MRI REPORT

OPEN DUST SOURCES AROUND IRON AND STEEL PLANTS

DRAFT

SPECIAL REPORT
ADDENDUM

Prepared for:

Industrial Environmental Research Laboratory
Environmental Protection Agency
Research Triangle Park
North Carolina 27711

Under Contract No. 68-02-2120
MRI Project No. 4123-L
Special Report
Date Prepared: January 11, 1977

by

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PREFACE

This report addendum was prepared for the Environmental Protection Agency (Mr. Robert V. Hendriks, Project Officer) to present the results of a survey of open dust sources around an iron and steel plant. The work was performed in the Environmental and Materials Sciences Division of Midwest Research Institute under EPA Contract No. 68-02-2120. This report was written by Dr. Chatten Cowherd and Mr. Russell Bohn.

Approved:

MIDWEST RESEARCH INSTITUTE

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January 11, 1977

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1.0 Introduction

Significant quantities of fugitive dust may be emitted from storage piles, vehicular traffic, and wind erosion of exposed areas around iron and steel plants. Reliable estimates of these emissions require the use of (a) data on source extent and/or activity levels and (b) emission factors which have been appropriately corrected for local climatic conditions and silt (fines) content of the emitting surface.

Table 1 lists the measures of source extent, the basic emission factor formulae, and the correction parameters associated with each pertinent source category. The mathematical expressions for each emission factor were derived from field measurements described in reports prepared by Midwest Research Institute (MRI).[1-3] Supporting information for several of these factors is presented in EPA's Emission Factor Handbook.[4] The factors presented in Table 1 describe emissions of particles smaller than 30 μ in diameter, the approximate effective cutoff diameter of a standard high volume particulate sampler (based on particle density of 2 to 2.5 g/cm^3).[1]

This report presents the results of a survey of open dust sources at a representative iron and steel plant, designated as Plant "C." Survey results and procedures are given below for each source category, following the format used in the report for Plants A and B, dated November 2, 1976.

2.0 Unpaved and Paved Roads

Table 2 lists source extent and activity factors, emission factor correction parameters, and calculated emission rates for specific unpaved and paved roads lying within the property boundaries of Plant C.

The experimentally determined emission factors for paved and unpaved roads given in Table 1, with an additional correction for vehicle weight, were used to calculate fugitive dust emissions. The appropriate measure of source extent is vehicle-miles traveled.

2.1 Source Extent

The following steps were used to develop the inventory of roads, vehicle types and mileage traveled:

1. Road segments with specific surface and traffic characteristics were identified and the length of each segment was determined by plant personnel.

Table 1. EXPERIMENTALLY DETERMINED FUGITIVE DUST EMISSION FACTORS

Source category	Measure of extent	Emission factor[a/] (lb/unit of source extent)	Correction parameters
Aggregate storage (sand and gravel; crushed stone)	Tons of aggregate put through storage cycle	$\frac{0.33}{(PE/100)^2}$	PE = Thornthwaites precipitation-evaporation index
Unpaved roads	Vehicle-miles traveled (light duty)	$0.49\ (s_u)\ \frac{S}{30}\ \frac{d}{365}$	s_u = road surface silt content (%) S = average vehicle speed (mph) d = dry days per year
Paved roads	Vehicle-miles traveled (light duty)	$9 \times 10^{-5}\ L\ s_p$	L = surface loading (lb/mile) s_p = fractional silt content of road surface material
Wind erosion	Acre-years of exposed land	$18\ \frac{esf}{(PE/50)^2}$	e = soil erodibility (tons/acre-yr) s = silt content of surface soil (%) f = fraction of time wind exceeds 12 mph PE = Thornthwaites precipitation-evaporation index

a/ Annual average emissions of dust particles smaller than 30 micrometers in diameter based on particle density of 2.5 g/cm^3.

Table 2. PLANT C: ROAD EMISSIONS

	Source extent			Correction factors				Emissions[a]		
Roads	Vehicle class[b] Light Duty A Medium Duty B Heavy Duty C	Road length[b] (miles)	Vehicle miles[c] traveled (miles/day)	Vehicle weight correction (based on observation)	Vehicle speed[b] (mph)	Road surface silt content[d] (%)	Surface loading[d] (lb material per mile)	Emission factor (lb/VMT)	Daily emissions (tons/day)	Yearly emissions (tons/year)
Unpaved	B	3.6	517	3.5	25	10	-	11.6	3.0	1,095
	C	1.6	222	8.0	25	10	-	26.4	2.9	1,059
Total		5.2	739						5.9	2,154
Dusty paved	B	3.2	253	3.5	25	10	15,000	0.5	0.06	22
	C	1.4	101	8.0	25	10	15,000	1.1	0.06	22
Other paved	B	12.0	927	3.5	25	10	5,000	0.2	0.09	33
	C	5.2	404	8.0	25	10	5,000	0.4	0.08	29
Total		21.8	1,685						0.29	106

a/ All emissions are based on particulates less than 30 μ in diameter.
b/ Obtained from plant personnel.
c/ Data calculated as an average of the daily VMT at Plants A and B.
d/ An assumed value.

2. The types and sizes of vehicles traveling on each road segment were specified by plant personnel.

3. Figures on the daily mileages traveled by each vehicle type were not furnished by plant personnel. MRI derived the daily mileages traveled by averaging mileage data from previously surveyed Plants A and B.

4. Information provided by plant personnel was used to apportion the mileage traveled by each vehicle type over the various road segments.

Approximately 76% of Plant C's 21.8 miles of roads are paved and on the whole have relatively low particulate surface loadings and resultant emission rates. There are 4.6 miles of "dusty-paved" roads within Plant C, as indicated by plant personnel. These roads have considerably higher surface particulate loadings with resultant higher emission factors than the other paved roads within the plant.

Vehicular traffic at Plant C was comprised of three basic vehicle types:

1. Type A - Light duty (automobiles and pick-up trucks--determined to be negligible).

2. Type B - Medium duty (flatbeds and other medium sized trucks).

3. Type C - Heavy duty (larger trucks with load capacity of 25 to 50 tons).

Data pertaining to the road length traveled by heavy vehicles within the plant (8.1 miles) was obtained from plant personnel. It was indicated that this mileage was evenly distributed over the various road types at the plant. The remaining road length was assigned to medium duty vehicles.

2.2 Correction Parameters

Because of adverse weather conditions during the time of the survey, it was not possible to obtain representative samples of road surface dust from which to determine silt content. Therefore, a silt content of 10% for the particulate loading on Plant C's roadways was assumed. Average vehicle speed for each segment of unpaved or paved road was estimated by plant personnel and the number of dry days per year for the plant locale was determined from the Climatic Atlas.[5/]

Because the experimentally determined emission factors for paved and unpaved roads were developed for light duty vehicles, it was necessary to apply vehicle weight correction multipliers to account for increased emissions from medium duty and heavy duty vehicles. It was assumed that emissions increase in proportion to vehicle weight. Ratios of average empty truck weights to average light-duty vehicle weight (4 tons) were used as correction multipliers, because trucks travel at higher speeds during the unloaded portions of travel cycles.

2.3 Aggregate Storage Piles

An inherent part of the operation of integrated iron and steel plants is the maintenance of outdoor storage piles of mineral aggregates used as raw materials and of process wastes. Storage piles are usually left uncovered, partially because of the necessity for frequent transport of material into or out of storage.

Dust emissions occur at several points in the storage cycle--during loading of material onto the pile, whenever the pile is acted on by strong wind currents, and during load-out of material from the pile. Truck and loading equipment traffic in the storage pile areas are also a substantial source of dust emissions.

Table 3 gives data on the extent of open storage operations involving primary aggregate materials at Plant C. This information was developed from (a) discussions with plant personnel, (b) plant statistics on quantities of materials consumed, and (c) field estimations during the plant survey.

The emission factor for aggregate storage piles given in Table 1 was derived from field measurements of dust emissions from active and inactive storage piles of sand, gravel, and crushed stone. The major operational contributions to storage pile emissions were found to be:

1. Loading onto piles from dump trucks,

2. Vehicular traffic around piles during 90-day storage,

3. Wind erosion during 90-day stroage, and

4. Load-out from piles to dump trucks utilizing high loaders.

As expected, the quantity of emissions is directly proportional to the amount of material put through the storage cycle.

Table 3. PLANT C: STORAGE PILE EMISSIONS

Material in storage	Source extent: Amount in storage (tons)[b/]	Source extent: Annual throughput (million tons)[b/]	Correction factors: Silt content (%)	Correction factors: Duration of storage (days)[c/]	Emission factors[a/]: Load-in (lb/ton stored)	Emission factors[a/]: Vehicular traffic (lb/ton stored)	Emission factors[a/]: Wind erosion (lb/ton stored)	Emission factors[a/]: Load-out (lb/ton stored)	Emission factors[a/]: Total storage cycle (lb/ton stored)	Yearly emissions (tons/year)
Coal										
Low volatility	31,795	0.05	5.5[d/]	90	0.11	1.7	2.8	0.13	4.74	119
High volatility	15,150	0.08	2[e/]	66	0.04	0.60	0.74	0.46	1.84	74
Iron ore screened										
Bed No. 1	2,032	0.04	18.8[d/]	18	0.38	g/	1.9	3.3	5.5	110
Bed No. 26E	18,996	0.03	18.8[d/]	45	0.38	g/	3.2	3.3	6.9	104
Blended ore (sinter input)	34,763	1.11	14.7[d/]	11	0.39	g/	0.91	2.5	3.8	2,109
Flue dust	-	0.03	14.0[d/]	90	0.37	8.4	7.1	3.2	19.1	286
Limestone										
Monarch	152,173	0.22	1.5[f/]	90	0.03	0.9	0.76	0.35	2.04	224
Dolomite	4,277	0.07	1.5[f/]	90	0.03	0.9	0.76	0.35	2.04	71
Total	259,186	1.63								3,097

a/ All emissions are based on particulates less than 30 μ in diameter.
b/ Obtained from plant personnel.
c/ Derived from given plant data.
d/ Determined by means of dry sieving.
e/ Assumed silt content based on previous sieving of similar materials.
f/ An assumed silt content.
g/ Determined negligible.

Because aggregate storage operations in the iron and steel industry are similar to operations described above, the experimentally determined emission factor and operational contributions were used as a basis for the development of estimated emission factors for each material/operation combination. In each case, the factor was adjusted to the content of silt (fines) in the given aggregate and to the degree of material-handling equipment activity in comparison with the operations used in the sand and gravel and crushed stone industries. Table 3 presents the emission factors for the storage of primary aggregate materials used in Plant C. The rationale for the derivation of the emission factor expression for each operation is given below.

2.3.1 Loading onto Piles

The method of loading onto storage piles at Plant C consisted of utilizing front-end loader (for flue dust) and movable stacker/reclaimers (for all other materials) coupled with a sizable conveyor network. The stacker method of loading onto piles was judged to emit less dust than the emission-tested load-in process, so an activity factor of 0.75 was incorporated into the load-in emission factor equation. Based on these assumptions, the load-in emission factor equation becomes:

$$EF_1 = 0.04 \frac{S}{1.5} K$$

where EF_1 = emission factor (pounds per ton of material transferred)

0.04 = experimentally determined emission factor for loading of sand and gravel

S = silt content of the aggregate material (percent)

K = activity factor related to method of loading onto the piles (1.0 for flue dust, 0.75 for all other materials)

2.3.2 Vehicular Traffic

Vehicular traffic around emission-tested aggregate (sand and gravel) storage piles, consisting of truck and high loader movements associated with the load-in and load-out, was generally more intense than traffic around storage piles at the iron and steel plant. The following stored aggregate materials were assigned a traffic-related emission factor of zero:

1. Iron ore, screened, and

2. Blended ore (sinter plant charge).

At Plant C there is vehicular traffic around the low and high volatility coal piles and the limestone-dolomite piles, as represented by an activity factor of 0.5. The flue dust pile was assigned an activity factor of 1 for vehicular traffic.

Based on these considerations, the emission factors for traffic around storage piles were calculated according to the following equation:

$$EF_2 = \frac{0.13\ (S/1.5)}{(PE/100)^2}\ K$$

where EF_2 = emission factor (pounds per ton of material stored)

PE = Thornthwaites precipitation-evaporation index (38)

S = silt content of the storage material (percent)

K = activity factor = 0.5 for coal and stone piles and for ore bedding, and 1 for flue dust

The value 0.13 lb/ton was the factor experimentally determined for piles with a silt content of 1.5% stored in a locality with a PE value of 100.

2.3.3 Wind Erosion

The correction factors deemed to be appropriate for dust emissions generated by wind erosion were silt content, PE index, and length of time material is in storage. The silt content and PE index were ratioed in the same manner as for the traffic related factor. Because the relationship of emissions to duration in storage was assumed to be linear, the correction multiplier is simply a direct ratio between the duration of given material in storage and the 90-day estimate of duration for the emission-tested aggregate materials. These assumptions are incorporated into the following equation.

$$EF_3 = \frac{0.11\ (S/1.5)}{(100/PE)^2}\ \frac{(D)}{90}$$

where EF_3 = emission factor (pounds per ton of material stored)

PE = Thornthwaites precipitation-evaporation index (38)

S = silt content of given stored material (percent)

D = duration of material in storage (days)

The value 0.11 lb/ton was the factor experimentally determined for wind erosion from sand and gravel piles with a silt content of 1.5% stored for 90 days in a locality having a PE index of 100.

2.3.4 Load-Out

Methods of loading out materials from the storage piles at Plant C included (a) stacker/reclaimers which "rake" the materials onto a conveyor and (b) front-end loaders which transfer the material to a conveyor bin, a process similar in nature to the load-out of emission-tested aggregate. Because the stacker/reclaimer method is less likely to produce dust emissions than the front-end loader method, an activity factor of 0.75 was assigned to the former method, and an activity factor of 1 to the latter. Based on these considerations, emission factors for aggregate load-out were calculated by the following equation:

$$EF_4 = \frac{0.05\ (S/1.5)}{(100/PE)^2} K$$

where EF_4 = emission factor (pounds per ton of material transferred)

PE = Thornthwaites precipitation-evaporation index (38)

S = silt content of the storage material (percent)

K = activity factor = 0.75 for Utah and blended ore, and 1.0 for coal, flue dust and stone

The value 0.05 lb/ton was the factor experimentally determined for load-out of sand and gravel and crushed stone storage piles with a silt content of 1.5% in a locality having a PE index of 100.

2.4 Wind Erosion of Exposed Areas

Unsheltered areas of bare ground around plant facilities are subject to atmospheric dust generated by wind erosion, whenever the wind exceeds the threshold velocity of about 12 mph. The bare ground area within the boundaries of Plant B was estimated to be 26.4 acres, based on plant map areas outlined by plant personnel. This is an extremely low value for bare area within an integrated iron and steel plant facility, reflecting the fact that the vast majority of active open areas within Plant C have been paved.

As indicated in Table 1, the parameters which influence the amount of dust generated by wind erosion are soil erodibility, silt content of surface soil, precipitation-evaporation index, and fraction of the time the wind speed exceeds 12 mph. Soil erodibility and silt content were derived from the soil type in the vicinity of Plant C. The calculated emissions from wind erosion are presented in Table 4.

2.5 Summary of Dust Emissions

A breakdown of calculated emissions from open dust sources at Plant C is presented in Table 5. Unpaved roads (40%) is the largest contributing dust source, followed by the blended ore pile (39%). The other sources of open dust at Plant C, as seen in Table 6, are relatively small in comparison.

Table 6 gives Plant C's emissions from open dust sources expressed in pounds of particulate per short ton of steel produced.

Table 4. PLANT C: OPEN AREA EMISSIONS

Source extent		Correction factors				Emissions		
Total plant area (acres)	Total open area (acres)	Soil erodibility[a] (tons/acre year)	Surface silt soil content (%)	Wind speed[b]	PE index[c]	Emission factor (lb/acre year)	Daily emissions (tons/day)	Yearly emissions (tons/year)
630[d]	26.4[d]	47[a]	15[e]	0.27	38	5,932	0.21	78

a/ Tons of material eroded per acre year.
b/ Fraction of the time the wind speed is greater than 12 mph.
c/ Thornthwaites precipitation-evaporation index.
d/ Obtained from plant personnel.
e/ Assumed value.

Table 5. PLANT C: SUMMARY OF OPEN DUST SOURCE EMISSIONS

Source	Tons of particulate/year	Percentage of total
1. Unpaved roads	2,154	40
2. Paved roads		
Dusty paved	44	1
Other paved	62	1
3. Total wind erosion - open areas	78	1
4. Storage piles		
Low volatility coal	119	2
High volatility coal	74	1
Iron ore screened		
Bed No. 1	110	2
Bed No. 26E	104	2
Blended ore (sinter input)	2,109	39
Flue dust	286	5
Limestone		
Monarch	224	5
Dolomite	71	1
Total all open sources	5,435	100

Table 6. PLANT C: UNIT EMISSIONS

Source	Pounds particulates[a] per short ton of steel produced
Unpaved roads	2.7
Paved roads	0.1
Wind erosion - open areas	0.1
Storage piles	3.9
Total	6.8

a/ Particulates less than 30 μ in diameter.

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