MIDWEST RESEARCH INSTITUTE

MRI REPORT

OPEN DUST SOURCES AROUND IRON AND STEEL PLANTS

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: February 4, 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

for L. J. Shannon, Director
Environmental and Materials
Sciences Division

February 4, 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 D. 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, and in the report for Plant C, dated January 11, 1977.

2.0 Unpaved Roads

Table 2 lists source extent and activity factors, emission factor correction parameters, and calculated emission rates for specific unpaved roads lying within the property boundaries of Plant D. The plant had no paved roads within its boundaries.

The experimentally determined emission factors for 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:

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 µ in diameter based on particle density of 2.5 g/cm^3.

Table 2. PLANT D - ROAD EMISSIONS

	Source extent			Correction factors			Emissions[d]		
Roads	Road length[a] (miles)	Vehicle class: Light Duty A Medium Duty B Heavy Duty C	Vehicle-miles traveled[b] (miles/day)	Vehicle weight correction (based on observation)	Vehicle speed[b] (mph)	Road surface silt content[c] (%)	Emission factor (lb/VMT)	Daily emissions (tons/day)	Yearly emissions (tons/year)
Unpaved	10.6	A	720	1.0	20	10	2.3	0.8	292
		B	440	3.5	20	10	8.1	1.8	657
		C	120	8.0	15	10	13.7	0.8	292
Total	10.6		1,280					3.4	1,241

a/ Determined from plant map.
b/ Data obtained from plant personnel.
c/ Assumed value.
d/ All emissions are based on particulates less than 30 μ in diameter.

1. Unpaved road segments with specific surface and traffic characteristics were identified by plant personnel, and the length of each segment was determined from a map of the plant.

2. The types and sizes of the vehicles traveling on unpaved roads were specified by plant personnel.

3. Figures on the daily mileages traveled by each vehicle type were furnished by plant personnel.

All of the roads at Plant D boundary are slag surfaced. As indicated in Table 2, total unpaved road mileage within the plant is 10.6 miles. These roads were indicated to be in good condition throughout the plant and to be regularly maintained.

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

* Type A - light duty, 36 vehicles (automobiles and pickup trucks).

* Type B - medium duty, 22 vehicles (flatbeds and other medium sized trucks).

* Type C - heavy duty, 6 vehicles (larger trucks with load capacity greater than 25 tons).

As indicated by plant personnel, these vehicles travel over all the unpaved roads in the plant. Thus, no specific plant road segments were identified as having higher than average traffic volumes.

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 road surface material was assumed. Average vehicle speed 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 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. Ratio 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.

3.0 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 transfer 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 aggregated materials at Plant D. 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 dumptrucks,

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

3. Wind erosion during 90-day storage, and

4. Load-out from piles to dumptrucks utilizing high loaders.

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

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. PLANT D - STORAGE PILE EMISSIONS

Material in storage	Source extent: Amount in storage (tons)[a]	Source extent: Annual thruput (million tons)[a]	Correction factors: Silt content (%)[b]	Correction factors: Duration of storage (days)[c]	Emission factors[f]: Load-in (lb/ton stored)	Emission factors[f]: Vehicular traffic (lb/ton stored)	Emission factors[f]: Wind erosion (lb/ton stored)	Emission factors[f]: Load-out (lb/ton stored)	Emission factors[f]: Total storage cycle (lb/ton stored)	Emission factors[f]: Yearly emissions (tons/year)
Low volatility coal	25,000	0.05	5.5	180	0.2	0.3	0.9	0.2	1.6	40
High volatility coal	30,000	0.06	2	360	0.1	0.1	0.7	0.1	1.0	30
Iron ore pellets	50,000	1.8	13	10	0.3	0.7	0.1	0.5	1.6	1,440
Screened iron ore	66,600	0.4	19	60	0.5	e/	1.1	0.7	2.3	460
Coke breeze	40,000	0.04	7	90	0.2	0.7	0.6	0.3	1.8	36
Screened limestone/dolomite	5,000	0.14	9[d]	13	0.2	0.9	0.1	0.3	1.5	105
Dolomite stone	12,000	0.04	1.5[d]	45	0.04	0.1	0.1	0.1	0.4	8
Total	216,600	2.49								2,119

a/ Data obtained from plant personnel.
b/ Assumed silt content based on sieving of similar materials.
c/ Calculated from data obtained from plant personnel.
d/ Assumed value.
e/ Determined negligible.
f/ All emissions are based on particulates less than 30 μ in diameter.

During the survey, weather conditions prohibited the collection of representative samples of the storage materials to be analyzed for silt content. Storage pile silt content values were assumed to be the same as the values obtained for similar materials previously sized at other steel plants.

Table 3 presents the emission factors for the storage of primary aggregate materials used in integrated iron and steel plants. The rationale for the derivation of the emission factor expression for each operation is given below.

3.1 Loading Onto Piles

The method of loading onto storage piles at Plant D consisted of utilizing front-end loaders for the coke breeze and screened stone piles; a stacker for the iron pellet piles; and an overhead gantry/clamshell drop for the screened iron ore, large stone, and for the coal piles. The front-end loader and gantry drop method of loading onto the piles is considered comparable to the operations for which field measurements were performed. The stacker method of pile formation 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 following equation was used to derive emission factors for the procedure of pile load-in:

$$EF_1 = 0.04\ (S/1.5)\ K$$

where EF_1 = emission factor (lb/ton of material transferred)

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

S = silt content of given aggregate material (percent)

1.5 = silt content of emission-tested material (percent)

K = activity factor (0.75 for iron pellets, 1.0 for all other materials)

3.2 Vehicular Traffic

Vehicular traffic around emission-tested aggregated storage piles, consisting of truck and high-loader movements associated with 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 reduced traffic-related activity factor:

Screened iron ore: K = 0 (no vehicular traffic)

Iron ore pellets: K = 0.5

Coal: K = 0.5

Large stone: K = 0.5

The coal, coke breeze, and screened stone storage piles at Plant D were worked in a manner similar to the emission-tested aggregate, and were thus assigned a K-factor of 1.

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

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

where EF_2 = emission factor (lb/ton of material stored)

PE = Thornthwaites precipitation-evaporation index (93)

S = silt content of given aggregate material (percent)

K = activity factor

The value 0.13 lb/ton was the factor experimentally determined for vehicle-generated emissions around the emission-tested aggregate piles. These test piles had an average silt content of 1.5% and the area where the testing occurred had a PE index of 100.

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 emission-tested aggregate materials. These assumptions are incorporated into the following equation:

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

where S = silt content of given stored material (percent)

PE = Thornthwaites precipitation-evaporation index (93)

D = duration of material in storage (days)

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

3.4 Load-out

The method of loading out from the piles at Plant D consisted of utilizing either a front-end loader pickup and dump into a conveyor bin (coal, ore pellets, coke breeze, and stone piles) or a gantry/clamshell removal and dump into a rail hopper car (iron ore) which released the material onto an undergound conveyor. The activity level (K-factor) for these two methods was judged to be similar in nature to the emission-tested load-out process.

Based on these considerations, emission factors for aggregate load-out were calculated by the following equation:

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

where EF_4 = emission factor (lb/ton of material stored)

S = silt content of stored material (percent)

PE = Thornthwaites precipitation-evaporation index (93)

K = activity factor = 1

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

4.0 Wind Erosion of Exposed Areas

Unsheltered areas of bare ground around plant facilities are subject to atmospheric dust generation by wind erosion, whenever the wind exceeds the threshold velocity of about 12 mph. The bare ground area within the boundaries of Plant D was estimated to be 10% of the plant property, based on discussions with plant personnel during the plant survey. To account for the sheltering effect of plant structures, the effective exposed area was taken to be 7.5% of the plant property.

As indicated in Table 1, the parameters which influence the amount of dust generation by wind erosion are soil erodibility, silt content of the surface soil, precipitation-evaporation index, and fraction of the time wind speed exceeds 12 mph. The soil erodibility factor (47) and the surface silt content (15%) were derived from previous sieving of similar surface soil materials at another steel plant. Thornthwaites precipitation-evaporation index for Plant D was determined to be 93.[1/] Finally, the value for the fraction of time the wind speed was greater than 12 mph (25%) was obtained from weather records.[5/] The results from wind erosion of Plant D's exposed areas are presented in Table 4.

5.0 Summary of Dust Emissions

A breakdown of calculated emissions from open dust sources at Plant D is presented in Table 5. For Plant D, the largest contributing source was the iron ore pellet piles. Unpaved roads were also a major contributor to Plant D's dust emissions inventory. The remaining sources have relatively minor impact. Table 6 gives Plant D's emissions from open dust sources, stated on a per ton of steel produced basis. Expressing emissions in this manner is useful when comparing the emissions from steel plants of various sizes.

Table 4. PLANT D - OPEN AREA EMISSIONS

Wind erosion	Source extent: Total plant area (acres)	Source extent: Total open area (acres)	Source extent: Effective open area fraction	Correction factors: Soil erodibility (tons/acre-year)	Correction factors: Surface soil silt content (%)	Correction factors: Wind speed[d]	Correction factors: PE index[e]	Emissions[f]: Emission factor (lb/acre-year)	Emissions[f]: Daily emissions (tons/day)	Emissions[f]: Yearly emissions (tons/year)[g]
Plant D open areas	1,100[a]	110[a]	0.75[a]	47[b]	15[c]	0.25	93	917	0.1	37

a/ Data obtained from plant personnel.
b/ Based on sieving of similar materials.
c/ Assumed value.
d/ Fraction of the time the wind speed is greater than 12 mph.
e/ Thornthwaites precipitation-evaporation index
f/ Based on particulates less than 30 μ in diameter.
g/ Yearly emissions = daily emissions multiplied by number of dry days per year.

Table 5. PLANT D - SUMMARY OF OPEN DUST SOURCE EMISSIONS

Source	Tons of particulate per year[a/]	Percentage of total
1. Unpaved roads	1,241	37
2. Wind erosion - open areas	37	1
3. Storage piles		
Low/high volatility coal	70	2
Iron ore pellets	1,440	42
Screened iron ore	460	14
Coke breeze	36	1
Stone piles	113	3
Total all open sources	3,397	100

a/ Based on particles less than 30 μ in diameter.

Table 6. PLANT D - UNIT EMISSIONS

Source	Pounds of particulates[a] per short ton of steel produced
Unpaved roads	1.7
Wind erosion - open areas	0.1
Storage piles	2.8
Total	4.6

a/ Based on particles less than 30 μ in diameter.

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