AP42 Section:	13.2.2
Reference:	7
Title:	*Fugitive Emissions Evaluation*, C. Cowherd, Jr., and T. Cuscino, Jr MRI-4343-L, Midwest Research Institute, Kansas City, MO, February 1977.

FUGITIVE EMISSIONS EVALUATION

by

Chatten Cowherd
Thomas Cuscino

FINAL REPORT

MRI Project No. 4343-L
February 1, 1977

for

Equitable Environmental Health, Inc.

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 ∘ 816 753-7600

PREFACE

This Final Report summarizes the accomplishments on Midwest Research Institute's Project No. 4343-L. The work described in this report has been conducted in the Environmental and Materials Sciences Division of Midwest Research Institute under the supervision of Dr. L. J. Shannon. This report was written by Dr. Chatten Cowherd, Jr. and Mr. Thomas A. Cuscino. Mathematical calculations were performed by Mr. Cuscino.

Approved for:

MIDWEST RESEARCH INSTITUTE

L. J. Shannon, Director
Environmental and Material Sciences
Division

TABLE OF CONTENTS

		Page
1.0	Introduction	2
2.0	Methodology for Quantifying Emissions	3
	2.1 Unpaved Roads	3
	2.2 Paved Roads	4
3.0	Input Data	6
4.0	Calculated Emissions	14
5.0	Evaluation of Control Options	22
	5.1 Option 1A	22
	5.2 Option 1B	22
	5.3 Option 2	23
	5.4 Option 3	23
	5.5 Comparative Evaluation	23
6.0	Uncertainty of Estimates	25
	References	27
	Appendix 1	28

SUMMARY

This report presents an evaluation of fugitive dust emissions generated by heavy-duty vehicular traffic over a series of paved and unpaved roads within an integrated iron and steel plant. The purpose of this evaluation was to determine the degree of emissions reduction achievable through the implementation of specified control measures including paving, sweeping, and applying dust suppressants.

The most effective control measures are found to be paving of unpaved road segments or application of dust suppressants (water or oil) to unpaved roads. Although the levels of uncertainty in these calculations are considerable, the projected emissions reductions are believed to be realistically achievable through the implementation of the specified control measures.

1.0 Introduction

This report presents the results of an evaluation of fugitive dust emissions generated by heavy-duty vehicles transporting aggregate materials at an integrated iron and steel plant in northwestern Indiana. The purpose of this evaluation was to determine the degree of reduction of current emissions achievable through the implementation of control measures.

This study focused on four active materials transport roads:

1. Blast furnace flue dust route,
2. Coal stocking and destocking route,
3. One stocking and destocking route, and
4. Blended blast furnace flue dust route.

Current emissions of fugitive dust were calculated for the unpaved and paved segments of each road. Plant data for these calculations were provided by Equitable Environmental Health, Inc. (EEH).

Four EEH-specified control options were evaluated:

1. Paving the unpaved portions of roadways associated with each of the four distinct material handling activities
   a. with a comprehensive maintenance and cleaning schedule
   b. without a comprehensive maintenance and cleaning schedule.
2. Performing a comprehensive maintenance and cleaning program for all paved segments of the four distinct material handling activities.
3. Performing a comprehensive wetting or oiling program on all unpaved segments of the four distinct material handling activities.

For each control option, estimated reductions in dust emissions were calculated to determine the relative effectiveness of control.

The following sections of this report discuss, in sequence; (a) methodology for quantifying road dust emissions, (b) input data supplied by EEH, (c) calculated emissions for each segment of paved/unpaved road, (d) evaluation of control options, and (e) reliability of estimates.

2.0 Methodology for Quantifying Emissions

The methodology for quantification of fugitive dust emissions from paved and unpaved roads is based on the use of predictive equations empirically developed by Midwest Research Institute (MRI). This section of the report presents the empirically validated equations along with the modifications necessary to extend the applicability of these equations to the specific cases at hand.

2.1 Unpaved Roads

The equation originally developed by MRI to estimate fugitive dust emissions from unpaved roads[1/] was:

$$E = 0.49 \quad S \cdot \left(\frac{V}{30}\right) \tag{1}$$

where E = Emission factor for particles less than 30 micrometers (μm) in diameter, based on a particle density of 2.5 g/cm^3 (lb/vehicle mile).

S = Silt content (particles less than 75 μm in diameter) of road surface material, as determined by dry sieving (percent).

V = Vehicle speed (mph).

This equation yields values within ± 20% of the actual measured emission factors. Under the following road and traffic conditions: (a) silt contents between 5 and 68%, (b) vehicle speeds between 30 and 40 mph, and (c) light-duty vehicles (automobiles and light trucks) having an average weight of 3 short tons. The equation is further restricted to apply only to dry days, that is, days with < 0.01 in. of rainfall.

In order to extend the emission factor expression given in equation 1 to heavy-duty vehicle weights of as much as 80 short tons, a correction factor must be applied. A recent study[2/] has indicated that the emission factor is directly proportional to the weight up to 8 short tons. However, the authors believe that extrapolation of this finding up to 80-ton vehicles yields emission rates many times higher than visual observations would indicate to be possible. Experiments will soon be conducted by Midwest Research Institute to quantify the emissions from heavy-duty truck traffic, thereby yielding an appropriate weight correction factor.

Since the objective of this evaluation is to estimate the amount of reduction of emission effected by various control techniques, it is felt that a conservative estimate of uncontrolled emissions, one with an adequate margin of safety, is in order. Therefore, the emissions given by Equation (1) will be scaled to heavy-duty vehicle weights through the following multiplicative weight correction factors (WCF):

$$\text{If } W \leq 30 \text{ tons,} \qquad WCF = \frac{W}{3} \tag{2a}$$

$$\text{If } W \geq 30 \text{ tons,} \qquad WCF = 10 \tag{2b}$$

Because the unloaded truck weights being considered range from 20 to 30 tons, the effect of these factors is essentially to approximate emissions from heavy-duty vehicles by 10 times the factor for light-duty vehicles.

Finally, in order to estimate emissions on a yearly basis, Equation (1) must be multiplied by the fraction of dry days per year in northwest Indiana, 245/365[1]. With these modifications, Equation (1) becomes:

$$E = 0.49 \quad S \left(\frac{V}{30}\right) \quad WCF \left(\frac{245}{365}\right) \tag{3}$$

2.2 Paved Roads

Figure 1 shows the results of field experiments performed by MRI to quantify fugitive dust emissions from paved roads.[3] The dashed lines in Figure 1 depict the extrapolation necessary to extend the experimental data to surface silt loadings projected for the subject iron and steel plant. The extrapolated lines do not pass through the highest data points since those data values were inflated by the uniformity of distribution after a planned spill. Because the experimental data shown in Figure 1 was developed with vehicles weighing 3 tons and traveling at 30 mph, both weight and speed corrections must be applied to the experimentally obtained values, as follows:

$$E = E_1 \ (WCF) \frac{V}{30} \tag{4}$$

where E = Emission factor for particles less than 30 µm in diameter, based on a particle density of 2.5 g/cm^3 (lb/vehicle mile).

E_1 = Emission factor from Figure 1 given as a function of surface silt loading.

WCF = Weight correction factor from Equation (2)

V = Vehicle speed (mph).

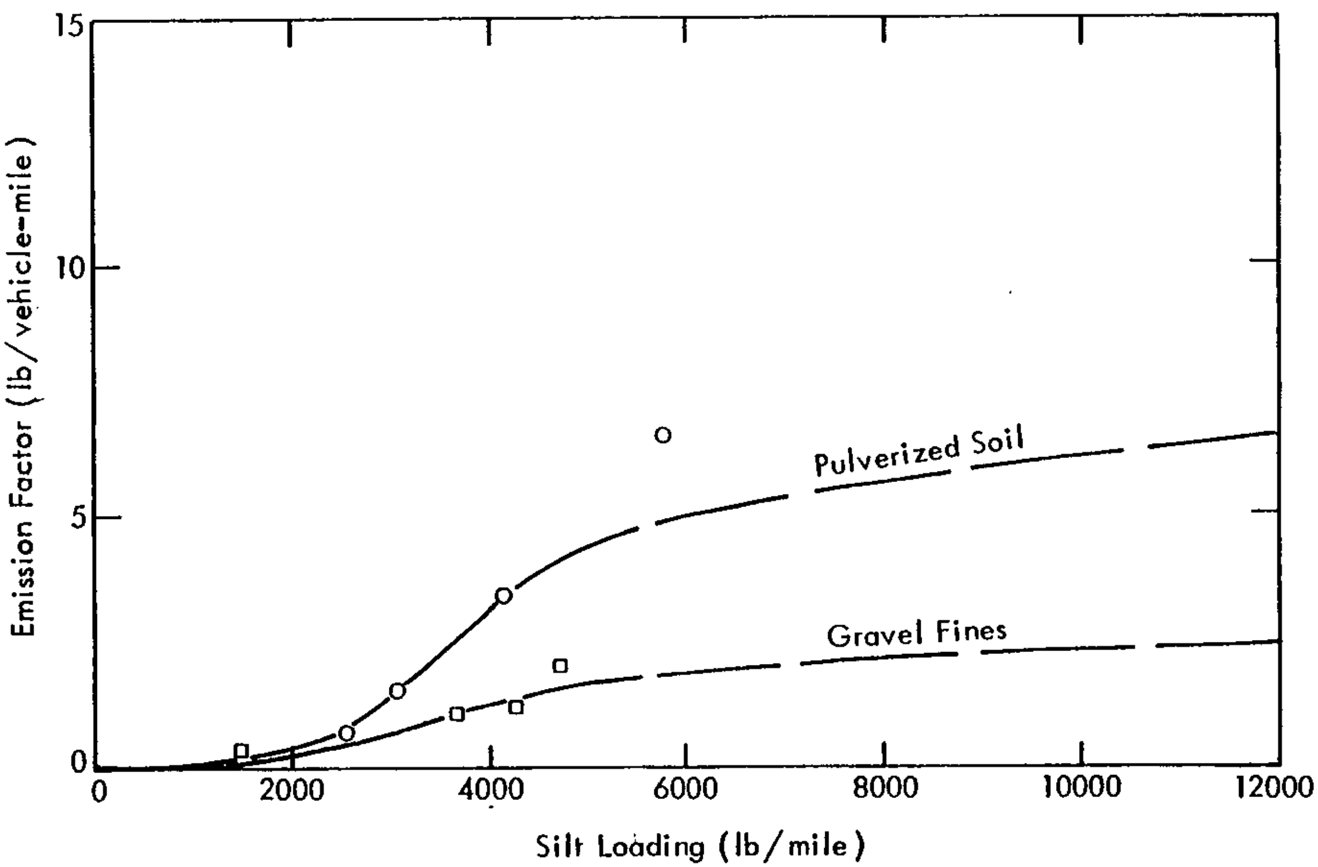

Figure 1. Data From the Paved Road Experiment

The total mass of loose surface dust on paved roads at the subject plant was estimated to be 26,000 lb/mile. This corresponds to a very dirty public road in an industrial area. The estimated dust loading was determined by studying photographs of various measured loadings and selecting the loading that appeared most representative of the paved roads observed at steel plants.

The silt content of the dust on the paved roads at the subject iron and steel plant was given a value equal to twice the silt content of the grab sample of surface material from the nearest connecting unpaved road. The rationale behind this selection is that the material on a paved road would be the same as that found on a connecting unpaved road but with twice the silt content, caused by continuous grinding between the vehicle tires and the rigid paved surface.

Silt loading, as used Figure 1, is obtained by multiplying the fractional content of silt on a given paved road by 26,000 lb/mile. The gravel fines curve in Figure 1 was used for the paved roads being considered because the hardness and density of the surface materials more closely approximated gravel fines than pulverized soil.

3.0 Input Data

Input data required for the calculation of road dust emissions with the equations shown in the previous section was provided by Equitable Environmental Health, Inc. The notable exception was the surface dust loading on the various paved segments, which was assumed to be 26,000 lb/mile. The given input data for each materials transport road are shown in Tables 1 through 6.

As indicated in the tables, the transport routes were divided into segments with the endpoints of each segment defined by a number. Each segment consisted of a single surface type, paved or unpaved. For each road segment, vehicle speeds and weights (loaded and unloaded) were provided. In the cases for which vehicle speed was given as a range of values (with no more than 5 mph difference) the higher end of the range was taken.

Samples of unpaved road surface material were obtained by EEH from roadside locations at key positions around the plant and shipped to MRI for silt analysis. A summary of the dry sieving methodology and results for these four samples is given in Appendix 1.

Tables 1 and 2 list the input data for the blast furnace flue dust route. Blast furnace 13 is considered separately from blast furnaces 1 through 12 because blast furnace 13 operates continuously and produces 385 tons/day of flue dust, while blast furnaces 1 through 12 operate intermittently and produce a total of 693 tons/day.

Table 3 shows the input data describing the transport of iron ore to and from the ore storage area. The trip from point 12 to point 14 is used in stocking the ore storage piles. The ore is hauled from the base of the ore handling crane on the east side of the barge slip to the ore storage piles. The trip from 14 to 17 and 17 to 15 is used for destocking the piles and hauling ore around to the blast furnaces on the west side of the slip.

Table 4 presents input data for the transport of coal from the silo to the bins. There are bins to the east and to the west of the silo with equal trips made to each side. The first three road segments lie to the west of the silo.

Tables 5 and 6, respectively, describe the transport of blended flue dust to the storage area 2.3 miles east of the blending area and to the sinter plant 0.9 miles north.

TABLE 1

INPUT DATA DESCRIBING THE TRANSPORT OF FLUE DUST FROM BLAST FURNACE 13 TO THE FLUE DUST BLENDING AREA

Road Segment	Road Surface Type	Vehicle Weight Loaded (short tons)	Vehicle Weight Unloaded (short tons)	Vehicle Speed (mph)	Road Surface Silt Content (%)	Length of Segment (miles)	Round Trips per Day
1 - 2A	Unpaved	60	30	10	22.8	0.5	13
2A - 3	Paved	60	30	15	45.6	0.22	13
3 - 4	Paved	60	30	10	45.6	0.14	13
4 - 5	Paved	60	30	20	45.6	0.39	13
5 - 6	Unpaved	60	30	10	22.8	0.25	13

TABLE 2

INPUT DATA DESCRIBING THE TRANSPORT OF FLUE DUST FROM BLAST FURNACES 1-12 TO THE FLUE DUST BLENDING AREA

Road Segment	Road Surface Type	Vehicle Weight Loaded (short tons)	Vehicle Weight Unloaded (short tons)	Vehicle Speed (mph)	Road Surface Silt Content (%)	Length of Segment (miles)	Round Trips per Day
Midpoint between 1 and 2 to 2A	Unpaved	60	30	10	22.8	0.325	23
2A - 3	Paved	60	30	15	45.6	0.22	23
3 - 4	Paved	60	30	10	45.6	0.14	23
4 - 5	Paved	60	30	20	45.6	0.39	23
5 - 6	Unpaved	60	30	10	22.8	0.25	23

TABLE 3

INPUT DATA DESCRIBING THE TRANSPORT OF ORE TO AND FROM THE STORAGE AREA

Road Segment	Road Surface Type	Vehicle Weight Loaded (short tons)	Vehicle Weight Unloaded (short tons)	Vehicle Speed (mph)	Road Surface Silt Content (%)	Length of Segment (miles)	Round Trips per Day
12 - 14	Unpaved	80	30	20	14.5	0.6	22
14 - 17	Unpaved	80	30	20	14.5	0.3	22
17 - 15	Paved	80	30	20	29.0	0.57	22

TABLE 4

INPUT DATA DESCRIBING THE TRANSPORT OF COAL FROM THE SILO TO THE BINS

Road Segment	Road Surface Type	Vehicle Weight Loaded (short tons)	Vehicle Weight Unloaded (short tons)	Vehicle Speed (mph)	Road Surface Silt Content (%)	Length of Segment (miles)	Round Trips per Day
7 to mean between 7 and 11	Paved	45	25	25	19.6	0.235	25
7 to 11	Paved	45	25	25	19.6	0.3	50
11 to mean between 11 and 9	Unpaved	45	25	25	9.8	0.14	50
7 to mean between 7 and 8	Unpaved	45	25	25	9.8	0.25	75

TABLE 5

INPUT DATA DESCRIBING THE TRANSPORT OF BLENDED FLUE DUST TO THE STORAGE AREA

Road Segment	Road Surface Type	Vehicle Weight Loaded (short tons)	Vehicle Weight Unloaded (short tons)	Vehicle Speed (mph)	Road Surface Silt Content (%)	Length of Segment (miles)	Round Trips per Day
6 - 19	Unpaved	52	30	10	22.8	0.25	14
19 - 11	Unpaved	52	30	25	9.8	0.5	14
11 - 7	Paved	52	30	25	19.6	0.3	14
7 - 8	Unpaved	52	30	25	9.8	0.5	14
8 - 20	Unpaved	52	30	25	14.5	0.75	14

TABLE 6

INPUT DATA DESCRIBING THE TRANSPORT OF BLENDED FLUE DUST TO THE SINTER PLANT

Road Segment	Road Surface Type	Vehicle Weight Loaded (short tons)	Vehicle Weight Unloaded (short tons)	Vehicle Speed (mph)	Road Surface Silt Content (%)	Length of Segment (miles)	Round Trips per Day
6 - 16	Unpaved	42	20	10	22.8	0.25	20
16 - 17	Paved	42	20	20	29.0	0.29	20
17 - 18	Unpaved	42	20	15	14.5	0.34	20

4.0 Calculated Emissions

The input data given in Section 3.0 were used with the modified prediction equations to yield average emission factors and hourly and yearly emission rates. These values are shown in Tables 7 through 12. Because the hourly emission rates were calculated by dividing the daily emission rates by 24, the hourly emission rate is an average. The yearly emission rate was calculated by multiplying the daily emission rate by 245, which is the number of dry days in northwest Indiana. It was assumed that the material transport operations occur every day of the year, since no other information was provided.

The hourly emission rates presented in Tables 7 through 12 are summarized in Table 13. It is clear from Table 13 that for the material transport processes studied, the unpaved roads yield the majority (85%) of the fugitive dust. The transport operation producing the most emissions is the transport of blended flue dust, which generates 35% of the total suspended particulate burden from the operations studied. The other three transport operations each yield approximately 20% of the total emissions.

TABLE 7

EMISSION FACTORS AND RATES ASSOCIATED WITH THE TRANSPORT OF FLUE DUST FROM BLAST FURNACE 13 TO THE FLUE DUST BLENDING AREA

Road Segment	Emission Factor [a/] (lb/vehicle mile)	Hourly Emission [b/] Rate (lb/hr)	Yearly Emission [c/] Rate (lb/yr)
1 - 2A	37.0	20.0	119,070
2A - 3	10.0	0.2	14,014
3 - 4	7.0	0.1	5,945
4 - 5	13.0	0.6	33,124
5 - 6	37.0	10.0	59,290

a/ Assumed identical for loaded and unloaded vehicles.
b/ Assumes 24 hr/day road usage.
c/ Assumes 245 dry working days/yr.

TABLE 8

EMISSION FACTORS AND RATES ASSOCIATED WITH THE TRANSPORT OF FLUE DUST FROM BLAST FURNACES 1-12 TO THE FLUE DUST BLENDING AREA

Road Segment	Emission Factor[a] (lb/vehicle mile)	Hourly Emission Rate[b] (lb/hr)	Yearly Emission Rate[c] (lb/yr)
Midpoint between 1 and 2 to 2A	37.0	23.0	136,220
2A - 3	10.0	0.4	24,790
3 - 4	0.7	0.2	10,520
4 - 5	13.0	0.10	58,604
5 - 6	37.0	18.0	104,860

a/ Assumed identical for loaded and unloaded vehicles.
b/ Assumes 24 hr/day road usage.
c/ Assumes 245 dry working days/yr.

TABLE 9

EMISSION FACTORS AND RATES ASSOCIATED WITH THE TRANSPORT OF IRON ORE TO AND FROM STORAGE

Road Segment	Emission Factor a/ (lb/vehicle mile)	Hourly Emission b/ Rate (lb/hr)	Yearly Emission c/ Rate (lb/yr)
12- 14	47.0	52.0	306,740
14 - 17	47.0	26.0	153,370
17 - 15	13.0	14.0	81,928

a/ Assumed identical for loaded and unloaded vehicles.
b/ Assumes 24 hr/day road usage.
c/ Assumes 245 dry working days/yr.

TABLE 10

EMISSION FACTORS AND RATES ASSOCIATED
WITH THE TRANSPORT OF COAL FROM THE SILO TO THE BINS

Road Segment	Emission Factor (Loaded Vehicle) (lb/vehicle mile)	Emission Factor (Unloaded Vehicle) (lb/vehicle mile)	Hourly Emission[a/] Rate (lb/hr)	Yearly Emission[b/] Rate (lb/yr)
7 to mean between 10 and 11	12.5	10.4	5.0	32,985
7 - 11	12.5	10.4	14.0	84,160
11 to mean between 11 and 9	40.0	33.3	21.0	125,685
7 to mean between 7 and 8	40.0	33.3	57.0	336,875

a/ Assumes 24 hr/day road usage.
b/ Assumes 245 dry working days/yr.

TABLE 11

EMISSION FACTORS AND RATES ASSOCIATED WITH THE TRANSPORT OF BLENDED FLUE DUST TO THE STORAGE AREA

Road Segment	Emission Factor a/ (lb/vehicle mile)	Hourly Emission b/ Rate (lb/hr)	Yearly Emission c/ Rate (lb/yr)
6 - 19	37.0	11.0	63,847
19 - 11	40.0	23.0	137,249
11 - 7	12.5	0.4	25,725
7 - 8	40.0	23.0	137,249
8 - 20	59.0	52.0	304,780

a/ Assumed identical for loaded and unloaded vehicles.
b/ Assumes 24 hr/day road usage.
c/ Assumes 245 dry working days/yr.

TABLE 12

EMISSION FACTORS AND RATES ASSOCIATED WITH THE TRANSPORT OF BLENDED FLUE DUST TO THE SINTER PLANT

Road Segment	Emission Factor (Loaded Vehicle) (lb/vehicle mile)	Emission Factor (Unloaded Vehicle) (lb/vehicle mile)	Hourly Emission[a] Rate (lb/hr)	Yearly Emission[b] Rate (lb/yr)
6 - 16	37.0	25.0	13	75,950
16 - 17	13.3	9.0	5	31,580
17 - 18	36.0	24.0	17	98,490

a/ Assumes 24 hr/day road usage.
b/ Assumes 245 dry working days/yr.

TABLE 13

HOURLY EMISSION RATES (lb/hr)

Material Transport Operation	Unpaved Roads	Paved Roads	Total
Transport of Flue Dust			
from blast furnace 13	30 (7%)[a/]	9 (2%)	39 (9%)
from blast furnaces 1-12	41 (9%)	16 (4%)	59 (13%)
Coal Handling	79 (18%)	19 (4%)	98 (23%)
Ore Handling	78 (18%)	14 (3%)	92 (21%)
Transport of Blended Flue Dust			
to sinter plant	29 (7%)	5 (1%)	34 (8%)
to storage area	109 (25%)	4 (1%)	113 (26%)
Total	367 (85%)	67 (15%)	434 (100%)

a/ % indicates percent of the grand total (434 lb/hr) contributed by either paved or unpaved portions.

5.0 Evaluation of Control Options

Four control techniques were evaluated for relative effectiveness:

1. Paving the unpaved portions of roadways associated with each of the four distinct material handling activities

    a. with a comprehensive maintenance and cleaning schedule
    b. without a comprehensive maintenance and cleaning schedule.

2. Performing a comprehensive maintenance and cleaning program for all paved segments of the four distinct material handling activities.

3. Performing a comprehensive wetting or oiling program on all unpaved segments of the four distinct material handling activities.

Two cleaning operations were considered: dry broom sweeping and vacuum sweeping.

For a given road segment the efficiency of control is given by the following expression:

$$\text{Control Efficiency} = \frac{\text{Uncontrolled E - Controlled E}}{\text{Uncontrolled E}} \qquad (5)$$

where E refers to the emission factor. This assumes that the control measure does not alter the traffic characteristics. The overall control efficiency for an N-segmented road may be obtained as follows:

$$\text{Overall Efficiency} = \sum_{i-1}^{N} e_i \; f_i \qquad (6)$$

where e_i is the efficiency and f_i is the fraction of total uncontrolled emissions contributed by the ith road segment.

5.1 Option 1A

Assuming that after paving a road the 26,000 lb/mile of road dust has a silt content equal to twice the value for the previous unpaved road, it may be shown that the efficiency of control equals 90%.

5.2 Option 1B

The control efficiency (e) of two sequentially applied control measures (such as paving and cleaning) is given by:

$$e = e_1 + e_2 - e_1e_2 \qquad (7)$$

In this case the efficiency of paving (e_1), under the assumptions listed above, is 90%. e_2 is the efficiency of cleaning method used on the paved surface.

5.3 Option 2

The efficiency of a dry broom street-sweep and a vacuum street-sweeper has been reported.[4/] The dry-type broom sweeper has been found to have negative efficiency for removing silt because it actually increased silt loading on the street surface; however, because the broom does remove some of the larger material which eventually would have been ground to silt, the broom sweeper has been given a nominal 15% control efficiency. The vacuum sweeper, on the other hand, removed 83% of the particles less than 43 µm in diameter, and it is assumed that this same efficiency would apply to silt.

5.4 Option 3

The efficiency of watering unpaved roads has been reported[5/] to be 50% if watered twice per day; however, the efficiency of oiling has not been found. It is assumed that the effect of oiling is similar to chemical stabilization which has a control efficiency of 50%.[5/] Although frequency of oil application is not specified, it can be assumed quarterly application is sufficient to achieve a 50% efficiency if spills do not cover the oiled surface. Table 14 shows the control efficiency achieved by applying a particular control option to all the roads involved in a particular material transport process. Applying the overall control efficiencies in Table 14 to the total emission rates in Table 13 yields the reduction in emissions for each control option and for each material transport process, as shown in Table 14. It is assumed that the silt loading on paved roads builds to its stable value between daily sweeping.

5.5 Comparative Evaluation

Examination of Table 14 leads to several conclusions. Sweeping the already paved roads with a broom sweeper yields negligible results with only 10.6 lb/hr total reduction. The vacuum sweeper operated on already paved roads is far more effective, with a 55 lb/hr reduction attributable to its use. Watering the unpaved roads on a regular basis (twice/day) can achieve a substantial reduction of 181 lb/hr but this reduction will be partially offset by the increase in emissions from the already paved roads resulting from carry out of moist dust from the unpaved to the connecting paved surfaces. Oiling of the unpaved roads will also

TABLE 14

OVERALL EMISSION RATE REDUCTIONS (lb/hr)

Material Transport Operation	Option 1A: Paving w/o cleaning (L = 26,000 lb/mile)	Option 1B: Paving with cleaning once/day		Option 2 Cleaning already Paved roads, once/day		Option 3 Watering unpaved Roads twice/day or Oiling unpaved roads 4 times/year
		Broom	Vacuum	Broom	Vacuum	
Flue Dust Transport from all Blast Furnaces	50	53	67	4.0	20	36
Coal Transport	68	69	77	3.0	16	36
Iron Ore Transport	71	72	76	2.0	12	39
Blended Flue Dust Transport to Sinter Plant	22	23	28	1.0	4	15
Blended Flue Dust Transport to Storage	95	97	107	0.6	3	55
Total Reduction	306	314	355	10.6	55	181
Overall Control Efficiency	90%	92%	98%	15%	83%	50%

yield a 181 lb/hr reduction; however, oiling can produce a water pollution problem if there is a lake, river or stream near the oiled roads that will collect the runoff.

Paving, while the most costly, is by far the most effective control option, resulting in a 306 lb/hr reduction if all unpaved roads were paved and minimally maintained at a loading of 26,000 lb/mile. This last caveat is important because the reduction reported will be achieved only if the paved road does not become dirtier than 26,000 lb/mile. Paving and broom sweeping once per day yields little difference from paving alone, but paving and vacuum sweeping increases the emission reduction to 355 lb/hr.

As indicated in Table 14, a 107 lb/hr reduction can be achieved solely by paving and vacuuming the roads involved with the transport of blended flue dust to the storage area. Actually a 184 lb/hr reduction will be achieved since the road involved in the blended flue dust transport to the storage area is the same road as used for coal transport.

The control options with the most promise would seem to be Option 1A (paving without cleaning) and Option 3 (watering or oiling unpaved roads). The first would involve an intense initial effort followed by a periodic maintenance program, while the second would require more continuous activity. In comparison, little is to be gained by sweeping paved surfaces.

6.0 Uncertainty of Estimates

Although the empirically derived emission factor relationships (Equation (1) and Figure 1) will predict emissions within ± 20% (90% confidence level) over the range of field conditions tested, much larger levels of uncertainty result from extrapolation of these relationships to heavy-duty vehicles and, in the case of paved roads, to heavy surface dust loadings. Additional uncertainty is introduced in the estimates of control efficiency for each control option. Finally, much of the input data provided by EEH consisted of estimated values, and MRI was required to estimate the values for total loading and silt content of surface dust on paved roads.

Consideration of the many sources of uncertainty listed above yields the following approximate uncertainty factors for the calculated emissions and emission reductions, based on a 90% confidence level:

Quantity	Uncertainty Factor
Current Emissions	
Unpaved Roads	2
Paved Roads	3
Emission Reductions	2

For example, if the current emissions for an unpaved road are calculated to be 100 lb/day, the probable true value lies between 50 and 200 lb/day.

Nevertheless, the calculated values presented in this report represent the best professional judgment of the authors based on several years of experience in quantifying and estimating dust emissions from industrial roads. Moreover, in estimating quantities for this evaluation, attention has been given to providing assurance that the calculated emission reductions are realistically achievable.

REFERENCES

1. Midwest Research Institute, "Development of Emission Factors for Fugitive Dust Source," EPA Report Number 450/3-74-037, June 1974.

2. Dyck, Rodney I. J., and James J. Stukel, "Fugitive Dust Emissions from Trucks on Unpaved Roads," Environmental Science and Technology, Volume 10, Number 10, pp. 1046-1048, October 1976.

3. Midwest Research Institute, "Quantification of Dust Entrainment from Paved Roadways, Draft Report," March 1976.

4. PEDCo-Environmental, "Analysis of Probable Particulate Non-Attainment in the Kansas City AQCR," prepared for U.S. EPA Region VII, February 1976.

5. PEDCo-Environmental, "Investigation of Fugitive Dust-Sources, Emissions, and Control," EPA 450/3-74-036A, June 1974.

APPENDIX 1

ENGINEERS
GEOLOGISTS
CHEMISTS
INSPECTORS

MET MIDCONTINENT ENGINEERING & TESTING CO.

3220 N W VIVION ROAD / P O BOX 9071 / RIVERSIDE MO 64168 / (816) 741-9466

December 29, 1976

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Attn: Mr. Tom Cusino

Re: Screen Analysis

Gentlemen:

At the request of Mr. Tom Cusino, four ore samples were picked up at your office and laboratory for moisture and screen analysis.

The samples were weighed in total as received and dried for moisture content.

Each entire sample was screened with the -200 recorded at 5, 20 and 40 minutes.

The test results are enclosed.

Very truly yours,

MIDCONTINENT ENGINEERING & TESTING CO.

John B. Baldwin
President

JBB:fo

% H20 - 7.4%
% -200 @ 5 minutes = 15.6%
% -200 @ 20 minutes = 20.5%
% -200 @ 40 minutes = 22.8%

MIDCONTINENT ENGINEERING & TESTING CO.
MET #11746

SIEVE ANALYSIS

Project Midwest Research Institute Blastfurnace Flue Dust Date 12-28-76

Boring No. ______ Sample No. 1

Total wt in grams of sample, W_s = 1291.7 | Wt in grams of material > No. 4 sieve =

Sieve Openings Inches	Sieve Openings Millimeters	U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained Partial	Percent Retained Total	Percent Finer by Weight
3.00		3-in.				@ 40 Min.
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.	24.5			98.1
0.375	9.52	3/8-in.	12.9			97.1
0.250	6.35	No. 3				
0.187	4.76	No. 4	89.7			91.2
		Pan				
0.132	3.36	No. 6				
0.094	2.38	No. 8				
0.079	2.00	No. 10	155.0			78.2
0.047	1.19	No. 16				
0.033	0.84	No. 20				
0.023	0.59	No. 30				
0.0165	0.42	No. 40	243.9			59.3
0.0117	0.297	No. 50				
0.0083	0.210	No. 70				
0.0059	0.149	No. 100				
0.0041	0.105	No. 140	465.9			23.3
0.0029	0.074	No. 200	6.0			22.8
		Pan	295.0			
Total weight in grams			1292.9			

$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______

% H20 - 5.8%
% -200 @ 5 minutes = 7.1%
% -200 @ 20 minutes = 8.9%
% -200 @ 40 minutes = 9.8%

MIDCONTINENT ENGINEERING & TESTING CO.

MET #11747

SIEVE ANALYSIS

Midwest Research Institute

Date 12-28-76

Project Coal Handling Road

Boring No. ______ Sample No. 2

Total wt in grams of sample, W_s = 4[illegible] | Wt in grams of material > No. 4 sieve =

Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				@ 40 Min.
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.	13.3			96.9
0.375	9.52	3/8-in.	16.9			92.9
0.250	6.35	No. 3				
0.187	4.76	No. 4	40.9			83.4
		Pan				
0.132	3.36	No. 6				
0.094	2.38	No. 8				
0.079	2.00	No. 10	82.2			64.1
0.047	1.19	No. 16				
0.033	0.84	No. 20				
0.023	0.59	No. 30				
0.0165	0.42	No. 40	143.1			30.6
0.0117	0.297	No. 50				
0.0083	0.210	No. 70				
0.0059	0.149	No. 100				
0.0041	0.105	No. 140	78.5			12.2
0.0029	0.074	No. 200	10.2			9.8
		Pan	42.0			
Total weight in grams			427.1			

$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______

% H20 - 9.0%
% -200 @ 5 minutes = 8.1%
% -200 @ 20 minutes = 13.5%
% -200 @ 40 minutes = 14.3%

MET MIDCONTINENT ENGINEERING & TESTING CO.

SIEVE ANALYSIS

Midwest Research Institute

Date 12-28-76

Project Base of Transfer Tower at Ore Handling Area

Boring No. ________ Sample No. 3

Total wt in grams of sample, W_s = [illegible] | Wt in grams of material > No. 4 sieve =

Sieve Openings: Inches	Sieve Openings: Millimeters	U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained: Partial	Percent Retained: Total	Percent Finer by Weight
3.00		3-in.				@ 40 Min.
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.	41.0			95.9
0.375	9.52	3/8-in.	20.9			93.9
0.250	6.35	No. 3				
0.187	4.76	No. 4	94.1			84.5
		Pan				
0.132	3.36	No. 6				
0.094	2.38	No. 8				
0.079	2.00	No. 10	104.0			74.2
0.047	1.19	No. 16				
0.033	0.84	No. 20				
0.023	0.59	No. 30				
0.0165	0.42	No. 40	214.9			52.9
0.0117	0.297	No. 50				
0.0083	0.210	No. 70				
0.0059	0.149	No. 100				
0.0041	0.105	No. 140	383.7			14.9
0.0029	0.074	No. 200	6.4			14.3
		Pan	143.8			
Total weight in grams			1008.8			

$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ________ Computed by ________ Checked by ________

% H20 - 1.0%
% -200 @ 5 minutes = 12.4%
% -200 @ 20 minutes = 13.9%
% -200 @ 40 minutes = 14.7

MIDCONTINENT ENGINEERING & TESTING CO.

11749

SIEVE ANALYSIS

Midwest Research Institute

Project Ore Storage Area

Date 12-28-76

Boring No. ______ Sample No. 4

Total wt in grams of sample, W_s = [illegible]					Wt in grams of material > No. 4 sieve =		
Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight
Inches	Millimeters			Partial	Total	
3.00		3-in.				@ 40 Min.
2.00		2-in.				
1.50		1-1/2-in.				
1.00	25.4	1-in.				
0.750	19.1	3/4-in.				
0.500	12.7	1/2-in.	0.0			100.0
0.375	9.52	3/8-in.	2.2			99.8
0.250	6.35	No. 3				
0.187	4.76	No. 4	22.9			98.1
		Pan				
0.132	3.36	No. 6				
0.094	2.38	No. 8				
0.079	2.00	No. 10	212.4			81.7
0.047	1.19	No. 16				
0.033	0.84	No. 20				
0.023	0.59	No. 30				
0.0165	0.42	No. 40	426.0			48.8
0.0117	0.297	No. 50				
0.0083	0.210	No. 70				
0.0059	0.149	No. 100				
0.0041	0.105	No. 140	388.9			18.7
0.0029	0.074	No. 200	51.8			14.7
		Pan	190.5			
Total weight in grams			1294.7			

$$\text{Partial percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{wt in grams of sample used for a given series of sieves}} \times 100$$

$$\text{Total percent retained} = \frac{\text{wt in grams retained on a sieve}}{\text{total wt in grams of oven-dry sample}} \times 100$$

For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve

Remarks

Technician ______ Computed by ______ Checked by ______