GUIDANCE FOR ESTIMATING FUGITIVE PARTICULATE MATTER EMISSIONS FROM MINING ACTIVITIES IN BRITISH COLUMBIA

British Columbia Ministry of Environment and Parks

Environmental Protection Division

Environmental Policy and Initiatives Branch

Victoria, British Columbia, Canada

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AG	Australian Government
AP	Air Pollutants
AP-42	Compilation of air pollutant emissions factors by the U.S. EPA
B.C.	British Columbia
DEJF	Dust Emissions Joint Forum
ECCC	Environment and Climate Change Canada
ENV	Ministry of Environment and Parks
ENVIRON	Environ Consultants Ltd.
EPA	U.S. Environmental Protection Agency
Kg	Kilogram
Mg	Megagram
µm	Micron
mm	Millimetre
MRI	Midwest Research Institute
NERDDC	National Energy Research and Demonstration Council
NPRI	National Pollutant Reporting Inventory
PM	Particulate Matter
PM_{10}	Particulate Matter with An Aerodynamic Diameter Less Than or Equal to 10µm
$PM_{2.5}$	Particulate Matter with An Aerodynamic Diameter Less Than or Equal to 2.5µm
SPCC	State Pollution Control Commission
TSP	Total Suspended Particulate
TPM	Total Particulate Matter
U.S.	the United States of America
VKT	Vehicle Kilometres Travelled
WRAP	Western Regional Air Partnership
WRF	Weather research and forecasting model

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- B.C. Ministry of Environment and Parks, Air Quality Section (Assessments and Stewardship), Environmental Monitoring and Analysis Branch (project team and reviewer), and
- B.C. Ministry of Environment and Parks, Air Team, Environmental Policy and Initiatives Branch (developed and verified the guidance document)

This guidance also benefited from valuable comments and feedback submitted by experts from industry, consulting companies, regulatory bodies, and other organizations.

1 INTRODUCTION

1.1 PURPOSE

The British Columbia Ministry of Environment and Parks (ENV) has compiled this document to offer guidance on fugitive dust emission estimation methodologies applicable to mining operations within B.C.

The primary objective of this guidance is to establish standardized techniques for estimation of hourly, daily, and annual fugitive particulate matter (PM) emissions stemming from B.C. mining activities. The guidance is designed to:

- Provide clarity to users regarding appropriate methods for estimating fugitive PM emissions,
- Streamline the regulatory review process, and
- Improve the consistency and accuracy of mining-related fugitive PM assessment.

Annual emission estimates can be used to develop emission inventories, whereas hourly and daily emission estimates are primarily intended for air dispersion modeling. The methodologies encompass the following elements:

- Emission estimation equations, emission factors, Input constants, and relevant variables,
- Activity rates,
- Applicable Conditions, limitations, and underlying assumptions, and
- Control efficiencies of various emission control techniques.

Fugitive emission estimates are often required as a key input to dispersion models used for air quality assessments of proposed mines. Emissions estimates may also be part of ongoing management of fugitive emissions for operating mines. For operating mines, on site sampling of key parameters such as silt content, is identified where appropriate to improve estimates. However, on site sampling may not be feasible or appropriate for proposed mines. Alternatives to onsite sampling are identified to cover these cases.

This guidance serves as a reference for industry and consulting professionals, regulatory bodies, and other organizations involved in fugitive PM emission estimation within the mining sector. It promotes a consistent approach for emission estimates but is not a regulatory requirement. Alternative approaches supported by scientific justification and clear documentation may be used upon approval.

1.2 SCOPE

1.2.1 TYPE OF MINES AND EMISSION ACTIVITIES

This guidance addresses various types within the mining industry, including:

- Open-pit coal mining
- Underground coal mining
- Open-pit metalliferous mining
- Underground metalliferous mining

For detailed information regarding the mining activities associated with each mine type in B.C., please refer to Sections 1.2.1.1 to 1.2.1.4. This guidance does not cover pit and quarry operations. While some of the methodologies described may be relevant to related activities, professional judgment should be exercised when applying them outside the intended scope.

1.2.1.1 OPEN-PIT COAL MINING

Open-pit coal mining typically involves a sequence of earthmoving processes. The first step involves topsoil and subsoil removal using heavy-duty equipment such as scrapers. Following removal, the topsoil can be utilized for reclamation or placed in temporary stockpiles. The next layer, overburden (earth between topsoil and coal seam), is then leveled, drilled, and blasted. Overburden is typically removed down to the coal seam using draglines, shovels and trucks, forming spoil piles. The coal seam is drilled, blasted, and loaded into haul trucks by shovels or loaders, transported to the tipple (or truck dump), and further processed (primary crushing, secondary crushing, screening, etc.). Crushed coal may be temporarily stored in piles, before being loaded onto rail cars or trucks for transportation. Throughout the various earthmoving, storing, mining and reclamation operations, disturbed areas, exposed surfaces and stockpiles (topsoil, overburden, coal) are susceptible to wind erosion.[1]

Primary sources of air emissions in open-pit coal mines include:

- Construction operation involving the removal of vegetation and topsoil,
- Drilling and blasting of overburden and coal,
- Handling and storage of aggregate materials, encompassing topsoil, overburden, and coal,
- Transporting materials,
- Coal processing, including crushing and screening procedures, and
- Wind erosion originating from exposed areas and stockpiles.[1]

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[1] U.S. Environmental Protection Agency (EPA), 1998. AP-42 Chapter 11.9. Western Surface Mining. https://www.epa.gov/sites/default/files/2020-10/documents/c11s09.pdf . Accessed in April 2025.

1.2.1.2 UNDERGROUND COAL MINING

Underground mining operations are typically conducted within horizontal tunnels that offer access to the surface through sizable vertical shafts. The excavation and construction of these tunnels, shafts, drill access points, ventilation systems and other parts of mine produce dust from various earthmoving activities. During operations, underground activities such as drilling and blasting, handling, loading, and transferring materials can give rise to fugitive dust within the tunnels. Ventilation shafts provide air flow, regulate temperature, and remove dust from underground. Underground mines may also have surface operations similar to open-pit coal mines that further contribute to fugitive dust.

1.2.1.3 OPEN-PIT METALLIFEROUS MINING

Open-pit metalliferous mining and open-pit coal mining share similar process operations though the emission factors for estimating fugitive dust emissions of some processes differ, including:

- Ore crushing (primary, secondary, or tertiary crushing),
- Dry grinding (with air conveying, or without air conveying),
- Screening, and
- Drying.

Wet grinding produces minimal fugitive dust emissions because water suppresses dust formation.

1.2.1.4 UNDERGROUND METALLIFEROUS MINING

Like underground coal mines, the activities within metalliferous mines that occur underground produce fugitive PM emissions. These emissions are released into the environment through ventilation shafts. Activities on the surface may closely resemble those commonly identified in open-pit metalliferous mining operations.

1.2.2 AIR POLLUTANTS

With respect to fugitive PM emissions generated from mining activities, the air pollutants of interest are:

- $PM_{2.5}$: PM with an aerodynamic diameter less than or equal to 2.5 µm,
- PM_{10}: PM with an aerodynamic diameter less than or equal to 10 µm, and
- TSP (total suspended particulate): particles that are solid or liquid and are suspended in the air

The potential for causing health effects is linked to the size of PM since the smallest particles can be inhaled deep into a human's lung or even the bloodstream[2]. $PM_{2.5}$, the fine fraction of PM, has the strongest correlation with adverse health outcomes and its major sources in Canada include fossil fuel combustion,

[2] U.S. EPA, 2024. Health and Environmental Effects of PM. https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm. Accessed in April 2025.

industrial activity, biomass burning, and dust [3]. The coarse fraction of PM_{10}, that is, particles between 2.5-10 µm in diameter typically originate from the mechanical process in areas such as roadways, construction sites, and farming[4].

1.2.2.1 $PM_{2.5}$

$PM_{2.5}$ can originate from both natural and human-made sources and can be categorized into primary or secondary based on how it is formed and emitted. Primary $PM_{2.5}$ is fine particulate matter that is directly emitted, while secondary $PM_{2.5}$ is formed in the atmosphere from precursor pollutants such as sulfur dioxide, nitrogen oxides, volatile organic compounds, and ammonia. These precursors can be emitted from stationary sources (e.g., power plants and industrial facilities), and area sources (e.g., agriculture).

Some common examples of $PM_{2.5}$ include[5]:

- Combustion particles (e.g., from biomass burning)
- Secondary organic aerosols (e.g., oxidation of aromatics from fossil fuel combustion)
- Metals (e.g. from industrial emissions)

1.2.2.2 PM_{10}

PM_{10} is defined as PM with an aerodynamic diameter less than or equal to 10 µm. This includes coarse particulates (diameter between 2.5-10 µm) and $PM_{2.5}$. Some common sources of PM_{10} include:

- Dust (e.g., from construction activities)
- Smoke particles (e.g., from residential wood burning)
- Natural or biogenic sources (such as mold spores)

1.2.2.3 TOTAL SUSPENDED PARTICULATE

Total Suspended Particulate (TSP) refers to particles captured by high-volume air samplers, which are monitoring equipment that collects all suspended materials with no preference for size selection. Although TSP particle sizes are not specified, AP-42 documents define an effective aerodynamic diameter cut-off point of 30 µm, while Canada's National Pollutant Release Inventory (NPRI) defines total particulate matter (TPM) as particles with aerodynamic diameters less than or equal to 100 µm.

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[3] Health Canada, 2022. Canadian Health Science Assessment for Fine Particulate Matter ($PM_{2.5}$). Health Canada, March 2022, https://publications.gc.ca/collections/collection_2022/sc-hc/H144-100-2022-eng.pdf. Accessed in April 2025.
Accessed in May 2025.

[4] Robert et. al, 2014. Hemodynamic, Autonomic, and Vascular Effects of Exposure to Coarse Particulate Matter Air Pollution from a Rural Location. Environ Health Perspectives, 2014 June; 122(6): 624–630. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4050508/. Accessed in April 2025.

[5] U.S. EPA,2024. Particulate Matter (PM) Basics. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics. Accessed in April 2025.

Consequently, PM with aerodynamic diameters of less than 30 µm (PM_{30}) is often used as a surrogate for TSP[6], and emission factors from AP-42 can also be applied to meet NPRI reporting requirements. TSP includes both PM_{10} and $PM_{2.5}$, making it a comprehensive measure of PM in the atmosphere. The sources of TSP can be quite diverse and may include:

- Industry sources (e.g., mining, grinding, and crushing equipment),
- Transportation (e.g., road dust, and traction materials),
- Agriculture activities (e.g., soil tilling, and material handling), and
- Construction and demolition activities.

[6] U.S. EPA, 1995. AP-42 Chapter 13.2. Fugitive Dust Sources. https://www.epa.gov/sites/default/files/2020-10/documents/13.2_fugitive_dust_sources.pdf. Accessed in April 2025.

2 EMISSION ESTIMATES

This section provides guidance on the calculation of fugitive PM emissions originating from sources associated with mining activities within B.C. Details for the following categories of fugitive PM emission sources or activities are provided in sections 2.3 to 2.9:

- Section 2.3: Unpaved roads,
- Section 2.4: Paved roads,
- Section 2.5: Wind erosion,
- Section 2.6: Blasting and drilling,
- Section 2.7: Material handling, transferring, and storage,
- Section 2.8: Underground Mining, and
- Section 2.9: Other sources.

These sections offer activity-specific emission estimation equations and practical look-up tables to assist with parameter selection (including input values, activity rates, and control efficiencies). All calculations use metric units. Where the original reference documents utilized imperial units, the equations and parameters have been converted to their metric equivalents.

Appendix 1 provides a useful checklist that catalogues specific emission sources relevant to B.C. mining operations. This facilitates the identification of activities that generate fugitive PM emissions.

2.1 GENERAL EQUATION

The general equation for emission estimation is given by the U.S. EPA AP-42[7] document, which defines the emission rate (E) as a function of the emission factor:

$$E = R \times A \times (1 - P/100) \qquad (1)$$

Where:

E = emissions,

R = emissions factor,

A = activity rate,

P = emission control efficiency (%).

[7] U.S. EPA,1995. AP-42 Introduction. https://www.epa.gov/system/files/documents/2024-01/introduction_2024.pdf . Accessed in April 2025.

This equation (1) is a simplified emission estimation method and may not be suitable for certain situations. Some processes may require modifying this equation, such as applying adjustment factors. For example, the effect of precipitation and snow cover can be applied using a natural mitigation adjustment factor (ADJ), expressed as: $E=R\times A\times(1-P/100)\times ADJ$.

2.2 REFERENCES

2.2.1 U.S. EPA

The primary reference for PM emission estimation is provided by the U.S. EPA's AP-42: Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources[8] and its follow-up updates related to particulate emissions[9]. 'AP-42' is the original U.S. Public Health Service/U.S. EPA document identifier from 1968 that refers to the document containing basic information about emission estimates for air pollution (AP). AP-42 goes through periodic updates to incorporate results from recent emission monitoring studies. It provides comprehensive emission estimates for broad categories of scenarios when site-specific information is lacking.

AP-42 underwent a major update in 1995 and key revisions in 2006 and 2011. Although not official EPA publications, additional guidance documents were introduced in 2006 to provide further insights into the use and interpretation of AP-42 data. These include Western Regional Air Partnership (WRAP) 2006[10] and Midwest Research Institute (MRI) 2006[11].

2.2.2 CANADA'S NATIONAL POLLUTANT REPORTING INVENTORY (NPRI) TOOL

Environment and Climate Change Canada (ECCC) provides tools for estimating fugitive PM emissions through NPRI reporting[12], including emission factors and equations for various mining activities.

These methods often draw upon resources such as the U.S. EPA AP-42 or the Australian National Pollutant Inventory (NPI)[13]. These established references help inform the calculation and reporting of PM emissions within Canada's NPRI framework.

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[8] U.S. EPA,1995. AP-42, Fifth edition, Volume I: Stationary Point and Area Sources. https://www.epa.gov/sites/default/files/2020-11/documents/ap42_5thed_orig.pdf. Accessed April 2025.

[9] U.S. EPA,2006. AP-42 Chapter 13.2, Introduction to Fugitive Dust Sources, January 1995; Chapter 13.2.1 Paved Roads, January 2011; Chapter 13.2.2 Unpaved Roads, November 2006; Chapter 13.2.4 Aggregate Handling and Storage Piles, November 2006; and Chapter 13.2.5 Industrial Wind Erosion. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-fifth-edition-volume-i-chapter-13-miscellaneous-0 . Accessed in April 2025.

[10] WRAP,2006. Fugitive Dust Handbook, prepared for: Western Governors' Association Colorado, Prepared by: Countess Environmental, USA 2006.

[11] MRI,2006. Background Document for Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors, prepared by Midwest Research Institute. MRI Project No. 110397, USA 2006.

[12] ECCC,2025. Tools to calculate emissions. https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/sector-specific-tools-calculate-emissions.html . Accessed in April 2025.

[13] AG (Australian Government) NPI, 2012. NPI emission estimation technique manual for mining, Version 3.1, January 2012 Australian Government, Department of Sustainability, Environment, Water, Population and Communities.

2.2.3 AUSTRALIA NPI

The Australian NPI Emission Estimation Technique Manual for Mining[13] offers detailed guidelines that describe procedures and approaches for estimating emissions from the mining of coal and metalliferous minerals. The manual refines and adapts emission estimation techniques to the context of Australian mining operations drawing on studies conducted by the Australian State Pollution Control Commission (SPCC) in 1983 and the National Energy Research and Demonstration Council (NERDDC) in 1988. It uses the comprehensive list of emission factors from the U.S. EPA AP-42 for reference.

2.3 UNPAVED ROADS

2.3.1 EMISSION FACTOR (R)

AP-42 Chapter 13.2.2[14] focuses on methods for estimating PM emissions and emission factors from unpaved roads. These methods can be applied in the context of B.C. mining activities to calculate fugitive PM emissions from unpaved roads. The different estimation methods for emission factors are presented in Section 2.3.1.1 for unpaved roads at industrial sites and in Section 2.3.1.2 for publicly accessible roads.

2.3.1.1 EMISSION FACTORS FOR INDUSTRIAL SITES

The following empirically derived equation, based on equation 1a of AP-42 Chapter 13.2.2, can be used to calculate fugitive PM emissions from vehicular movement on unpaved surfaces at industrial sites. Equation (2) is expressed in metric units and illustrates the calculation of the emission factor as follows:

$$R = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{2.72}\right)^{b} \qquad (2)$$

Where: k, a, b are empirical constants (see Table 2-1)

R = *size-specific emission factor (kg/ vehicle km travelled (VKT))*

s = *surface material silt content (%)*

W = *mean vehicle weight (tonnes)*

Table 2-1: Constants to Calculate Fugitive PM Emission Factors for Unpaved Industry Roads (Metric units)

Constant	TSP	PM_{10}	$PM_{2.5}$
k (kg/VKT)	1.381	0.423	0.042
a	0.7	0.9	0.9
b	0.45	0.45	0.45

[14] U.S. EPA, 2006. AP 42 Chapter 13.2.2 Unpaved Roads.
https://www.epa.gov/sites/default/files/2020-10/documents/13.2.2_unpaved_roads.pdf
Accessed in April 2025.

2.3.1.2 EMISSION FACTORS FOR PUBLICLY ACCESSIBLE ROADS

For vehicles (primarily light-duty vehicles) traveling on publicly accessible roads, the emission factor as expressed in Imperial units is provided by Equation 1b of AP-42 Chapter 13.2.2. Equation (3) below provides the metric adaptation of Equation 1b for estimating the emission factor:

$$R = k\frac{\left(\frac{s}{12}\right)^{a}\left(\frac{S}{48.28}\right)^{d}}{\left(\frac{M}{0.5}\right)^{c}} - C \qquad (3)$$

Where: k, a, d, c are empirical constants (see Table 2-2)

R	=	*size-specific emission factor (kg/VKT)*
s	=	*surface material silt content (%)*
M	=	*surface material moisture content (%)*
S	=	*mean vehicle speed (km/h)*
C	=	*emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear (kg/VKT)*

Table 2-2: Constants to Calculate Fugitive PM Emission Factors for Unpaved Publicly Accessible Roads (Metric units)

Constant	TSP	PM_{10}	$PM_{2.5}$
k (kg/VKT)	1.69	0.507	0.0507
a	1	1	1
d	0.3	0.5	0.5
c	0.3	0.2	0.2
C (kg/VKT)	0.000132	0.000132	0.000101

2.3.1.3 INPUT VARIABLES

Estimating fugitive PM emissions from unpaved roads requires four input variables: surface material silt content, surface material moisture content, mean vehicle weight, and mean vehicle speed. Using site-specific values for these input variables is essential.

Procedures for determining road surface silt contents and moisture contents are detailed in AP-42 Appendices C.1[15] and C.2[16], providing comprehensive guidance for accurate measurements. According to AP-42 Appendix C.1, the recommended procedures for sampling surface material involve designing sampling plans for areas surrounding individual industrial facilities, including networks of unpaved and paved roads, as well as material storage piles.

It is beneficial to collect separate samples from each significant dust source within the facility. This source-specific approach provides the granularity needed for identifying key contributors and prioritizing cost-effective control measures. For broader geographic areas, such as cities with extensive public road networks, collecting individual samples from every potential source is typically impractical. In such cases, AP-42 advises sampling a representative subset of each source category. Similarly, for geographically large mining operations, it is appropriate to focus on collecting representative samples that reflect the diversity of source types within the site. If sampling strategies deviate from those specified in AP-42 Appendices C.1 and C.2, they should be selected in consultation with and approved by ENV, based on a balanced consideration of accuracy, practicality, and available resources.

AP-42 Chapter 13.2.2 suggests that for accurate data collection, samples should be gathered at various times throughout the year. This document recommends collecting samples twice annually, once in summer and once in winter. However, if only one set of samples is feasible, it should ideally be obtained during hot summer conditions to ensure the data reflects the dustiest conditions. When repeated calculation of emission is required, ENV recommends a three-year sampling interval for unpaved roads, provided road conditions remain stable, that is, with no significant changes in road surface, traffic volume or composition, or local weather patterns. If any of these conditions change, a new sampling cycle should be initiated to maintain accurate and representative emission estimates.

Newly proposed projects have the following three options to obtain road surface silt content and moisture content:

- Measurements of parent soil, which AP-42 allows as a conservative approximation. Tests show that actual road silt content is normally lower than the surrounding parent soil. This is because passing vehicle traffic blows away the fine dust, leaving behind a higher percentage of heavy, coarse particles[14].
- Measurements from any pre-existing mines of similar types operating in the same region, either under the same corporate entity or under a different corporate entity, or
- Default mean value derived from Table 13.2.2-1 of AP-42 13.2.2[14], or Table 6-1 and 6-2 of WRAP[10].

Site-specific data may need to be submitted to ENV after the mine is constructed.

Vehicle-related input variables refer to mean vehicle weight and mean vehicle speed. AP-42 Chapter 13.2.2 provides an approach for obtaining these onsite vehicle-related input variables. For example, if 98 percent

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[15] U.S. EPA, 1993. Appendix C.1 Procedures for Sampling Surface/Bulk Dust Loading. https://www.epa.gov/sites/default/files/2020-11/documents/app-c1.pdf . Accessed in April 2025.
[16] U.S. EPA, 1993. Appendix C.2 Procedures for Laboratory Analysis of Surface/Bulk Dust Loading Samples. https://www.epa.gov/sites/default/files/2020-11/documents/app-c2.pdf . Accessed in April 2025.

of the traffic on the road consists of 2-tonne cars and trucks, and the remaining 2 percent consists of 20-tonne trucks, the mean vehicle weight is calculated as 2.4 tonnes. This average weight of 2.4 tonnes, representing all vehicles on that road segment, should be used when calculating the emission factor. The same principle applies to mean vehicle speed, ensuring that emission estimations accurately reflect road usage.

Vehicle-related input data can be established through visual observations of traffic. However, in some cases, it may be possible to ascertain vehicle parameters for industrial unpaved roads by reviewing maintenance records or consulting other available information sources at the facility.[10] For newly proposed projects, the design parameters or data from nearby mines with similar activities in the same region can be used.

2.3.1.4 CONDITIONS AND LIMITATIONS

Calculations for unpaved road emission factors are subject to the following conditions and limitations:

- TSP and PM_{10} emission factors are derived from stepwise linear regressions based on field emission test results of vehicles traveling over unpaved surfaces. The $PM_{2.5}$ emission factor is scaled based on the results for PM_{10}.
- The emission factor equation for unpaved public roads estimates particulate emissions solely from resuspended road surface material. It does not account for PM from vehicle exhaust, brake wear, and tire wear. This approach avoids double counting since PM emissions from vehicle exhaust, brake wear, and tire wear are currently included in the MOVES model[17]. Directly emitted PM from vehicle exhaust, brake, and tire wear must be separately estimated using MOVES or another technique.
- The equations were developed using a range of source conditions, as shown in Table 2-3. The quality ratings (B), provided for the emission factors, pertain to the mid-range of the measured source conditions for these equations. U.S. EPA assigns quality ratings from A (excellent) to E (poor)[7]. If any of the site-specific variables fall outside the range indicated in Table 2-3, the quality ratings are downgraded, and you have the option to seek alternative solutions. However, it is crucial to thoroughly document these alternatives (in your model plan if for modelling purposes).
- The equations are established under the assumption that no controls are applied to the road surfaces to mitigate emissions.

[17] U.S. EPA, 2025. Latest Version of Motor Vehicle Emission Simulator (MOVES). https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves. Accessed in April 2025.

Table 2-3: Range of Source Conditions Used in Developing Equations for Unpaved Roads

Emission Factor	Surface Silt Content, %	Mean Vehicle Weight	Mean Vehicle Speed	Mean No. of Wheels	Surface Moisture Content, %
		Mg	km/h		
Industrial Roads	1.8-25.2	1.8-260	8-69	4-17	0.03-13
Public Roads	1.8-35	1.4-2.7	16-88	4-4.8	0.03-13
Note: The information provided here is sourced from AP-42 13.2.2 2006, Table 13.2.2-3.					

2.3.2 ACTIVITY RATE (A)

VKT represents the activity rate that gives rise to dust emissions from unpaved roads. Once an emission factor per VKT is established for a given unpaved road segment based on defined conditions (e.g., surface material silt content, surface material moisture content, mean vehicle weight, and mean vehicle speed), it is assumed to remain constant for all VKTs occurring under those same conditions. The total emissions can then be calculated by multiplying the emission factor by the total VKT. This approach applies to both industrial and publicly accessible unpaved roads, provided surface and traffic conditions are consistent.

To obtain VKT data, users can use odometer readings or the total length of roads within the facility and the number of vehicles entering the facility over a specific time. In cases where no such data is available, surveys can be conducted throughout the year on representative days of operation to estimate the VKT. For further guidance, refer to ECCC's "Road Dust Emissions from Unpaved Surfaces: Guide to Reporting".[18]

2.3.3 EMISSION CONTROL EFFICIENCY (P)

There are two primary methods commonly employed for controlling fugitive PM emissions from unpaved roads: watering and chemical stabilization using dust suppressants. Table 2-4 lists these emission control methods along with their respective efficiencies.

Table 2-4: Emission Control Methods and Efficiencies

Emission Control Methods	Control Efficiencies (P)
Watering twice a day	55%
Watering more than twice a day	70%
Chemical dust suppressants	80%

[18] ECCC, 2024. Road dust emissions from unpaved surfaces: guide to reporting. https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/sector-specific-tools-calculate-emissions/road-dust-unpaved-surfaces-guide.html Accessed in April 2025.

Emission Control Methods	Control Efficiencies (P)
Note: The information provided here is sourced from "Road Dust Emissions from Unpaved Surfaces: Guide to Reporting"[18]	

To apply emission control efficiencies for calculating emission rates for unpaved roads, follow these instructions:

- Refer to Table 2-4 and apply the corresponding efficiency value when calculating the emission rate for short periods (hourly or daily) for all seasons other than Season 4 (Winter 2, as defined in the B.C. Modelling Guideline[19]). Season 4 is treated separately because snow cover and frozen ground provide a high natural suppression effect, significantly reducing emissions even without active control measures. The five seasonal categories are shown as follows:
    - Season 1: Midsummer with lush vegetation.
    - Season 2: Autumn with cropland that has not been harvested.
    - Season 3: Winter 1, late autumn after frost, no snow on the ground.
    - Season 4: Winter 2, snow on the ground and subfreezing.
    - Season 5: Transitional spring with partially green short annuals.

  Select the appropriate value based on the facility's fugitive PM control methods. If the facility's control methods differ from those in Table 2-4 and users opt for alternative control efficiencies, users need to provide detailed justification, including references, calculations, and other supporting information.

- To calculate emission rate for short periods (hourly or daily) during Season 4 (Winter 2), use the lesser of the following:
    - An efficiency of 94%, and
    - The calculated natural control efficiency accounting for factors such as precipitation, snow cover, as derived using the ECCC method calculating road dust emissions from unpaved surfaces[18].

  The 94% value is based on a research paper considering frozen or snow-covered and wet conditions during winter in northern Canada. Refer to Golder 2010[20] for further information.

- For the annual emission rate, apply ADJ[18] for precipitation, snow cover, and frozen days, along with the emission control efficiency (if applicable) in Table 2-4, as demonstrated in Equations (4) and (5):

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[19] B.C. ENV, 2022. British Columbia Air Quality Dispersion Modelling Guideline. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/air/reports-pub/bc_dispersion_modelling_guideline.pdf . Accessed in April 2025.

[20] Golder Associates, 2010. Literature Review of Current Fugitive Dust Control Practices within the Mining Industry, submitted to: The Centre for Excellence in Mining Innovation. August 2010.

$$E = R * A * (1 - P/100) * ADJ \qquad (4)$$

$$\mathrm{ADJ} = \frac{Working\ Days - (pre + snow)}{Working\ Days} \qquad (5)$$

Where:

E = *emission rate (kg)*

R = *size-specific emission factor (kg/VKT)*

A = *activity rate (VKT)*

P = *emission control efficiency (%)*

ADJ = *adjustment factor for precipitation, snow cover and frozen days (fraction)*

Working Days= *the number of operating days per year*

Pre = *estimated annual working days with precipitation exceeding 0.2 mm*

Snow = estimated annual working days when the roads were frozen or snow-covered and wet for winter

The "pre+snow" value for a specific month must be not greater than the number of days worked in that month. If it is greater, then use the number of days worked instead. Additionally, double counting of precipitation days and snow-covered days should be avoided. For a more comprehensive understanding of this adjustment, refer to the ECCC document titled "Road Dust Emissions from Unpaved Surfaces: Guide to Reporting."[18]

2.4 PAVED ROADS

2.4.1 EMISSION FACTOR (R)

U.S. EPA AP-42 Chapter 13.2.1[21] provides an empirical equation to estimate fugitive PM emissions from paved roads, which can be applicable for mines in B.C. The silt loading present on the road surface and the average weight of vehicles traveling the road are two key factors affecting the PM emissions from paved roads.

In accordance with AP-42 13.2.1, the PM emission factors due to vehicle travel on a dry paved road are estimated from the following empirical expression in Metric units:

$$R = k(sL)^{0.91}(1.1023W)^{1.02} \qquad (6)$$

Where:

R	=	*particulate emission factor (g/ VKT)*
k	=	*particle size multiplier for particle size range(g/VKT) (*Table 2-5*)*
sL	=	*road surface silt loading (g/m^2)*
W	=	*mean vehicle weight of the vehicle travelling the road (tonnes)*

Table 2-5: Particle Size Multipliers for Paved Roads (Metric Units)

Constant	TSP	PM_{10}	$PM_{2.5}$
k (g/VKT)	3.23	0.62	0.15

2.4.1.1 INPUT VARIABLES

Estimation of fugitive PM emissions from paved roads involves the consideration of two key variables: road surface silt loading and mean vehicle weight. It is imperative to utilize site-specific values for these input variables when available. Detailed procedures for determining road surface silt loading can be found in AP-42 Appendices C.1[15]and C.2[16] , with further guidance provided in Section 2.3.1.3.

In most regions of B.C., road surface silt loading tends to be heaviest during late winter and early spring when residual materials from snow and ice control measures accumulate to their peak. The surface silt

[21] U.S. EPA, 2011. AP 42 Chapter 13.2.1 Paved Roads. https://www.epa.gov/sites/default/files/2020-10/documents/13.2.1_paved_roads.pdf . Accessed in April 2025.

loading then reaches an equilibrium value once the replenishment of fresh material is eliminated. Measurements of surface silt loading for two types of paved roads (industrial and public) must be taken at two distinct times. One is during summertime to represent normal baseline conditions, and the other is during late winter or early spring to represent wintertime baseline conditions with the application of antiskid material[21]. Where repeated calculations of emissions are required, ENV recommends a sampling interval of five years for paved roads, provided that road conditions remain stable, that is, there are no significant changes in road surface, traffic volume, or local weather patterns. If any of these conditions change, a new sampling cycle should be undertaken to ensure that emission estimates remain accurate and representative.

To calculate fugitive PM emissions from paved roads for Season 1, Season 2, and Season 3 as defined in B.C. modelling guideline[19], apply the normal surface silt loading value. For Season 4 and Season 5, use the wintertime surface silt loading.

For the newly proposed projects, surface silt loading can be determined using:

- Representative mean values obtained from similar mining operations within the same geographic region, even if located at slightly different sites and under different corporate ownership, provided that road surface composition, traffic conditions, and dust control practices are demonstrably similar, or
- Default values from Table 13.2.1-2 of AP-42 Chapter 13.2.1 for public paved roads and Table 13.2.1-3 for industrial paved roads.

Submission of the site-specific data may be requested once the mine is constructed.

Additionally, mean vehicle weight should be obtained in accordance with the procedures outlined in Section 2.3.1.3 to ensure consistency and accuracy in the estimation process.

2.4.1.2 CONDITIONS AND LIMITATIONS

The calculation for the emission factor is subject to the following conditions and limitations[21]:

- Equation (6) is grounded in a robust regression analysis comprising 83 tests, encompassing various sources from public paved roads and controlled/uncontrolled industrial paved roads, with a specific focus on PM_{10} emissions.
- It is important to recognize that the emission factor equation for paved roads exclusively addresses particulate emissions from resuspended road surface material. Other PM emissions sources, such as those from vehicle exhaust, brake wear, and tire wear, are estimated separately using the U.S. EPA's MOVES[17] model.
- The equation is developed under a range of source conditions, as delineated in Table 2-6. When applied within the specified range of source conditions, the equation merits a quality rating of A for PM_{10} only (rating of D for $PM_{2.5}$). U.S. EPA assigns quality ratings from A (excellent) to E (poor)[7]. If any of the site-specific variables fall outside the range indicated in Table 2-6, the quality rating is downgraded. In such cases, users may seek alternative solutions, which must be justified and documented.

Table 2-6: Range of Source Conditions Used in Developing Equation for Paved Roads

Variable	Unit	Range
Silt loading	g/m^2	0.03 - 400
Mean vehicle weight	tonnes	1.8 - 38
Mean vehicle speed	Km/h	1 - 88

2.4.2 ACTIVITY RATE (A)

VKT serves as the activity rate responsible for dust emissions from paved roads. Once an emission factor per VKT is established for a given paved road segment, based on defined conditions such as road surface silt loading and mean vehicle weight, it is assumed to remain constant for all VKTs occurring under those same conditions. The procedures for acquiring road specific VKT data are detailed in Section 2.3.2.

2.4.3 EMISSION CONTROL EFFICIENCY (P)

Emission factors from controlled industrial roads were used in the development of Equation (6). The preferred approach for evaluating controls (i.e., sweeping) on silt loading involves locally measured silt loadings both before and after the application of control measures. This method ensures the most accurate assessment of control efficiency. When such measurements are not available to verify control efficiency of sweeping, no control efficiency can be applied when calculating hourly or daily fugitive PM emission factors.

In line with AP-42 13.2.1, for long-term average emissions (annual or seasonal), a correction factor related to precipitation frequency can be applied. This correction term is included in Equation (7), with daily-basis meteorology:

$$R = (k(sL)^{0.91}(1.1023W)^{1.02})(1 - \frac{Pre}{4N}) \quad (7)$$

Where:

Pre = *number of "wet" days with at least 0.254 mm of precipitation during the averaging period, and*

N = *number of days in the averaging period (e.g., 365 for annual, 91 for seasonal).*

When calculating long-term average emissions using hourly-basis meteorology, the Equation (7) becomes:

$$R = (k(sL)^{0.91}(1.1023W)^{1.02})(1 - \frac{1.2Pre}{N}) \quad (8)$$

Where:

Pre = *number of hours with at least 0.254 mm of precipitation during the averaging period, and*

N = *number of hours in the averaging period (for example: 8760 for annual, 2124 for seasonal).*

For a more comprehensive understanding of the precipitation correction term, refer to AP-42 Chapter 13.2.1[21].

2.5 WIND EROSION

Wind-generated PM emissions are governed by the frequency of surface disturbance, and each disturbance, such as mechanical action for loading or unloading, recharges the erodible surface reservoir, restoring its potential to generate dust. The interval between disturbances is the time period during which the surface remains undisturbed.

The emission factors for fugitive PM emissions generated from wind erosion are detailed in two sections:

- Section 2.5.1 for wind erosion from industrial exposed areas, and
- Section 2.5.2 for wind erosion from elevated stockpiles with a height-to-base ratio greater than 0.2.

Flat stockpiles with a height-to-base ratio of 0.2 or less are treated as industrial exposed areas according to U.S. EPA AP-42 Chapter 13.2.5[22].

Sand tailings dams are classified as industrial exposed areas due to their massive, flat geometry. Disturbances that create new erodible layers on the dam include:

- Physical operational changes, such as deposition of new material, or discharge pipe relocation,
- Utilization of heavy equipment, such as graders, dozers, or maintenance traffic, and
- Environmental forces, such as stormwater runoff.

2.5.1 EMISSION FACTORS (R) FOR WIND EROSION FROM INDUSTRY EXPOSED AREAS

The size-specific emission factors for wind-generated fugitive PM emissions from large, flat, exposed areas or flat piles that are disturbed are determined using the equation below sourced from U.S. EPA AP-42 Chapter 13.2.5:

$$R = k \sum_{i=1}^{N} P_i \qquad (9)$$

Where:

R = *particle size-specific emission factor per year (g/m^2 per year)*

k = *particle size multiplier (shown in* Table 2-7*)*

N = *number of disturbances per year*

P_i = *erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances (g/m^2)*

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[22] U.S. EPA, 2006. AP 42 Chapter 13.2.5 Industrial Wind Erosion. https://www.epa.gov/sites/default/files/2020-10/documents/13.2.5_industrial_wind_erosion.pdf Accessed in April 2025.

Table 2-7: Particulate Size Multipliers for Wind Erosion

Particle Size	k
TSP	1
PM_{10}	0.5
$PM_{2.5}$	0.075
Note: sourced from AP-42 Chapter 13.2.5[22].	

The erosion potential (usually viewed as the emission factor per disturbance) for a dry, exposed surface is calculated using the following equation:

$$P_i = 58(u^* - u_t{}^*)^2 + 25(u^* - u_t{}^*) \qquad (10)$$
$$P_i = 0 \quad \text{for} \quad u^* \leq u_t{}^*$$

Where:

u^* = friction velocity (m/s)

u_t^* = threshold friction velocity (m/s)

Because of the nonlinear form of the erosion potential function, each erosion event must be treated separately.

The friction velocity *u^** is a measure of the wind shear stress on the erodible surface, as determined from the slope of the logarithmic wind speed profile[22]:

$$u^* = \frac{u(z)}{ln\left(\frac{z}{z_0}\right)} k \quad (z > z_0) \qquad (11)$$

Where:

u^* = friction velocity (m/s)

$u(z)$ = wind speed (m/s)

z = height above test surface (m)

z_0 = roughness height (m)

k = Von Karman's constant = 0.4 (dimensionless)

As per AP-42 13.2.5.2, if typical values for threshold wind speed at 15 cm are corrected to typical wind sensor height (7 - 10 m), the resulting values exceed the upper extremes of hourly mean wind speeds observed in most areas of the country. Mean atmospheric wind speeds are not sufficient to sustain wind erosion from flat surfaces of certain types of soil. Estimated emissions should be related to the gusts of the highest magnitude rather than mean atmospheric wind speeds. The meteorological variable most used to represent the magnitude of wind gusts is the fastest mile. The fastest mile wind speed corresponds to one mile of air passing by a fixed location in the least amount of time. First, the anemometer heights of reporting weather stations should be corrected to a 10 m reference height using Equation (11). Then, the hourly mean wind speed at 10 m is converted to an equivalent fastest mile wind speed by multiplying a gust factor of 1.24 (consistent with ECCC guide)[23] as follows:

$$u^+ = 1.24\,u \qquad (12)$$

Where:

u^+ = fastest mile wind speed (m/s)

u = mean hourly wind speed at reference height 10 m during the period between disturbances (m/s)

The friction velocity is calculated using Equation (13) and assuming a typical roughness height of 0.005 m for open terrain and a reference anemometer height of 10 m above ground. If a site-specific roughness height is available, it should be used.

$$u^* = \frac{0.4}{ln(\frac{10}{0.005})}\,u^+ = 0.053\,u^+ \qquad (13)$$

Where:

u^* = friction velocity (m/s)

u^+ = fastest mile of reference anemometer (10m) for period between disturbances (m/s)

2.5.2 EMISSION FACTORS (R) FOR WIND EROSION FROM STORAGE PILES

PM emissions from wind erosion of storage piles can be estimated using the method outlined in AP-42 Chapter 13.2.5[22], which is based upon windblown emissions from a flat reservoir. This method adjusts friction velocities for different regions of the pile, as determined through wind tunnel experiments. Since the basis of the emission estimation uses the flat reservoir method, the emission calculations presented in

[23] ECCC, 2023. Stockpiles and exposed area wind erosion calculator: guide to reporting. https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/tools-calculating-emissions/stockpiles-exposed-area-wind-erosion-calculator.html Accessed in April 2025.

Section 2.5.1 can be adapted to storage piles by dividing each pile into subareas, as described in AP-42 Chapter 13.2.5.

The u_s/u_r gives the ratios of surface wind speed (u_s) to approach wind speed (u_r), which have been derived from wind tunnel studies. The u_s/u_r ratios, including 0.2, 0.6, 0.9, and 1.1, have been developed for two representative pile shapes. These two representative pile shapes—conical and oval with flattop, both with 37-degree side slopes—are illustrated in Figure 13.2.5-2 of AP-42 Chapter 13.2.5. This figure is reproduced as Figure 2-1 in this guidance. The area fraction within each contour pair is specified in Table 2-8. These results correspond to an actual pile 11 m high, a reference (upwind) anemometer height of 10 m, and a pile surface roughness height (z_o) of 0.5 cm. The measured surface winds correspond to a height of 25 cm above the surface[22].

Table 2-8: Subarea Distribution for Regimes of u_s/u_r

Pile subarea	Pile Surface Area Percentage (%)			
	Pile A	Pile B1	Pile B2	Pile B3
0.2a	5	5	3	3
0.2b	35	2	28	25
0.2c	NA	29	NA	NA
0.6a	48	26	29	28
0.6b	NA	24	22	26
0.9	12	14	15	14
1.1	NA	NA	3	4

The profiles of u_s/u_r in Figure 2-1 can be used to estimate the friction velocity for similarly shaped piles. However, users can also utilize site-specific data, obtained through on-site measurements or validated alternatives such as computational fluid dynamics modeling, provided that these are properly justified and documented.

The fastest mile value (u_s^+) that corresponds to the elevated surface can be obtained from the following Equation (14).

$$u_s^+ = \left(\frac{u_s}{u_r}\right) \times u^+ \qquad (14)$$

where:

u_s^+ = *fastest mile value surface wind speed distribution (m/s)*

u_s/u_r = ratio of the surface wind speed to the reference approach wind speed

u^+ = fastest mile value at reference height 10 m (m/s) during the period between disturbances

Equation (15) is then used to calculate the equivalent friction velocity (u*) for any subarea of the pile surface having a narrow range of surface wind speed.

$$u^* = \frac{0.4}{ln(\frac{25}{0.5})} {u_s}^+ = 0.10{u_s}^+ \qquad (15)$$

The remaining steps for calculating erosion potential for the elevated storage pile are identical to those used for the exposed area (Section 2.5.1).

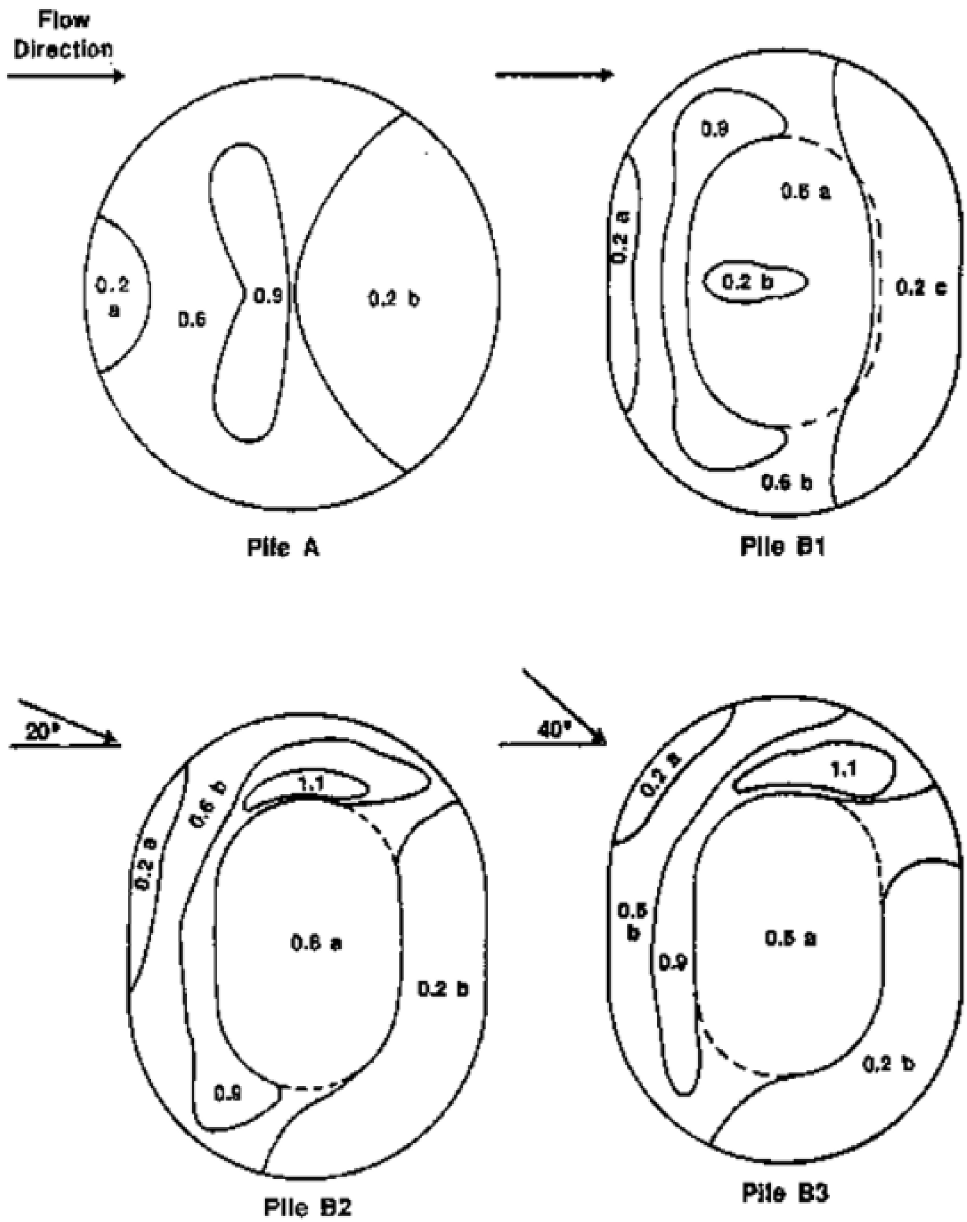

Figure 2-1: Contours of normalized surface windspeeds, U_s/U_r

(Sourced from AP-42 Chapter 13.2.5, Figure 13.2.5-2)

2.5.3 INPUT VARIABLES

Hourly wind speed during the period between disturbances

The hourly average wind speeds can be obtained from the following sources:

1. Nearest weather station from the Government of Canada historical climate data site,
2. An on-site weather station, and
3. Prognostic meteorological data (i.e., WRF data).

Threshold Friction Velocity

For un-crusted surfaces, the threshold friction velocity is best estimated from the dry aggregate structure of the soil. A simple hand sieving test of surface soil can be used to determine the mode of the surface aggregate size distribution by inspection of relative sieve catch amounts, following the procedure described in AP-42 Chapter 13.2.5.

Typical threshold velocities recommended by U.S. EPA for a selection of surfaces can be found in Table 2-9. Users may either apply these published values or use site-specific data where available. Alternative data sources may also be accepted, subject to prior approval, provided that the values are clearly documented and supported by sound scientific justification.

Table 2-9: Threshold Friction Velocities for a Selection of Surfaces

Material	Threshold Friction Velocity, m/s	Roughness height, cm	Threshold Wind Velocity at 10m, m/s	
			z_o = actual	z_o = 0.5 cm
Overburden	**1.02**	**0.3**	**21**	**19**
Scoria (roadbed material)	**1.33**	**0.3**	**27**	**25**
Ground coal (surrounding coal pile)	**0.55**	**0.01**	**16**	**10**
Un-crusted coal pile	**1.12**	**0.3**	**23**	**21**
Scraper tracks on coal pile	**0.62**	**0.06**	**15**	**12**
Fine coal dust on concreate pad	**0.54**	**0.2**	**11**	**10**
Note: Sourced from AP-42 Chapter 13.2.5 Table 13.2.5-2				

2.5.4 CONDITIONS AND LIMITATIONS

Equations (9) and (10) in Section 2.5.1 are specifically tailored for dry, exposed materials that possess limited erosion potential. The emission factor calculated from those two equations remains valid exclusively for durations equal to or exceeding the intervals between disturbances. The estimated emissions represent intermittent events and, therefore, should not be directly input into dispersion models that assume steady-state emission rates.

2.5.5 ALTERNATIVE METHOD: ENVIRON/ WRAP RMC METHOD

The Dust Emissions Joint Forum (DEJF) of WRAP[10] contracted with Environ Consultants Ltd. (ENVIRON) to develop a particulate emission calculation method for open area wind erosion. It is documented in WRAP Fugitive Dust Handbook Section 8.4.4[10]. The ENVIRON/WRAP RMC windblown dust method utilizes wind-tunnel-based emission algorithms for different soils and accounts for land uses and local meteorology. For detailed information on the method, refer to ENVIRON's final report[24].

Use of the ENVIRON/WRAP RMC method as an alternative methodology for estimating wind-generated fugitive PM emissions is contingent upon the approval of ENV. Additionally, it is strongly recommended that users meticulously review the inputs to ensure the most accurate and representative data is used for PM emissions calculations. For example, threshold friction velocity must be obtained from measurements or reliable public sources rather than calculated using equations. Step-by-step justifications, including references and calculations, should be documented in the emission report.

2.5.6 ACTIVITY RATE (A)

The activity rate for wind erosion emissions is based on the active exposed surface area measured or calculated in square meters, with larger areas indicating greater fugitive PM emissions.

2.5.7 EMISSION CONTROL EFFICIENCY (P)

For the calculation of hourly or daily emission rates, ECCC "Stockpiles and Exposed Area Wind Erosion Calculator: Guide to Reporting"[23] outlines the emission control techniques and corresponding control efficiencies. ECCC's default control efficiencies for common techniques are as follows:

- Three-side enclosure: 75%
- Apply dust suppressants or gravel: 84%
- Revegetate or apply cover: 90%

It is crucial for users to select values that align with their specific dust control methods. In cases where dust control strategies deviate from the ones listed above or alternative control efficiencies are employed (e.g., water application with efficiencies ranging from 50 to 95% dependent on the daily application rate), a justification is required. This justification should encompass detailed references, calculations, and other pertinent documentation.

Furthermore, when calculating annual emissions, it is acceptable to apply an adjustment factor defined in ECCC document[23]. This factor accounts for natural mitigation resulted from total precipitation, including

[24] ENVIRON 2006. Fugitive Wind-Blown Dust Emissions and Model Performance Evaluation Phase II Final Report. ENVIRON, May 2006.

both rainfall and the water equivalent of total snowfall, measured in millimeters (mm), as well as the presence of snow cover.

2.6 BLASTING AND DRILLING

2.6.1 EMISSION FACTOR (R)

In accordance with the procedures outlined by AP-42, Chapter 11.9[25], specifically referencing Table 11.9-2, an empirical formula has been developed to quantify the fugitive PM emissions from blasting activities in overburden or coal. This formula, derived from field data, is presented below for the estimation of PM emissions:

$$R = 0.00022(A)^{1.5}\ k \qquad (16)$$

Where:

R = *emission factor (kg/blast),*

A = *horizontal area blasted (m²) per blast, and with blasting depth <21 m. Not for vertical face of a bench.*

k = *particle size multiplier*

The particle size multipliers are also provided by AP-42, Chapter 11.9, as detailed in Table 11.9-2. These values are cataloged in Table 2-10, which provides a breakdown of the particle size fractions pertinent to the calculation of fugitive PM emissions.

Table 2-10: Blasting Particulate Size Multipliers

Particle Size	k
TSP	**1.0**
PM_{10}	**0.52**
$PM_{2.5}$	**0.03**

To estimate drilling emissions, AP-42 Chapter 11.9 Table 11.9-4 provides simple TSP emission factors for western surface coal mines. For drilling in overburden,

$$R = \ 0.59\, k \qquad (17)$$

For drilling in coal,

[25] U.S. EPA, 1998. AP 42 Chapter 11.9 Western Surface Coal Mining. https://www.epa.gov/sites/default/files/2020-10/documents/c11s09.pdf . Accessed in April 2025.

$$R = k\ 0.10 \qquad (18)$$

Where:

R = emission factor, kg/hole

k = particle size multiplier

U.S. EPA does not offer designated emission factors for PM_{10} and $PM_{2.5}$. To address this gap, particle size multipliers in Table 2-11 can be used. These multipliers have been sourced from the "Pits and Quarries Reporting Guide" published by ECCC[26].

Table 2-11: Drilling Particulate Size Multipliers

Particle Size	k
TSP	**1.0**
PM_{10}	**0.52**
$PM_{2.5}$	**0.52**

2.6.2 ACTIVITY RATE (A)

The activity rate for blasting refers to the frequency with which explosives are detonated to break rock or ore into smaller, manageable pieces. This rate is usually measured in terms of the total number of blasts carried out over a specific period, such as a day, a month, or a year. The number of blasts conducted directly correlates with the fugitive PM emissions generated during blasting operations.

Similarly, for drilling, the activity rate is determined by the number of holes drilled during a specific time frame. The more holes that are drilled, the greater the potential for generating fugitive PM emissions.

2.6.3 EMISSION CONTROL EFFICIENCY (P)

The factors provided in Section 2.6.1 represent uncontrolled emissions and are based on typical field conditions for blast depth or drill hole depth. The guidance does not specify emission control efficiencies regarding blasting and drilling operations. Users have options to select a value that aligns with their site-specific dust control techniques (e.g. water sprays, enclosures). Users should provide clear justifications and references for their selected control efficiencies, ensuring transparency and accountability in addressing fugitive PM emissions.

[26] ECCC, 2022. Pits and quarries reporting guide. https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/pits-quarries-guide.html. Accessed in April 2025.

2.7 MATERIAL HANDLING, TRANSFERING, AND STORAGE

Several mining activities fall under the category of material handling, transferring, and storage, including:

- General loading/unloading of overburden/waste rock,
- Track loading/unloading of coal,
- Bulldozing on coal and overburden,
- Dragline on overburden,
- Grading, and
- Scraper.

Emission estimation methods are detailed in Sections: 2.7.1 - 2.7.6.

For aggregate material input variables, such as silt content and moisture content, users should refer to the sampling procedures outlined in AP-42 Appendices C.1[15] and C.2[16], with additional guidance provided in Section 2.3.1.3. If repeated emissions calculations are required, then annual sampling is recommended, as long as the aggregate material source remains consistent over time.

For newly proposed projects, the silt content and moisture content of aggregate material can be determined using:

- Representative mean values obtained from similar mining operations within the same geographic region, even if located at slightly different sites and under different corporate ownership, or
- Default values from Table 13.2.4-1 of AP-42 Chapter 13.2.4[27].

Site-specific data may need to be submitted to ENV after the mine is constructed.

2.7.1 GENERAL LOADING/UNLOADING OF OVERBURDEN/WASTE ROCK

Adding or removing aggregate material from a storage pile results in dropping the material onto the receiving surface. Truck dumping on the pile or loading out from the pile onto a truck using a front-end loader are examples of batch drop operations. Adding material to the pile by a conveyor stacker is a continuous drop operation[27].

2.7.1.1 EMISSION FACTORS (R)

AP-42 Chapter 13.2.4[27] offers the estimation methods for emissions generated by different types of drop operation. NPI[133] also recommends the drop operation emission factor for excavators, shovels, and front-end loaders (on overburden), for convey transfer points, and for wheel and bucket operations using Equation (19), sourced from AP-42 chapter 13.2.4:

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[27] U.S. EPA, 2006. AP 42 13.2.4. Aggregate Handling and Storage Piles. [AP42 13.2.4 Aggregate Handling And Storage Piles](#) . Accessed April 2025.

$$R = 0.0016\left(\frac{U}{2.2}\right)^{1.3} / \left(\frac{M}{2}\right)^{1.4} k \qquad (19)$$

Where:

R = *emission factor (kg/tonnes of material loaded),*

U = *mean wind speed in (m/s), and*

M = *the material moisture content (%)*

k = *Particulate Size Multipliers (dimensionless)*

The particle size multipliers are shown in Table 2-12.

Table 2-12: Particulate Size Multipliers for General Loading/Unloading of Overburden/Waste Rock

Particle Size	k
TSP	0.74
PM_{10}	0.35
$PM_{2.5}$	0.053

Equation (19) indicates that the emission factor for general loading and unloading activities is a function of wind speed. To incorporate time-varying emissions in dispersion modeling, ENV recommends using hourly wind speed data from either the nearest meteorological station or prognostic model outputs (e.g., WRF). Alternatively, emission factors may be stratified into wind speed bins for use with models such as CALPUFF following this procedure:

- Group hourly wind speeds into one of those six bins defined in Group 12 of the CALPUFF control file. Those six bins include 0 - 1.54 m/s, 1.54 - 3.09 m/s, 3.09 - 5.14 m/s, 5.14 - 8.23 m/s, 8.23 - 10.8 m/s, and >10.8 m/s,
- Average hourly wind speeds within each bin to obtain a representative mean wind speed, and
- Apply the mean wind speed for each bin to Equation (19) to calculate bin-specific emission factors.

The activity rate for this estimation is typically quantified based on the material handled during a specific period, such as a day, month, or year.

The equation provided in AP-42 Section 13.2.4 has its limitations and specific conditions as outlined in Table 2-13. If on-site data falls outside the established limitation or conditions in Table 2-13, the quality rating level of estimates derived from the equation is reduced, and users are encouraged to exercise caution. Alternatively, users may explore and choose other methods that better align with their specific operational conditions.

Table 2-13: Ranges of Source Conditions for Emission Estimation

Variable	Ranges of Source Conditions
Silt Content (%)	0.44 – 19
Moisture Content (%)	0.25 – 4.8
Wind Speed (m/s)	0.6 – 6.7

2.7.2 TRUCK LOADING/UNLOADING OF COAL

Emissions from truck loading or unloading of coal (for materials other than coal, refer to Section 2.7.1) are based on Table 11.9-2 of AP-42 Chapter 11.9[1], and are given by Equation (20),

$$R = k\frac{K}{M^b} \qquad (20)$$

Where:

R = truck loading emission factor (kg/tonne) of material moved

K = *operation specific factor (kg/tonne)*

k = *particle size multiplier*

M = *material moisture content (%)*

The particle size multiplier k, operation specific factor *K*, and exponent *b* are listed in Table 2-14.

Table 2-14: Particle Size Multipliers, Operation Specific Factors, and Exponents for Truck Loading or Unloading of Coal

Particle Size	k	K (kg/tonne)	b
TSP	1	0.58	1.2
PM_{10}	0.75	0.0596	0.9
$PM_{2.5}$	0.019	0.58	1.2

The inclusion of on-site measurements of moisture content is crucial, as it accounts for the moisture levels inherent to the coal being handled, which can impact emissions.

The activity rate for this estimation is based on the quantity of material moved during a specified period, which could be a daily, monthly, or annual timeframe. This metric offers a robust basis for assessing the fugitive PM emissions associated with coal transportation.

2.7.3 BULLDOZING

The emissions for bulldozing on coal and bulldozing on overburden are based on Table 11.9-2 of AP-42 Chapter 11.9[1], and are shown as follows:

$$R = k\frac{Ks^b}{M^c} \quad (21)$$

Where:

R = emission factor (kg/h)

K = operation specific factor (kg/h)

k = particle size multiplier

s = material silt content (%)

M = material moisture content (%)

The particle size multiplies k, operation specific factor *K*, and exponents *b and c* are listed in Table 2-15.

Table 2-15: Particle Size Multipliers, Operation Specific Factors, and Exponents for Bulldozing

Material Type	Particle Size	k	K (kg/h)	b	c
Coal	**TSP**	1	35.6	1.2	1.3
	PM_{10}	0.75	8.44	1.5	1.4
	$PM_{2.5}$	0.022	35.6	1.2	1.3
Overburden	**TSP**	1	2.6	1.2	1.3
	PM_{10}	0.75	0.45	1.5	1.4
	$PM_{2.5}$	0.105	2.6	1.2	1.3

This emission estimation for bulldozing operations utilizes on-site measured silt contents and moisture contents for coal or overburden when it is available, allowing for a precise assessment of the characteristics of site-specific data. Where on-site measurements are not available, use the procedures described in Section 2.7 for newly proposed projects.

A key element of this estimation approach is the activity rate, which is determined by the number of bulldozing operation hours. This metric can be calculated for various timeframes, including daily and annually, depending on the specific requirements of the emissions assessment.

2.7.4 DRAGLINE ON OVERBURDEN

Equation (22) below, recommended by U.S. EPA (Table 11.9-2 of AP-42 Chapter 11.9)[1] should be used to calculate emissions for dragline operations on overburden.

$$R = k\frac{Kd^b}{M^c} \qquad (22)$$

Where:

R = emission factor (kg per m^3 of overburden moved)

K = operation specific factor (kg per m^3 of overburden moved)

k = particle size multiplier

d = drop height (m)

M = material moisture content (%)

The particle size multiplier k, operation specific factor *K*, and exponents *b and c* are listed in Table 2-16.

Table 2-16: Particle Size Multipliers, Operation Specific Factors, and Exponents for Dragline Operation on Overburden

Particle Size	k	K (kg/m³)	b	c
TSP	1	0.0046	1.1	0.3
PM_{10}	0.75	0.0029	0.7	0.3
$PM_{2.5}$	0.017	0.0046	1.1	0.3

This method involves the utilization of on-site measured moisture content and drop height. Drop height data, obtained from designs or from site-specific measurements, are integral to accurately calculating fugitive PM emissions from dragline operations.

The activity data used for this estimation is quantified by the volume of material removed by the dragline. This volume is often expressed in terms of bank cubic meters (BCM), representing the in-situ volume of material before blasting or excavating.

2.7.5 GRADING

The emissions for grading operation are also calculated based on Table 11.9-2 of AP-42 Chapter 11.9, and are shown as follows:

$$R = kKS^c \qquad (23)$$

Where:

R = grading emission factor (kg per VKT or grader travelled)

K = operation specific factor (kg per VKT or grader travelled)

k = particle size multiplier

S = mean vehicle speed (km/h)

The particle size multiplies k, operation specific factor *K*, and exponent *c* are listed in Table 2-17.

Table 2-17: Particle Size Multipliers, Operation Specific Factors, and Exponents for Grading

Particle Size	k	K (kg/VKT)	c
TSP	1	0.0034	2.5
PM_{10}	0.60	0.0056	2.0
$PM_{2.5}$	0.031	0.0034	2.5

The emission factors for grading operations, as indicated by Equation (23), are proportional to the mean vehicle speed (S). To determine the mean vehicle speed, users should refer to Section 2.3.1.3.

In this estimation approach, the activity rate is quantified as VKT. This metric aligns with the same activity rate used for estimating emissions from unpaved roads and paved roads.

2.7.6 SCRAPING

The emissions estimate for scraping operations are divided into three primary activities based on Table 13.2.3-1 of AP-42 Chapter 13.2.3[28]:

- Scraper (unloading topsoil)
- Scraper (travel mode)
- Scraper (removing topsoil)

The method for general loading/unloading detailed in Section 2.7.1 is used for emission estimation from Scraper (unloading topsoil). Scraper (travel model) and scraper (removing topsoil) are described in Sections 2.7.6.1 and 2.7.6.2.

2.7.6.1 SCRAPER (TRAVEL MODE)

Equation (24) below from NPI[13] is used for estimating emissions from scraper in travel mode.

[28] U.S. EPA, 1995. AP 42 13.2.3 Heavy Construction Operations. https://www.epa.gov/sites/default/files/2020-10/documents/13.2.3_heavy_construction_operations.pdf. Accessed in April 2025.

$$R = k \times 9.6 \times s^{1.3} W^{2.4} / (10^6) \qquad (24)$$

Where:

R = scraping emission factor (kg per VKT or scraper travelled)

k = particle size multiplier

s = silt content of material (%)

W = gross vehicle weight (tonnes)

The particle size multipliers are listed in Table 2-18.

Table 2-18: Particle Size Multipliers for Scraper (Travel Mode and Removing Topsoil)

Particle Size	k
TSP	1
PM_{10}	0.1375
$PM_{2.5}$	0.031
Note: Use NPI[13] Section 1.1.12 data for PM_{10} and the same particle size multiplier as grading for $PM_{2.5}$.	

This emission estimation for a scraper in travel requires silt contents (either measured on site or obtained using the procedures described in Section 2.7 for newly proposed projects) and gross vehicle weight. The activity rate is vehicle kilometers traveled.

2.7.6.2 SCRAPER (REMOVING TOPSOIL)

Table 11.9-4 of AP-42 Chapter 11.9[1] offers the emissions factor of 0.029 kg/tonne for TSP for scraper (removing topsoil). The particle size multipliers for PM_{10} and $PM_{2.5}$ are 0.1375 and 0.031, respectively, which are the same as the ones for scraper (travel mode). The activity rate used for this estimation is quantified by the weight of material removed by the scraper.

2.7.7 SINGLE-VALUED EMISSION FACTORS

Table 11.9-4 of AP-42 Chapter 11.9[1] provides single-valued emission factors for various types of mining activities, including:

- Train loading coal (batch or continuous drop)
- Truck loading by power shovel overburden (batch drop)
- End dump truck unloading coal (batch drop)
- Bottom dump truck unloading overburden and coal (batch drop)
- Scraper unloading topsoil (batch drop)

These factors represent conditions as summarized in Tables 11.9-5 and 11.9-6 of AP-42 Chapter 11.9.

Although these emission factors offer a simplified way to estimate emissions from these activities, it is recommended to use the predictive emission factor equations presented in AP-42 Chapter 13.2.4[27] for more accurate estimates of emissions, as detailed in Section 2.7.1 of this guidance. The higher quality ratings assigned to the equation from Chapter 13.2.4 are applicable only if: (1) the reliable values of correction parameters (i.e., wind speed and moisture content) have been determined for the specific sources of interest, and (2) the correction parameter values lie within the ranges tested in developing the equations. When using the Chapter 13.2.4 equations, it is essential to use only the unbound moisture content for input[27].

2.7.8 EMISSION CONTROL EFFICIENCY (P)

This guidance does not provide specific emission control efficiencies for mining activities under the category of material handling, transporting, and storage. Instead, it acknowledges the variability in dust control efficiency as recommended by various jurisdictions, such as U.S. EPA AP-42[9], NPI[13], and WRAP[10]. This approach allows flexibility for users to select and justify the appropriate control efficiency values based on their specific dust control methods and site conditions.

2.8 UNDERGROUND MINING

Activities like drilling, blasting, and material handling are fundamental processes common to both open-pit and underground mining operations. However, underground mining presents unique conditions due to enclosed spaces and ventilation complexities that necessitate specialized approaches for estimating and mitigating emissions.

In underground mining, fugitive PM emissions generated from various activities are typically aggregated within the mine's enclosed spaces. They are released through ventilation points (i.e., shafts), which serve as pathways for the discharge of airborne contaminants from the underground environment. The estimation of fugitive PM emissions in underground mining should be based on either measured or designed PM concentrations and flow rates (or direct emission rates) at these ventilation points.

Underground mines also have surface activities, such as haul roads and stockpiles, which may closely resemble those found in open-pit mining operations.

To actively control and mitigate air emissions from underground activities, the implementation of control equipment such as cyclones or baghouses at ventilation exits is recommended. These control technologies are designed to capture and remove PM from the ventilation air before it is released into the atmosphere.

2.9 OTHER SOURCES

AP-42 does not provide fugitive PM emission factors for crushing/screening/grinding specifically for coal mining operations. Coal processing methods vary widely, and some may fall under industrial process rather than the mining sector. Where site-specific testing or manufacturer data are available, they should be used to estimate emissions from coal processing.

In the absence of coal-specific data, emission factors from AP-42 Chapter 11.19.2[29] may be used as surrogates for crushing, screening, and other activities. However, due to differences in material properties such as moisture content, friability, and bulk density, caution should be exercised when applying these factors to coal.

Emission factors in Chapter 11.19.2 are provided for TPM defined as PM_{100} (PM with an aerodynamic diameter less than or equal to 100 µm).

Furthermore, the following subsections identify two additional sources and provide detailed descriptions for each:

- metallic minerals processing, and
- activities during the mine construction stage.

2.9.1 METALLIC MINERALS PROCESSING

AP-42 Chapter 11.24[30] and NPI Table 3[13] provide single-valued TSP and PM_{10} emission factors (factors represent uncontrolled emissions unless otherwise noted) for various types of mineral processing activities under the category of high moisture content ores and low moisture contents ores, including:

- Primary crushing,
- Secondary crushing,
- Tertiary crushing,
- Screening,
- Dry grinding with air conveying, and
- Dry grinding without air conveying.

The emissions factors are summarized in Table 2-19. These emission factors for metalliferous mines are different from those for coal mines.

[29] U.S. EPA, 1995. AP-42 Chapter 11.19.2. Crushed Stone Processing and Pulverized Mineral Processing. https://www.epa.gov/sites/default/files/2020-10/documents/c11s1902.pdf . Accessed in April 2025.
[30] U.S. EPA, 1995. AP-42 Chapter 11.24. Metallic Minerals Processing. Access: https://www.epa.gov/sites/default/files/2020-10/documents/c11s24.pdf . Accessed in April 2025.

Table 2-19: Emission Factors for Metallic Minerals Processing

Material	Source	TSP Emission Factor[C] (kg/tonne)	PM_{10} Emission Factor[C] (kg/tonne)
High moisture ore [a]	Primary crushing	0.01	0.004
	Secondary crushing	0.03	0.012
	Tertiary crushing	0.03	0.01
	Screening	-	-
	Dry grinding with air conveying and/or air classification	14.4	13
	Dry grinding without air conveying and/or air classification	1.2	0.16
Low moisture ore [b]	Primary crushing	0.2	0.02
	Secondary crushing	0.6	-
	Tertiary crushing	1.4	0.08
	Screening	0.08	0.06
	Dry grinding with air conveying and/or air classification	14.4	13
	Dry grinding without air conveying and/or air classification	1.2	0.16

Notes:

a: High-moisture ore is defined as the ore with the moisture content of 4% by weight or greater, measured at the primary crusher inlet or at the mine.

b: Ore is defined as low moisture when a dryer precedes the operation under consideration or when the ore moisture content at the mine or primary crusher is less than 4% by weight.

c: Sourced from AP-42 Chapter 11.24[30] and NPI Table 3[13].

It is important to note the following:

- The activity rates for emission factors in Table 2-19 are the mass weight of the material processed.

- If $PM_{2.5}$ emission factors cannot be obtained from the available publicly published standards/guidance, assume $PM_{2.5} = PM_{10}$ as a conservative assumption.
- Emission factors are not provided for wet grinders because the high moisture content in these operations can reduce emissions to negligible levels.
- It is assumed that filterable PM and PM_{10} can represent total TSP and PM_{10}, respectively.
- Emissions from metallic mineral processing plants are usually controlled with wet scrubbers or baghouses. Users have options to select and justify control efficiency based on design and/or manufacturer data available for this type of control equipment.

2.9.2 ACTIVITIES DURING MINE CONSTRUCTION STAGE

Activities associated with the mine construction stage include demolition and debris removal and site preparation (earth moving). AP-42 Chapter 13.2.3[28] provides emission estimation methods for these construction operations.

Fugitive PM emissions generated from construction activities may not be steady or follow a discernable annual cycle due to the temporary nature of construction. The following two factors should be considered:

- The construction operations have a definable beginning and an end.
- Activities vary over different phases of the construction process.

For these reasons, AP-42 guidance recommends breaking down the construction process into component operations and then calculating emissions for each component. Table 13.2.3-1 of AP-42 Chapter 13.2.3 provides recommended emission factors for construction operations. Since the activities involved in the construction operations are similar to those described previously for normal mining operations, most approaches, including emission control efficiencies, refer to methods described in Section 2 of this document.

3 SUMMARY

This guidance provides the fugitive PM emission estimation methodologies recommended for mining operations within B.C. These methodologies rely on emission factors sourced from the U.S. EPA AP-42, Canadian NPRI tool, and Australian NPI.

The guidance recommends a two-year transition period for implementing on-site sampling and testing, following the publication of the document for existing facilities. During this transition period, users have the flexibility to utilize default values based on AP-42 or WRAP or use measured onsite data for input variables such as silt contents, moisture contents, and road surface silt loadings. After the two-year transition period, onsite measurements are expected for these input variables, except for newly proposed projects, which may use alternative approaches as outlined in Section 2. Following the transition period or once a newly proposed project is constructed, submission of updated sampling and testing results may be required to verify assumptions that were made for the assessment.

Although the guidance offers a comprehensive framework, users retain the flexibility to choose alternative emission estimation methods and emission control efficiencies that are not explicitly detailed within this guidance. Such choices should be thoroughly justified to ensure transparency and accuracy in emissions estimations. A systematic approach for providing justifications includes:

- Understanding the site-specific condition and dust control methods,
- Consulting reliable public guidance, standards, or research papers, such as U.S. EPA AP-42, NPI, WRAP,
- Choosing estimation methods and control efficiency values that align with site-specific condition, dust control measures and technologies implemented,
- Clearly citing the sources of selected estimation methods and control efficiency values,
- Providing design results, calculations, and/or long-term monitoring data to support selections.
- Considering site-specific factors such as material characteristics, climate, or operational practices.
- Documenting your justification and providing rationales.

Below are some common sources of uncertainty when using published emission factors:

- Different mining sites and operations can have unique characteristics that are not fully represented by generic emission factors,
- The data used to derive the emission factors may not be comprehensive or up-to-date, and
- Emission factors often rely on certain assumptions and default values.

The following strategies can help to address these uncertainties and enhance the accuracy of emissions estimates:

- Collecting site-specific data such as silt and moisture content, as outlined in this guidance, helps account for unique conditions and characteristics.
- Regularly reviewing and updating emission estimate methods as conditions change (e.g., AP-42 chapters are updated) ensure that estimates remain reflective of current practices and technology.
- Engaging with industry experts and specialists in emissions estimation provides valuable insights and guidance and helps improve the accuracy of estimates.

- Implementing monitoring programs and conducting sensitivity analyses provides a proactive approach to understanding and managing potential discrepancies in emissions estimates.

APPENDIX 1: EMISSION SOURCE CHECKLIST

Category	ID	Emission Sources/Activities	Check (Y/N)
Wheel generated dust	1	Unpaved roads (industrial roads)	
	2	Unpaved roads (publicly accessible roads)	
	3	Paved roads	
Wind erosion	4	Wind erosion from active exposed areas	
	5	Wind erosion from active stockpiles	
Blasting and drilling	6	Blasting (overburden and coal)	
	7	Drilling (overburden and coal)	
Material handling, transporting and storage	8	Bulldozing overburden	
	9	Bulldozing coal	
	10	Grading	
	11	Dragline (on overburden)	
	12	Scraper (travel mode)	
	13	Scraper (removing topsoil)	
	14	General loading/unloading of overburden/waste rock	
	15	Truck loading or unloading of coal	
	16	Specific loading: train loading coal (batch or continuous drop)	
	17	Specific loading: truck loading by power shovel overburden (batch drop)	
	18	Specific unloading: end dump truck unloading (batch drop) Coal	
	19	Specific unloading: bottom dump truck unloading (overburden and coal) batch drop	
	20	Specific unloading: scraper unloading Topsoil (batch drop)	
Metallic Minerals Processing	21	Screening, crushing, grinding, drying, and others	
Construction Operations	22	Demolition and debris removal & Site Preparation (earth moving)	
Underground mining	23	Fugitive dust generated underground exhausted via ventilation points	
Other sources	24	Other activities not mentioned above	

APPENDIX 2: OVERVIEW OF FUGITIVE PM EMISSION ESTIMATION TECHNIQUES FOR MINING ACTIVITIES IN BRITISH COLUMBIA

Category	ID	Emission Activity	Recommended Methodology	Source of Size-Specific Emission Factors	Units of Emission Factors	Emission Estimation Equations for Fugitive PM			Variables				
						TSP	PM_{10}	$PM_{2.5}$	Surface Silt Content (s) (%)	Moisture Content (M) (%)	Mean Wind Speed (S) (m/s)	Mean Vehicle Weight (W) (tonnes)	Others
Wheel generated dust	1	Road dust from unpaved roads (industrial roads)	EPA AP-42, Chapter 13.2.2, equation 1a Where: s = surface material silt content (%) W = mean vehicle weight (tonnes)	EPA AP-42, Chapter 13.2.2	kg/VKT	$1.381\ (s/12)^{0.7} \times (W/2.72)^{0.45}$	$0.423\ (s/12)^{0.9} \times (W/2.72)^{0.45}$	$0.042\ (s/12)^{0.9} \times (W/2.72)^{0.45}$	on site data	-	-	on site data	-
	2	Road dust from unpaved roads (publicly accessible roads)	EPA AP-42, Chapter 13.2.2, equation 1b Where: s = surface material silt content (%) M = surface material moisture content (%) S = mean vehicle speed (km/h)	EPA AP-42, Chapter 13.2.2	kg/VKT	$1.69\ (s/12) \times (S/48.28)^{0.3} / (M/0.5)^{0.3} - 0.000132$	$0.507\ (s/12) \times (S/48.28)^{0.5} / (M/0.5)^{0.2} - 0.000132$	$0.0507\ (s/12) \times (S/48.28)^{0.5} / (M/0.5)^{0.2} - 0.000101$	on site data	on site data	on site data (km/h)	-	
	3	Road dust from paved roads	EPA AP-42, Chapter 13.2.1, equation 1 Where: sL = road surface silt loading (g/m^2), W = mean vehicle weight (tonnes)	EPA AP-42, Chapter 13.2.1	g/VKT	$3.23\ (sL)^{0.91} \times (1.1023W)^{1.02}$	$0.62\ (sL)^{0.91} \times (1.1023W)^{1.02}$	$0.15\ (sL)^{0.91} \times (1.1023W)^{1.02}$	-	-	-	on site data	on site data: road surface silt loading, g/m^2

Category	**ID**	**Emission Activity**	**Recommended Methodology**	**Source of Size-Specific Emission Factors**	**Units of Emission Factors**	**Emission Estimation Equations for Fugitive PM**			**Variables**				
						TSP	**PM_{10}**	**$PM_{2.5}$**	**Surface Silt Content (s)** **(%)**	**Moisture Content (M)** **(%)**	**Mean Wind Speed (S)** **(m/s)**	**Mean Vehicle Weight (W)** **(tonnes)**	**Others**
Wind erosion	4	Wind erosion from exposed areas	EPA AP-42, Chapter 13.2.5 Where: u* =friction velocity (m/s) u_t*=threshold friction velocity (m/s) u_{10}^+ is the fastest mile for a reference anemometer at 10 meters height	AP-42 Chapter 13.2.5 <u>(Users can choose to use the WRAP RMC method. However, it is strongly recommended that the user review the inputs required for the method.</u>	g/m^2	$P_i=58(u^*-u_t^*)^2+25(u^*-u_t^*)$ $P_i=0$ for $u^* \le u_t^*$ $u^*=0.053 \times u_{10}^+$	0.5 × TSP	0.075 × TSP	-	-	representative time-varying hourly wind speed	-	(1) On site or representative threshold friction velocity (u_t*) (2) A typical roughness height (z_o) of 0.5 cm (0.005 m) has been assumed for open terrain. A site-specific roughness height should be used if it is available.
	5	Wind erosion from active stockpiles	EPA AP-42, Chapter 13.2.5 Where: Pi = erosion potential for the ith period between disturbances u* =friction velocity (m/s) u_t*=threshold friction velocity (m/s) u_{10}^+: fastest mile value at the reference height of 10m u_s/u_r: ratio of surface wind speed (u_s) to approach wind speed (u_r)	AP-42 Chapter 13.2.5	g/m^2	$P_i=58(u^*-u_t^*)^2+25(u^*-u_t^*)$ $P_i=0$ for $u^* \le u_t^*$ $u^*=0.10(u_s/u_r) \times u_{10}^+$ The profiles of u_s/u_r in Figure 13.2.5-2 and subarea size in Table 13.2.5-3 can be used to estimate the surface friction velocity for each subarea of similarly shaped piles.	0.5 × TSP	0.075 × TSP	-	-	representative time-varying hourly wind speed	-	(1) On site or representative threshold friction velocity (u_t*) (2) A typical roughness height (z_o) of 0.5 cm (0.005 m) has been assumed. A site-specific roughness height should be used if it is available.
Blasting and drilling	6	Blasting (overburden and coal)	EPA AP-42, Chapter 11.9 Where: A = horizontal area (m^2), with blasting depth ≤ 21 m. Not for vertical face of a bench.	AP-42 Table 11.9-2	kg/blast	$0.00022(A)^{1.5}$	0.52 × TSP	0.03 × TSP	-	-	-	-	on site data (horizontal area blasted per blast A, m^2)
	7	Drilling (overburden and coal)	EPA AP-42, Chapter 11.9	AP-42 Table 11.9-4 for TSP. Particle Size Multipliers based on ECCC "Pits and Quarries Reporting Guide"	kg/hole	0.59 kg/hole for overburden, and 0.10 kg/hole for coal	0.52 × TSP	0.52 × TSP	-	-	-	-	-
Material handling, transporting, and storage	8	Bulldozing overburden	EPA AP-42, Chapter 11.9 Where: M = material	AP-42 Table 11.9-2	kg/h	$2.6 (s)^{1.2}/(M)^{1.3}$	$0.75 \times (0.45 (s)^{1.5}/(M)^{1.4})$	0.105 × TSP	on site data	on site data	-	-	-

Category	ID	Emission Activity	Recommended Methodology	Source of Size-Specific Emission Factors	Units of Emission Factors	Emission Estimation Equations for Fugitive PM			Variables				
						TSP	PM_{10}	$PM_{2.5}$	Surface Silt Content (s) (%)	Moisture Content (M) (%)	Mean Wind Speed (S) (m/s)	Mean Vehicle Weight (W) (tonnes)	Others
			moisture content (%) s = material silt content (%)										
	9	Bulldozing coal	EPA AP-42, Chapter 11.9 Where: M = material moisture content (%) s = material silt content (%)	AP-42 Table 11.9-2	kg/h	$35.6 (s)^{1.2}/(M)^{1.3}$	$0.75 \times (8.44 (s)^{1.5}/(M)^{1.4})$	$0.022 \times$ TSP	on site data	on site data	-	-	-
	10	Grading	EPA AP-42, Chapter 11.9 Where: S = mean vehicle speed (km/h)	AP-42 Table 11.9-2	kg/VKT	$0.0034 (S)^{2.5}$	$0.60 \times (0.0056 (S)^{2.0})$	$0.031 \times$ TSP	-	-	on site data (km/h)	-	
	11	Dragline (on overburden)	EPA AP-42, Chapter 11.9 Where: d = drop height (m) M = material moisture content (%)	AP-42 Table 11.9-2	kg/m^3	$0.0046 (d)^{1.1}/(M)^{0.3}$	$0.75 \times (0.0029 (d)^{0.7}/(M)^{0.3})$	$0.017 \times$ TSP	-	on site data	-	-	on site data (drop height, m)
	12	Scraper (travel mode)	NPI 2012 (Section 1.1.12) Where: s = surface material silt content (%) W = mean vehicle weight (tonnes)	NPI 1.1.12 for TSP and PM_{10}. Use the same Particle Size Multiplier as grading for $PM_{2.5}$	kg/VKT	$9.6\ s^{1.3} \times W^{2.4}/(10)^6$	$1.32\ s^{1.3} \times W^{2.4}/(10)^6$	$0.031 \times$ TSP	on site data	-	-	on site data	-
	13	Scraper (removing topsoil)	EPA AP-42, Chapter 11.9	AP-42 Table 11.9-4 for TSP. PM_{10} and $PM_{2.5}$ Particle Size Multipliers are the same as the ones for scraper (travel mode)	kg/Mg	0.029 kg/Mg	$0.1375 \times$ TSP	$0.031 \times$ TSP	-	-	-	-	-
	14	General loading/unloading of overburden/waste rock (also used for miscellaneous transfer and conveying based on NPI 2012)	EPA AP-42 Chapter 13.2.4, equation 1 Where: U = mean wind speed (m/s) M = material moisture content (%)	AP-42, Chapter 13.2.4	kg/Mg	$0.74 \times (0.0016) \times (U/2.2)^{1.3}/(M/2)^{1.4}$	$0.35 \times (0.0016) \times (U/2.2)^{1.3}/(M/2)^{1.4}$	$0.053 \times (0.0016) \times (U/2.2)^{1.3}/(M/2)^{1.4}$	-	on site data	U: hourly varying wind speed or six mean wind speeds (hourly varying wind speeds binned to six wind speed categories defined by CALPUFF), m/s	-	-
	15	Truck loading or unloading of coal	EPA AP-42, Chapter 11.9 Where: M = material moisture content (%)	AP-42 Table 11.9-2	kg/Mg	$0.58/(M)^{1.2}$	$0.75 \times (0.0596/(M)^{0.9})$	$0.019 \times$ TSP	-	on site data	-	-	-

Category	ID	Emission Activity	Recommended Methodology	Source of Size-Specific Emission Factors	Units of Emission Factors	Emission Estimation Equations for Fugitive PM			Variables				
						TSP	PM_{10}	$PM_{2.5}$	Surface Silt Content (s) (%)	Moisture Content (M) (%)	Mean Wind Speed (S) (m/s)	Mean Vehicle Weight (W) (tonnes)	Others
	16	Specific loading-train loading coal (batch or continuous drop)	EPA AP-42, Chapter 11.9 Table 11.9-4	AP-42 Table 11.9-4 for TSP, PM_{10} and $PM_{2.5}$ Particle Size Multipliers are the same as the ones for Aggregate Handling (AP-42 13.2.4)	kg/Mg	0.014 kg/Mg	0.47 × TSP	0.072× TSP	-	-	-	-	-
	17	Specific loading-truck loading by power shovel overburden (batch drop)	EPA AP-42, Chapter 11.9 Table 11.9-4	AP-42 Table 11.9-4 for TSP, PM_{10} and $PM_{2.5}$ Particle Size Multipliers are the same as the ones for Aggregate Handling (AP-42 13.2.4)	kg/Mg	0.018 kg/Mg	0.47 × TSP	0.072 × TSP	-	-	-	-	-
	18	Specific unloading-end dump truck unloading coal (batch drop)	EPA AP-42, Chapter 11.9 Table 11.9-4	AP-42 Table 11.9-4 for TSP, PM_{10} and $PM_{2.5}$ Particle Size Multipliers are the same as the ones for Aggregate Handling (AP-42 13.2.4)	kg/Mg	0.004 kg/Mg	0.47 × TSP	0.072 × TSP	-	-	-	-	-
	19	Specific unloading-bottom dump truck unloading (overburden and coal) batch drop	EPA AP-42, Chapter 11.9 Table 11.9-4	AP-42 Table 11.9-4 for TSP, PM_{10} and $PM_{2.5}$ Particle Size Multipliers are the same as the ones for Aggregate Handling (AP-42 13.2.4)	kg/Mg	0.001 kg/Mg for overburden; 0.033 kg/Mg for coal	0.47 × TSP	0.072 × TSP	-	-	-	-	-
	20	Specific unloading-scraper unloading Topsoil (batch drop)	EPA AP-42, Chapter 11.9 Table 11.9-4	AP-42 Table 11.9-4 for TSP. PM_{10} and $PM_{2.5}$ Particle Size Multipliers are the same as the ones for Aggregate Handling (AP-42 13.2.4)	kg/Mg	0.02 kg/Mg	0.47 × TSP	0.072 × TSP	-	-	-	-	-
Metallic minerals Processing	21	Processing (such as screening, crushing, grinding, drying, etc.) and other activities	Use AP-42 Chapter 11.24 Table 11.24-1 as the primary reference for high moisture content ores and low	AP-42 Table 11.24-1, with AP-42 Table 11.19.2-1, NPI 2012, ECCC, and other reliable public sources as	-	PM values in AP-42 Table	PM_{10} values in AP-42 Table (if PM_{10} emission factors are not available, use NPI 2012 Table 3 PM_{10}/TSP ratio to obtain PM_{10})	If $PM_{2.5}$ emission factors are not provided by AP-42, NPI 2012, and ECCC, assume $PM_{2.5}$ = PM_{10} as a conservative assumption	-	-	-	-	-

Category	ID	Emission Activity	Recommended Methodology	Source of Size-Specific Emission Factors	Units of Emission Factors	Emission Estimation Equations for Fugitive PM			Variables				
						TSP	PM_{10}	$PM_{2.5}$	Surface Silt Content (s) (%)	Moisture Content (M) (%)	Mean Wind Speed (S) (m/s)	Mean Vehicle Weight (W) (tonnes)	Others
			moisture content ores. If the emission factors are not available in Table 11.24-1, then use AP-42 Table 11.19.2-1, NPI 2012, ECCC, and other reliable public sources as additional references. Their use should be clearly documented and justified.	additional references									
Activities associated with mine construction stage	22	Demolition and debris removal & site preparation (earth moving)	EPA AP-42 Chapter 13.2.3 Table 13.2.3-1	Refer to the emission estimation for ID# 1 to 21 in this table for each activity, correspondingly	-	-	-	-	-	-	-	-	-
Underground mine	23	Air pollutant concentration at ventilation points (i.e., vertical shaft) and flow rate can be used to calculate emissions underground, including fugitive PM emissions	Measured or designed	-	-	TSP concentration multiplied by flow rate	PM_{10} concentration multiplied by flow rate	$PM_{2.5}$ concentration multiplied by flow rate	-	-	-	-	-
Other sources	24	Coal processing (such as screening, crushing, grinding) and other activities	EPA AP-42, NPI 2012, ECCC NPRI Tools, and other reliable public sources as additional references	-	-	-	-	-	-	-	-	-	-

Notes:
(1) For activities not in this table, obtain emission factors for these specific activities from reliable references (for example, US EPA AP-42, NPI 2012, ECCC NPRI Tools). You need to detail them in the model plan and get approval from B.C. ENV.

(2) ID numbers with a dark yellow background indicate that the activity emission estimation methodology is not generic but specific to the described conditions, with emission factors rating D or E. Users should use them as alternative methods. Predictive emission factor equations, which generally provide more accurate emissions estimates, are presented in AP-42 Chapter 13.2.4.

(3) Emission control efficiencies for the relevant activities are detailed in Section 2.