IMPACTS OF FUGITIVE DUST EMISSIONS
FROM A MODEL COPPER-NICKEL MINE AND MILL

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Minnesota Environmental Quality Board
Regional Copper-Nickel Study

Author: Peter Ashbrook
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INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state executive branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.
Copper-nickel development would add several new sources of air pollutants to those already existing in the region (see section III.C.3.). The new sources include the construction and operation of mines, mills, smelter, and tailings basins; secondary development such as new roads; and the shut down phase, where abandoned mine areas may contribute to fugitive dusts.

Construction: Construction activities generally expose large areas of soil. Fugitive dust emissions arise during human activities such as excavation and vehicle traffic and from wind erosion of exposed surfaces. Construction of one facility (mine, mill, smelter, or tailings basin) may take up to three years. In some cases facilities are built concurrently; however, some construction may occur for many years. Dust emissions would be expected to increase with human activity and dry and windy conditions. Short-term mitigation may occur naturally by precipitation or artificially through the use of water or other dust control agents. Permanent mitigation of dust emissions can be obtained by regenerating vegetative cover over the previously exposed construction site.

Mine/Mill Operation: Open pit mining exposes large areas of the ground. Both open pit and underground mining generate large volumes of waste rock, which is usually placed in storage piles. These activities combined with wind can generate large volumes of fugitive dust emissions. Water can be used for temporary mitigation, while revegetation of storage piles can provide long-term control. In underground mines dust control is accomplished by venting dust to the surface. Drilling and blasting produce large amounts of dust on an intermittent basis. Transfer of ore from the mine to mill can be the largest source
of fugitive dust emissions. Loading of trucks, travel of trucks over unpaved haul roads, and dumping of ore at the mill all produce dust. Dust suppression materials such as water or chemicals provide partial control of dust from unpaved roads. Processing of ore at the mill produces large volumes of dust. Point sources of dust from mills can be controlled by use of wet processes and stack controls; however, fugitive emissions from the mill are difficult to control.

Smelter Operations: Air pollutants from smelters can be classified into three groups: 1) sulfur oxides and 2) particulates, which include 3) metals. Sulfur oxides are produced by roasting of sulfide ores to remove sulfur. Control of sulfur oxides is accomplished by means of a sulfur recovery facility, usually a sulfuric acid plant. Such a control may prevent emission of over 90 percent of the sulfur oxides; however, some sulfur oxides are released through stacks since controls are not 100 percent effective. Sulfur oxides may also be released as fugitive emissions from the smelter or during upset conditions. These latter two cases are difficult to control.

Stack emissions of particulates can be controlled in a number of ways, yielding control efficiencies close to 100 percent. Fugitive emissions from the plant and particulates released during upset conditions are difficult to control. Metals are included in particulates, but are mentioned separately because some of them are concentrated during the processing of ore and may reach significantly high levels by the time they are released from the smelting stage.

Smelting stack emissions warrant special interest even though they are easier to control than fugitive emissions, because the emissions that are released are injected into the atmosphere at a higher elevation and can be transported large distances.
Tailings Basin Operations: Tailings basins can be sources of fugitive dust emissions because of the large open area with a tailing basin and the dike surrounding a basin. Dust can be controlled by keeping the tailing basin under water and through vegetating both the dike and the tailing basin after it is filled.

Secondary Development: Copper-nickel development will spur secondary development which will influence air quality through construction of new roads, homes, and businesses; increased traffic; and energy needs of both industry and individuals.

Shut Down: After the ore body is exhausted, a number of sources of air pollutants may remain for many years. These include the open pit mine, tailings basin, waste rock piles, and other open areas. In many cases, revegetation in these areas will provide long-term control of fugitive dust emissions. Open pit mines are sometimes filled with water to produce lakes.

Potential air pollution impacts may determine where development can be sited. Northeast Minnesota is divided into two air quality regions designated as Class I and Class II. Class I regions, which include the BWCA, have strict limitations on the amount of air pollutants a new industry is permitted to release. Class II regions, which include most of northeast Minnesota, have less stringent limitations on air pollutants from a new industry. Because of the proximity of the BWCA to potential copper-nickel development sites, some development sites may be prohibited because air emissions would exceed the strict limitations of a Class I region (see section III.C.4.).

Fugitive Dust (Non-point source)

Air quality impacts resulting from non-point sources of fugitive dust were modeled by means of the Climatological Dispersion Model (Busse and Zimmerman...
1973; Brubaker et al. 1977). Fugitive dust emission factors were experimentally determined by Midwest Research Institute as part of a study on the taconite mining industry (Bohn et al. 1978).

**Strengths and Limitations of the Model**

The Climatological Dispersion Model (CDM) has been widely used in air pollution modeling. The model utilizes local meteorological data, but does not take into account local topography. It has been widely tested and yields results for annual averages which correlate well with actual measurements.

The model is heavily dependent on accurate input of emission factors. These emission factors are often based on a number of assumptions and best guesses, each of which may be off by 50 percent or more. Although fugitive dust emissions constantly occur on a small scale, the bulk of the emissions occur in discrete stages, such as a truck driving over an unpaved road or a gust of wind causing dust lift-off from a tailings basin. Therefore, results from this model must be considered "ballpark" estimates and not highly accurate determinations of ambient dust levels.

**Copper-Nickel Model Scenario**

Sources of fugitive dust included for this study were blasting, unpaved haul roads, waste rock dumping, crushing/grinding, waste rock piles, ore storage (surge piles) in the mill, conveyors and dumping onto surge piles, and a tailings basin; other sources were considered negligible. The mine model assumed a 20 million metric tons per year open pit mine (see Technical Assessment section). Smaller open pit mines and underground mines would yield lower dust levels.
The mine-mill-waste rock pile-tailings basin site was modeled as follows (Figure 1). The open pit mine covers 200 hectares at maximum development. Haul roads emerge from the east end of the pit to the waste rock piles and to the mill. The tailings basin covers 1,650 hectares and is east of the mill. This orientation is dictated by the fact that to the west of the Duluth Contact is the Mesabi Iron Range and to the north and south of an open pit mine are other mineralized portions of the Duluth Contact. Over the 25 year life of the mine there would be a total of 13 waste rock piles of 60 hectares each. Reclamation of waste rock piles and the tailings basin dike was assumed to take five years.

Meteorological data concerning wind direction, speed, and stability class were obtained from International Falls. Average afternoon and nocturnal mixing heights were estimated to be 1,300 and 400 meters, respectively. Emission height of fugitive dust emissions was estimated to be ten meters. Receptor sites were chosen in a grid with the emission sources at the center. Particulate levels were calculated for 36 receptors at three-mile intervals (Figure 1). Estimated dust emissions from the various sources are shown in Table 1 (see Appendix).

III.D.2.d. Results

Estimated annual average increases in particulate levels due to dust emissions generated from the operation of a 20 million metric ton per year open pit mine and a corresponding processing plant as determined by the CDM are illustrated in Figure 1. The greatest increase, 13.2 ug/m³, occurred 0.5 mile north of the northern waste rock pile. This was the only receptor site with an increase greater than the background level of 11 ug/m³. Combining the background level of 11 ug/m³ with the greatest estimated increase of 13.2 ug/m³ gives an estimated level of 24.2 ug/m³. This value of 24.2 ug/m³ is less than half
of both the primary (75 ug/m$^3$) and secondary (60 ug/m$^3$) Minnesota Ambient Air Quality Standards.

Annual average concentrations can be statistically converted into 24-hour averages (Larson 1971). Although this conversion method has drawbacks, it is appropriate for use here to estimate whether this mine-mill model would be in compliance with the Prevention of Significant Deterioration (PSD) requirements of the 1977 Clean Air Act Amendments (P.L. 95-95) shown in Table 2. None of the receptor sites exceed the annual average increment permitted for Class II regions; however, four sites exceed the permitted increment of 5 ug/m$^3$ for a Class I region. Application of Larson's (1971) method of converting annual averages (assuming 60 samples per year, a geometric standard deviation=2; and a z value of 1.94) shows that to meet the 24-hour PSD increments, the annual average increments may not exceed 9.6 ug/m$^3$ for Class II regions or 2.6 ug/m$^3$ for Class I regions. Using criteria for Class II regions, two receptor sites would be expected to exceed the 24-hour PSD increment; however, these sites are virtually on the premises of the mine-mill development.

Using criteria for Class I regions, 6 of the 36 receptor sites would be expected to exceed the 24-hour PSD increment.

**Discussion**

The air quality standards that will be the most difficult to meet are the 24-hour PSD increments. According to this modeling study of dust sources from a large mine-mill development, Class II 24-hour PSD increments may be exceeded in close proximity to industrial activity, while Class I 24-hour PSD increments may be exceeded up to 10 kilometers away from industrial activity in some directions. If such a development were not allowed to use up the entire PSD increment, an even larger area may not be in compliance with permit requirements.
Although the CDM estimates are somewhat crude, they do indicate the relative importance of different sources of dust from potential mine-mill operation and where additional control efforts would be most beneficial.
REFERENCES


Table 1. Estimated fugitive dust emissions from a mine and mill.*

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>ESTIMATED RANGE OF EMISSIONS (metric tons/yr)</th>
<th>ESTIMATED USE FOR MODEL (metric tons/yr)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Blasting</td>
<td>1.5-1,600</td>
<td>10</td>
<td>Assumes 100 mtpy is midpoint estimate &amp; 10% of dust escapes the pit</td>
</tr>
<tr>
<td>2) Hauling</td>
<td>840-4,200</td>
<td>2,100</td>
<td>Assumes dust control of 50%</td>
</tr>
<tr>
<td>3) Waste rock dumping</td>
<td>8-400</td>
<td>10</td>
<td>Uses most recent MRI formula</td>
</tr>
<tr>
<td>4) Waste rock piles erosion</td>
<td>2.4-400</td>
<td>60</td>
<td>Uses most recent MRI formula (silt content=0.5%)</td>
</tr>
<tr>
<td>Mill:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5) Ore storage</td>
<td>2-210</td>
<td>10</td>
<td>Assumes 95% control</td>
</tr>
<tr>
<td>6) Conveyors dumping on surge pile</td>
<td>1-100</td>
<td>10</td>
<td>Assumes 90% control</td>
</tr>
<tr>
<td>7) Crushing/grinding</td>
<td>200-20,000</td>
<td>500</td>
<td>Based on Minntac's new plant (Stage 3) and conversation with MPCA</td>
</tr>
<tr>
<td>8) Tailings basin</td>
<td>0-480</td>
<td>100</td>
<td>Assumes 80% of basin under water</td>
</tr>
</tbody>
</table>

*Assumes an open pit mine producing $20 \times 10^6$ metric tons of ore per year and removing $26 \times 10^6$ metric tons of waste rock per year. Estimates are for particulates less than 30 um.
Table 2. PSD permitted increments for total suspended particulates (ug/m³).

<table>
<thead>
<tr>
<th></th>
<th>CLASS I</th>
<th>CLASS II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>24-hour Average</td>
<td>10*</td>
<td>37*</td>
</tr>
</tbody>
</table>

SOURCE: Air Quality Section.

*May be exceeded once per year.
APPENDIX

Estimates of dust emissions from a 20 million metric tons per year open pit mine and processing plant and associated activities.

A. Calculations used for the CDM model, pp.1-8

B. Extrapolations of annual averages to 24-hour averages, p.9

Peter Ashbrook
September, 1978
Blasting

A. Minimum estimate: 0.00015 \( \text{lb/short ton} \)

\[
(0.00015 \text{ lb/ton})(20 \times 10^6 \text{ metric tons}) \left( \frac{2000 \text{ metric tons}}{1 \text{ short ton}} \right) = 3307.5 \text{ lb/yr}
\]

or 1.5 metric tons/yr.

B. Maximum estimate: 0.16 \( \text{lb/short ton} \)

\[
(0.16 \text{ lb/ton})(20 \times 10^6 \text{ metric tons}) \left( \frac{2000 \text{ metric tons}}{1 \text{ short ton}} \right) = 2,528,000 \text{ lb/yr}
\]

or 1600 metric tons/yr.

C. Estimate for CDM model.

1. Approximate geometric mean = 100 metric tons/yr
2. Assume 10% of dust escapes the pit
3. Therefore 10 metric tons/yr emitted

Source: MRI, August 1978.
Haul Roads

Formula: \[ 5.9 \times \left( \frac{5}{40} \right) \times \left( \frac{W}{S} \right)^{0.6} \times \left( \frac{1}{385} \right) \text{ lbs/vehicle mile} \]

- \( S \) = silt content of road dust = 6% (2% < 5\( \mu \)m; 4% 5-30\( \mu \)m)
- \( S \) = average vehicle speed = 16 mph
- \( W \) = vehicle weight = 100 tons (formula has not been tested above 100 tons)
- \( d \) = dry days per year = 240

Calculation:

\[ \frac{(5.9)(4)(16)(\frac{100}{24})^{0.6}(240)}{(12)(30)(385)} = 17.1 \text{ lbs/vehicle mile} \]

A. Hauling ore to mill: 18 one-mile trips/hr; 24 hrs/day; 350 days/yr.

\[ \text{Dust emitted} = 17.1 \times 18 \times 24 \times 350 = 2,585,520 \text{ lbs/yr} \]

\[ \frac{2,585,520}{62,400} = 117.3 \text{ metric tons/yr} \]

B. Hauling waste rock to piles: 23.1 two-mile trips/hr; 24 hrs/day; 350 days/yr.

\[ \text{Dust emitted} = 17.1 \times 23.1 \times 2 \times 24 \times 350 = 6,727,362 \text{ lbs/yr} \]

\[ \frac{6,727,362}{62,400} = 107.9 \text{ metric tons/yr} \]

Total dust emitted = 117.3 + 107.9 = 225.2 metric tons/yr (no controls)

Estimate for CDM model

Assume 50% dust control; therefore 112.6 metric tons/yr

Source: MCI, March 1978
Dumping waste rock on piles

Minimum estimate (Source: MRI, March 1971):

\[
\frac{0.005(\frac{1}{2})(\frac{1}{2})}{(\frac{1}{2})^2(\frac{1}{2})} \text{ lbs/ton of material}
\]

\( s = \text{silth content of waste rock} = 1\% \)
\( U = \text{average wind speed} = 8.34 \)
\( M = \text{moisture content of ore} = 0.5 \%
\)
\( Y = \text{loader bucket capacity} = 100 \text{ yd}^3 \)

\[
\frac{0.005(\frac{1}{2})(\frac{1}{2})}{(\frac{1}{2})^2(\frac{1}{2})} = 0.00061021 \text{ lbs/ton of material}
\]

\[
(0.00061021 \text{ lbs/short ton})(26 \times 10^6 \text{ metric tons})(\frac{2205}{3800}) = 17,356 \text{ lbs/yr}
\]

or
\( 8 \text{ metric tons/yr} \)

B. Maximum estimate (Source: Shell report)

\[
\frac{0.33(x)}{(E-E)^2} \text{ lbs/ton of material}
\]

\( x = \text{Proportion of formula for dumping} = 0.12 \)
\( P = \text{Thorntower's Precipitation-Evaporation Index} = 1/2 \)

\[
\frac{0.33(0.12)}{(0.12)^2} = 0.31568 \text{ lbs/ton of material}
\]

\[
(0.31568 \text{ lbs/short ton})(26 \times 10^6 \text{ metric tons})(\frac{2205}{3800}) = 909,191,63 \text{ lbs}
\]

for
\( 960 \text{ metric tons} \)

Estimate for CDM model:

10 metric tons/yr (maximum formula based on earlier MRI work)
Waste rock pile dust emissions

A. Minimum estimate (M.R.I., March 1978)

\[ \frac{3400 \left( \frac{e}{50} \right) \left( \frac{r}{18} \right) \left( \frac{f}{28} \right)}{\left( \frac{e}{50} \right)^2} \text{ pounds/acre/year} \]

- \( e \) = surface evaporation = 3.7 tons/acre/year
- \( s \) = silt content of waste rock = 6%
- \( f \) = % of time wind exceeds 12 mph = 30%
- \( P \times E \) = Thornthwaite's Precipitation-Evaporation Index = 112

\[ \frac{3400 \left( \frac{3.7}{50} \right) \left( \frac{18}{18} \right) \left( \frac{30}{28} \right)}{\left( \frac{e}{50} \right)^2} = 18.43 \text{ lbv/acre/yr} \]

Assuming revegetation takes 5 years and one waste pile = 160 acres, a maximum of 1.75 piles would be exposed.

\[ (18.43)(1.75)(160) = 5308 \text{ lbv/yr or } 2.4 \text{ metric tons/yr} \]

B. Maximum estimate (M.R.I., August 1978)

\[ 3.5 \left( \frac{e}{18} \right) \left( \frac{r}{50} \right) \left( \frac{D}{\text{dry days/year}} \right) \text{ lbv/acre/year} \]

- \( s \) = silt content of waste rock = 6%
- \( D \) = dry days per year = 240
- \( D \) = duration of material storage = 365 days

\[ 3.5 \left( \frac{3.7}{18} \right) \left( \frac{18}{50} \right) \left( \frac{365}{240} \right) = 43.99 \text{ lbv/acre/yr} \]

Assuming all 13 waste rock piles exposed.

\[ (43.99)(13)(160) = 9050 \text{ lbv/yr or } 428 \text{ metric tons/yr} \]

Estimate for CDM model:

- Takes maximum estimate but assumes maximum of 1.75 waste rock piles exposed.
- Therefore 60 metric tons/yr
Mill storage pile (surge pile)

Formula:

\[ 0.05 \left( \frac{d}{15} \right) \left( \frac{d}{15} \right) \left( \frac{p}{100} \right) \text{ lbs/ton of material} \]

- \( s = 51.14 \) content of ore = 44%
- \( d = \) dry days per year = 270
- \( t = \) % of time wind exceeds 12 mph = 30%
- \( D = \) duration of material storage = maximum of \( t \) usually 1-3.

\[ 0.05 \left( \frac{270}{15} \right) \left( \frac{30}{100} \right) \left( \frac{7}{90} \right) = 0.021182 \text{ lbs/ton e of material} \]

A. Maximum estimates assume no controls

\[ (0.021182 \text{ lbs/short ton}) (20 \times 10^5 \text{ metric tons}) \left( \frac{2205}{10000} \right) = 423,345 \text{ lbs/yr} \]

\[ \frac{423,345}{210} = 2 \text{ metric tons/yr} \]

B. Minimum estimates assume 97% control

\[ 210 \times 0.01 = 2 \text{ metric tons per yr} \]

Estimate for CDI0 model

Assumes 95% control

Therefore 10 metric tons/yr

Source: NPI, March 1978
Conveyors in mill (nominal)

Formula: \[
\frac{0.0016 \left( \frac{3}{2} \right) \left( \frac{U}{5} \right)}{(\frac{H}{2})^2} \text{ lb/ton of material}
\]

- \( s = \) salt content of ore = 4%  (crushed to -14")
- \( U = \) average wind speed = 8.89 mph
- \( M = \) moisture content of ore = 1%

\[
\frac{(0.0016) \left( \frac{3}{2} \right) \left( \frac{8.89}{5} \right)}{(\frac{1}{2})^2} = 0.0101876 \text{ lb/ton of material}
\]

A. Maximum estimate (no controls):

\[
(0.0101876 \text{ lb/ton})(26 \times 10^4 \text{ metric tons/yr})(\frac{2205 \text{ lb/short ton}}{\text{1000 lb/ton}}) = 220,578 \text{ lb/yr or 100 metric tons/yr}
\]

B. Minimum estimate (99% control):

\[
(100)(0.01) = 1 \text{ metric ton/yr.}
\]

Estimate for CDM model

Assume 90% control

Therefore 10 metric tons/yr

Source: MRI, March 1979
Crushing, grinding in the mill

A. Estimates based on new Minatare plant (Stage 3). About 1000 tons/yr particulate emissions from primary & secondary crusher, milling, and concentrators.

B. This plant produces 6x10^6 tons/yr pellets from approximately 19x10^6 tons/yr of ore (approximately the same as range to 121977 for Cu-Ni).

C. Minatare uses mostly scrubbers which are not as efficient as the baghouse filters proposed for Cu-Ni. Baghouse filters would reduce figure of 1000 tons/yr to 200-500 tons/yr.

D. Estimate that Minatare's controls are 90-95% efficient. Therefore 10,000 - 105,000 tons/yr of dust generated.

E. Based on these numbers I estimated a range of 200 - 2500 tons/yr emissions for Cu-Ni.

Estimate for CDM model

Used 500 metric tons/yr based on information in C.

SOURCE: Conversation with Bill Rathschofer at PCA on 9/3/78
phone: 396 - 7373
Formula:
\[
\frac{\nu \cdot (\frac{e}{s}) \cdot (\frac{c}{f})}{(\frac{P-E}{10})^2} \text{ lbs/acre exposed land}
\]

\(c = \text{surface credibility} = 3.1 \text{ pounds/acre/yr.}\)
\(s = \text{silt content} = 70\% \text{ for fine tails}\)
\(f = \% \text{ of time wind exceeds 12 mph} = 30\%\)
\(P-E = \text{Thornthwaite's Precipitation-Evaporation Index} = 112\)

\[
3900 \left(\frac{3.1}{112}\right)^{0.70} \left(\frac{3.1}{112}\right) = 258 \text{ lbs/acre/yr.}
\]

**Maximum estimate:**

Basin = 4016 acres, all tails exposed are fine tails, 100% exposure

\[
(258 \text{ lbs/acre})(4016 \text{ acres}) = 1036,272 \text{ lbs/yr or 480 metric tons/yr}
\]

**Minimum estimate:**

Basin completely under water

Therefore 0 metric tons/yr

Estimate for CDM model

Assume 20% exposure

Therefore 100 metric tons/yr
Concentration of annual averages to 24-hr averages

**Formula:**

\[
C = m_y \times \frac{z}{s_y}
\]

- \(C\): calculated concentration
- \(m_y\): annual geometric mean
- \(s_y\): geometric standard deviation = 2.0
- \(z\): number of standard deviations from the mean.

**24-hr PSD permitted increments for particulates:**

- **Class I:** 10 \(\mu g/m^3\)
- **Class II:** 37 \(\mu g/m^3\)

**May be exceeded once per year.**

**A.** PCA samples 60 times per year.

To estimate highest reading:
\[ z = 2.33 \]

To estimate 2nd highest reading:
\[ z = 1.97 \] (Sewell report).

**B. To meet Class I PSD \(c = 10 \mu g/m^3\):**

\[
10 = m_y \times (2)^{1.97}
\]

or
\[
m_y = 2.6 \mu g/m^3
\]

This means that any CDM increment above 2.6 \(\mu g/m^3\) annual average would be expected to exceed the Class I 24-hr PSD increment.

**C. To meet Class II PSD \(c = 37 \mu g/m^3\):**

\[
37 = m_y \times (2)^{1.97}
\]

or
\[
m_y = 9.6 \mu g/m^3
\]

This means that any CDM increment above 9.6 \(\mu g/m^3\) annual average would be expected to exceed the Class II 24-hr PSD increment.