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EMISSIONS FROM THE CRUSHED GRANITE INDUSTRY: State of the Art

Industrial Environmental Research Laboratory
Office of Research and Development
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Cincinnati, Ohio 45268

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EMISSIONS FROM THE CRUSHED GRANITE INDUSTRY
State of the Art

by

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TABLE 1. MASS EMISSIONS FROM VARIOUS OPERATIONS IN THE CRUSHED GRANITE INDUSTRY

Unit operation	Emission factor, kg/metric ton	Particulates[a]				Free silica	
		U.S. total kg/yr	Percent of total	Severity for representative plant	Percent respirable	U.S. total kg/yr	Severity for representative plant
Drilling	3.99×10^{-4}	38,500	0.4	3.7×10^{-3}	10.0	1,040	8.5×10^{-2}
Blasting	7.96×10^{-2}	7,681,400	74.4	0.74	16.9	353,000	28.7
Loading onto haul trucks	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Dumping to primary crusher	2.1×10^{-4}	20,300	0.2	1.9×10^{-3}	3.6	200	1.6×10^{-2}
Primary crusher	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Secondary crushing and screening	2.2×10^{-2}	2,123,000	20.6	0.20	3.6	20,800	1.7
Conveying	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Unloading to stockpiles	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Loading from stockpiles	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Vehicular movement on dry unpaved roads	4.91×10^{-3}	473,800	4.6	4.5×10^{-2}	17.6	22,700	1.8
Windblown emissions	[b]	[b]	[b]	[b]	[b]	[b]	[b]
TOTAL[c]	1.07×10^{-1}	10,325,500	100.0	0.99	14.3	402,000	32.7

[a] The values shown are for total particulates.

[b] Negligible.

[c] Data may not add to totals due to independent rounding.

APPENDIX B

SAMPLING - DETAILS AND RESULTS

SAMPLING SITE DESCRIPTION

The purpose of the sampling is to obtain data on plant emissions from various unit operations for which no published data were available.

Two crushed granite plants were chosen whose operations are representative of the crushed granite industry. Further, these plants were located in areas with favorable meteorological conditions for sampling.

Plant A

At this site, the blasted rock is loaded into the primary crusher by a front-end loader or shell loader. The granite rock, processed through the primary crusher 2.13-m cone and secondary crusher 1.68-m cone, is fed by a conveyor to a screen tower where it falls into a bin. From the bin, the material is loaded into railroad cars or trucks. The material may then be delivered directly to customers, or it may be stockpiled. The crushed granite from the stockpile is loaded into trucks by a conveyor.

The plant operates on a continuous basis at 10 hr/day for 5 days/week. The average production rate of material processed through the primary crusher is 680 metric tons/hr; that through the secondary screening house is 430 metric tons/hr.

The major dust emission control method is the application of water to the haul roads from the quarry area to the plant. The quarry operations and the primary crushing take place in a pit and hence are only minor contributors to the overall plant emissions. The major contributor is the secondary crushing and screening unit. The sampling data and the results are given in Table B-1.

Plant B

At this site, the blasted material is loaded out with two 4.2-m^3 shovels into six 32-metric ton trucks to be hauled and dumped into a 107-cm x 122-cm jaw crusher. The material is then processed through two scalping screens and then through two 1.7-m

TABLE B-1. SAMPLING DATA AND RESULTS

Unit operation	Coordinates, m[a] x	y	z	Wind speed, mph	Sampling time, min	Concentration, µg/m³	Emission rate, g/s	Total or respirable particulate[b]	Atmospheric stability class
Plant A - Run 1									
Secondary crushing-screening	300	0	0	5.0	230	687.7	1.870	T	C
Secondary crushing-screening	310	120	0	5.0	230	759.6	2.641	T	C
Secondary crushing-screening	390	0	0	5.0	230	628.3	2.281	T	C
Secondary crushing-screening	320	100	0	5.0	230	1,154.8	3.890	T	C
Drilling, dry	78	20	0	3.0	4	1,540.0	3.562×10^{-1}	R[c]	C
Dump to first crusher	60	0	0	3.0	4	370.0	3.235×10^{-3}	R[d]	C
Dump to first crusher	60	0	0	3.0	4	260.0	2.273×10^{-3}	R	D
Plant A - Run 2									
Secondary crushing-screening	288	83	0	6.7	235	949.6	2.153	T	D
Secondary crushing-screening	258	209	0	6.7	235	632.9	2.421	T	D
Secondary crushing-screening	375	108	0	6.7	235	775.6	2.482	T	D
Secondary crushing-screening	274	193	0	6.7	235	1,006.6	3.631	T	D
Blasting	2,300	0	230	7.0	45	763.4	1.908×10^{6}	T	D
Plant B - Run 1									
Overall plant emission	540	0	0	4.0	235	424.2	1.009	T	D
Overall plant emission	570	120	0	4.0	235	525.6	1.609	T	D
Overall plant emission	660	0	0	4.0	235	323.2	9.573×10^{-1}	T	D
Overall plant emission	520	180	0	4.0	235	518.3	1.858	T	D
Secondary crushing	60	15	0	2.0	4	720.0	3.606×10^{-2}	T	B
Secondary crushing	60	15	0	2.0	4	1,190.0	5.959×10^{-2}	R[e]	B
Secondary crushing	60	15	0	2.0	4	1,320.0	6.610×10^{-2}	R	B
Secondary crushing	120	30	0	2.0	4	200.0	3.939×10^{-2}	R	B
Secondary crushing	120	30	0	2.0	4	150.0	2.954×10^{-2}	R	B
Secondary crushing	160	0	0	2.0	4	380.0	5.520×10^{-2}	R	B
Secondary crushing	60	0	0	2.0	4	2,330.0	5.650×10^{-2}	R	B
Secondary crushing	60	0	0	2.0	4	2,570.0	6.232×10^{-2}	R	B
Secondary crushing	160	40	0	2.0	4	140.0	4.888×10^{-2}	R	B
Drilling, wet	90	22	0	2.0	4	70.0	1.159×10^{-2}	T	D
Drilling	90	22	0	2.0	4	130.0	2.152×10^{-2}	T	D
Drilling	90	0	0	2.0	4	560.0	6.728×10^{-3}	T	D
Drilling	90	22	0	2.0	4	130.0	2.152×10^{-2}	T	D
Drilling	90	0	0	2.0	4	120.0	1.442×10^{-3}	R	D
Drilling	90	0	0	2.0	4	130.0	1.562×10^{-3}	R	D

[a] See Figure B-1. [b] T = total particulate; R = respirable particulate. [c] Two dumps. [d] One dump. [e] One truck passed.

cone crushers. From here, crushed granite is conveyed by a 152-m belt conveyor to a secondary plant.

At the secondary plant, 13 screens separate the aggregate sizes, and the crushed granite is then fed into one of two blending tunnels. From that blender, it is either trucked to customers or to storage, or loaded into railroad cars. The fine crushings are fed to two 2.1-m short-head crushers and transferred to a sand plant. The wet slurry from the screenings is fed to a sump that pumps it to a settling pond. About 90% of the pond water is reused in the process.

The plant operates on a continuous basis at 10 hr/day for 5 days/week. The average production rate through the primary crusher is 590 metric tons/hr, the same as the processing rate through the secondary crusher.

The major dust emission control method is the use of wet screening operations. However, unlike Plant A, vehicular traffic on the haul roads is a major contributor of overall plant emissions. The sampling data and the results are given in Table B-1.

SAMPLING PROCEDURES

Samplers

General Metal Works® high-volume (hi-vol) samplers were positioned around an area as shown in Figure B-1. For this arrangement, the origin was defined as the source, and all remaining points were in the usual Cartesian coordinate system. The angle of mean wind direction was θ. The downwind distance of any point y_i perpendicular to the wind direction centerline was computed in the following manner:

$$m_1 = \tan \theta$$

and for point S_i with coordinates x_i, Y_i

$$m_2 = \frac{y_i}{x_i}$$

the angle α was found from

$$\alpha = \arctan \frac{m_1 - m_2}{1 + m_1 \cdot m_2}$$

the lateral distance, Y_i, is:

$$Y_i = (\sin \alpha) \sqrt{x_i^2 + y_i^2}$$

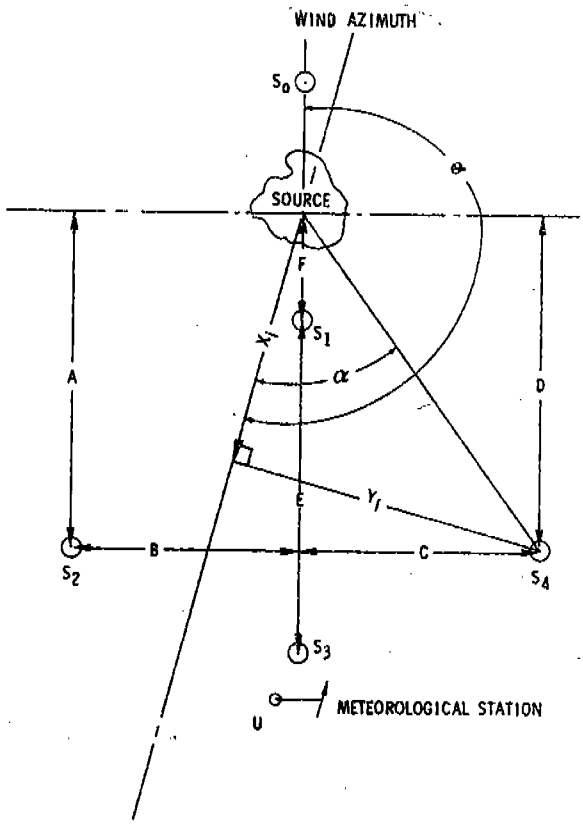

Figure B-1. Sampling arrangement.

and the downwind distance, X_i, is:

$$X_i = (\cos \alpha) \sqrt{x_i^2 + y_i^2}$$

These values are used in appropriate dispersion models. The sampling time for hi-vol samplers was about 4 hours. Five different hi-vol samplers were used to monitor the area emissions at positions S_0, S_1, S_2, S_3, and S_4.

A GCA[a] respirable dust monitor was used to obtain downwind concentrations of respirable and total particulates from unit operations (29). The sampling time for the GCA instrument was about 4 minutes, so only one unit was necessary to monitor at all the positions (not simultaneously).

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[a]GCA Corporation, Technology Division, Redford, Massachusetts.

(29) Lilienfeld, P., and J. Dulchinos. Portable Instantaneous Mass Monitor for Coal Mine Dust. Americal Industrial Hygiene Association Journal, 33(3):136, 1972.

The hi-vol samplers collect particles <100 μm in size, while the GCA unit collects <10-μm particles with a cyclone separator and <50-μm particles without a cyclone separator.

Models

Diffusion models, normally used to predict concentrations surrounding a point source of known strength, are used in reverse for open source sampling. Several concentration readings are taken to calculate the source strength of an open source.

Models applicable to the sampling arrangement and source characteristics are chosen and utilized for each emissive source. Two models are used in this study. The first represent emissions from secondary crushing and screening, dry drilling, dump to first crusher, overall plant emission, secondary crushing, wet drilling, and drilling.

This is the point source model (7) where:

$$\chi\ (x,\ y,\ z;\ H) = \frac{Q}{2\pi\sigma_y\sigma_z u}\ \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \cdot \cdot$$

$$\cdot \cdot \cdot \left\{ \exp\left[-\frac{1}{2}\left(\frac{z - H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z + H}{\sigma_z}\right)^2\right]\right\} \qquad \text{(B-1)}$$

The notation used to depict the concentration is χ (x, y, z; H). H, the height of the plume centerline from the ground level when it becomes essentially level, is the sum of the physical stack height, h, and the plume rise, ΔH. The following assumptions are made: the plume spread has a Guassian distribution in both the horizontal and vertical planes, with standard deviations of plume concentration distribution in the horizontal and vertical of σ_y and σ_z, respectively; the mean wind speed affecting the plume is u; the uniform emission rate of pollutants is Q; and total reflection of the plume takes place at the earth's surface, i.e., there is no deposition or reaction at the surface. Any consistent set of units may be used. The most common is χ in g/m^3, Q in g/s, u in m/s, and σ_y, σ_z, H, x, y, and z in meters. The concentration χ is a mean over the same time interval as the time interval for which the σ's and u are representative. The values of both σ_y and σ_z are evaluated in terms of the downwind distance, x, and stability class. Stability classes are determined conveniently by graphical methods as shown in Figure B-2 (26). Given the downwind distance, x (30), continuous functions are

(30) Eimutis, E. C., and M. G. Konicek. Derivations of Continuous Functions of the Lateral and Vertical Atmospheric Dispersion Coefficients. Atmospheric Environment, 6(11):859-863, 1972.

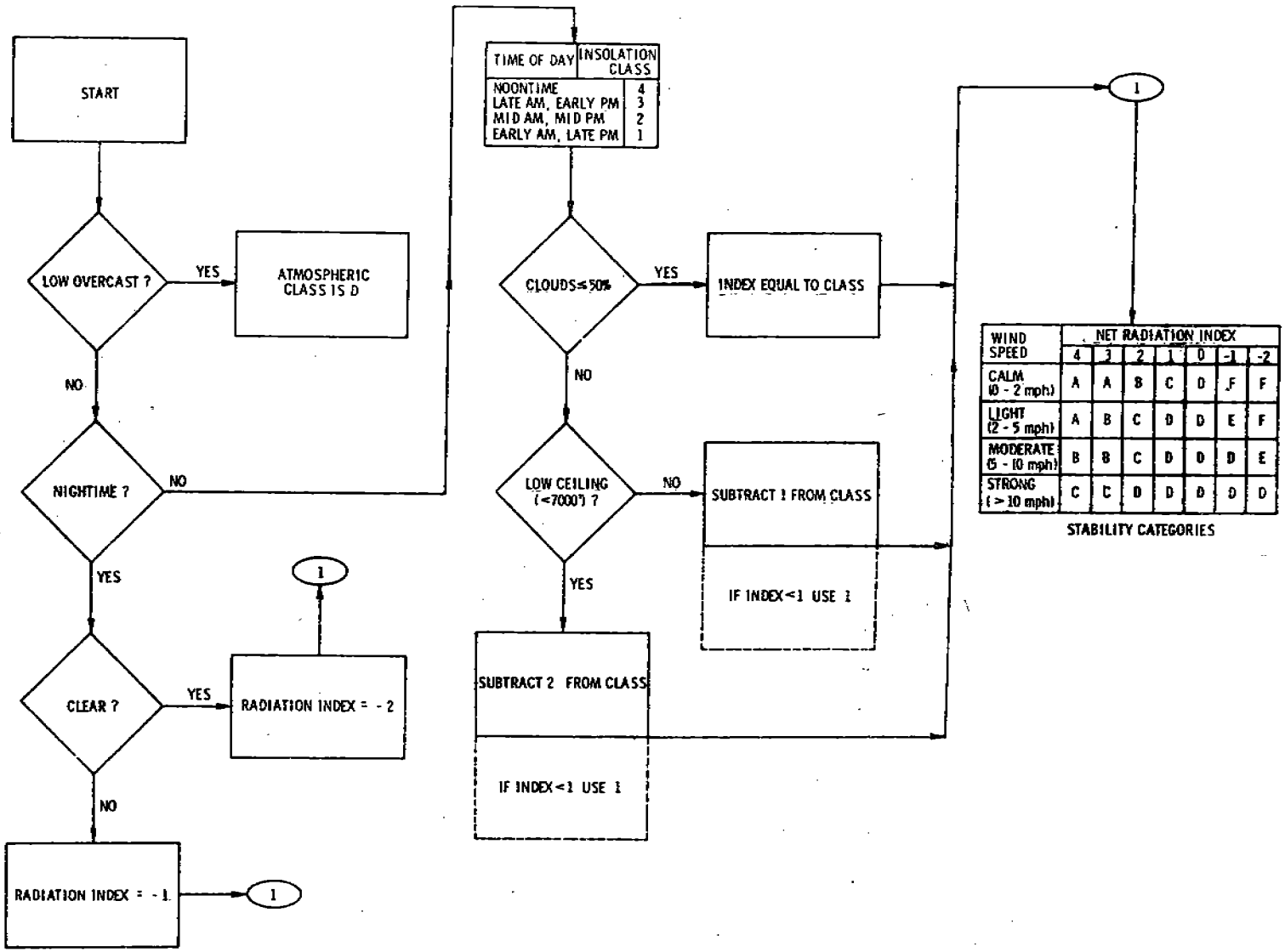

Figure B-2. Flow chart of atmospheric stability class determination (26).

then used to calculate values for σ_y, and σ_z, using the constants shown in Table B-2 and Table B-3 (31). In open source sampling, the sampler is maintained in the center of the plume at a constant distance; the plume has no effective height (H = 0); and the concentrations are calculated at ground level. Equation B-1 thus reduces to (7):

$$\chi\ (x,\ 0,\ 0;\ 0) = \frac{Q}{\pi \sigma_y \sigma_z u} \qquad \text{(B-2)}$$

The second model is used in computing total dose from a finite release in blasting. This is calculated from the dose model, Equation B-3 (7):

$$D_T = \frac{Q_T}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \qquad \text{(B-3)}$$

Q_T is the total release in grams from the source, and D_T is the total dose in $g\text{-}s/m^3$. Other parameters in Equation B-3 are the same units as Equation B-1. Again, the dose is the product of the concentration and sampling time.

Data Collection

Each variable for each of these models was determined in the field by high volume sampling at a nonportable meteorological station. Wind speeds were averaged every minute with a mean recorded for each 15-minute interval. The mean wind speed was calculated from the average of the 15-minute recordings over the entire run. The wind direction variation was less than ±45° from the centerline during the samplings. The samplers were therefore maintained within the plume during sampling.

The concentration at sampler S_0 was subtracted from the concentrations at S_1, S_2, S_3, and S_4 to yield those due to the source emissions. Mass emission rate was then calculated as an average of the calculations done for N sampler readings using the appropriate dispersion equation.

The respirable dust monitor was mounted on the portable meteorological station shown in Figure B-3. Each monitor concentration reading was displayed by direct digital readout. The wind meter, connected to the anemometer atop a 3.05-m pole, was read every 15 s. The mean wind speed was determined by averaging the 15-s

(31) Martin, D. O., and J. A. Tikvart. A General Atmospheric Diffusion Model for Estimating the Effects on Air Quality of One or More Sources. Presented at the 61st Annual Meeting of the Air Pollution Control Association, St. Paul, Minnesota, June 23-27, 1968. 18 pp.

TABLE B-2. CONTINUOUS FUNCTION FOR LATERAL ATMOSPHERIC DIFFUSION COEFFICIENT σ_y (30)

$$\sigma_y = Ax^{0.9031}$$

Stability class	A
A	0.3658
B	0.2751
C	0.2089
D	0.1471
E	0.1046
F	0.0722

TABLE B-3. CONTINUOUS FUNCTION FOR VERTICAL ATMOSPHERIC DIFFUSION COEFFICIENT σ_z (31)

$$\sigma_z = Ax^B + C$$

Usable range, m	Stability class	Coefficient		
		A_1	B_1	C_1
>1,000	A	0.00024	2.094	-9.6
	B	0.055	1.098	2.0
	C	0.113	0.911	0.0
	D	1.26	0.516	-13
	E	6.73	0.305	-34
	F	18.05	0.18	-48.6
		A_2	B_2	C_2
100 to 1,000	A	0.0015	1.941	9.27
	B	0.028	1.149	3.3
	C	0.113	0.911	0.0
	D	0.222	0.725	-1.7
	E	0.211	0.678	-1.3
	F	0.086	0.74	-0.35
		A_3	B_3	C_3
<100	A	0.192	0.936	0
	B	0.156	0.922	0
	C	0.116	0.905	0
	D	0.079	0.881	0
	E	0.063	0.871	0
	F	0.053	0.814	0

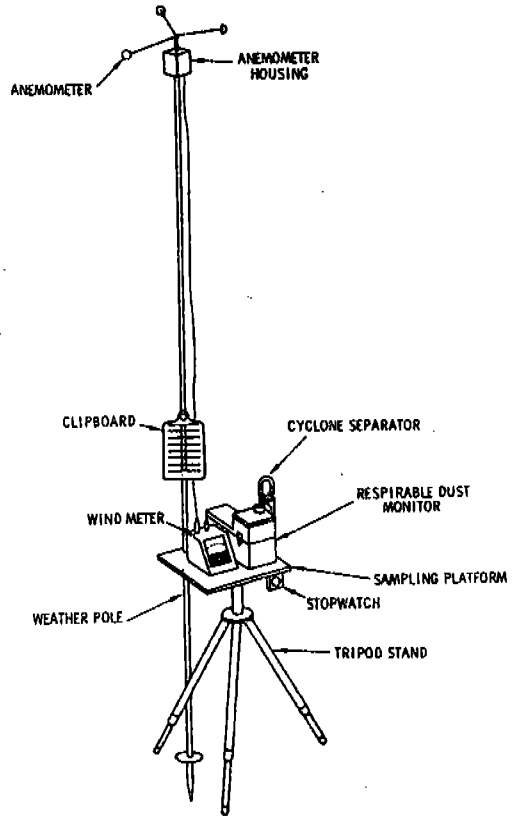

Figure B-3. Sampling apparatus.

readings. Distance x was approximated by pacing over the rough terrain. For each sampling run, all these data were recorded in the field on the form shown in Figure B-4. The time of day and atmospheric stability (determined according to the flow chart in Figure B-2) were recorded periodically on the bottom of the form.

The terms used on the field data form are explained in Table B-4.

Any factors that might have affected concentration or emission rate were mentioned in the column labeled "Comments." When this form was completed, the data were programmed into a computer and the emission rate, Q, calculated in accordance with the model specified in the column labeled "M."

EMISSION LEVELS

The parameters in Equation B-1 were measured in the field to obtain the emission rate (Q) per unit operation. These data were recorded on the form shown in Figure B-4 and printed out via computer. These values are shown in Table B-1, where the value of Q from the appropriate dispersion model was automatically computed. Using the site data presented earlier in this appendix, emission factors were computed as follows for each operation.

MODEL: POINT = 1
LINE = 2
DOSE = 3

SOURCE TYPE _____

DATE _____

BY _____

UNIT OPERATION	WIND SPEED, MPH	DISTANCE, FT. X	Y	Z	TIME, MIN.	READ., mg/m^3	CONC. $\mu g/m^3$	R/T	BGD, $\mu g/m^3$	Δ, $\mu g/m^3$	Q, g	S'	M	COMMENTS

TIME OF DAY ____ ____ ____ ____ ____

ATM. STABILITY ____ ____ ____ ____ ____

TOTAL SAMPLING TIME	MULTIPLY READING BY
4 MINUTES	1
8 MINUTES	0.46
16 MINUTES	0.23
20 MINUTES	0.184
30 MINUTES	0.122
37 MINUTES	0.1

Figure B-4. Field data form.

TABLE B-4. EXPLANATION OF FIELD DATA FORM TERMS

Term	Meaning
Read, mg/m^3	Concentration reading
Conc., $\mu g/m^3$	Converted concentration for sampling times greater than 4 min (lower right-hand corner)
R/T	Ratio of respirable to total particulate
BGD, $\mu g/m^3$	Background concentration
Δ, $\mu g/m^3$	The difference between the converted concentration and the background
Q, g or g/s	Calculated emission rate
S'	Stability for the time of day the unit operation was sampled
M	The model used referenced as 1, 2, or 3 (point, line, or dose, respectively)

Blasting

From the sampling data (Plant A, run 2), the emission rate of total particulates due to blasting is 1.9×10^6 g/blast. Assuming that one blast supplies the primary crusher with 3.5 days work (data from plant personnel) and knowing that Plant A has a production rate of 750 tons/hr operating for a 10-hr day, the amount of rock released by each blast is:

$$750 \frac{\text{tons}}{\text{hr}} \times 10 \frac{\text{hr}}{\text{day}} \times 3.5 \text{ days} = 26{,}250 \text{ tons}$$

The emission factor for total particulate due to blasting is thus:

$$EF = \frac{(1.9 \times 10^6 \text{ g})(10^{-3} \text{ kg/g})}{(26{,}250 \text{ tons})(0.9078 \text{ metric ton/ton})}$$

$$= 7.96 \times 10^{-2} \text{ kg total particulate/metric ton}$$

Sampling of crushed stone operations indicates that the ratio of respirable particulates to total particulate (R/T) is 0.169. Assuming the same ratio for crushed granite blasting, the emission factor is:

$EF = (7.96 \times 10^{-2})(0.169) = 1.35 \times 10^{-2}$ kg respirable particulate/ metric ton

Drilling

It is assumed that the representative plant uses wet drilling and that the total drilling time per blast is 176 hours. The emission rate for drilling is the average of the four wet drilling emission rates (Plant B, run 1) and is equal to 0.015 g total particulate/s. The emission factor is therefore:

$$EF = \frac{(0.015\ g/s)(176\ hr/blast)(3{,}600\ s/hr)(10^{-3}\ kg/g)}{(26{,}250\ tons/blast)(0.9078\ metric\ tons/ton)}$$

$$= 3.99 \times 10^{-4}\ kg\ total\ particulate/metric\ ton$$

Since the average of the two respirable emission rates is 1.5×10^{-3} g/s, the ratio of respirable particulates to total particulates (R/T) is thus 10%. The respirable particulate emission factor is:

$$EF = (3.99 \times 10^{-4}\ kg/metric\ ton)(0.10)$$

$$= 3.99 \times 10^{-5}\ kg\ respriable\ particulate/metric\ ton$$

Secondary Crushing and Screening

The average emission rate from secondary crushing and screening (Plang A, runs 1 and 2) is 2.67 g togal particulate/s. Using the production rate for Plant A, the emission factor is:

$$EF = (2.67\ g/s)(3{,}600\ s/hr)(hr/475\ tons)$$

$$(10^{-3}\ kg/g)(ton/0.9078\ metric\ ton)$$

$$= 2.2 \times 10^{-2}\ kg\ total\ particulate/metric\ ton$$

From the sampling data (Plant B, run 1), the R/T ratio can be calculated for secondary crushing. The average emission rate for secondary crushing is 4.84×10^{-2} g respirable particulate/s. The emission rate for total particulates as sampled by hi-vol samplers (determined from averaging the emission rates for overall plant emission) is 1.356 g total particulate/s. The R/T ratio for secondary crushing is thus:

$$\frac{4.84 \times 10^{-2}}{1.356} = 0.036$$

The respirable particulate emission factor from secondary crushing and screening is assumed to be 3.6% of the total particulate emission factor and is equal to 8.58×10^{-4} kg respirable particulate/metric ton.

Secondary Crushing Only--
From the sampling data (Plant B, run 1), the average emission rate of respirable particulates due to secondary crushing (excluding the run during which one truck passed the sampling area) is 4.84×10^{-2} g respirable particulate/s. Assuming R/T equals 0.039, the emission rate of total particulates is 1.24 g total particulate/s. Using the production rate for Plant B, the emission factor is:

$$EF = (1.24 \text{ g/s})(3{,}600 \text{ s/hr})(\text{hr}/650 \text{ tons})$$

$$(\text{ton}/0.9078 \text{ metric ton})(10^{-3} \text{ kg/g})$$

$$= 7.6 \times 10^{-3} \text{ kg total particulate/metric ton}$$

The plant used wet screening and, hence, there were no significant emissions from the screening operation.

Secondary Screening Only--
Since dry screening was used in Plant A, the emission factor is determined by subtracting the secondary crushing emission factor from the secondary crushing and screening emission factor.

$$EF = 2.2 \times 10^{-2} \text{ kg/metric tons} - 7.6 \times 10^{-3} \text{ kg/metric tons}$$

$$= 1.44 \times 10^{-2} \text{ kg total particulate/metric ton}$$

Dumping to Primary Crusher

The sampling data (Plant A, run 1) show two emission rates for respirable particulates during dumping to the primary crusher:

$$Q_1 = 3.235 \times 10^{-3} \text{ g/s for 2 dumps}$$

$$Q_2 = 2.273 \times 10^{-3} \text{ g/s for 1 dump}$$

Dividing Q in half to give the emission rate per dump and averaging Q_1 and Q_2 gives 1.68×10^{-3} g respirable particulate/s. Assuming that 25 trucks/hr dump at the primary crusher and that each truck has a capacity of 32 metric tons, the emission factor is:

$$EF = \frac{(1.68 \times 10^{-3} \text{ g/s})(3{,}600 \text{ s/hr})(\text{hr}/25 \text{ trucks})(\text{truck}/32 \text{ metric tons})}{10^3 \text{ g/kg}}$$

$$= 7.56 \times 10^{-6} \text{ kg respirable particulate/metric tons}$$

Emissions due to dumping at the primary crusher are assumed to be similar to emissions from secondary crushing; thus they have a R/T ratio of 0.036. The emission factor then for total particulates for dumping to the primary crusher is:

$$EF = 7.56 \times 10^{-6}/0.036 = 2.1 \times 10^{-4} \text{ kg total particulate/metric ton}$$

Vehicular Movement on Unpaved Roads

During a sampling run of secondary crushing operations (Plant B), one truck passed, creating an emission due to vehicular movement on an unpaved road. This emission rate may be determined from the secondary crushing data by averaging the emission rates (excluding the run during which the truck passed) and subtracting this average from the emission rate which includes that run. The difference is the vehicular movement emission rate:

6.61×10^{-2} g/s - 4.84×10^{-2} g/s = 1.77×10^{-2} g respirable particulate/s

The emission factor can be calculated by assuming that 8 trucks or loaders are in operation on dry unpaved roads for one hour and that the ratio of respirable particulate to total particulate (R/T) is comparable to the R/T ratio for vehicular movement on wetted roads in a crushed stone plant (0.176). The emission rate for total particulates is calculated as 1.01×10^{-1} g/s. The emission factor for total particulates is:

$$EF = \frac{(1.01 \times 10^{-1} \text{ g/s truck})(8 \text{ trucks})(3{,}600 \text{ s/hr})(10^{-3} \text{ kg/g})}{(650 \text{ tons/hr})(0.9078 \text{ metric tons/ton})}$$

$$= 4.91 \times 10^{-3} \text{ kg total particulate/metric ton}$$

Similarly, the respirable particulate emission factor is 8.64×10^{-4} kg/metric ton.

Total and respirable particulate emission factors for each source and the respective R/T ratio are tabulated in Table B-5. The overall emission factor for total particulates is 1.07×10^{-1} kg/metric ton. Similarly, the overall emission factor for respirable particulates is 1.53×10^{-2} kg/metric ton.

TABLE B-5. EMISSION FACTORS AND R/T RATIOS FOR PARTICULATE

Source	Total, kg/metric ton	R/T	Respirable, kg/metric ton
Blasting	7.96×10^{-2}	0.169	1.35×10^{-2}
Drilling	3.99×10^{-4}	0.10	3.99×10^{-5}
Secondary crushing and screening	2.2×10^{-2}	0.036	8.58×10^{-4}
Dumping to primary crusher	2.1×10^{-4}	0.036	7.56×10^{-6}
Vehicular movement on unpaved roads	4.91×10^{-3}	0.176	8.64×10^{-4}
TOTAL	1.07×10^{-1}	0.143	1.53×10^{-2}

COMPOSITION

The emissions from both plants were analyzed (6) for free silica, fibers, and trace elements. Fiber analysis of emissions from crushed granite operations is presented below.

Dust Samples from Granite Quarries

Table B-6 shows elemental analyses of dust samples from crushed granite quarries.

TABLE B-6. ELEMENTAL ANALYSIS OF DUST SAMPLE FROM GRANITE QUARRIES

	Weight percent				
	Plant A		Plant B		
Element	Run 1	Run 2	Run 1	Run 2	Plant A Blasting
Si	>10	>10	>10	>>10	>10
Fe	>10	>10	>10	>10	>10
Al	5-10	5-10	5-10	5-10	>10
Ca	5-10	5-10	5-10	5-10	>10
Na	4	4	4	3	4
Mg	0.7	2	3	5	1
Ti	1	1	1	0.8	3
Mn	0.2	0.3	0.2	0.5	0.2
Pb	0.02	N.D.[a]	N.D.	N.D.	N.D.
Ga	0.004	0.004	N.D.	N.D.	N.D.
Cr	0.002	0.002	N.D.	N.D.	N.D.
V	0.004	0.01	0.02	0.01	N.D.
Cu	0.004	0.002	0.08	N.D.	N.D.
Zr	N.D.	0.01	0.01	0.1	N.D.
Ag	N.D.	N.D.	N.D.	N.D.	0.04
Cl[b]	2-3	3-4	0.01	0.01	4-5
S[b]	4-5	3-4	5-6	∿10	∿11
K[b]	∿13	∿11	∿7	∿10	∿20

[a]Not detected.

[b]Semiquantitative estimates (±50%) by XRF. XRF measurements were performed directly on the filters. Emission spectrographic analyses were performed on loose particulates from the filters.

Free Silica Analysis from Crushed Granite Quarries

Table B-7 presents the results of free silica analysis of respirable emissions from crushed granite quarries.

TABLE B-7. FREE SILICA ANALYSIS FROM CRUSHED GRANITE QUARRIES TAKEN ON THE RESPIRABLE EMISSIONS

Sample source	Free silica, percent
Plant A	33.3
Plant A	30.1
Plant B	19.6

Mean value (Plants A and B): 27.7%
Standard deviation: 8.56%

Fiber Analysis of Emissions from Crushed Granite Operations

A fiber is a particle greater than 5 μm in length with a L/D of 3 or greater.

Field area = 0.005 mm^2

Count = 100 fields

Average count/field (Plant A, blasting) = 0.12

Ground level concentration (x = 701 m, y = 0, and z = 70 m from the source) = 0.03 fibers/mℓ

Emission factor for fibers = 3.13×10^9 fibers/metric ton

The mean source severity due to fiber emissions is 0.454 and the population affected by representative plant emissions with a severity of 0.1 is 227 persons, as calculated in Appendix C.