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Reasonably Available Control Measures for Fugitive Dust Sources. "RACM"

Ohio Environmental Protection Agency

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PREFACE

Rule 3745-17-08 of the Ohio Administrative Code gives examples of reasonably available control measures (RACM) which should be employed for various types of fugitive dust sources. The rule covers a large number of diverse types of sources and, of necessity, is written in general terms.

The burden of developing an acceptable control program, which will meet the requirements of this rule and result in the use of reasonably available control technology (RACT) for one or more fugitive dust sources, lies with the owner/operator of the source(s). The type of control measures which are presently used by industry throughout the nation and which would constitute RACT for specific sources can, in general, be easily discerned by researching available environmental control publications and literature.

The Office of Air Pollution Control (OAPC) realizes that Ohio industry will need assistance in developing acceptable control programs and that the Agency's field office personnel will need assistance or guidance in reviewing those programs. This document has been prepared to specifically address those needs.

The OAPC would like to emphasize that the definitions of RACT in this document for the various types of fugitive dust sources are not "cast in concrete". Deviations from the general definitions or recommendations will be permitted based upon source-specific considerations; however, as stated earlier, the burden will be upon the owner/operator of an affected facility to demonstrate that the proposed, overall control program constitutes RACT and meets the requirements of rule 3745-17-08.

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The OAPC, Division of Engineering project team was responsible for the preparation of the complete, final document. Revisions were made by the project team to the draft sections prepared by PEDCo. In addition, the project team prepared the entirety of Sections 2.17 thru 2.30. Mr. James A. Orlemann, Division Chief, served as the Project Officer. He was assisted by Mr. Thomas J. Kalman, Engineering Operations Section Chief, and Mssrs. James A. Cummings and Edwin Y. Lim, Environmental Scientists.

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2.0 REASONABLY AVAILABLE CONTROL MEASURES (RACM)

The purpose of this report is to provide agency personnel with information on industry categories relating to potential fugitive dust problems, and available means to alleviate the problems. In accomplishing this purpose, the guideline presents detailed data on 30 industry categories. The information supplied includes a general process description of the industry; identification of fugitive dust sources; a listing of available fugitive dust emission factors; available data on particle characteristics and potential adverse impacts; data on available control techniques, their effectiveness, and costs; and selection of RACM for each emission source.

The process description is a general explanation of the process operations in which each potential fugitive emission source is identified. Available emission factors for these sources are listed along with a reliability rating for each. The reliability ratings are indicative of the supportive data used to develop the factor. The following rating system is employed:

A - Excellent - Supportable by a large number of tests, process data, and engineering analysis work.

B - Above average - Supportable by multiple tests, moderate process data, and engineering analysis work.

C - Average - Supportable by multiple tests.

D - Below average - Supportable by limited test data and engineering judgment.

E - Poor - Supportable by best engineering judgment (visual observation, emission tests for similar sources, etc.).

Available data on composition, size range, and potential environmental and/or health effects of the fugitive particles are presented to provide insight into the potential impacts of the fugitive emissions.

For each of the fugitive dust sources identified, available control measures are described. Data on the effectiveness and costs are also included. Costs in the document have been adjusted to reflect 1980 dollars as described in Appendix A. The costs are presented as an order-of-magnitude guide and should not be considered as accurate for a site-specific application.

Of the available control techniques, one is selected that exemplifies RACM. The selection is based upon technological feasibility, economic feasibility, and cost-effectiveness. The selection process was judgmental; and it should be emphasized that for retrofit applications, control characteristics are highly plant-specific and could dictate another control technique as RACM. This document provides guidelines to selecting RACM for various processes and is not meant to preclude consideration of other control measures in site-specific analyses.

2.1 GENERAL FUGITIVE DUST EMISSION SOURCES

The general fugitive dust category presents a description of those dust sources which would be common to a number of industries. These sources include fugitive dust from 1) plant roadways and parking areas, 2) aggregate storage piles, 3) material handling, and 4) mineral extraction. These four fugitive dust sources have been grouped together and treated as a separate section in order to avoid redundancy within the remainder of the text.

The location or placement of a given fugitive dust source will vary greatly within a specific industry. An example of this variability is illustrated by a conveying operation. The conveyor may be located at a number of points within the industrial process: unloading of raw material, transport from a storage facility, and movement of material within the industrial process itself. Because of the great variation in placement, it is not possible to devise a typical flow diagram for these sources. However, to give the reader of this document a feel for the possible order and location of each general fugitive dust source, two hypothetical industrial settings are provided. Figure 2.1-1 presents a hypothetical flow diagram for an unspecified industry with fugitive dust sources from 1) plant roadways and parking areas, 2) aggregate storage piles, and 3) material handling operations. Figure 2.1-2 presents another hypothetical flow diagram depicting a mineral mining operation. The fugitive dust sources illustrated in this figure are common to mineral extraction operations.

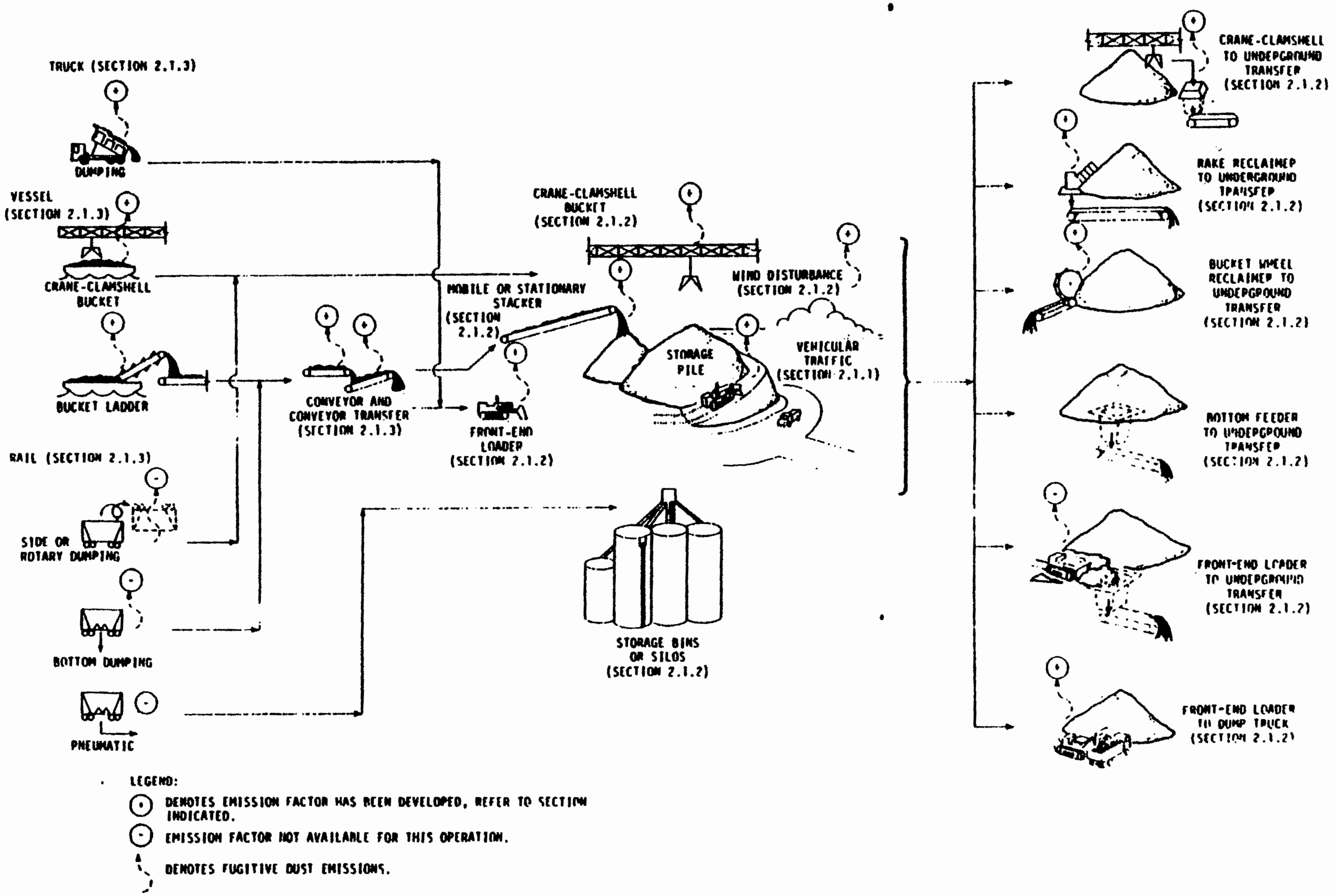

Figure 2.1-1. Order and location of general fugitive dust sources in a hypothetical industrial setting.

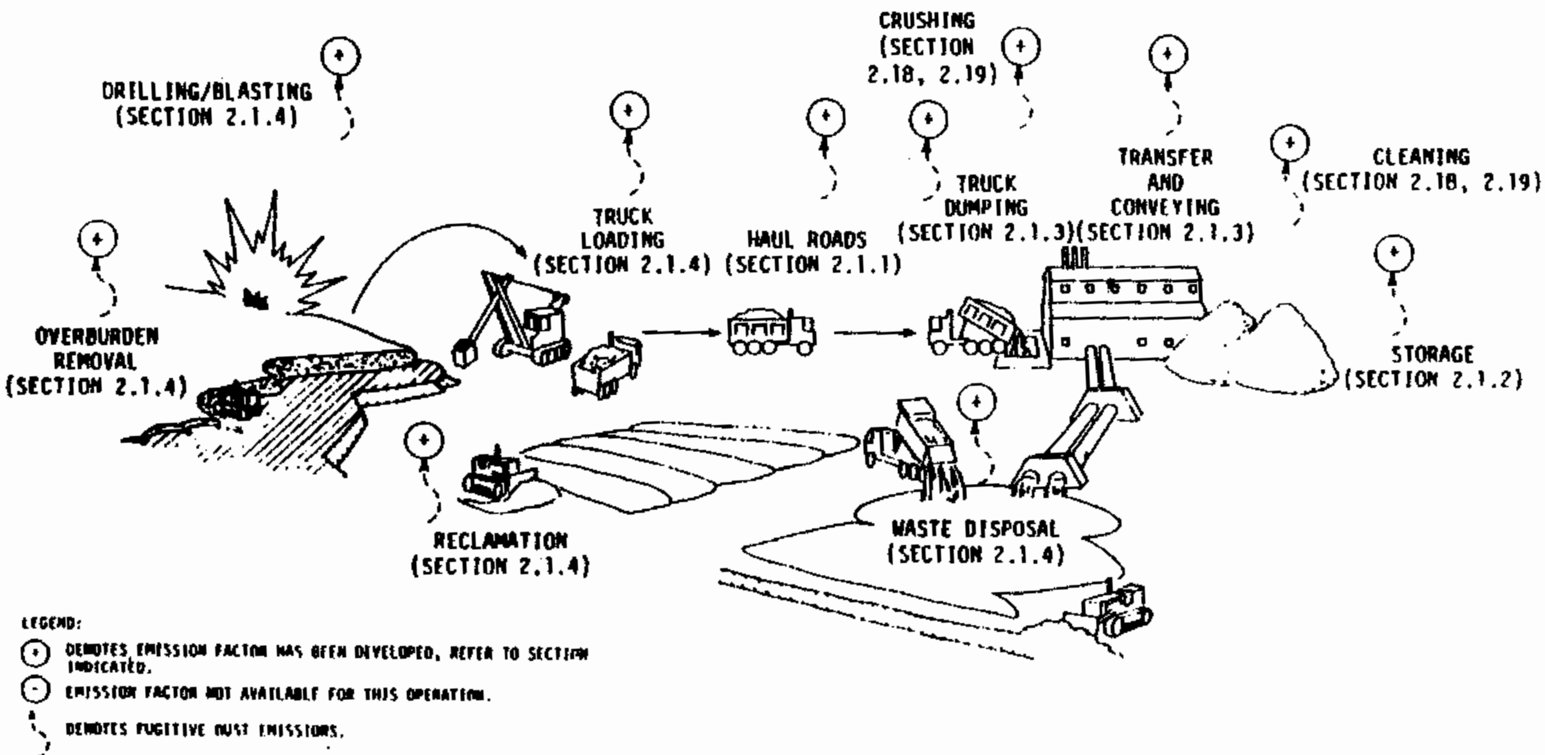

Figure 2.1-2. Order and location of general fugitive dust sources in hypothetical mineral mining operation.

2.1.1 Plant Roadways and Parking Areas

2.1.1.1 Source Description--

The roadways and parking areas located on plant property can be significant sources of fugitive dust. The potential that a given road or parking area surface has for generating fugitive dust is dependent upon traffic volume and the nature of its surface. The surface can be categorized as either paved (concrete or asphalt) or unpaved (gravel or dirt).

Dust generated from paved surfaces results from vehicle activity that agitates the "surface loading" and causes that loading to become airborne. Surface loading is defined as the amount of foreign material present on a paved surface having the potential to become suspended. The amount of surface loading on a paved surface is the composite result of: 1) deposition of mud and dirt carryout, 2) spillage or leakage from moving vehicles, 3) pavement surface wear, 4) runoff or erosion of adjacent land areas, 5) atmospheric fallout, 6) biological debris, 7) wear from tires and brake linings, 8) exhaust emissions, 9) litter, and 10) application of ice control materials.[1]

In contrast to paved surfaces the source of dust generation from unpaved and untreated surfaces is largely from actual road bed material rather than any "surface loading".

In both cases, paved and unpaved, the actual suspension of fugitive dust is the result of vehicular traffic on the surface. Both road bed and surface loading material are mechanically broken down by the tires and subsequently entrained in the ambient air by the air turbulence created by the moving vehicle. In addition to vehicle entrainment, a smaller amount of dust may also be suspended as a result of wind disturbance of the surface loading.

In some instances the unpaved road shoulders can be another source of fugitive dust. This occurs when the roadway is narrow and is ineffectively curbed. Vehicles traveling the road may at times stray from the road surface onto the shoulders and cause significant additional dust generation.

2.1.1.2 Fugitive Dust Emission Factors--

Emission factors for both paved and unpaved surfaces have been determined from field test data on public roadways. Adequate data on the condition of plant roads or parking areas serving private property is not available. Lacking specific data for private plant roads, the public roadway emission factors are modified for use here.

Emission factors for both paved and unpaved surfaces are directly related to the number of vehicle miles travelled (VMT).

The U.S. Environmental Protection Agency provides an average emission factor for dust entrainment from paved roads as 5.6 g/mi.[1] This average emission factor includes tire wear and exhaust emissions (0.53 g/mi), and entrained fugitive dust (5.07 g/mi). Although this "average" value could be used, it would probably not be representative of industrial and commercial roadways as it is based on light duty, four-wheeled vehicles.

A more vehicle-specific emission factor can be determined through modifications to the components of the "average" emission factor.

The method for calculating a specific emission factor for vehicles travelling paved surfaces is given in the following equation:[1]

$$EF = P[(E) + 0.20\ (T/4) + 5.07\ (T/4)] \qquad \text{Equation 1}$$

where:

EF = emission factor, g/VMT,

P = fraction of particulate which will remain suspended (diameter less than 30 μm) from a paved road surface, 0.90 (Reference 1, p. 11.2.5-1),

E = particulate emission originating from vehicle exhaust (see Table 2.1.1-1),

0.20 = tire wear in g/VMT, representing a four-wheeled vehicle,

5.07 = entrained dust in g/VMT, representing a four-wheeled vehicle, and

T = number of tires per vehicle.

The average and specific vehicle emission factors for paved surfaces are given in Table 2.1.1-1. The exhaust emissions and tire wear included in the EPA's average paved road emission factor[1] are representative of a fleet composed primarily of light-duty, four-wheeled gasoline vehicles. However, because of the great variety of vehicles which transit plant property, specific emission factors are presented for ten, twelve, and eighteen-wheeled, heavy-duty gasoline and diesel vehicles.

TABLE 2.1.1-1. EMISSION FACTORS FOR VEHICLES TRAVELLING PAVED SURFACES (g/mi)

Vehicle type	Exhaust (E)[a]	Tire wear[b,c]	Reentrained[c] dust	Initial[d] emission factor	Final emission factor[e]	Emission factor reliability
Average[f]	0.53		5.07	5.6	5.0	g
Light-duty gasoline (4-wheeled)	0.34	0.20	5.07	5.6	5.0	g
Heavy duty gasoline (10-wheeled)	0.91	0.50	12.68	14.1	12.7	g
Heavy duty diesel (12-wheeled)	1.30	0.60	15.21	17.1	15.4	g
Heavy duty diesel (18-wheeled)	1.30	0.90	22.82	25.0	22.5	g

[a] Exhaust emissions are specific for fuel and vehicle type.[1]

[b] The tire wear component is based upon 0.20 g/VMT for a four-wheeled vehicle and can be adjusted upwards for vehicles with large numbers of wheels.[1]

[c] The reentrained dust component is estimated to be directly proportional to the number of tires. An additional multiplication factor of 2.5 should also be applied to the tire wear and reentrained dust columns when considering large wheeled equipment, i.e., mining haul trucks and wheeled-tractors, loaders or dozers.[2]

[d] The initial emission factor is the sum of the exhaust, tire wear, and reentrained dust components.

[e] The final emission factor is the initial emission factor multiplied by a factor of 0.90. The factor of 0.90 accounts for that amount of particulate which will remain suspended.[1]

[f] Reference 1.

[g] Reference 1 fugitive dust emission factor equations and their resulting emission factors are not assigned reliability values.

Fugitive dust from unpaved surfaces can be determined using the EPA's published procedure. This procedure is expressed in the following equation:[1]

$$EF = (P)\ (0.81)\ (s)\ (S/30)\ ((365-W)/365)\ (T/4) \qquad \text{Equation 2}$$

where:

EF = emission factor, lb/VMT,

P = fraction of particulate which will remain suspended (diameter less than 30 μm) from a gravel road bed, 0.62; from a dirt road bed, 0.32 (see Table 2.1.1-2),

s = silt content of road bed material, percent; 12 percent approximate average value (values range between 5 and 15 percent),

S = average vehicle speed, mph,

W = days with 0.01 inch or more of precipitation,[2] and

T = average number of tires per vehicle.

When using Equation 2 for vehicles with oversized tires, a multiplication factor of 2.5 should be included. This factor will account for the comparative difference in the width of tire faces between average road vehicles and oversized tire vehicles. This factor (2.5) can be used to estimate entrained dust emissions from most wheeled construction equipment, i.e.,wheeled-tractors, loaders or dozers, and mining haul trucks.[3]

Emission factors or emission factor equations have not been developed specifically for dust generation from road shoulders, and such emissions have not received much attention in the literature. If dust from this source is considered a significant problem, it is suggested that the unpaved road emission factor be used to estimate the emissions from a dirt or gravel shoulder in lieu of a specific emission factor.

2.1.1.3 Characterization of Fugitive Dust Emissions--

The chemical or mineral composition of road dust depends directly on the type of material deposited on the paved surface or the type of material used in the road bed of the unpaved surface.

Size distribution--The particle size range for fugitive dust from plant roadways and parking lots depends upon the type of road surface. Table 2.1.1-2 gives the size distribution of fugitive dust by surface type.

TABLE 2.1.1-2. TYPICAL SIZE DISTRIBUTION OF FUGITIVE DUST PARTICLES BY SURFACE TYPE[a] (percentages)

Size range	Paved surface	Unpaved surfaces	
		gravel	dirt
<5 μm	50	23	8
5-30 μm	40	39	24
>30 μm	10	38	68

[a] Reference 1, p. 11.2.1-4.

Density and composition--The density and composition of fugitive dust from paved and unpaved surfaces will vary widely depending upon the type of material used to construct the pavement or road bed and the type of material deposited on the surface.

Health effects--When considering possible effects on human health, fugitive particulates can be characterized as being either toxic, pneumoconiosis producing, or of general nuisance.[4]

The toxic components of fugitive dust will vary depending upon the type of material on the road surface and the vehicles traveling that surface. Possible toxic components of surface loading on roadways are lead, asbestos, and the combustion products of fuel (this excludes any toxic compounds specific to the material being hauled which may have been spilled on the road surface). Organic and inorganic lead contaminants originate from the combustion of gasoline with lead-based anti-knock ingredients. The inhalation of lead compounds from automotive exhaust is not considered to be a significant cause of acute lead poisioning; however, prolonged exposure to automotive exhaust can produce chronic lead poisoning.

The environmental impact of lead determined directly from auto exhaust and from reentrained dust has been established.[5,6] Lead comprises only 0.5 percent of the road dust on heavily traveled roads.[6] Thus, the lead component in reentrained dust from plant surfaces can probably be considered as insignificant due to a lower traffic volume and the use of diesel and other fuels containing lower lead content.

Neither asbestos from brake lining wear nor combustion products from vehicles have been a subject of specific epidemiological studies that would define their potential health-effect role as a component of road dust. In the absence of specific quantitative information, the presence of lead, asbestos and combustion products in fugitive dust arising from plant roadways can not be addressed from a health effects standpoint.

Pneumoconiosis is an ailment commonly associated with dust inhalation. Literally translated, pneumoconiosis means "dust in lungs "; however, a more functional and contempory definition states that it is "the accumulation of dust in the lungs and the lung tissue reaction to its presence." In the case of fugitive dust, the potential for pneumoconiosis exists only if substances like asbestos and silica are present in large enough concentrations. No documentation exists on quantitative amounts of these substances in road dust.

The most viable impact fugitive road dust has is in its role as a nuisance dust. The term nuisance applies to any particulate producing debility due to its physical presence in the lungs. The effects of nuisance dust are usually reversible and cannot be considered as being toxic. They are more properly an irritant, especially to individuals already possessing some pulmonary ailment, i.e., asthma or emphysema.[4]

2.1.1.4 Control Methods--

A number of control methods are available for minimizing fugitive dust generation from plant roadways and parking areas. These control measures are presented by roadway surface type (paved or unpaved). Control measures available for paved surfaces are sweeping (broom and vacuum), flushing operations, general housekeeping measures, and speed reduction programs. The

No.

control measures for unpaved surfaces include the application of chemical stabilizers (dust suppressants), road oiling, physical improvements to the road surface (including paving) and speed reduction.

Techniques, efficiencies and costs for controlling fugitive dust from paved surfaces--Sweeping and flushing paved surfaces are the primary control measures used for reducing fugitive dust from paved surfaces. Accumulated surface loading can be removed with sweeping or flushing measures alone or in combination. Good housekeeping is a preventative measure used to limit the on-going accumulation of particulate matter on the surface. Sweeping as a control measure is recommended with one note of caution: The actual effectiveness of sweeping control measures has not been clearly established, and it has been suggested that broom sweepers may actually produce and suspend more fines than they remove.[3]

However, estimated control efficiencies for broom sweepers are reported as 70 percent when used on a biweekly schedule.[7] The initial cost of a broom sweeper designed for industrial roadway use ranges from 5,000 dollars for a trailer-type sweeper to 15,000 dollars for a self-propelled unit (includes water spray system).[7] Annual operating costs have been estimated at 22,000 dollars per year.[7] The estimated control efficiency for a vacuum sweeper has been reported at 75 percent. The initial cost for a vacuum sweeper is 27,000 dollars with annual operating expenses running approximately 25,000 dollars per year.[7] These figures have been adjusted to reflect costs in January 1980 dollars as have all the costs presented in this document.

Flushing of paved surfaces with water reduces the amount of material available for reentrainment. Water flushing is considered to be more effective than sweeping. However, flushing paved surfaces adjacent to unpaved road shoulders may increase mud tracking and carry-on. This increased carry-on has the potential to be a significant source of fugitive dust emissions.

A weekly water flushing operation is estimated to have an effective control efficiency of approximately 80 percent. The initial cost of a 3,000 gallon capacity flusher is approximately 13,000 dollars (excludes truck chassis) with an annual operating cost estimated to be 22,000 dollars per year.[7]

Good housekeeping practices, although a control measure in itself, should be used in conjunction with a more direct removal technique such as flushing. Housekeeping measures include 1) rapid removal of spillage, 2) covering of haul truck beds to prevent wind losses, and 3) cleaning truck tires and under carriages to reduce carryout. No estimate of control efficiencies or costs are available.

A summary of these control efficiencies and costs are presented in Table 2.1.1-3.

<u>Techniques, efficiencies and costs for controlling fugitive dust from unpaved surfaces and road shoulders</u>--The options available for controlling fugitive dust from unpaved plant surfaces

TABLE 2.1.1 -3. SUMMARY OF TECHNIQUES, EFFICIENCIES AND COSTS FOR CONTROLLING FUGITIVE DUST FROM PAVED AND UNPAVED SURFACES

Control method	Estimated control efficiency, %	Initial cost, 1980 dollars	Annual operating cost, 1980 dollars
Paved surfaces			
° Sweeping			
- Broom	70	5,000-15,000[a]	22,000/year
- Vacuum	75	27,000	25,000/year
° Flushing			
- Water	80	13,000[b]	22,000/year
Unpaved surfaces			
° Chemical stabilization[c]	90-95	6,000-13,000/mile	5,000-12,000/mile[d,e]
° Road oiling[c]	75	1,200-2,500/mile	(Re-oil once a month)
° Watering[c]	50	12,000	4,000/mile[e,f]
° Surface improvements			
- Aggregate	30	NA	NA
- Oil and double chip	80	11,000/mile	2,500-5,000/mile[e,g]
- Paving	90	34,000-61,000/mile	(Resurface every five years)
° Speed reduction[h]			
- 30 mph	25	NA	NA
- 20 mph	65	NA	NA
- 15 mph	80	NA	NA

[a] The lower value is for a trailer-type sweeper, the upper value is for a self-propelled unit.

[b] Value represents cost of 3,000 gal. capacity unit excluding truck chassis.

[c] Applies to both unpaved roadways and road shoulders.

[d] Frequency of application was unspecified.

[e] Based on a plant having 6.3 miles of unpaved roads, this average was determined from unpaved road mileage at four steel plants, Reference 7, page 6-16.

[f] Represents a frequency of two waters per day.

[g] Value based upon resurfacing once a year.

[h] Assumes an uncontrolled speed of 40 mph.

(unpaved roads, road shoulders and parking lots) are chemical stabilization through the use of dust suppressants, road oiling, surface improvement and speed reduction.

The suppression of fugitive dust from unpaved surfaces can be achieved using a variety of chemical stabilizers. The chemicals used for this purpose are either wetting or binding agents which are diluted with water and sprayed over the unpaved surface. Effective use of a chemical stabilizer can only be achieved when it is used as part of a continual application program with the frequency of application related to the relative use of the roadway. The control efficiency for this measure is estimated to be between 90 and 95 percent.[7] The initial costs are estimated to be between 6,000 and 15,000 dollars per mile of roadway (approximately 130 thousand square feet).[7] Annual operating costs range between 5,000 and 12,000 dollars per mile of roadway.[7] A summary of the types of chemicals used, their costs, and application rates is presented in Appendix B.

Cost estimates for oiling unpaved roadways and parking areas were obtained from private contractors operating in Cincinnati, Cleveland and Columbus.

The initial cost estimate of a contract road oiling project is based upon three factors: 1) the total amount of surface area to be treated; 2) the configuration of the surface area; and 3) the availability of waste oil. The first factor, surface area, is obviously related to the cost of the task. The larger the area to be treated, the more time and material required and, as a result, the higher the final cost. Contractors in Ohio were not willing to discount the cost of the project on a volume basis. The second factor, configuration of the surface area, means that an area with a large number of curves or corners requires excessive stopping and starting of the application vehicle. This action wastes oil and, as a result, increases the total cost of the project. The third factor, availability of waste oil, determines the price the contractor must pay for the raw materials. Despite the current oil problems, waste oil prices have not increased to the same degree as other petroleum products. The contract cost estimates, determined for three metropolitan areas in the State of Ohio, are given in Table 2.1.1-4.

Road oiling contractors use two types of waste oil for application purposes: crankcase oil (oil from garages and service stations) and industrial oil (waste oil from industrial processes). The crankcase oil is preferred over the industrial oil because it contains fewer amounts of contaminants (chemicals and water soluble substances) and, as a result, has a wider range of application.[9] The possible impact on adjacent plant life and landscaping is a factor to be considered when oiling unpaved surfaces. An additional problem with road oiling is that it can significantly increase the amount of surface runoff. Oiling large areas may require special precautions to handle the excess volume of water.[3] The control efficiency for road oiling is estimated to be 75 percent.[7] The initial (contract) cost of

TABLE 2.1.1-4. CONTRACT COST ESTIMATES FOR OILING UNPAVED ROADWAYS (1980 Dollars)

Metropolitan area[a]	Dollars per gallon	Dollars per 10^3 square ft.[b]	Gallons per 10^3 square ft.
Cincinnati	0.21	9.50 - 11.50	50
Cleveland	0.31	11.50	37
Columbus	0.28	13.50	48

[a] Cincinnati area, two responses. Cleveland and Columbus areas, one response each.[10]

[b] Variations in the cost per 10^3 square ft. result from both the differences in the cost of waste oil and each contractor's estimate of the amount of oil necessary to cover the 10^3 square ft. area.

oiling a one mile length of unpaved roadway (approximately 130 thousand square feet) ranges between 1,200 and 1,800 dollars depending on the contractor.[7] Values as high as 2,500 dollars have been reported.[7]

Another method of dust suppression for unpaved surfaces is watering. This method, although often considered less expensive than chemical treatment, in fact has many drawbacks and can be more expensive. The most obvious drawbacks are 1) the need for a continuous application program, 2) decreased efficiency during dry weather conditions, 3) the increased potential to add mud carry-on to nearby paved surfaces and 4) limited applicability during cold winter periods. The estimated control efficiency for this measure is approximately 50 percent.[7] The initial costs for watering are 12,000 dollars (the cost of equipment and truck) with annual operating costs approximately 4,000 dollars per mile per year based upon 2 applications per day.[3,7]

Surface improvements can also be used to control fugitive dust from unpaved roads. These include 1) coverage with a low silt aggregate, 2) oil and double chip surfacing and 3) paving.

Covering an unpaved road with aggregate assumes that the aggregate material (limestone, river gravel, etc.) has a lower silt content than the dirt roadbed, thus reducing the amount of fines available for entrainment. The control efficiency for this technique is very low, approximately 30 percent.[7] Surface coating of this type requires continuous road maintenance to sustain the 30 percent level of effectiveness.[7] Initial and annual operating costs for this technique are not available.

The second surface improvement method, oil and double chip surfacing, achieves a higher degree of control than aggregate and requires much less maintenance. The control efficiency for this technique is 80 percent, and the initial cost per mile (130,000 ft^2) is 11,000 dollars.[7] The annual cost will depend on how often the road will need to be resurfaced. Assuming a resurfacing frequency of once every 2 to 4 years the costs will range between 2,500 and 5,000 dollars per year.[7]

The third method for controlling fugitive dust from unpaved surfaces is to pave the surface. The control efficiency for this measure is the highest of the surface improvement techniques, approximately 90 percent.[7] The initial cost of paving one mile of unpaved surface with asphaltic concrete is between 34,000 and 61,000 dollars depending upon the type of road bed required. The roadway will generally have to be resurfaced at 5 year intervals.[7]

Speed reduction also can be used as a control measure for reducing fugitive dust from unpaved surfaces. This method is attractive in that the initial and operating costs may be very low (no actual cost estimates are available). However, speed reduction measures could require additional trucks and drivers to maintain production levels.[11] Also, the enforcement of speed restrictions is often very difficult to maintain. The effective control efficiencies for speed reduction increase as the speed is reduced. Based on an assumed uncontrolled speed of 40 miles per hour, a speed restriction to 30 mph will result in a 25 percent control efficiency; a 20 mph restriction, 65 percent; a 15 mph restriction, 80 percent.[1]

A summary of the control efficiencies and costs for minimizing dust from paved and unpaved roadways are presented in Table 2.1.1-3.

The tables do not contain figures for the cost-effectiveness of control due to the variability in types of vehicles and mileage of plant roads from plant to plant. Selection of Reasonably Available Control Measures (RACM) is also hampered by the variability of the problem from plant to plant and industry to industry. However, a selection can be made based on a typical situation with the caveat that RACM can differ in unusual economic or logistic situations. For paved roads, the recommended control measure is the use of water flushing supplemented by a good-housekeeping program to minimize spills and carry-on of dirt and mud. The program would consist of such measures as covering trucks, prompt clean up of spills, elimination of carry-on by avoidance of unpaved areas where practicable, and water washing of wheels where necessary.

For control of unpaved areas, the recommended control technique is the use of chemical stabilization or oiling, coupled with speed reduction. Where the plant has large unpaved areas, frequently traveled, and to be used for many years, it may be economically justifiable to pave the road (oil and double chip or asphaltic concrete). This must be justified on a case-by-case basis.

Benefits of control measures--The control of fugitive dust from plant roadways and parking areas does not provide an obvious economic benefit. However, this control may indeed have a few hidden benefits which may result in cost savings to the industry. The primary theme underlying each of the control measures described in this section is to maintain a good surface upon which industry vehicles will operate. Surface improvements can be expected to result in reduced equipment wear. Dust suppression will increase driver visibility and may result in less down time due to equipment cleaning and maintenance. In many cases where a facility is located near residential areas, the control of fugitive dust from roadways and parking areas will increase the aesthetic appeal of the property.

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2.1.2 Aggregate Storage Piles

2.1.2.1 Source Description--

A storage pile is any mound of material (usually mineral) placed in a temporary outdoor location. The storage piles are usually uncovered allowing the stored material to be exposed to the elements. This characteristic lack of cover or housing around a storage pile is a result of the frequent necessity to transfer material from the storage site to a process operation.

Dust emissions can occur at several points in the storage cycle of an aggregate: 1) during load-in (addition) of material onto the pile, 2) during wind disturbance of the pile, 3) during the movement of vehicles in the storage area, and 4) during load-out (removal) of material from the pile.[1]

2.1.2.2 Fugitive Dust Emission Factors--

The fugitive dust generated from aggregate storage piles occurs as a result of the four major emission-producing activities given above. Their relative percent contributions vary depending upon the type of material being stored and the exact method of storage being used. The calculation of fugitive dust emission factors from aggregate storage piles can be approached in two fashions: 1) using a gross overall emission factor equation or 2) using a set of emission factor equations specific for each of the four operating activities.

Gross Overall Emission Factor Equation

The gross estimate of fugitive dust emissions to be expected from aggregate storage piles, based upon the number of tons of material placed in storage, can be determined using Equation 1.[1]

$$EF = 0.33/(PE/100)^2 \qquad \text{Equation } 1^{1}$$

where:

EF = Emission factor, lb/ton of material placed in storage, and

PE = Thornthwaite's precipitation-evaporation index (Figure 2.1.2-1).

Equation 1 represents the fugitive particulate emissions with a diameter less than 30 μm. This particulate size was determined[2] to be the effective cutoff diameter for the capture of aggregate dust by a standard high-volume filter based on a particulate density of 2.0 to 2.5 g/cm^3. The emission values calculated by this equation express only that amount which is likely to remain suspended indefinitely.[1] No details on the development of this equation or the estimated accuracy were available from the reference.

Equation 1 contains one correction parameter, the PE index or Thornthwaite's precipitation-evaporation index, which accounts for the changes of climate throughout the United States.[3] The PE index is an approximation of the average amount of surface moisture characteristic to a particular area. The PE index values for the State of Ohio and adjacent areas are given in Figure 2.1.2-1.

Table 2.1.2-1 shows how the total emission factor in Equation 1 can be divided into the individual contributions of the

Figure 2.1.2-1. Thornthwaite precipitation-evaporation (PE) indices for the State of Ohio.[3]

TABLE 2.1.2-1. PERCENT CONTRIBUTION OF AGGREGATE STORAGE PILE ACTIVITIES TOWARD THE TOTAL FUGITIVE EMISSION RATE[2]

Source activity	Approximate percent contribution[a]
Loading of the material onto piles	12
Wind disturbance and erosion of stored material	33
Loadout of the material from piles	15
Vehicle movement	40
Total	100

[a] The emission contributions of each source activity are based on field tests of suspended dust emissions from crushed stone, sand and gravel storage piles. A 3-month storage cycle was assumed.[2]

four source activities. This distribution of emissions by source activity is representative of aggregate storage piles in general, but may vary for any specific source or stored material.

Specific Emission Factor Equations

Specific emission factor equations are available for each of the four major sources of fugitive dust associated with the storage cycle of aggregate material.[4] The equations are for specific types of equipment and storage material; thus, they should be used with caution when applied to other situations. Emissions from the first stage in the storage cycle, loading of material onto the pile, can be exemplified by means of a conveyor/stacker (continuous load-in) or a front-end loader (batch load-in). Emissions from the second stage in the cycle, wind disturbance of the pile, are exemplified by using a wind erosion equation. Emissions from the third stage are exemplified by using an equation for determining vehicular traffic around the storage piles. Emissions from the final stage, the load-out of material from the pile, are exemplified by the transfer of aggregate by a front-end loader from the pile to a truck.

The emissions from the operation of a conveyor/stacker (continuous load-in) are determined using Equation 2.[4] The base emission rate is corrected by three variables, the silt content of the material being stored, the moisture content of the material being stored, and the mean wind speed occurring during the operation.

$$EF_{(continuous)} = 0.0018 \frac{(S/5)(U/5)}{(M/2)^2} \qquad \text{Equation } 2^4$$

where:

EF = emission factor, lb/ton of material loaded onto the pile by a continuous operation,

S = silt content of the stored material in weight percent (see Table 2.1.2-2),

M = moisture content of the stored material in weight percent (see Table 2.1.2-2), and

U = mean wind speed, mph (see Table 2.1.2-3).

Emissions from the operation of a front-end loader (batch load-in) are determined using Equation 3.[4] The base emission rate is corrected by four variables: the silt content, mean wind speed, material moisture content and effective loader capacity.

$$EF_{(batch)} = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)} \qquad \text{Equation } 3^4$$

where:

EF = emission factor, lb/ton of material loaded onto the pile by a batch operation,

S = silt content of the stored material, in weight percent (see Table 2.1.2-2),

M = moisture content of the stored material, in weight percent (see Table 2.1.2-2),

U = mean wind speed, mph (see Table 2.1.2-3), and

Y = effective loader capacity, cubic yards.

The effective loader capacity is the working bucket capacity of the front-end loader being used to add material to the storage pile. The "mean wind speed" can be determined for a given study

TABLE 2.1.2-2. REPRESENTATIVE SILT CONTENT, MOISTURE CONTENT AND THE DURATION OF STORAGE PARAMETERS FOR SPECIFIC STORAGE MATERIALS[4,5]

Material in storage	Silt content, weight %	Moisture content, weight %	Duration of storage, days
Coal	4	6	107
Coke	1	1	50
Iron ore	11	1	43
Limestone	2	2	76
Sand	10		
Sinter	1.5	1	90
Slag	2	1	60
Top soil	40		

period (using actual field measurements) or estimated using the data given in Table 2.1.2-3.

The fugitive emissions occurring as a result of wind blown erosion of the storage pile can be determined using equation 4.[4] The base emission rate for wind erosion is adjusted by four correction parameters: the silt content of the storage material, the duration of storage, the number of dry days*, and the percentage of time that wind speeds exceed 12 mph.

$$EF = 0.05\ (S/1.5)(D/90)(d/235)(f/15) \qquad \text{Equation 4}$$

where:

EF = emission factor, lb/ton stored,

S = silt content of the stored material, weight percent (see Table 2.1.2-2),

D = duration of storage, days (Table 2.1.2-2),

d = dry days* per year (Figure 2.1.2-2), and

f = percentage of time wind speed exceeds 12 mph (References 6 and 7).

The percentage of time that the wind speed exceeds 12 mph is most appropriately obtained from actual on-site monitoring. However, should this type of data be unavailable, hourly wind speed for each day (recorded at the nearest metropolitan airport) can be obtained from the National Weather Service.[7]

Fugitive dust emissions occurring from vehicle traffic around storage piles can be determined using the unpaved roadway emission equation given in Section 2.1.1. However, a method of

* Dry days are those days with <0.01 inches of precipitation.[6]

TABLE 2.1.2-3. THIRTY-YEAR ANNUAL WIND SPEED FOR SELECTED OHIO CITIES[6]

City	Mean wind speed, mph
Akron	9.9
Cincinnati	9.1
Cleveland	10.8
Columbus	8.7
Dayton	10.2
Mansfield	11.0
Toledo	9.5
Youngstown	10.0

calculating vehicle traffic emissions, specific for activity around the storage piles, is given in Equation 5.[4]

$$EF = 0.10\ K\ (S/1.5)(d/235) \qquad \text{Equation } 5^{4}$$

where:

EF = emission factor, lb/ton (of material put through the storage cycle),

K = activity factor, dimensionless (Table 2.1.2-4),

S = silt content of stored material, weight percent (see Table 2.1.2-2), and

d = dry days per year (see Figure 2.1.2-2).

The activity factor (K) is related to the type of loading (or haul) equipment employed and its level of usage as considered typical for various types of materials. The activity factor is a dimensionless number that places a value on the piece of equipment being used for specific materials relative to the equipment used in the original test study (front-end loader) on gravel operations. Table 2.1.2-4 gives values for K.

The final source of fugitive dust emissions that can be determined for a specific portion of the storage pile cycle is the load-out of material from the pile. The base emission rate for load-out of material from the pile by a front-end loader into a truck is adjusted by four correction parameters: the silt content of the storage material, the moisture content of the storage material, the mean wind speed, and the effective loader capacity.

The emission factor for the load-out of material from a storage pile by a front-end loader is presented in Equation 6.[4]

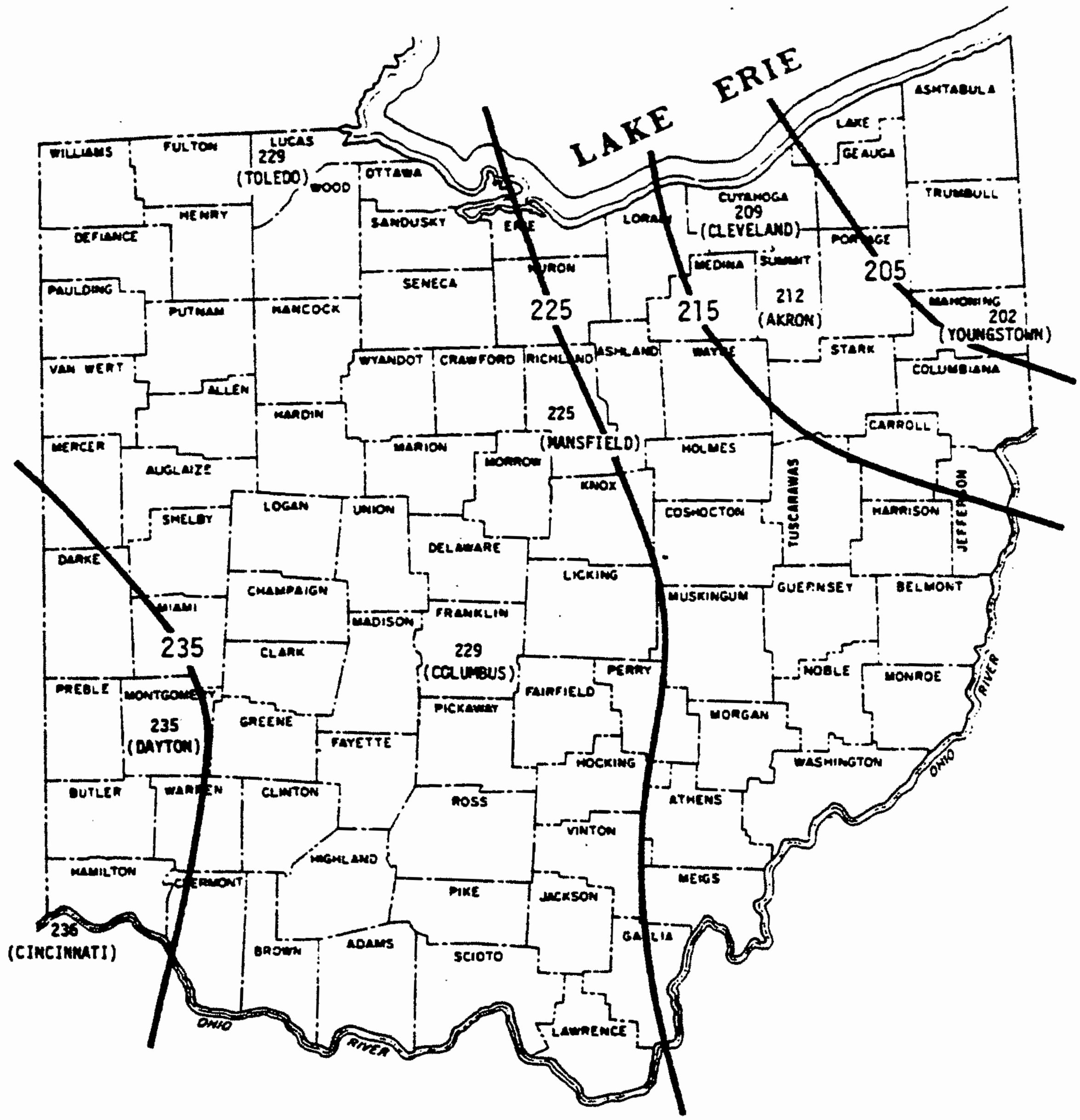

Figure 2.1.2-2. Mean number of dry days(less than 0.01 inch of precipitation) in the State of Ohio.[1,6]

TABLE 2.1.2-4. VEHICULAR ACTIVITY FACTORS[4]

Material	Range	Mean
Coal	0.0-0.25	0.08
Coke	0.0-1.0	0.25
Gravel[a]	0.25	-
Iron ore[b]	0.0-0.25	0.06
Limestone[c]	0.25	-
Sand[d]	1.0	-
Sinter	0.0	-
Slag	1.0	-
Top soil	-	-

[a] Large stone aggregate.

[b] Values are for both lump ore and pellets, 0.25 was determined for pelletized ore.

[c] Dolomite limestone.

[d] Sand and gravel.

$$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)} \qquad \text{Equation } 6^{4}$$

where:

EF = emission factor, lb/ton of material transferred,

S = silt content of stored material, weight percent (Table 2.1.2-2),

M = moisture content of stored material, weight percent (Table 2.1.2-2),

U = mean wind speed, mph (Table 2.1.2-3), and

Y = effective loader capacity, cubic yards.

The effective loader capacity of the front-end loader will vary depending upon its intended use. A typical front-end loader used for the purpose of loading gravel will have an effective loader capacity of 3 cubic yards.

Details regarding the actual development of Equations 2 through 6 and the accuracy and limitations of application are not available; but given the generalities of application, the estimates should be considered to be within an order-of-magnitude at best.

A summary of the emission factor equations and correction parameters are presented in Table 2.1.2-5.

2.1.2.3 Particle Characterization--

Particle Size, Density, and Composition

The particle size of airborne fugitive dust from aggregate storage piles does not vary greatly and can be stated to be somewhat independent of the material being stored.[8] Typical particulate size ranges for fugitive dust from aggregate storage piles are given in Table 2.1.2-6. Recent information does

TABLE 2.1.2-5. SUMMARY OF EMISSION FACTOR EQUATIONS AND CORRECTION PARAMETERS

Emission category	Emission factor equation
Gross overall emission rate[a]	$EF = 0.33/(PE/100)^2$
Load-in (continuous operation)[b]	$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2}$
Load-in (batch operation)[b]	$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)}$
Wind erosion[b]	$EF = 0.05\ (S/1.5)(D/90)(d/235)(f/15)$
Vehicle activity[b]	$EF = 0.10\ K\ (S/1.5)(d/235)$
Load-out[b]	$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)}$

Correction parameters

Symbol - Description	
PE - Thornthwaite's Precipitation Evaporation index	Figure 2.1.2-1
D - Duration of material in storage, days	Table 2.1.2-2
d - Number of dry days per year	Figure 2.1.2-2
f - Percent of time wind speed exceeds 13 mph	Reference 6,7
K - Activity correction	Table 2.1.2-4
M - Material surface moisture content, %	Table 2.1.2-2
S - Material silt content, %	Table 2.1.2-2
U - Mean wind speed, mph	Table 2.1.2-3
Y - Effective loader capacity, yd^3	Specific to equipment

[a] Reference 1.

[b] Reference 4.

TABLE 2.1.2-6. TYPICAL PARTICULATE SIZE RANGES FOR FUGITIVE DUST FROM AGGREGATE STORAGE PILES[a]

Size range	Percent by weight of emissions
<3 µm	30
3-30 µm	23
>30 µm	47

[a] Reference 9.

indicate that, although the particle size distribution may be fairly independent of the material being stored, the condition of the storage pile surface (disturbed or undisturbed) can influence the size distribution. Studies of coal storage piles indicate that an undisturbed pile surface will generate a smaller percentage of particles under 30 μm (approximately 9%) than a disturbed surface (approximately 21%).[10]

The density and composition of the fugitive emissions from aggregate storage piles will be directly related to the material being stored.

<u>Hazardous or Toxic Nature of Fugitive Emissions from Aggregate Storage Piles</u>

The hazardous or toxic nature of fugitive emissions from aggregate storage piles is almost entirely dependent upon the type of material being stored. It is not possible to discuss the nature of a health hazard without first knowing the storage material in question. The reader is directed to the health effects discussion in Section 2.1.1.3 which outlines the health problems associated with fugitive emissions from paved and unpaved surfaces for information on emissions generated during vehicle activity around the storage pile. For other storage pile activities, specific knowledge of the storage material is necessary. The hazardous properties of specific industrial materials can be found in Reference 11.

2.1.2.4 Control Methods--

The control methods available for reducing fugitive dust from activities associated with the storage of material in open piles are presented in this section by each type of activity: load-in, wind disturbance, vehicle traffic and load-out.

Techniques, Efficiencies and Costs for Controlling Fugitive Dust Emissions from Storage Pile Load-In

The control techniques for reducing dust from load-in activities consist of enclosures, chemical stabilization, and operating precautions. The enclosures include silos, stone ladders, wind guards and telescopic chutes. The chemical stabilization includes watering, the application of dust retardant, and the use of crusting agents. The final group of control techniques concern themselves with precautionary operating habits such as reducing the drop height of front-end loader buckets and making operators aware of the necessity of dust control.

Enclosures - Enclosure techniques include storage site enclosure (e.g., silos) and material handling enclosures (e.g., chutes). Storage site enclosures, like silos or warehouses, must be specifically designed for the material being handled. Additional structural considerations such as ability to withstand snow loads, wind or precipitation affect the design of any given silo or enclosing structure. Due to this degree of specificity, it is hard to place an exact efficiency rating or cost estimate on the use of storage silos or buildings. It is expected that a properly built storage silo would substantially reduce load-in emissions when accompanied with control of the emissions from the material transfer into the silo.

Stone ladders are permanent devices which aid to guide material from a stacker to the pile. A stone ladder is a vertical tube with openings at various heights. The storage material will fill the tube until it reaches an opening, at this point the material will begin to flow out on to the pile. The estimated control efficiency for this device as compared to the emissions from a front-end loader is approximately 80 percent, and the initial investment is about 24,500 dollars.[4]

Wind guards are closely related to telescopic chutes except that they are of a fixed length. The wind guard covers the discharge end of a stacker helping to decrease the effective dispersing action of the wind. The estimated control efficiency for a wind guard on a stacker (when compared to a front-end loader) is approximately 50 percent.[4] The initial cost is estimated at between 12,000 and 61,000 dollars.[4]

A telescopic chute consists of a series of thin-walled cylinders which help to guide the material being dropped from the stacker to the pile. The telescopic chute retracts as the pile grows. This feature makes its use suitable for both stationary or mobile stackers. The purpose of a telescopic chute is to reduce a long drop distance to a few feet. The estimated control efficiency for a telescopic chute (compared to a front-end loader) is approximately 75 percent. The initial cost can be approximately 8,500 dollars.[4,8]

Chemical stabilization - The primary forms of chemical stabilization used during load-in activities are watering and wetting agent application. The water or wetting agent is applied by a spraying system at the discharge end of the stationary or mobile stacker. Relative to the use of a front-end loader, a stationary or mobile stacker with a spray system has been estimated by various sources to have a control efficiency of from 75 percent[4] to as high as 80 to 90 percent.[12] The initial investment in equipment is approximately 13,500 dollars.[4] This figure does not include the annual operating costs and assumes the use of water only. The application of chemical wetting, crusting or suppression agents to the storage pile results in higher costs. Depending on the agent used, costs can be between 0.5 and 1.5 cents per square foot of surface area.[4] A summary of common chemical agent costs is presented in Table 2.1.2-7.

Precautions - Operational precautions are assumed to have some potential to decrease the amount of fugitive dust generated when material is dropped from a front-end loader or height adjustable stacker. The ability of the equipment and operator to reduce the drop distance of the storage material can help to reduce the amount of fugitive dust emitted. A properly operated "variable height" stacker can gain a 25 percent control effiency over normal front-end loader operation.[4] The control efficiency gained through lowering the drop distance of a front-end loader was not addressed in the available literature. A summary of the

TABLE 2.1.2-7. CHEMICAL STABILIZING AGENTS FOR USE ON AGGREGATE STORAGE PILES[a,b]

Stabilization agent	Dilution	Application rate per 10^3 ft^2	Application cost, 1980 dollars per 10^3 ft^2
Organic polymers			
° Johnson-March SP-301[c]	Full strength	10 gal. concentrate	16.50[d]
° Apollo			
Pentron DC-3[e]	10% solution	1.2 gal. concentrate	4.20
Pentron DC-5[e]	10% solution	1.2 gal. concentrate	4.50
° Houghton Rexosol 5411-B[c]	2% solution	3 gal. concentrate	8.50
Petroleum resin water emulsion			
° Witco Chemical Coherex[c]	20% solution	20 gal. concentrate	4.90
Latex type synthetic liquid adhesive			
° Dowell M145 chemical binder[c]	4% solution	1.8 gal. concentrate	4.90

[a] Mention of a company or product name should not be construed as an endorsement by either the author of this document or the Ohio Environmental Protection Agency. It should also be noted that the table represents an example of the wide range of chemicals available for use. It does not attempt to include all chemical companies or all of their products.

[b] The figures given in this table are approximations and can be used in only a very cursory comparison of costs (on a usage basis).

[c] Reference 4, pages 6-11.

[d] Based upon a cost of 1.65 dollars per gallon, which assumes that the stabilizer will be purchased in quantities of 45 or more drums (at 55 gal. per drum).

[e] Reference 13.

control techniques and efficiencies for storage pile load-in activities are given in Table 2.1.2-8.

Techniques, Efficiencies and Costs for Controlling Fugitive Dust Due to Wind Disturbance of Aggregate Storage Piles

The control techniques for reducing fugitive dust from wind disturbed storage piles consist of building enclosures, applying chemical stabilizers or in some instances taking precautionary maintenance measures. The enclosures used to reduce wind disturbance include both silos and wind breaks. The chemical stabilization techniques include watering and application of surface crusting agents. The precautionary measure consists of maintaining as low a pile height as possible.

Enclosures - The protection of storage piles from the direct action of wind erosion and dispersion can be accomplished through the use of total (silo) or partial (wind break) enclosures. Silos are not often used for controlling fugitive dust. Instead they are usually constructed for the protective storage of special materials. In one instance, storing coal in a single large silo effectively eliminated from 95 to 100 percent of the wind generated emissions.[4,6]

The cost for constructing silos will vary for different materials. An approximate cost of 75 dollars per ton of material stored has been suggested.[4] Wind breaks, such as trees, shrubs or other vegetation, or man-made structures, have been estimated to provide a control efficiency of 30 percent.[4] The cost of such structures will vary greatly. For vegetative wind breaks, a

TABLE 2.1.2-8. A SUMMARY OF CONTROL TECHNIQUES, EFFICIENCIES AND COSTS FOR FUGITIVE DUST EMISSIONS FROM AGGREGATE STORAGE PILES

Emission source and control techniques	Estimated control efficiency, %[a]	Initial cost, (1980 dollars)	Annual operating costs, (1980 dollars)
<u>Load-in</u>			
° Enclosures			
- Silo	-	(see wind disturbance)	NA
- Stone ladders	80	24,500	NA
- Wind guards	50	12,000 to 61,000	NA
- Telescopic chutes	75	8,500	NA
° Chemical stabilization	75 to (80-90)	13,500	$4.20 to 16.50/10^3 ft^2
° Precautions	0-25	NA	NA
<u>Wind disturbance</u>			
° Enclosures			
- Silo	95-100	75 per ton of material stored	NA
- Vegetation wind break	30	45-425 per tree	NA
° Chemical stabilization	80-99	13,500+	$4.20 to 16.50/10^3 ft^2
° Precautions	30	NA	NA
<u>Vehicular traffic</u>	(See Section 2.1.1 Plant Roadways and Parking Areas)		
<u>Load-out</u>			
° Reclaimer systems	80-85	2-6 million[b]	NA
° Dust suppression (includes bucket reclaim system and spray)	95	75,000+	NA

[a] Reported overall efficiencies for various materials. Not tailored to any one type of material stored.
[b] Based upon a mobile stacker/reclaimer system.

single tree can range between 45 dollars for an 8 foot specimen to 425 dollars for a 25 foot specimen.[4]

Chemical stabilization - The act of using a substance to stabilize the surface of an aggregate storage pile is often referred to as "surface stabilization." This process binds the loose surface material into a solid, nonerodible crust through the use of a chemical crusting agent. Also, water (with or without a wetting agent) can be used to keep the surface moist and promote the adhesion of small particles to larger ones. In order to wet the surface of the pile, a system of towers, sprinklers and pipes must be constructed. The initial cost of this equipment has been estimated at approximately 13,500 dollars.[4] An estimate of spray and application costs can be determined through Table 2.1.2-7. The control efficiency of a spraying system is given to be approximately 80 percent using water and up to 99 percent when chemical agents are used.[4]

Precautions - The lowering of the storage pile height takes advantage of the fact that wind speed generally increases with height above ground level. Lower storage piles result in lower surface wind speeds which result in reduced wind erosion. The maintenance of low storage piles can not be directly associated with any change in cost. An estimated control efficiency of 30 percent is assigned to this technique.[4]

Techniques, Efficiencies and Costs for Controlling Fugitive Dust from Vehicular Traffic Around Storage Piles

The requirements for controlling fugitive dust from unpaved access roads on or near aggregate storage piles is not unlike the requirements for other unpaved plant roadways. The reader is referred to Section 2.1.1, Plant Roadways and Parking Areas, for a discussion of controlling dust from unpaved plant surfaces.

Techniques, Efficiencies, and Costs for Controlling Fugitive Dust from Storage Pile Load-Out

The control techniques for reducing dust from load-out activities include the use of reclaimer systems and dust suppressants.

The load-out of material from storage piles can be accomplished with the use of either front-end loaders or reclaiming systems. The reclaiming of material from storage piles is accomplished by use of underground conveyors and raking or bucket equipment. In either of these cases the reclaimer systems minimize the amount of fugitive dust generated during load-out operations (as compared to a front-end loader).

Rake reclaimers move along the surface of the pile directing material toward an underground conveyor system. The bucket system consists of a bucket wheel which moves along the pile perpendicular to its face. The buckets move material from the pile surface onto a conveyor. The reclaiming system may also be passive in nature, in which case material is fed to the conveyor beneath the pile by gravity alone.

The control efficiencies for these systems (as compared to a front-end loader) are 85 percent for the rake reclaimer and approximately 80 percent for the gravity feed and bucket reclaimer.[4,8] Reclaiming systems will vary greatly in cost depending upon the type of system chosen and the desired design capacity. Initial costs of a mobile stacker/reclaimer system range between 2 and 6 million dollars.[4]

The mechanism behind dust suppression is similar in nature to chemical stabilization. The technique consists of the application of water or chemical wetting agents to the storage pile prior to disturbance by load-out equipment. This technique can include simple surface spraying of the pile, or the use of a specialized spray system which wets the storage material as it is being disturbed. The control efficiency of wetting the pile surface prior to disturbance (by a front-end or reclaimer) is not documented in the literature. The actual efficiency is assumed to be low. The control efficiency of a bucket wheel reclaimer with spray system (as opposed to a front-end loader alone) is estimated to be 95 percent.[4] The estimated cost of a spray system for use with an existing mobile bucket wheel reclaimer is at least 75,000 dollars.[4] No annual operating cost estimates are available.

RACM selections for storage piles must be made on a site specific and material basis. Some materials are amenable to wet control techniques with no effects on material quality, while others cannot tolerate increased moisture. RACM for a specific site should also be made by evaluating the severity of the emissions and the costs for the various control alternatives. Specific RACM selections are made for storage activities of various materials in the later industry-specific sections.

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2.1.3 Material Handling

2.1.3.1 Source Description--

Material handling is the description given to the movement of raw process materials from receiving sites (truck depots, vessel docking facilities and rail spurs) to industrial storage sites (aggregate storage piles or silo enclosures) or directly to proc operations, the transfer of materials between process operations, and transfer of products to storage or shipment. The actual material handling is a combination of unloading, transfer, and conveying operations. These three types of operations are common to virtually all process industries. A pictorial representation of these operations is given in Figure 2.1.3-1. This figure depicts the relative position of each material handling operation within a hypothetical industrial setting.

The unloading operations are presented in this section according to the transportation mode of the vehicle being unloaded (truck, vessel or rail car). The types of unloading operations frequently associated with material handling are: dumping by truck; crane-clamshell and bucket ladder removal from vessels; and side dumping, rotary dumping, bottom dumping and pneumatic removal of material from rail cars.

The transfer and conveying of material are accomplished with belt conveyors, screw conveyors, bucket elevators, vibrating conveyors and pneumatic equipment. The actual loss of material or the generation of dust from material handling will occur at

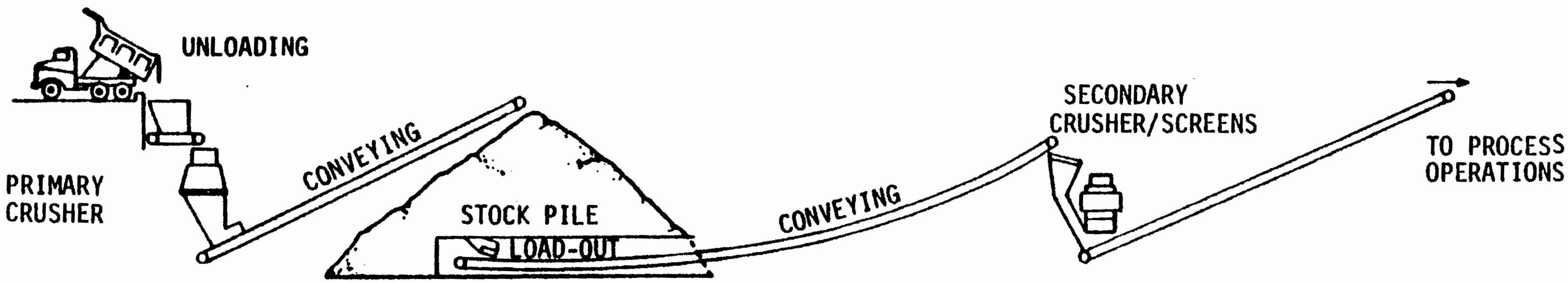

Figure 2.1.3-1. Typical materials handling operation.

the feeding, transfer, and discharge points along the system. Review of the literature indicates that a majority of the material loss generated is due to spillage and is superseded by wind erosion only when the handling system is improperly enclosed.[1]

2.1.3.2 Fugitive Dust Emission Factors--

The fugitive dust emissions generated from the handling of process materials vary depending upon the method of unloading or transferring used and the type of material being handled. In most cases, the available emission factors for material handling are based upon engineering judgment or limited on-site measurements. Table 2.1.3-1 presents the available emission factors for unloading of material. Table 2.1.3-2 gives the emission factors for the conveying and transfer of material. In using these factors for materials not listed, it is best to select the factor for the listed material that would most likely have similar properties to the material in question.

2.1.3.3 Particle Characterization--

Particle Size, Density and Composition--The particulate size of fugitive dust generated from material handling operations can be considered not to vary with the type of aggregate material in storage. It can be assumed that the size distribution of the dust will be somewhat independent of the type of material being handled, because the surface condition of the transported material (crusted or aggregated versus fine or disaggregated) will

TABLE 2.1.3-1. EMISSION FACTORS FOR THE UNLOADING OF MATERIAL

Vehicle	Method of unloading	Material unloaded	Uncontrolled emission factor (lb/ton of material unloaded)	Reliability
Truck	° Dumping	Aggregate	0.02[a]	D
		Rock and gravel	0.04[a]	E
		Granite	0.00034[a]	E
		Grain	2-8[b]	D
			0.64[c]	B
Vessel	° Crane-clamshell bucket	Grain	3-8[b]	D
	° Bucket ladder	d	d	
Rail	° Side dump	d	d	
	° Rotary dump	d	d	
	° Bottom dump	Taconite pellets	0.03[b]	E
		Coal	0.4[b]	E
		Grain	3-8[b]	D
			1.30[c]	B
	° Pneumatic	d	d	

[a] Reference 5, pages 37-40.

[b] Reference 2, page 2-17.

[c] Reference 3, page 12.

[d] Data not available.

TABLE 2.1.3-2. EMISSION FACTORS FOR THE CONVEYING AND TRANSFER OF MATERIAL

Material handling operation	Material being handled	Uncontrolled emission factor (lb/ton handled)	Uncontrolled emission factor reliability
Conveying and transfer	Coal	0.04 - 0.96[a] 0.02[b] 0.02[e]	E D E
	Coke	0.023 - 0.13[a]	D
	Grain	2.0 - 4.0[a] 0.11 - 1.40[c]	E B
	Granite	Negligible[b]	E
	Iron ore	2.0[a] 0.046[c]	E E
	Lead ore	1.64 - 5.0[a]	E
	Sand	0.3[a]	E
Transfer (only)	Coal (spillage)	0.8[c,d]	E

[a] Reference 2, p. 2-7.

[b] Reference 1, page 3-42.

[c] Reference 3, page 12.

[d] Value includes dust and large aggregate, much of which will never be suspended.

[e] Reference 5, pages 44-47.

influence the final size distribution found in the fugitive dust emissions[2,3] (see Table 2.1.2-6, column b).

The density and composition of the fugitive emissions from material handling activities will be directly related to the type of material involved.

Hazardous or Toxic Nature of Fugitive Emissions From Material Handling Activities--The hazardous or toxic nature of fugitive emissions from material handling activities is almost entirely dependent upon the type of material being handled. As in the case of particulate characteristics, it is not possible to discuss the nature of a health hazard without first knowing the material in question. The hazardous properties of specific industrial materials can be found in Reference 4.

Data Availability--Review of the literature has produced only two examples of particulate size distribution for aggregate material that would be unloaded or transported by a material handling system (see Table 2.1.2-6). Knowledge of exactly what portion of the fugitive emissions from other handling operations will remain in suspension is needed. A few of the conveying and transfer emission factors are indicated as including large portions of "spillage," material which is much too large to ever become suspended.

2.1.3.4 Control Methods--

The control methods available for reducing fugitive dust from material handling activities are specific to the site of dust release, i.e., the site of unloading, conveying operations, or points of transfer. The control methods, efficiencies and costs discussed in this section will be addressed according to the individual sites of dust generation.

Techniques, Efficiencies and Costs for Controlling Fugitive Dust From Unloading Activities--The minimization of dust from unloading activities can be accomplished through 1) the total or partial enclosure of the unloading facility and the removal of the particulate to a bag filter system, 2) enclosure without bag filter system, and 3) use of a water or chemical spraying system.[1,5]

The control of fugitive dust from truck dumping activities can be accomplished with either the enclosure or spray system techniques. The application of control practices to truck dumping sites are dependent largely on the industry or material involved. A 90 to 95 percent reduction of fugitive dust from truck dumping activity can be accomplished when the site is enclosed and the captured particulate is vented to a control device.[5] A 50 percent control efficiency can be achieved with a water spray system.[5] Cost estimates for these spray systems were not available.

Fugitive dust emissions can be controlled through the enclosure of rail car unloading stations accompanied by dust collection with bag filters. This method of control can effectively reduce 99 percent of the fugitive dust. This type of system is estimated to have an initial cost of approximately $120,000.[1] No annual operating costs are available. Depending on the type of material involved, fugitive dust from rail car unloading operations can also be controlled using spray systems. This measure results in an effective control efficiency of 80 percent at an annual cost of $37,000.[1] The use of chemical stabilizers may improve the efficiency of this control measure. The addition of chemicals to the spray system, however, will increase the cost of operation (see Table 2.1.2-7).

Data on dust suppressants, their costs, and application rates are presented in Appendix B.

Techniques, Efficiencies, and Costs for Controlling Fugitive Dust From Conveying and Transfer Activities--The control of dust from conveying and transfer operations can be accomplished through methods similar to those used during unloading operations. Conveying or transfer emissions can be minimized through the use of enclosures or spray systems. Enclosure of conveying systems can be either partial (top) or total. The control efficiency of a partial enclosure system is rated at 70 percent with an initial cost of $43.00 per foot of conveyor.[1] The total enclosure of a conveying system which includes the use of a dust collection system, e.g., bag filter, can result in a control efficiency increase to 99 percent with an initial cost of $86.00 per foot of conveyor.[1] No annual operating costs were available for either of these control measures.

Transfer stations located along the course of a conveying operation can be significant sources of fugitive dust. The control of dust from these sources is also accomplished using enclosures and/or spray systems. The total enclosure of a transfer point can effectively reduce fugitive emissions by 70 percent at an initial cost of $3,700.[1] The addition of a bag filter to a transfer point enclosure can raise the control efficiency to approximately 99 percent. This additional equipment will increase the initial cost to approximately $22,000.[1] Effective control of dust from transfer stations can also be accomplished using water and chemical spray systems. The spray system has an added advantage in that the aggregate subject to chemical spray is adequately treated to effect dust suppression throughout the entire material handling system. The control efficiency of spray systems at transfer points is estimated to be between 70 and 95 percent.[1] The initial cost of implementing a spraying system for a single transfer point is approximately $18,000. The cost of one multiple system was estimated at $245,000 (based on a plant handling 2.2 million tons of material a year). The annual operating cost of a single transfer station ranges between 0.02 to 0.05 dollars per ton of material handled.[1] PEDCo estimates that the capital costs for a system such as shown in Figure 2.1.3-1 is approximately $70,000, with annualized costs of $23,700.

A summary of the control measures for unloading, conveying, and transfer operations is presented in Table 2.1.3-3.

Reasonably Available Control Measures (RACM) for material handling operations must, of course, be site specific and material specific. In most cases, where the material characteristics will not suffer from increased moisture content, water or

TABLE 2.1.3-3. A SUMMARY OF CONTROL TECHNIQUES, EFFICIENCIES, AND COSTS FOR FUGITIVE EMISSIONS FROM UNLOADING, CONVEYING, AND TRANSFER OPERATIONS

Control method	Estimated control efficiency, %	Initial cost (1980 dollars)	Annual cost (1980 dollars)
Unloading			
Truck			
• Enclosure			
- total with fabric filter	95	76,000[a]	17,000[a]
- partial with fabric filter	90	50,000[a]	12,500[a]
• Spray system-water	50	b	b
Vessel			
• Enclosed bucket elevator leg, vent to fabric filters	95	51,600[a]	11,600[a]
Rail			
• Enclosures			
- total with fabric filter	99[c]	120,000[d]	b
- total without fabric filter	70	b	b
• Spray systems with chemicals	80	37,000[d]	b
Conveying			
• Partial (top) enclosure	70[e]	43/ft[d]	b
• Total enclosures	99[f]	86/ft[d]	b
Transfer			
• Enclosures	70 - 99[g]	4,000 to 22,000[d]	b
• Spray systems with chemicals	70 - 95	18,000 to 245,000[d,h]	0.02 to 0.05 per ton of material treated[i]

[a] Reference 6, pages 6-23 through 6-75.

[b] Unavailable.

[c] Enclosure is accompanied with high efficiency (99+%) bag filter.

[d] Reference 1, page 6-3.

[e] "Weather-tight" system; no active dust collection system.

[f] Value utilized active dust collection system.

[g] Lower value represents simple enclosure; high value includes bag filter.

[h] Lower value represents cost of control at a single transfer station; high value represents total cost for a large multiple transfer station system.

[i] Annual cost applies to single transfer station only.

chemical sprays offer good control efficiencies at reasonable costs. However, where material characteristics or specifications preclude wetting, the emissions should be controlled by enclosure and ventilation to a fabric filter. Again a case-by-case assessment must be made to ascertain the severity of the emissions and the relative economics of control. Details on RACM selections for specific materials and operations are presented in the industry-specific sections of this report.

Benefits of Control Measures--Material handling operations move what is usually considered to be a "valuable" commodity from one point to another within a given industrial setting. Because the material has been acquired at some cost to the industry, the loss of a portion of this material constitutes an expensive waste. In some cases, e.g., grain elevators, the cost of installing collection devices can be partially offset by the market value of the material which has been captured. This type of side benefit associated with collection devices may have applications in a number of other industries.

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