PolyMet Mining Inc

Supplemental Mine Site AERA

Risk Analysis and Respirable Fraction of Dust-Based Emissions

Version 2

July 18, 2012

Preface

This document addresses topics that have arisen in preliminary discussion of potential risk estimates at the NorthMet Project Mine Site based on the latest risk analysis spreadsheet (RASS) available from MPCA. These topics include:

1. Particulate Metal Emissions Based on PM_{10} or total PM (~PM_{30})
2. Respirable Particulate
3. Cobalt
4. Metal Concentrations in Rock
5. Air Dispersion Modeling and Risk Estimation

This version of the document (Version 2) addresses comments received on the first version and proposes an alternate approach for treatment of potential metals emissions related to fugitive dust.

Each topic is addressed below.

Particulate Metal Emissions Based on PM_{10} or Total PM (~ PM_{30})

- For the 2008 Mine Site AERA, particulate metal emission estimates were based on total particulate (~PM30). Incremental inhalation risk from particulate metals at the Mine Site boundary and the more distant mining zoning boundary was found to be acceptable using the conservative emission estimation approach.
- The Work Plan for the Supplemental AERA for the Mine Site was accepted by the MPCA and the other reviewers (Version 2, November 14, 2011) and states that emission estimates will be based on criteria pollutant emissions used in Class II modeling (i.e., PM_{10} emissions – total PM is not modeled): *"… Emission estimates for Mine Site sources, including fugitive dust (from haul roads, loading/unloading of waste rock and ore, crushing and screening of construction rock) and diesel combustion emissions (from haul trucks and locomotives), will be updated to reflect any changes in operations. Estimates of potential emissions for toxic air pollutants will be based on the approach used to estimate criteria pollutant air emissions for use in Class II modeling. …".*
- For other mining projects, particulate metal emissions from material handling and haul roads have been based on both PM_{10} and total particulate (PM; ~PM_{30}).
    - PM_{10} basis: Keetac Expansion Project (February 2009 Human Health Screening-Level Risk Assessment); Mesabi Mining Project (August 2009 AERA)

- Total particulate basis: Essar Steel Expansion Project (January 2011; PolyMet Mining, 2008 Mine Site AERA)

Conclusion: Using PM_{10} emissions to estimate potential respirable particulate metal emissions is consistent with the AERA Work Plan (although it is not stated explicitly) and with previous risk assessments conducted for other mining projects. However, regulatory agencies have commented that the available metal concentration data is for bulk materials and that they feel that total PM emission rates are a closer surrogate for the bulk material than PM_{10} emission rates. In lieu of adjusting particulate metal emission rates for the respirable dust fraction, changes to the modeling procedures are proposed below in the Air Dispersion Modeling and Risk Assessment section.

Respirable Particulate

- For inhalation risk the size fraction of interest is 10 microns in aerodynamic diameter or smaller ($\leq PM_{10}$) as this size fraction is defined as "respirable particulate matter" (California Air Resources Board, 2005; USEPA 2004).
- More recently, USEPA (2009) indicates that $PM_{2.5}$ is commonly used to identify the respirable size fraction. Fine (2.5 microns or smaller) and ultrafine (0.1 microns or smaller) particles are of most concern for potential ambient air health effects (Minnesota Dept. of Health (MDH), "Air Quality Particles and Your Health"; http://www.health.state.mn.us/divs/eh/air/pm.html). However, fugitive dust emissions are predominantly larger than 10 microns in size (Reed and Organiscak, 2007; Michigan DEQ, 2005).
- The goal of a risk analysis is to provide a conservative estimate of potential risks which could result from the project so that regulatory agencies and the general public can make informed decisions about potential project impacts. Conversely, the goal of the risk analysis is to neither underestimate potential risks nor to introduce a level of conservatism as to exceed the bounds of the exposure concept(s) being evaluated. Assuming that a receptor at the property boundary or more distant mining zoning boundary is exposed to total particulate (PM_{30}) and that the large particles are inhaled and enter the lungs is a conservative assumption not supported by accepted inhalation assessment methodologies (see first bullet) and in our opinion does not represent any potential exposure scenario, not even under the MEI concept.

Conclusion: The respirable size fraction of interest is 2.5 microns or smaller ($PM_{2.5}$) (USEPA 2009; MDH "Air Quality Particles and Your Health", http://www.health.state.mn.us/divs/eh/air/pm.html). In our opinion, conducting an inhalation risk analysis for particulate metals that have emissions based on PM_{10} emissions provides sufficient conservatism to the analysis. However, as an alternate approach, the proposed modeling methodology has been modified to address the transportability of larger particles.

Cobalt

- The reference concentration (RfC) and cancer unit risk for cobalt that are included in the MPCA's Risk Assessment Screening Spreadsheet (RASS) are both a "provisional peer reviewed toxicity value" (PPRTV). The RfC is based on an occupational (i.e., worker) exposure to total particulate matter. The cancer unit risk is based on a dosing study using mice where particulate matter was

size-fractionated (i.e., the fine fraction was used as the "dose"). The provisional values for cobalt will be used to estimate initial risks.

- In previous risk analyses, the toxicity values in the MPCA's RASS have been applied to modeled PM_{10} air concentrations without adjustment for size fractions.
- Applying the toxicity values for cobalt to the modeled PM_{10} based air concentration for cobalt is consistent with MPCA's AERA methodology.

Conclusion: In our opinion, it would be reasonable to apply the toxicity value for cobalt to the modeled respirable (i.e. PM_{10} based) air concentration without modification for an ambient air inhalation risk assessment, consistent with previous applications of other inhalation toxicity values (e.g., USEPA IRIS, California OEHHA, and the Minnesota Dept. of Health) contained in the MPCA's RASS . However, a change to the modeling procedures has been proposed instead to provide a reasonable estimate of potential exposure to cobalt.

Chemical Concentrations in Rock

- Metal concentrations used in emissions calculations use the worst case composition of all rock types that would be used or processed at each emission source. The table in Attachment A describes the rock type used to determine the metal concentrations in each source type.
- In sediment and soil, higher concentrations of metals can occur in the fine fractions (clay and silt size fractions) (USGS 1985; USEPA 1992).
- It is uncertain whether the blasting or physical crushing of rock to a smaller size fraction (one-quarter inch to 3-inch size chunks) results in increased metal concentrations in fine particles. This uncertainty will be discussed in the Uncertainty Analysis section of the AERA Report.

Conclusion: It is uncertain whether blasting or the physical act of crushing rock to be used in haul road construction materials results in higher concentrations of metals in the smaller size fractions. This uncertainty will be discussed in the Uncertainty Analysis section of the AERA report.

Air Dispersion Modeling and Risk Estimation

- For the Supplemental Mine Site AERA, two general receptor locations are being evaluated: 1) potential maximum exposed individual (MEI) at the Mine Site boundary; 2) a resident/farmer receptor at the more distant mining zoning boundary.
- The model will be run following the procedures used in the Class II Mine Site PM_{10} modeling analysis, with the primary change being that total particulate emission rates will be modeled with the resulting modeled concentrations speciated for the metals of interest for the AERA. As with the Class II modeling, an algorithm to account for particle deposition will estimate metals concentrations at the modeled receptors by accounting for plume depletion due to dry deposition.
- Following the agreed upon methodologies in the Supplemental Mine Site AERA work plan, the procedures used in the Class II Mine Site PM_{10} dispersion modeling analysis will be retained as much as possible for the AERA. The primary difference in modeling total particulate matter

(PM_{30}) instead of respirable particulate matter (PM_{10}) is that the particulate depletion/ deposition methodology will be modified to account for plume depletion of the larger particulates being modeled. Specifically, the particulate depletion half-life time step will be changed from 1,100 seconds (PM_{10} gravitational settling basis) to 370 seconds (PM_{30} gravitational settling basis). The half-life of 370 seconds (0.103 hours) for PM_{30} was developed in: *Iron Range Air Quality Analysis* (Maxwell and Hodgin, 1979), and the relevant sections from this report are included in Attachment B. Attachment C to the Mine Site Protocol (March 2012) contains a detailed description of the particulate depletion calculations and it is included as Attachment C to this document.

- $PM_{2.5}$ emissions will be modeled without considering particulate depletion. $PM_{2.5}$ emissions account for approximately 2% of total particulate emissions.
- Each Mine Site source will be modeled as two sources: one source will account for non-deposition pollutants (tailpipe emissions and $PM_{2.5}$ fugitive dust emissions), and the other source will model total particulate matter including the half-life plume depletion term. Post-processing of modeling output postfiles will combine the contributions from all modeled sources.
- The AERMOD model will be used to estimate maximum air concentrations for the one-hour and annual averaging time periods for each chemical being quantitatively evaluated.
- Similar to the 2008 Mine Site AERA, the initial approach for risk estimation is to conservatively assume that the maximum modeled air concentrations for all chemicals being quantitatively evaluated occur in one location. In other words, risks are not separated in time nor in space.
- Additional refinements to the initial risk estimates will include:
    - Use of alternative toxicity values (e.g., alternative values for dioxins/furans, similar to the 2008 Mine Site AERA)
    - For noncancer chronic risk estimates, risks can be partitioned by target endpoint.
    - The MPCA's Q/CHI methodology can be used to partition risks in space (i.e., estimate potential risk by receptor node location).

Conclusion: For the initial risk estimates, all maximum modeled air concentrations at the Mine Site boundary will be assumed to occur in one location, and all maximum modeled air concentrations at the more distant mining zoning boundary will be assumed to occur in one location. Refinements to the initial risk estimates will follow accepted risk assessment methodology (MPCA, USEPA).

References

California Air Resources Board (CARB, 2005). "Particulate Matter – Overview"; http://www.arb.ca.gov/research/aaqs/caaqs/pm/pm.htm

Michigan DEQ, 2005. Managing Fugitive Dust. A guide for compliance with the air regulatory requirements for particulate matter generation. Michigan Department of Environmental Quality, Environmental Science and Services Division, Clean Air Assistance Program.

Minnesota Dept. of Health (MDH). "Air Quality Particles and Your Health"; http://www.health.state.mn.us/divs/eh/air/pm.html).

Maxwell, Christine M. and Hodgin, C. Reed, *Iron Range Air Quality Analysis*. Midwest Research Institute. Kansas City, Missouri. June 5, 1979.

PolyMet Mining Inc. Work Plan for a Supplemental Air Emissions Risk Analysis (AERA) for the NorthMet Mine Site. Version 2: November 14, 2011

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USEPA 1992. Ground Water Issue: Behavior of metals in soils. U.S. Environmental Protection Agency, Office Solid Waste and Emergency Response. EPA/540/S-92/018. October 1992.

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USEPA, 2009. Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F.

USGS 1985. A Primer on Trace Metal – Sediment Chemistry. U.S. Geological Survey Water-Supply Paper 2277. U.S. Dept. of Interior, U.S. Geological Survey.

Attachment A – Emission Sources and Rock Type Used to Determine Metal Concentration

The emission calculations for the fugitive dust based emissions from ore and waste rock use data from drill core analyses and apply the metal content of the appropriate rock type to the particulate emissions from each source. The composition of overburden used in the calculations is based on a sampling program conducted at the Mine Site in 2008. The references below provide additional information on the metals composition data.

Screened overburden or crushed Category 1 waste rock may be used as the Haul Road surface. The metals composition used in the calculation is the worst case of the two potential materials for each metal.

The table below indicates the type of rock used at each emission source and the worst case scenario rock type that is used to calculate emissions from the source. Note that for the chemicals of interest, the Haul Roads account for approximately 75-83% of the emissions of those chemicals.

Source Type	**Rock types in use at source**	**Rock type used for emissions**
Surface overburden loading, unloading, screening and storage	Overburden	Overburden
Category 1 Waste Rock drilling, loading, unloading	Category 1 Waste Rock	Category 1 Waste Rock
Category 2 Waste Rock drilling, loading, unloading	Category 2 Waste Rock	Category 2 Waste Rock
Category 3 Waste Rock drilling, loading, unloading	Category 3 Waste Rock	Category 3 Waste Rock
Category 4 Waste Rock drilling, loading, unloading	Category 4 Waste Rock	Category 4 Waste Rock
Ore drilling, loading	Ore	Ore
Haul Roads	Overburden, Category 1 Waste Rock	Category 1 Waste Rock
Portable Crushing Plant	Overburden, Category 1 Waste Rock	Category 1 Waste Rock

References

Barr Engineering Co. Metals Concentrations in Waste Rock and Ore: Supporting Information for NorthMet Mine Site Emission Inventory. August 28, 2011.

Stephen Day and Christy Kearney. Memo: Results of Analysis from Overburden Drilling Program – Update for March 2010 Test Pit Program. To: Stuart Arkley. August 13, 2010.

Attachment B –Total Particulate Matter Depletion

IRON RANGE AIR QUALITY ANALYSIS

by

Christine M. Maxwell
C. Reed Hodgin

DRAFT FINAL REPORT SECTIONS

MRI Project No. 4523-L(2)

June 5, 1979

For

Minnesota Pollution Control Agency
Division of Air Quality
1935 West County Road B-2
Roseville, Minnesota 55113

Attn: Mr. Gary Eckhardt

The grid system used in the Iron Range air quality analysis was based on the UTM coordinate system, with a basic grid size of 2 by 2 km. Where emission density varied slowly (in some of the secondary areas away from taconite mining operations), 10 by 10 km grids were used instead. The area source emissions inventories described in Section 5.0 (1976) and Section 6.0 (1982) supplied the input used in the model. A total of 600, 2 by 2 km, and 27, 10 by 10 km, area source grids were included in the modeling effort.

The CDMQC does not apply plume rise techniques to the area source emissions but allows a user-specified effective emission height. This parameter was used in the study to account for the effects of elevated emissions (such as batch load-in operations), fugitive emissions with an initial vertical velocity component (such as road dust), and emissions from elevated points (such as wind erosion of storage piles). An effective emission height of 5 m was used in the study. No special allowance was made for emissions originating below ground level (in pits).

7.5 Particle Size Distribution

As discussed earlier, CDMQC was adapted to treat TSP in two size ranges: respirable (approximately 0 to 5 μm Stokes diameter) and settleable (approximately 5 to 30 μm Stokes diameter). A pollutant half-life parameter was included in CDMQC to adjust concentrations for depletion of the plume by chemical or physical processes. Half-life was used in the study to simulate removal of particulates due to settling.

The expression in CDMQC that accounts for plume depletion is:

$$\exp.\left[\frac{-0.692\ X}{UT}\right]$$

where:

X = distance from source, m

U = representative wind speed, m/sec

T = pollutant half-life, hr

Respirable particles were assumed to remain aloft indefinitely and were assigned a half-life of 99,999.0 hr, the largest value allowed by the algorithm. ← 11.4 yr

Determination of settleable particle half life was more difficult. The average drift distance (X_d) for settleable particles was determined using Stokes' formula for terminal velocity and a logarithmic vertical profile of wind speed. The settling parameters used in the calculation are shown in Table 7-5. Next it was assumed that random vertical turbulence would cause half of the particles by weight to settle out between the source and the average drift distance. Setting the CDMQC plume depletion expression equal to one-half at $X = X_d$ and using the 1976 average wind speed at Hibbing (4.2 m/sec at 4 meters), a settleable particle half-life of 0.103 hr was determined.

TABLE 7-5

PARTICLE SETTLING PARAMETERS

Mass Mean Particle Diameter	12.25 μm
Particle Density	3.0 g/cm^3
Wind Speed at 4 Meter Height	4.2 m/sec
Average Injection Height	5.0 m
Ground Roughness Height	5.0 cm
Average Drift Distance	1,347 m
Atmospheric Half-Life	0.103 hr

As applied in the model, this half-life allowed the depletion of settleable emissions beginning immediately after release, with a loss of 50% after approximately 6 min and 75% after approximately 12 min, etc. Thus, the modeled impact of settleable particles fell off very rapidly with distance from the source.

The emission rates determined in the 1976 and 1982 emissions inventories represented all particles smaller than 30 μm in Stokes diameter. The emissions from each source (and each source category for area sources) were separated into respirable and settleable portions for the modeling effort. The apportioning was accomplished using particle size information obtained during this and previous studies. Table 7-6 lists the apportioning methodology for the 21 area source categories.

Particle size distributions for Erie Mining Company point source emissions varied from stack to stack at their operations and were included in the model based on information supplied by the company. Data were insufficient to apportion the emissions from other point sources in the Mesabi Iron Range; stack emissions at these source were assumed to be entirely respirable.

Attachment C – Non-Default Modeling Options

I. PM_{10} Particulate Deposition

PM_{10} modeling conducted to date has used the OPENPIT option for the mining pit areas. The OPENPIT option requires particle size data (particle size category, mass fraction, density) as model inputs. The particle size data required by the OPENPIT option are also necessary model inputs for modeling sources including deposition. However, it was noted in preliminary modeling for the NorthMet Draft Environmental Impact Statement (DEIS) that in using the OPENPIT option along with particulate deposition for the remaining sources, the AERMOD model produced results that were not consistent with expected concentration patterns and were therefore unrealistic. Specifically, the model showed maximum concentrations from the pit at far receptors in a bull's eye pattern. Both the OPENPIT algorithm and the particulate deposition algorithm in the model are complex. While the internal calculations of the model are not readily apparent, the inconsistency of the results indicated that the model was not producing reliable results for particulate deposition and OPENPIT sources.

To address this issue, an alternative approach to accounting for particulate deposition was proposed and approved for the DEIS modeling. The same approach will be used for the modeling for the Supplemental Draft Environmental Impact Statement (SDEIS). In this alternative approach, particulate deposition is represented by the Decay Term (D). As stated in the model user's guide: "The Decay Term in Equation (1-1) is a simple method of accounting for pollutant removal by physical or chemical processes."

The decay term is calculated as a half-life as follows:

$$D = \exp [- \psi \ x / u_s]$$

Where: ψ = decay coefficient (s^{-1})
x = downwind distance (m)
u_s= wind speed (corrected for release height)

and $\psi = 0.693 / T_{1/2}$

$T_{1/2}$ = pollutant half life (s)

Example :
$T_{1/2}$ = 900 s
x = 1000 m
u_s = 4 m/s

$$D = \exp [- (0.693/900) 1000 / 4]$$
$$= 0.825$$

In this case, 17.5% of the plume would be removed for a receptor at 1 km distance from the source. The model applies the Decay Term after conducting the other dispersion calculations.

The pollutant half life ($T_{1/2}$) is used to represent the various physical mechanisms which remove particulate mass from the plume. Deposition occurs from gravitational settling, removal by vegetation, particle agglomeration, and other mechanisms. The pollutant half life was estimated using the gravitational settling velocity (Stoke's Law) term as described in the model user's guide, as follows.

$$v_g = (\rho - \rho_{air}) g d_p^2 c_2 / [18 \mu] * S_{CF} \qquad \text{(Equation 1-84)}$$

Where:
- v_g = gravitational settling velocity (cm/s)
- ρ = particle density (g/cm^3) = 2.7 for haul roads (crushed ore)
- ρ_{air} = air density (= 1.2 x 10^{-3} g/cm^3)
- d_p = particle diameter (μm) = 7.4 for mass-mean particle size
- c_2 = units conversion constant (1 x 10^{-8} cm^2/μm^2)
- μ = viscosity of air (1.81 x 10^{-4} g/cm/s)
- S_{CF} = slip correction factor (see Equation 1-85; for a 7.4 μm particle S_{CF} = 1.02)
- g = acceleration due to gravity (981 cm/s^2

For the particle characteristics given above (7.4 μm diameter, 2.7 g/cm3 density), the gravitational settling term v_g = 0.455 cm/s.

To calculate the pollutant half life, it was assumed that the time required for a 7.4 μm particle to settle from an average release height of 5 m would approximate the time-dependent component of deposition. For a 5 m release height, the settling time is T = 5 m x 100 cm/m / 0.455 cm/s = 1,100 s.

The calculation of pollutant half life and use of the decay coefficient to represent deposition was used in Midwest Research Institute's report prepared for the MPCA entitled: Iron Range Air Quality Analysis (June 1979). The MRI report also provided detailed emission inventories and modeling analysis (including model calibration) which were required for EPA approval of Minnesota's State Implementation Plan (SIP). During the late 1970s, the Iron Range was in nonattainment for TSP, and the 1979 modeling analysis was part of determining the actual attainment status and identifying mitigation measures and future attainment status. An important component of the modeling analysis was to adequately address particulate deposition so that the model results could be directly compared

to monitoring data. To account for particle deposition, the 1979 modeling assumed a particle density of 3 g/cm^3, a particle diameter of 12.25 µm, and a release height of 5 m, for a half life of 370 s.

The proposed pollutant half life of 1,100 s is 3 times greater than was assumed in the MRI study, with the greatest difference in the half life resulting from the smaller particle diameter used in this analysis. The 1979 analysis also assumed that particles less than 5 µm did not settle out. For this analysis, we propose to model particles less than 2.5 µm as though they do not deposit. For the mining fugitive dust sources, $PM_{2.5}$ accounts for 10% of the total PM_{10}. Therefore, the modeled emission rate will be scaled by a factor of 1.1 to account for the $PM_{2.5}$ portion of the PM_{10} that would not be predicted to settle out.

Reference:

Midwest Research Institute, 1979. *Iron Range Air Quality Analysis*. Draft Final Report. MRI Project No. 4532-L(2). June 5, 1979. Prepared for Minnesota Pollution Control Agency.

USEPA, 1995. User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. Volume II – Description of Model Algorithms. USEPA – OAQPS. RTP, NC. September 1995.

USEPA, 2004. AERMOD Deposition Algorithms – Science Document (Revised Draft). March 19, 2004. http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod.

Determination of the mass mean particle diameter of 7.4 µm

A size distribution curve representative of mechanically generated particulates is shown in Figure 2 on the Particle Size Categories page appended at the end of this discussion or can be accessed at the following website. http://www.epa.gov/air/oaqps/eog/bces/module3/category/category.htm (http://www.epa.gov/eogapti1/module3/category/category.htm).

This Figure 2 shows the frequency % particle by mass for three types of atmospheric particulates (ultrafine, fine, and coarse - supercoarse). The Particle Formation page http://www.epa.gov/air/oaqps/eog/bces/module3/formation/formate.htm (http://www.epa.gov/eogapti1/module3/formation/formate.htm) goes into some detail over the mechanisms associated with formation of the three classes of atmospheric particulates shown in Figure 2. As described on the Particle Formation page, physical attrition (mechanically generated) particles are shown to be primarily greater than PM_{10} and correspond to the coarse - supercoarse curve on Figure 2.

The mass mean particle diameter used in the proposed decay coefficient reflects mechanically generated particulate. EPA's size spectrum shown in Figure 2 was used to apportion the particulate matter between 3 and 10 microns and develop the mass mean particle diameter. Figure 2 is generic in that it is representative of atmospheric particulates and is not specific to any industry or source type. Using Figure 2 for this calculation was recommended by MPCA on a previous project. Interpolation of the coarse - supercoarse curve for the coarse particle size range (between 2.5 and 10 microns which is representative of the fugitive PM_{10} modeling) of Figure 2 leads to a mass mean diameter of 7.4 microns as shown below in Table 1 and Figures 3 and 4:

Table 1 – PM_{10} Mass Percent from EPA Figure 2

Particle Size	Frequency % Particles by Mass [1]	Normalized Mass %	Cumulative Normalized Mass %
3	0.6	2.7%	2.7%
4	1.2	5.3%	8.0%
5	1.8	8.0%	16.0%
6	2.7	12.0%	28.0%
7	3.4	15.1%	43.1%
8	3.8	16.9%	60.0%
9	4	17.8%	77.8%
10	5	22.2%	100.0%

Figure 3 shows the cumulative mass % (normalized to 100%) derived from EPA's Figure 2. Note that Figure 3 did not use a mathematical representation of EPA's Figure 2 as one was not provided in EPA's references. Instead, Figure 3 was obtained by selecting the particle size and reading the mass % off of the Y-axis in Figure 2. The total mass % was normalized to 100% as shown in Table 1 above. Figure 4 shows the linear interpolation for the cumulative mass percent between the 7 and 8 µm particle sizes in Figure 3. As shown in Figure 4, the 50% cumulative mass percent intersects the 7.4 µm particle size.

[1] Interpolated from Figure 2 for the midpoint of the category (e.g., 10 micron frequency % is midpoint between 9 and 10 microns).

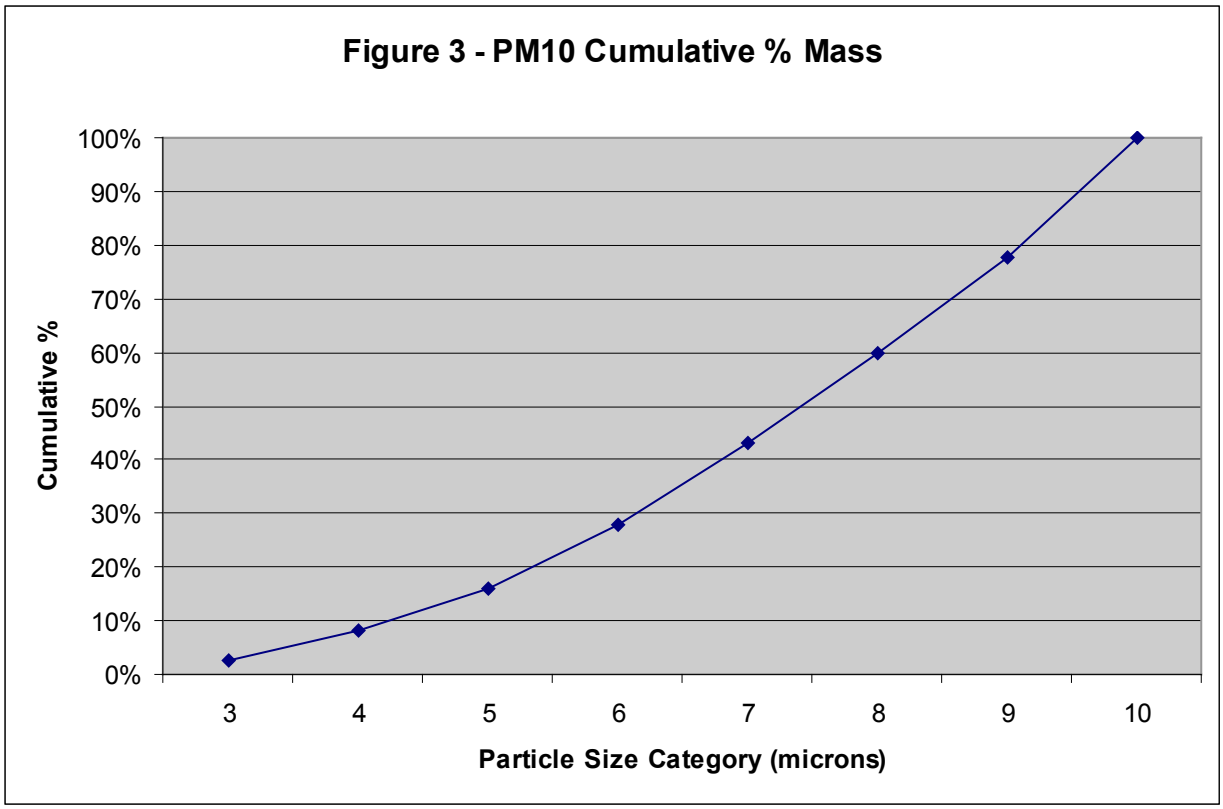


Figure 3 is derived from EPA's Figure 2 for the coarse particle size distribution curve.

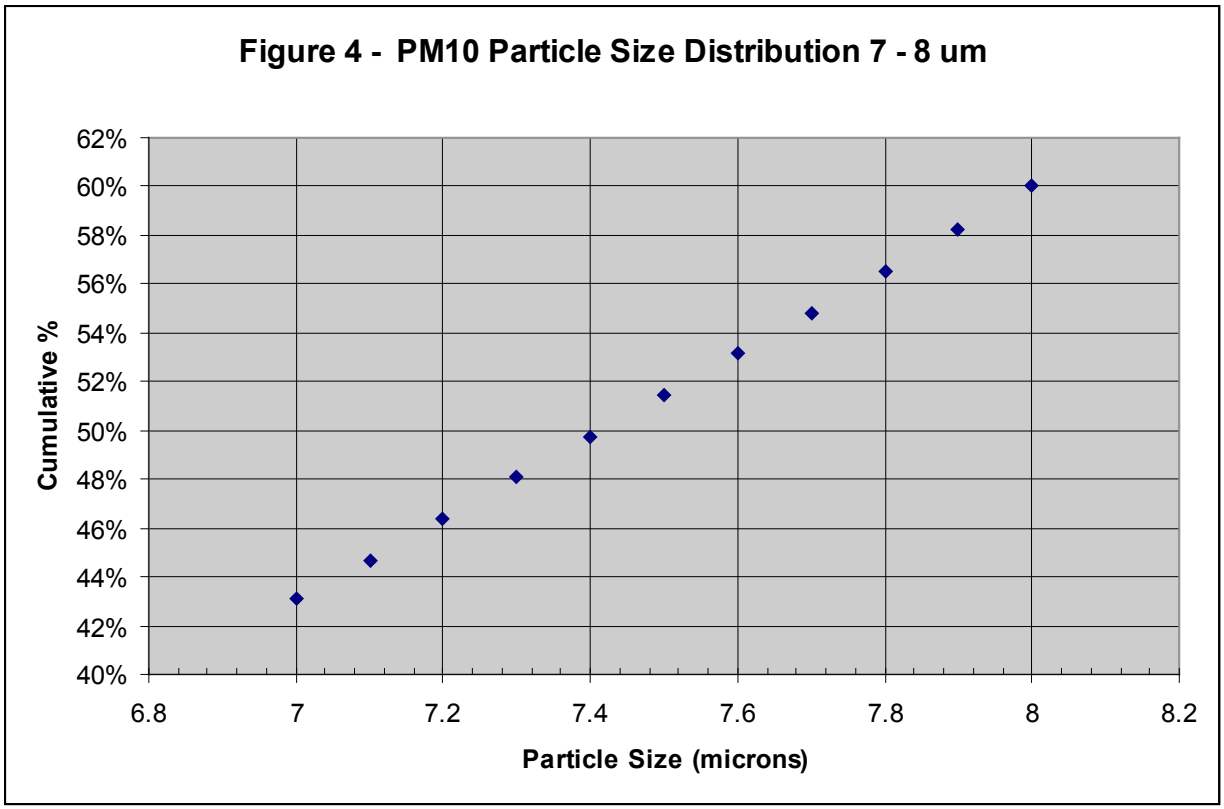


Figure 4 shows the linear interpolation between the 7 and 8 µm particle size categories from Figure 3 to determine the 7.4 µm mass mean particle size.

Basic Concepts in Environmental Sciences

Module 3: Characteristics of Particles - Particle Size Categories

EPA Particle Size Terminology

Since the range of particle sizes of concern for air emission evaluation is quite broad it is beneficial to divide this range into smaller categories. Defining different size categories is useful since particles of different sizes behave differently in the atmosphere and the respiratory system.

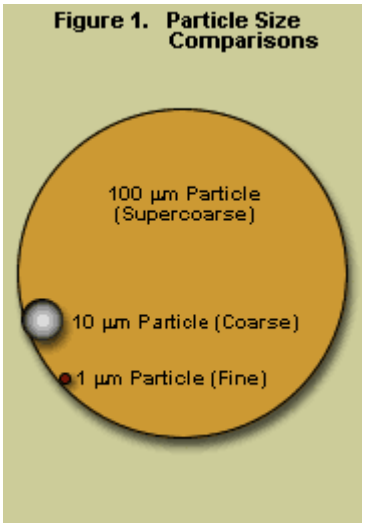
The EPA has defined four terms for categorizing particles of different sizes. Table 1 displays the EPA terminology along with the corresponding particle sizes.

Table 1. EPA Terminology for Particle Sizes

EPA Description	Particle Size
Supercoarse	$d_{pa} > 10\ \mu m$
Coarse	$2.5\ \mu m < d_{pa} \leq 10\ \mu m$
Fine	$0.1\ \mu m < d_{pa} \leq 2.5\ \mu m$
Ultrafine	$d_{pa} \leq 0.1\ \mu m$

Figure 1 provides a visual comparison of the size of a fine particle (1.0 μm), coarse particle (10 μm), and a supercoarse particle (100 μm). There is a substantial difference in size between these particles, all of which are considered moderate-to-large in air pollution control.

Figure 1. Particle Size Comparisons



Regulated Particulate Matter Categories

In addition to the terminology provided in Table 1 the EPA also categorizes particles as follows:

Total Suspended Particulate Matter (TSP)

PM_{10}

$PM_{2.5}$

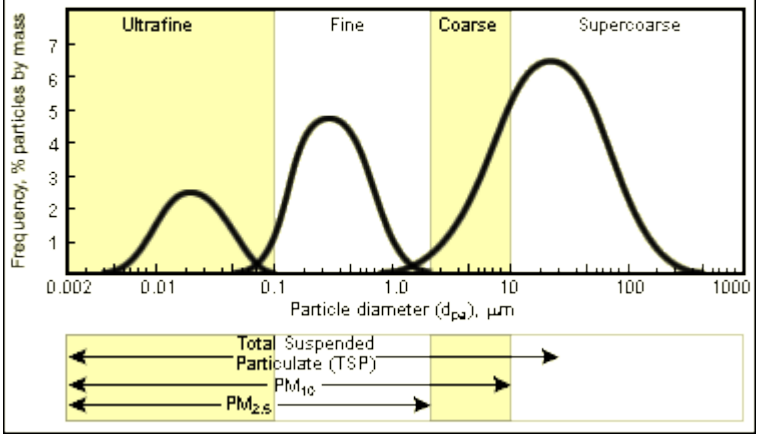
Particles less than 0.1 μm

Condensable Particulate Matter

These particle categories are important because particulate matter is regulated and tested for under these categories. The National Ambient Air Quality Standard for $PM_{2.5}$ was remanded by a District of Columbia court in May of 1999 and is under litigation as of the writing of these modules (December 1999). Air quality standards are presented in these modules as they were promulgated by the EPA, with no presumptions made regarding the outcome of the pending litigation.

Figure 2 displays a typical size distribution of atmospheric particulate matter that combines the two classification schemes discussed above.

Figure 2. Ambient Particulate Matter Size Distributions



Total Suspended Particulate Matter

Particles ranging in size from 0.1 micrometer to about 30 micrometer in diameter are referred to as **total suspended particulate matter (TSP)**. TSP includes a broad range of particle sizes including fine, coarse, and supercoarse particles.

PM_{10}

The U.S. EPA defines PM_{10} as particulate matter with a diameter of 10 micrometers collected with 50% efficiency by a PM_{10} sampling collection device. However, for convenience in these modules, the term PM_{10} will be used to include all particles having an aerodynamic diameter of less than or equal to 10 micrometers.

PM_{10} is regulated as a specific type of "pollutant" because this size range is considered respirable. In other words, particles less than approximately 10 micrometers can penetrate into the lower respiratory tract. The particle size range between 0.1 and 10 micrometers is especially important in air pollution studies. A major fraction of the particulate matter generated in some industrial sources is in this size range. PM_{10} is discussed in more detail in Module 6.

Attachment C – Non-Default Modeling Options

II. PM_{10} Half-Life Modeling Analysis

The AERMOD model is setup that when the half-life option is selected it is applied to every source in the input file and does not allow the user to specify which sources it can be applied to (similar to the urban source option). The purpose of modeling PM_{10} with half-life is to account for the deposition of particulate matter from mechanically generated fugitive dust sources. There are currently four sources included in the Mine Site modeling analysis that are not considered mechanically generated. They are the emergency generator stacks (SV326, SV337), the lime silo (SV425), and the Wastewater Treatment Facility space heater (WWTSH). In order to model all of the PM_{10} Mine Site sources together, the LAKES AERMOD-View Multi-Chem utility will be used to combine the post-files of the mechanically generated half-life sources and the non-half-life sources together by each hour and receptor to determined the combined 24 hour and annual PM_{10} NAAQS and Increment concentration results.

The LAKES Multi-Chem utility allows the user to model multiple emission rates for the same input file by splitting out a single AERMOD input file into individual source, unitized model runs. Each source is modeled individually at 1 g/s with an output plot file and post file for the maximum 1hour concentration. Multi-Chem then post-processes the individual source files, combining them together by hour and receptor and multiplying each source's individual concentration results by an emission rate specified in a text file input to the software. Using this utility creates a significant amount of data files due to a post file created for every individual source. Since the format of the post-files is the same whether for a single source or a combination of sources, PolyMet is proposing to use the Multi-Chem post-processing capabilities, but not for individual source, unitized post file runs.

The PM_{10} modeling for the Mine Site will be divided into two separate modeling files. The first file will model the non-half life sources listed in the paragraph above in regulatory default mode using the hourly PM_{10} emission rates calculated in the emission inventory. The input file will be setup to model the 1 hour concentration and output the maximum 1 hour high 1^{st} high concentration plot file and post file. The second file will model the mechanically generated fugitive dust sources using the half-life option using the hourly PM_{10} emission rates calculated in the emission inventory multiplied by 1.1 to account for the 10% of the PM_{10} that is made up of $PM_{2.5}$ and is not subject to deposition. The output will be the maximum 1 hour high 1^{st} high concentration plot file and post file similar to the first input file. Using the Multi-Chem post-processing utility, these post files will be combined

on an hour by hour basis for each receptor. Because the actual modeled hourly PM_{10} emission rates will be accounted for in the post files, the emission rate text file that is required for the Multi-Chem utility will list the emission rates for the two post-files as 1 g/s. In this way, the half-life and non-half-life sources will be combined in time and space and the 24 hour PM_{10} high 2^{nd} high plot file can be produced for determining the Increment results and the high 1^{st} high through high 6^{th} high plot files can be produced for determining the NAAQS results. Using this method provides the option of modeling half-life for specific sources without the necessity of creating individual input files and an overwhelming number of post files.

Attachment C – Non-Default Modeling Options

III. $PM_{2.5}$ Secondary Formation

This section describes the proposed 24-hour $PM_{2.5}$ NAAQS modeling methodology to account for secondary formation of $PM_{2.5}$ due to the space heater and emergency generator combustion sources. The modeling analysis will use the off-set ratio method described in the National Association of Clean Air Agencies (NACAA) Report[2] published January 7, 2011. The method multiplies the direct $PM_{2.5}$ emissions of combustion sources with an offset ratio to reflect the $PM_{2.5}$ created from secondary formation. The offset ratio represents the amount of NO_X or SO_2 that contributes to $PM_{2.5}$ concentrations through secondary formation. This value is called the total equivalent primary $PM_{2.5}$ emission rate. The equation (Primary $PM_{2.5}$ [TPY] + [SO_2 TPY]/15 + [NO_X TPY]/77) was used to calculate the total equivalent $PM_{2.5}$ emission rates for each of the combustion sources.

The combustion sources used the hourly SO_2 and NO_X emission rates converted to TPY to calculate the total equivalent $PM_{2.5}$ emissions. The offset ratios for NO_X and SO_2 used in this equation are from the NAACA document and were developed in that report for a source located in Northern Minnesota.

The majority of $PM_{2.5}$ emissions at the Mine Site are mechanically generated; the three combustion sources make up only 0.4% of the total direct $PM_{2.5}$ emissions. Therefore, secondary particulate formation is not expected to contribute significantly to the maximum modeled $PM_{2.5}$ concentration.

[2] "$PM_{2.5}$ Modeling Implementation for Projects Subject to National Ambient Air Quality Demonstration Requirements Pursuant to New Source Review", NACAA $PM_{2.5}$ Modeling Implementation Workgroup