud/dirt carryout and thus might be used for this purpose.[5]

As part of the permit application, recordkeeping should be one of the main conditions for approval. Records of site activity and control should be submitted to the regulatory agency on a monthly basis as indicated above. These records must be certified by a responsible party as to their completeness and accuracy. All site records should be maintained by the local agency for the duration of the project.

To enforce the dust control plan submitted as part of the permit application, field audits of key control parameters should be made by regulatory personnel. The results of these audits would then be compared to site records for that period to determine compliance with permit conditions. If differences are found between application of the control(s) observed onsite and those recorded by site operating personnel, this would constitute a violation and would be grounds for further enforcement action. An example form to be used by regulatory personnel during inspection of the site is shown in Figure 5-7. To illustrate this process an abbreviated example will be given.

Assume a large demolition project consisting of the demolishing of a block of buildings is to be conducted in a large metropolitan area. The site dust control plan calls for watering of all truck routes to and from the active demolition every two hours as well as cleanup of mud/dirt carryout from the access point on a twice daily basis. Also, watering of debris during demolition and load-out to haul trucks is to be conducted on days without measurable rainfall. An agency inspector observes the site activity from the public street for a period of 3 hours. During this period, no water truck is observed to be in operation and debris are not watered prior to loading into trucks.

At the end of the month, the inspector checks the submittal from the site operators and finds start and stop times for the water truck operator which indicates operation during the observation period. The inspector also notes that the water cannon used for debris control was broken down and was in a repair shop. It is clear from this analysis that the operator is in clear violation of the dust control plan for watering of unpaved surfaces. In this case, a citation or other enforcement action could be taken against the site operator.

As noted by the above example, no quantitative data are required for enforcement of the dust control plan. This eliminates the need for a set performance standard (e.g., opacity limits) against which the site operator is evaluated. This approach is, however, predicated on the fact that strict implementation of the dust control plan will achieve certain reductions in PM_{10} emissions associated with site operation.

1. Type of construction activity (check one)

   a. Residential _____
   b. Commercial _____
   c. Industrial _____

   Additional description (i.e., multi unit, residential or suburban commercial, etc.)

2. How long have you worked at this location? __________________

   Note: In the case of a multi-year project, we are only interested in the current season.

3. How long is the job projected to last? __________________

4. What percentage of the work is completed, percent? __________

5. What construction activities are you currently performing?

6. What construction activities have you been performing over the past week to 10 days?

7. What is the construction activity's source extent which is currently being performed (e.g., tons of earth moved/day or yards of concrete poured/day)?

8. Estimate the number of daily vehicle passes through the site entrance (check 1).

9. What types of vehicle enter the site daily and what percentage of the traffic is of each type?

Vehicle type	Percent
a. Cars	______
b. Pickups/vans	______
c. Medium duty trucks	______
d. Other	______

10. Do you employ control measures to keep dust down? If yes, what type?

11. What is the usual frequency and intensity of application? When was the most recent application?

Figure 5-7. Questionnaire for construction site personnel.

5.5.2 Opacity Standards

Another regulatory format which could be used is the use of visible emissions (i.e., opacity) as a semiquantitative measure of the performance of the dust control measure being employed. One state, Tennessee, has developed a formalized procedure for reading and recording of visible emissions (VE) from fugitive sources which is the basis for enforcement of a VE standard.

The use of visible emissions for determination of compliance for fugitive dust sources has been discussed previously in this document and thus will not be belabored here. In general, fugitive sources are extremely diffuse in nature and the plume generated is dependent on a number of factors including wind speed and the physical dimensions of the source. Therefore, it is difficult, if not impossible, to derive even semiquantitative relationships between particulate mass and visible emissions for most source types and thus a measure of control performance.

There is one particular source at construction sites where observation of visible emissions might be used with some degree of confidence as an enforcement tool. This source is rock drills which emit dust from one confined area (i.e., the hole being drilled) and thus might be considered as a point emissions source under traditional definitions. Additional work will be necessary, however, to determine appropriate visible emissions limits for rock drills based on the control techniques currently available.

5.5.3 Other Indirect Measures of Control Performance

The final regulatory format to be presented in this section relates to various indirect measures of control performance. These could be used in conjunction with or in lieu of the other approaches discussed above. They will, however, require more effort and expense to implement but should be at least somewhat defensible as measures of control efficiency.

The most obvious approach to indirectly measuring control performance involves the collection and analysis of material samples from various sources operating onsite. For mud/dirt carryout, collection of surface samples at site access points and analysis of these samples for silt content would indicate the efficacy of control for this particular source. The silt loadings obtained could be compared with "typical" surface loading values for similar uncontrolled sites to determine the degree of loading (and thus emissions) reductions achieved. This would, of course, necessitate the availability of a data base of "uncontrolled" silt loadings due to mud/dirt carryout for a wide variety of construction and demolition sites for comparison with site-specific data. An example form to be used for collection of paved surface loading samples has been provided previously in Section 2.4 above which has been reproduced as Figure 5-8.

Another indirect measure of control efficiency is the collection and analysis of material samples from unpaved surfaces and materials handling and storage operations. In this case, analysis of the moisture content of these samples would indicate the amount of water applied and thus the degree of control achieved by wet suppression. Appropriate equations presented in Section 5.3 would be used to determine control efficiency based on the sample data.

5.5.4 Example Rule

The following is a discussion of an example regulatory format for construction activities. A more detailed discussion is presented in Appendix G.

5.5.4.1 Conditions for Construction.

Conditions for Construction: No person shall engage in any construction-related activity at any work site unless all of the following conditions are satisfied:

(1) Dust control implements in good working condition are available at the site, including water supply and distribution equipment adequate to wet any disturbed surface areas and any building part up to a height of 60 feet above grade.

(2) A dust control plan is approved by the APCO which demonstrates that an overall x percent (e.g., 75 percent) reduction of PM_{10} emissions from construction/demolition and related activities will be achieved by applying reasonably available control measures. Such measures may include, but need not be limited to, the following: application of water or other liquids during dust-producing mechanical activities including earth moving and demolition operations; application of water or other liquids to or chemical stabilization of, disturbed surface areas; surrounding the work site with wind breaks to reduce surface erosion; restricting the access of motor vehicles on the work site; securing loads and cleaning vehicles leaving the work site; enclosing spraying operations; and other means as specified by the APCO.

Paved Road Logging

Run No. ______________________ Date ______________________

MRI Project No. ______________________ Recorded By ______________________

Type of Material Sampled: ______________________

Site of Sampling: ______________________ No. of Traffic Lanes ______________________

Type of Pavement: Asphalt/Concrete Surface Condition ______________________

Sample No.	Vac. Bag	Time	Location*	Sample Area	Broom Swept? (y/n)

*Use code given on plant map for segment identification and indicate sample location on map.

Figure 5-8. Example paved road sample log.

(3) The owner and/or operator is in possession of a currently valid permit which has been issued by the APCO. (Example permit attached, see Figures 5-9 and 5-10).

5.5.4.2 Control Mud/Dirt Carryout.

Street Cleaning: No person shall engage in any dust-producing construction related activity at any work site unless the paved streets (including shoulders) adjacent to the site where the construction-related activity occurs are cleaned at a frequency of not less than x (e.g., once) a day unless,

(1) vehicles do not pass from the work site onto adjacent paved streets, or

(2) vehicles that do pass from the work site onto adjacent paved streets are cleaned and have loads secured to effectively prevent the carryout of dirt or mud onto paved street surfaces.

The measures used to clean paved roads may include, but are not limited to: water flushing, vacuum sweeping, and manual cleaning of the access point.

5.5.4.3 Control of Haul Road Emissions.

Construction Site Haul Roads: No person shall allow the operation, use, or maintenance of any unpaved or unsealed haul road of more than x (e.g., 50) feet in length at any work site engaged in any construction-related activity, unless no more than x (e.g., 10) vehicular trips are made on such haul road per day and vehicular speeds do not exceed x (e.g.,10) miles per hour.

5.5.4.4 Stabilize Soils at Work Sites.

Stabilization of Soils at Completed Work Sites: No owner and/or operator shall allow a disturbed surface site to remain subject to wind erosion for a period in excess of x (e.g., 6) months after initial disturbance of the soil surface or construction-related activity without applying all reasonably available dust control measures necessary to prevent the transport of dust or dirt beyond the property line. Such measures may include, but need to be limited to: sealing, revegetating, or otherwise stabilizing the soil surface.

5.5.4.5 Record Control Application. The owner and or operator shall record the evidence of the application of the control measures. Records shall be submitted upon request from APCO and shall be open for inspection during unscheduled audits.

5.5.4.6 Modification of Permit Provisions

The provisions of this permit may be modified after sufficient construction is completed by the mutual consent of the APCO and the permittee; or, by the APCO if it determines that the stipulated controls

THIS PERMIT WILL BE PROMINENTLY DISPLAYED IN THE
ONSITE CONSTRUCTION OFFICE

Location: ______________________ No. of Acres: ______

Name of Project: ______________________

PERMITTEE: ______________________ Telephone No. ______

Address: ______________________

Prime Contractor: ______________________ Telephone No. ______

Subcontractor: ______________________ Telephone No. ______

Issue Date of Permit: __________ Expiration Date of Permit: ______

PERMIT NO: __________ FEE $__________ RECEIPT NO. ______

THE PERMITTEE SHALL COMPLY WITH THE FOLLOWING CONDITIONS:

1. (Reference to local APCD regulation for construction/demolition-related activities)

2. The PERMITTEE is responsible for dust control from commencement of project to final completion. Areas which will require particular ATTENTION:

   a. Unimproved access roads used for entrance to or exit from construction site.
   b. Areas in and around building(s) being constructed.
   c. Dirt and mud deposited on adjacent improved streets and roads.

3. If wind conditions are such that PERMITTEE cannot control dust, PERMITTEE shall shut down operations (except for equipment used for dust control).

4. The PERMITTEE is responsible for ensuring his contractor(s) and/or subcontractor(s) and all other persons abide by the conditions of the permit from commencement of project to final completion.

5. The PERMITTEE also is subject to compliance with all applicable State, county, and local ordinances and regulations. Issuance of this permit shall not be a defense to violation of above-referenced statutes, ordinances, and regulations.

6. Onsite permit conditions (attached)

____
Air Pollution Control Division (date)

Figure 5-9. Example dust permit.

ONSITE PERMIT CONDITIONS

Condition number	Source category[a]	Minimum control efficiency	Control measure	Application level (frequency amount, etc.)	Recordkeeping	Reporting requirements
6a.	(e.g., unpaved roads)	(e.g., 80 percent)	(e.g., chemical stabilization, 39 percent call in water and supplemental watering)	(e.g., sufficient to maintain an average surface moisture content of 2 times the the offroad soil moisture)	(e.g., log of salt solution and supplemental water volume, time, and date)	Records submitted upon request (in writing) and open for inspection during unscheduled audits)

[a]Other source categories that also could be regulated with permit conditions include open areas, grading, streets, and haul trucks.

Figure 5-10. Example permit for construction/demolition activities.

are inadequate. Deviations from the dust control plan (e.g., increased source activity) may result in modifications to the permit.

5.6 REFERENCES FOR SECTION 5

1. Cowherd, C., Jr., and J. S. Kinsey. 1986. Identification, Assessment and Control of Fugitive Particulate Emissions. EPA-600/8-86-023, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina.

2. Kinsey, J. S., et al. 1983. Study of Construction Related Dust Control. Contract No. 32200-07976-01, Minnesota Pollution Control Agency, Roseville, Minnesota. April 19, 1983.

3. Grelinger, M. A. 1988. Gap Filling PM_{10} Emission Factors for Selected Open Area Dust Sources. EPA-450/4-88-003, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

4. Muleski, G. E. 1987. Update of Fugitive Dust Emission Factors in AP-42 Section 11.2. Final Report, U. S. Environmental Protection Agency, Contract 68-02-3891, Work Assignment 19.

5. U. S. Environmental Protection Agency. 1985. Compilation of Air Pollution Emission Factors, AP-42. U. S. Environmental Protection Agency, Research Triangle Park, North Carolina.

6. Englehart, P. J., and J. S. Kinsey. 1983. Study of Construction Related Mud/Dirt Carryout. EPA Contract 68-02-3177, Assignment 21. July 1983.

7. Kinsey, J. S., et al. 1985. Control Technology for Sources of PM_{10}. Draft Final Report, EPA Contract 68-02-3891, Assignment 4. September 1985.

8. Zimmer, R. A., et al. 1986. Field Evaluation of Wind Screens as a Fugitive Dust Control Measure for Material Storage Piles. EPA-600/7-86-027, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina. July 1986.

9. Struder, B. J. B., and S. P. S. Arya. 1988. Windbreak Effectiveness for Storage Pile Fugitive Dust Control: A Wind Tunnel Study. Journal of the Air Pollution Control Association, 38:135-143.

10. Ohio Environmental Protection Agency. 1980. Reasonably Available Control Measures for Fugitive Dust Sources. Columbus, Ohio. September 1980.