Ontario

DRAFT RATIONALE REPORT

FOR THE

DEVELOPMENT OF AN ONTARIO TECHNICAL STANDARD TO MANAGE AIR POLLUTION FOR THE MINING SITES (MINING SITES – INDUSTRY STANDARD)

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DRAFT – for discussion purposes

Ontario Ministry of the Environment and Climate Change
Environmental Sciences and Standards Division
Standards Development Branch
XXXXXXXXXX, 2017

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DRAFT

Table of Contents

1.0 INTRODUCTION

1.1 Background

Regulating air contaminants from industrial sources is a priority in Ontario. Ontario's local air quality regulation (O. Reg. 419/05: Air Pollution – Local Air Quality) works within the province's air management framework by regulating air contaminants released into communities by various sources including local industrial and commercial facilities. The ministry regulates contaminants in air because we want to be protective of communities who live close to industrial sources. Ontario has a unique regulatory approach to improving local air quality that starts with setting science-based standards to protect human health and the environment. While these standards may not always be achievable due to limitations in technology or economics, the goal is to reduce emissions through continuous improvement and best available technologies and practices over time. Some facilities that are not able to meet an air standard may request a site-specific or technical standard. These standards require companies to invest in the best available technologies and practices to reduce air emissions and improve air quality over time. These standards are all about getting new investments in modern air pollution approaches with the goal of minimizing air pollution over time.

The regulation includes three compliance approaches for industry to demonstrate environmental performance and make improvements when required. Industry can:

- meet the air standard;
- request and meet a site-specific standard; or
- register and meet the requirements under a sector-based technical standard (if available).

All three approaches are allowable under the regulation.

Site-specific and technical standards are developed with full public transparency through public meetings and consultations. The ministry closely oversees the companies' progress to ensure they are achieving the desired results. We have seen vast improvements to address air emissions as a result of our regulatory approach. The ministry consults the public on all applications for site-specific and technical standards and public input plays an integral role in the ministry's review of proposals.

In 2011, the Ministry introduced new/updated standards for eight contaminants, which included an annual standard for nickel (Ni) and nickel compounds, which took effect on July 1, 2016. In 2012, the Mining Sites sector in Ontario through the Ontario Mining Association (OMA) identified that some of its members will be challenged to meet this new standard and requested we work with them to develop a technical standard compliance approach (see Appendix 4.1 letter from the President of the Ontario Mining Sites Association (OMA)).

A technical standard is a technology-based solution designed for two or more facilities in a sector that are not able to meet an air standard due to technical or economic limitations. This approach can include technology, operation, monitoring and reporting requirements.
Once established, any facility in the sector (that may or may not meet the air standard) may request to be registered under the technical standard. Technical standards can be used to manage air emissions for multiple facilities within one or more sectors and can include a wide range of contaminants.

- As set out in the Regulation, the Minister has the authority to establish two types of technical standards:
  - **<u>Industry standards</u>** (deals with all sources of specified contaminants from a specific sector), and
  - **<u>Equipment standards</u>** (only addresses one source of contaminant, but may apply to multiple sectors)

The Ministry is proposing a Mining Sites – Industry Standard (hereafter referred to as Mining Sites IS or MSIS). If all sources of a contaminant from a facility are addressed by one or more technical standards, and the facility is registered under these compliance approaches, and complies with the industry standard regulatory requirements, then the facility is deemed to be in compliance with the regulation for those contaminants. If facilities emit contaminants from sources that are not considered to be part of the technical standard for this sector, or if they are not registered for those contaminants, they must comply with the regulation either through the air standard or site-specific standard compliance approach.

When the Ministry develops a technical standard, representative facilities in the sector are compared to what other facilities around the world are required or capable of achieving to determine whether the same can be required of Ontario facilities. Development of a technical standard includes a better understanding of the specific sources of contaminants for that sector, benchmarking technology to address the sources of contaminants, and consideration of economic issues that relate to the sector. The goal is to have a more efficient legislative tool to better manage air emissions from various industrial and commercial facilities in a sector.

The technical standards publication specifies the classes of facilities and the contaminants the technical standard applies to and the steps and time periods for compliance. Industry standards and equipment standards are published in the document "Technical Standards to Manage Air Pollution". This Technical Standards Publication (PIBS #7306e) may be updated from time to time, based upon public consultation consistent with the Ontario Environmental Bill of Rights legislation. Although industries participating in the technical standards will in most cases not meet certain standards in the Regulation, they are still expected to make continual improvements to better manage air emissions over time to the extent that the technology and methods make this possible.

1.2 Purpose and Scope of Mining Sites Industry Standard

The purpose of this report is to set out the rationale for the development of a proposed Mining Sites IS for the mining sector which includes:

- Consideration of appropriate Canadian and other jurisdictional methods and technologies to assess, reduce and control emissions from relevant processes and equipment;
- Consultation and consideration of input from industry regarding the technical aspects and potential impacts of a proposed technical standard for the mining sector;
- Consultation and consideration of input from the public and other stakeholders located in the communities surrounding Ontario's mining facilities; and
- Development of a proposed technical standard that fosters continuous improvement in reducing emissions from Ontario's mining facilities.
- Note: this proposed Mining Sites IS does not apply to smelters or refineries.

The scope for the proposed Mining Sites IS is summarized below:

Scope of Technical Standard for Mining Sector

"IN" Scope
• **Determine the North American Index Classification System (NAICS) code(s) applying to the Mining Sites IS.** • **Consider of all significant air emissions sources (point and fugitive) of nickel and nickel compounds from metal mining sites operations, including mills, mine ventilation exhaust, non-ore bearing rock and tailings.** • **Harmonization with requirements (as appropriate) for metal mining sites under the *Canadian Environmental Protection Act*.** • **Identification and assessment of best available control technologies and applicable operational practices that can better manage air emissions from metal mining sites operations.** • **Cost effectiveness and economic achievability, as appropriate and as identified by the sector.** • **Public consultation as well as consideration of input from Indigenous communities.** • **Proposal initially considered emissions of nickel and nickel compounds from metal mines but also include other contaminants included in the ore identified during the course of discussions with the technical committee that will also be reduced by the same technology or operational practices considered for nickel and nickel compounds.**

1.3 Organization of Report

Chapter 1.0 provides background to Ontario's local air quality regulation including the three compliance pathways available to facilities along with the underpinning authority through which the Ministry administers technical standards. The overall organization of the report is also presented in this chapter.

Chapter 2.0 provides an overview of the mining sector in Ontario.

Chapter 3.0 summarizes the processes and equipment utilized in the mining sector, identifies key contaminants associated with those processes/equipment and identifies the dominant sources of air emissions.

Chapter 4.0 summarizes the technical requirements associated with mining operations across several jurisdictions including Environment Canada, the United States of America and the

European Union (EU). The focus is on the technical requirements rather than on how these other jurisdictions regulate mining operations.

Chapter 5.0 examines current practices available around the world and being used at Ontario facilities to mitigate air emissions from mining sites operations.

Chapter 6.0 defines the types of technically feasible methods available to address air emissions from mining operations, and concludes by providing a summary of the recommended air pollution control strategies which consider cost effectiveness issues identified by the sector.

Chapter 7.0 summarizes the public consultation efforts to date which were carried out in support of this proposal for a Mining Sites IS and the planned path forward.

Chapter 8.0 takes into consideration the first seven chapters of this report, and presents the proposed structure for the Mining Sites IS. The rationale for the proposed requirements is discussed and the means of assessing continuous improvement are explored.
Chapter 9 is a summary of the conclusions and recommendations.

1.4 Authority

The Regulation (see sections 38 thru 44) provides authority to the Minister of the Environment and Climate Change to publish and amend the Technical Standards publication entitled "Technical Standards to Manage Air Pollution". The Technical Standard publication is available through the Ministry website and the Ministry's Public Information Centre and version 5.0 was last amended July 27, 2016. The Ministry proposes to update this Technical Standards Publication to include the Mining Sites IS into Chapter 8. A draft of this proposal has been provided in a separate document for review during the consultation period.

2. SECTOR OVERVIEW

The purpose of mining is to extract metal and mineral resources from the earth that are used to develop infrastructure and to produce goods and materials for society. Mining activities can include the extraction of ferrous metal or base metal minerals, coal, or industrial minerals that are used in the chemical sector or for construction purposes. This proposed Mining Sites-Industry Standard is intended to apply to base metal mines from facilities identified as part of the North American Industry Classification System maintained for Canada by Statistics Canada (NAICS) code 212232 (nickel-copper mines) and 212233 (copper-zinc mines). However, general mining information is provided here for the reader's reference.

A review of the literature indicates that the roots of mining in Canada go back over 6000 years, in the Lake Superior area. Early mining activity included nothing more than excavation of simple pits by First Nations (Indigenous) people who used the copper they produced to fashion tools and jewelry to trade with neighboring tribes. The first Europeans to mine in Canada were the Vikings, around 998 A.D. on the easternmost shore of L'Anse Aux Meadows, Newfoundland.

Current mining practices commenced in the mid-to-late 1600's in New Brunswick with the extraction and export of coal. Other milestones in Canadian mining history include:

1729 - first smelting of iron at the Forges du St. Maurice, Trois-Rivières, Quebec
1823 - discovery of gold in Quebec
1883 - discovery of a copper - nickel ore body near Sudbury, Ontario

DRAFT

1903 - discovery of silver at Cobalt, Ontario
1912 - first oil sands boom begins in Fort McMurray, Alberta
1950 - discovery of uranium deposits in the Athabasca basin in northern Saskatchewan
1998 – first diamonds commercially mined from kimberlite at Ekati mine in Yellowknife.

Mining accounts for a significant portion of Canada's economy. According to Natural Resources Canada the total value of Canadian mineral production in 2015 was $42.8 billion, only slightly lower (-2.6%) than the 2014 value of $43.9 billion.
Canada's mining and exploration companies are also dominant players in the global mining industry. More than 800 Canadian companies are active in more than 100 countries and have foreign assets totalling more than C$129 billion. Canadian mining companies operate over 350 mines in off-shore locations in the US, South America, Africa, Australasia and Europe.

In 2013, there were 30 operating metal mines in Ontario. More than half are gold mines; the rest are base metals (nickel, copper and zinc) mines, with a palladium and one iron mine also in operation. The rest of Ontario's mines are mainly located in the southern part of the province and produce non-metallic minerals such as silica, gypsum, talc and salt.

Figure 2-1: Types of mines operating in Ontario shows the breakdown of mines in Ontario (provided by the Ontario Ministry of Northern Development and Mines (MNDM)). Additional information on gold, platinum and diamond mines are provided for background purposes only. However, this proposal is only for base metals (nickel, copper and zinc) mines in Ontario.

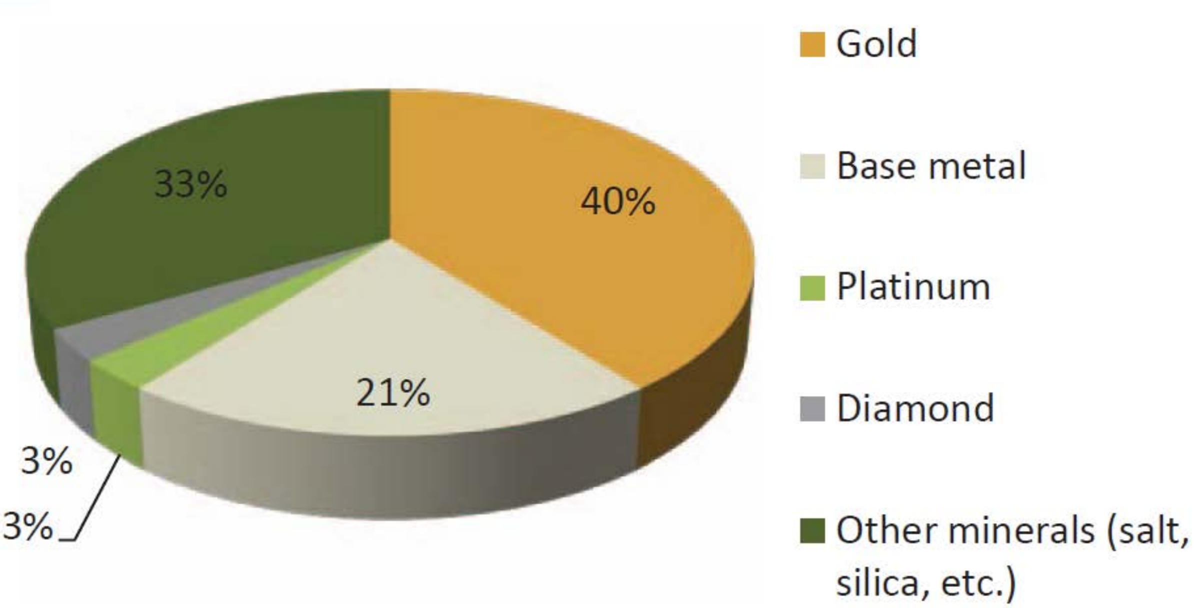


Figure 2-1: Types of mines operating in Ontario (MNDMF 2011)

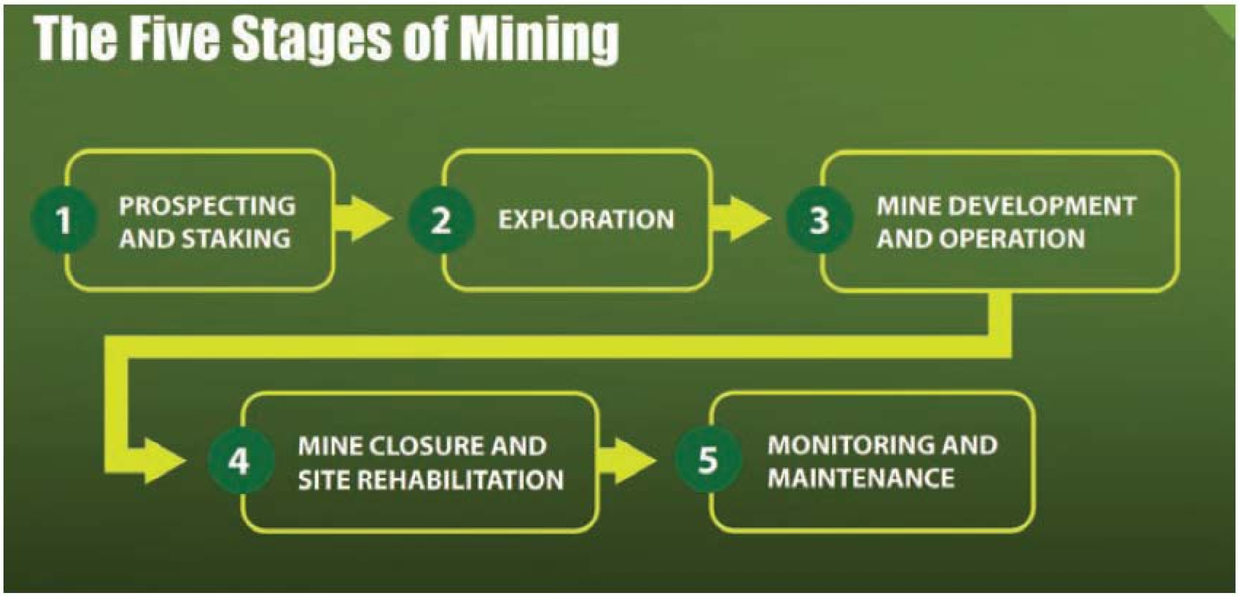
The following are the different phases and timelines of a mine:

- Prospecting and Claim Staking:1-2 years
- Basic and Intermediate Exploration: 3-4 years
- Advanced Exploration: 5-10 years

- Development and Production: 5-100 years
- Closure and Rehabilitation: 2-10 years
- Monitoring: 5-100 years

These steps are summarized in Figure 2-2: The Five Stages of Mining.

Figure 2-2: The Five Stages of Mining



Typically, the mine and the mineral processing plant are designed to extract as much marketable product(s) as possible. The residue and overall environmental management is then designed as a consequence of these process steps. The management of the residues produced, such as, the topsoil, overburden, the tailings and the non-ore bearing rock presents an undesired financial burden on operators.

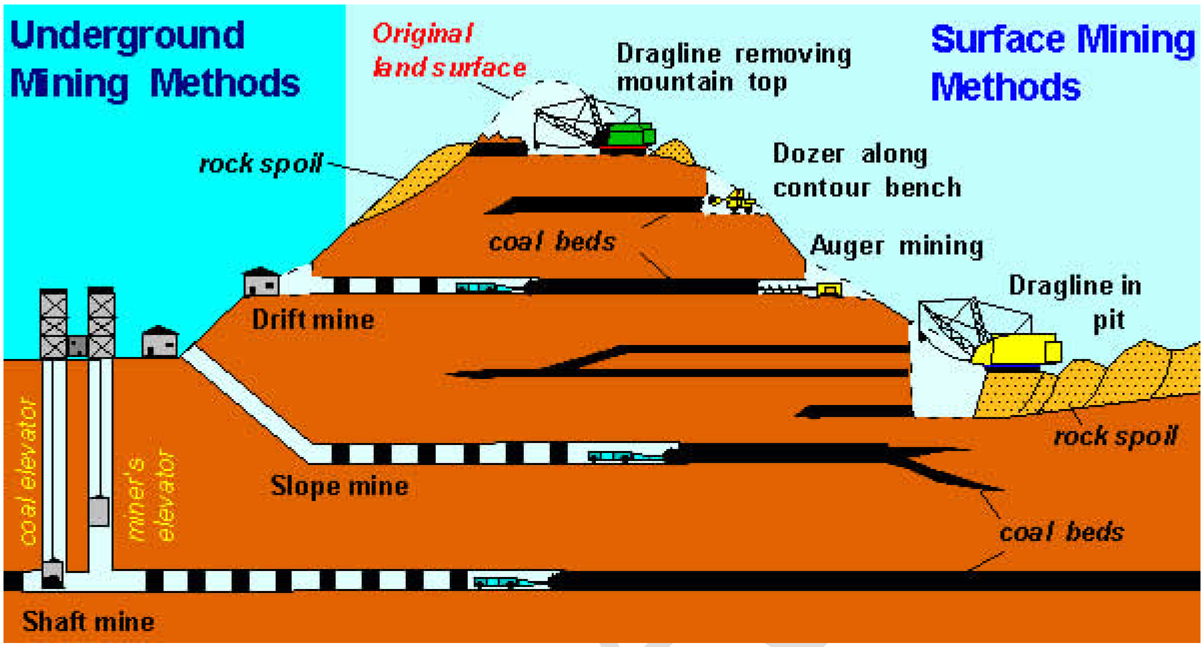
2.1 Mining Methods

The topographic, geological and hydro geological situation, as well as the geometry and morphology of the ore deposit, determine the mining method used (surface or underground mining). The chemical composition and mineralogy of the ore deposit determine to a large extent the type of processing, and the reserves and the economic conditions determine the production rate. For example, if two copper ores have respective contents of 7% and 0.7%, for 1 tonne of copper produced, the first one will produce 11.5 tonnes of non-ore bearing rock while the second will produce 164.4 tonnes.

Open pit mining is generally used for large, low-grade mineral deposits that are close to the surface, while underground mining is generally used for deeper, concentrated deposits. Open pit and underground operations may be conducted on the same site.

The set of activities that describe the different stages of mining is called the mining sequence. It is helpful to understand the mining sequence, as each part of this sequence comes with different demands on communities and the environment. Below is a description of some common mining methods.

Figure 2-3: Mining Methods



2.1.1 Surface Mining

Surface mines are mining operations that delve into rock to extract deposits of mineral resources that are close to the surface. In most forms of surface mining, heavy equipment, such as earthmovers, remove the overburden (the soil and rock above the deposit). Next, huge machines such as drag line excavators extract the mineral. Once the material has been removed, the land is recovered for safe use on the surface through a process called reclamation.

Following are some of the variations of surface mining.

2.1.1.1 Placer Mining

Placer mining involves any type of mining where raw minerals are deposited in sand or gravel or on the surface and are picked up without having to drive, use dynamite or any other significant means. This is an older form of mining. For example, the simplest technique of placer gold mining is panning. In panning, some sediment is placed in a large metal pan, combined with a generous amount of water, and agitated so that the sand flows over the side. Any gold particles contained in the sand, due to the higher density of gold, will tend to remain on the bottom of the pan after all of the sand and mud have been removed. The same principle may be employed on a larger scale by constructing a short sluice box, with barriers along the bottom to slow the movement of gold particles. This method better suits excavation with shovels or similar implements to feed sediment into the device.

2.1.1.2 Strip Mining

Strip mining is the practice of mining a seam of mineral ore by first removing all the soil and rock that lies on top of it (the overburden). It is like open-pit mining in many regards. Strip mining is only practical when the ore body to be excavated is relatively near the surface. Since colossal quantities of material often need to be removed, the excavating machinery used in strip mining is often among the largest equipment ever constructed. Drag line excavators and bucket-wheel excavators are common examples. There are two forms of strip mining - area strip mining, which is used on flat terrain to extract deposits over a large area and contour strip mining, which is usually used in hilly terrain and involves cutting terraces in mountainsides following the contour of the land.

2.1.1.3 Mountaintop Removal

Mountaintop removal is a relatively new form of coal mining that involves the mass restructuring of earth to reach sediment as deep as 1,000 feet below the surface. Mountaintop removal requires that the targeted land be first clear-cut and then levelled by explosives.

2.1.1.4 Hydraulic

Hydraulic mining involves high pressure water. The water is sprayed at an area of rock and/or gravel and the water breaks the rock up, dislodging ore and placer deposits. The water/ore mixture is then milled. Due to the destructive impacts of this type of mining method, many jurisdictions do not allow it.

2.1.1.5 Open Pit

Open pit mines involve digging large open holes in the ground as opposed to a small shaft in hard rock mining. This method of mining is most often used with minerals like copper and molybdenum. Open pit mines are very large and mostly away from urban areas but there are some exceptions.

2.1.1.6 Dredging

Dredging is a method often used to bring up underwater mineral deposits. Although dredging is usually employed to clear or enlarge waterways for boats, it can also recover significant amounts of underwater minerals relatively efficiently.

2.1.2 Underground Mining

Underground mining refers to a group of techniques used for the extraction of valuable minerals or other geological materials from the earth. In contrast to the other main type of excavation, surface mining, underground or sub-surface mining requires equipment and people to operate under the surface of the earth.

2.1.2.1 Drift Mining

Drift mining is a method of accessing valuable geological material, such as coal, by cutting into the side of the earth, rather than tunnelling straight downwards. Drift mines have horizontal entries into the coal seam from a hillside. Drift mines are distinct from slope mines, which have

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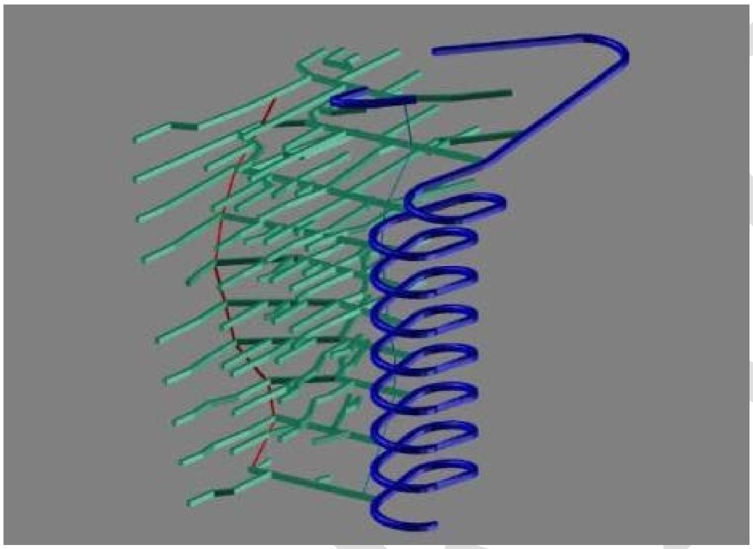
an inclined entrance from the surface to the coal seam. If possible, drifts are driven at just a slight incline so that removal of material can be assisted by gravity.

2.1.2.2 Slope Mining

Slope mining is a method of accessing valuable geological material, such as coal. A sloping access shaft travels downwards towards the coal seam. Slope mines differ from shaft and drift mines, which access resources by tunnelling straight down or horizontally, respectively. Declines (see Figure 2-4: Decline Mining) can be a spiral tunnel which circles either the flank of the deposit or circles around the deposit. The decline begins with a box cut, which is the portal to the surface. Depending on the amount of overburden and quality of bedrock, a galvanized steel culvert may be required for safety purposes.

Figure 2-4: Decline Mining



2.1.2.3 Shaft Mining

Shaft mining is a type of underground mining done by use of a mine shaft. A mine shaft is a vertical passageway used to access an underground mine. On the surface above the shaft stands a building known as the head frame, which in previous years contained a winding engine and in modern times contains an electric hoist controller. This raises and lowers the cage within the shaft. The cage serves as a lift for the transportation of minerals, equipment, and workers.

2.1.2.4 Hard Rock Mining

Hard rock mining refers to various techniques used to mine ore bodies by creating underground "rooms" supported by surrounding pillars of standing rock. Terms for this include stope and pillar, room and pillar, long hole stopping, benching, vertical crater retreat, block caving, and sub level caving. Hard rock mining is used for mining many ore types such as gold, copper, zinc and diamonds. There are several mining methods that are used to extract the mineral bearing rock from the host rock. Typically, some means of support is required to maintain the openings that are made by mining. This can be done by pillars, which are then mined following the backfilling of the initial slopes. Coarse ore is mucked out using gravity to help move it down rock raises or shafts to waiting trains of ore cars used to move it to the surface. These trains can travel

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through long drifts or tunnels ending in portals to the mills on the surface. Ore is also moved in skip buckets hauled up shafts and emptied into bins beneath surface head frame towers for transport to the mill. Ore is also hauled in large trucks to the surface.

2.1.2.5 Borehole Mining

Borehole mining is a remotely operated method of mining mineral resources through boreholes by means of high pressure water jets. This process can be carried out from the land surface, open pit floor, underground mine, floating platform, or vessel through pre-drilled boreholes.

2.2 Existing Ontario Nickel-Copper–Zinc Ore Mining Facilities

This proposed Mining Sites-Industry Standard is intended to apply to base metal mines from facilities identified as part of the North American Industry Classification System maintained for Canada by Statistics Canada (NAICS) code 212232 (nickel-copper mines) and 212233 (copper-zinc mines). A total of 37 Ontario facilities reported to the National Pollutant Release Inventory (NPRI) in 2012 under NAICS code 2122 (Metal Ore Mining); seventeen are nickel-copper mines (NAICS code 212232) and one is a copper-zinc mine (NAICS code 212233).

A more detailed, updated description is given in Table 2-1:

Table 2-1: Ontario Nickel-Copper-Zinc ore mining facilities

Nr.	***Company/ operation***	***Ore***	***Location***	**Mining method**
1	First Nickel Inc. – Lockerby Mine	Nickel-Copper	Chelmsford	
2	FNX Mining Company Inc. – McCreedy West Mine	Nickel-Copper	Levack	Decline - Hardrock
3	FNX Mining Company Inc. – Levack Mine	Copper	Levack	Shaft - Hardrock
4	Liberty Mines-McWatters Mine	Nickel-Copper	South Porcupine	
5	Liberty Mines Inc.-Redstone Mine and Mill	Nickel-Copper	South Porcupine	
6	Vale - Coleman Mine	Nickel-Copper	Levack	Underground
7	Vale - Creighton Mine	Nickel-Copper	Lively	Underground

Nr.	***Company/ operation***	***Ore***	***Location***	**Mining method**
8	Vale - Garson Mine	Nickel-Copper	Garson	Underground
9	Vale – Copper Cliff North Mine	Nickel-Copper	Copper Cliff	Underground
10	Vale - Copper Cliff South Mine	Nickel-Copper	Copper Cliff	Underground
11	Vale – Frood-Stobie Mine	Nickel-Copper	Sudbury	Underground
12	Vale-Totten Mine	Nickel-Copper	Worthington	Underground
13	Vale- Ellen Pit Mine	Nickel-Copper	Lively	Open pit and Underground
14	Vale-Gertrude Mine	Nickel-Copper	Lively	Open pit
15	Glencore Canada Corp.- Sudbury Integrated Nickel Operations – Fraser Mine	Nickel-Copper	Onaping	Underground
16	Glencore Canada Corp.- Sudbury Integrated Nickel Operations – Craig Mine (Operated by KGHM International)	Nickel-Copper	Onaping	Underground
17	Glencore Canada Corp.- Sudbury Op. Mines and Mill- Thayer Lindsley Mine	Nickel-Copper	Val Caron	Inactive closing
18	Glencore Canada Corporation – Sudbury Integrated Nickel Operations .- Nickel Rim South Mine	Nickel-Copper	Skead/ Sudbury	Underground

Nr.	***Company/ operation***	***Ore***	***Location***	**Mining method**
19	Glencore Canada Corporation – Sudbury Integrated Nickel Operations - Strathcona Mill	Nickel-copper	Onaping	Flotation
20	Glencore Canada Corporation – Sudbury Integrated nickel Operations Montcalm Mine	Nickel-Copper	Timmins	Inactive
21	Glencore Canada Corporation – Kidd Mine	Copper - Zinc	Timmins	

This proposed Mining Sites IS will offer a level playing field to address compliance related issues for existing and future mining facilities to be developed in Ontario. Efforts will be made to harmonize with other environmental initiatives and ensure public transparency.

Nickel

Nickel is an element that exhibits chemical valences of 0, +1, +2 and +3. Metallic nickel is not commonly found in nature; however, nickel is found in many minerals.
Nickel has a general concentration 0.008% in the earth's crust. It is found in the soil in two different types of mineralisation: sulphidic and lateritic (oxides). The world has two major reserves of nickel ore types – sulphides (~40%) and laterites (~60%).[22]

Most historical production has come from sulphide ores, with lesser production from laterite ores. Nickel laterite ores are metallurgically complex and not readily amenable to concentration, pyro metallurgical smelting and refining to metal.

Nickel is used primarily in the manufacturing of stainless steel and other alloys due to its favourable properties of hardness, corrosion-resistance, heat-resistance and strength. Examples of alloys include copper-nickel alloys and nickel-chromium alloys. Nickel is also used as a catalyst, in plating, coins, batteries, electrodes, electrical contacts, spark plugs and machinery parts.
Figure 2-5: World nickel mine production 2010-2011 summarizes the world production rates for nickel in different parts of the world including Canada.

Figure 2-6: World nickel reserves summarizes where nickel reserves exist in the world.

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Figure 2-5: World nickel mine production 2010-2011

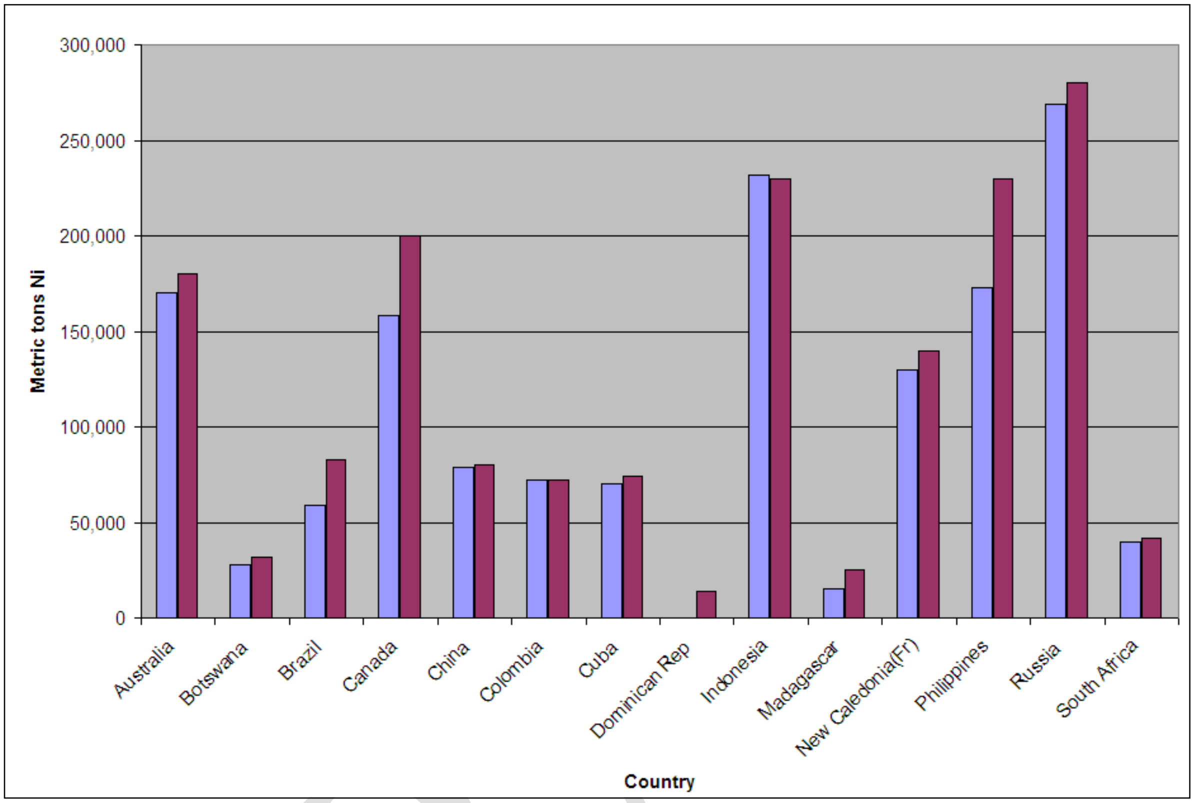

Figure 2-6: World nickel reserves

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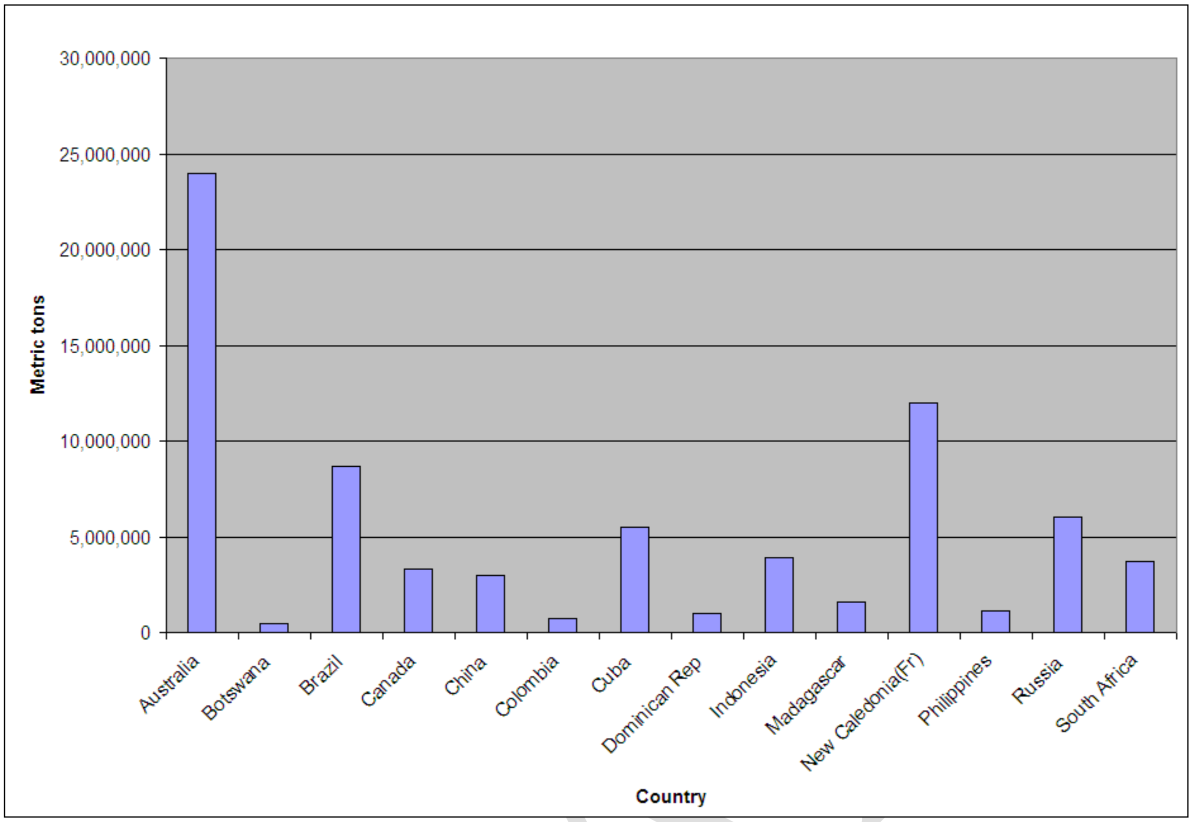

3.0 IDENTIFICATION OF KEY CONTAMINANTS SOURCES AND MANAGEMENT METHODS

3.1 Description of Mineral Processing Techniques/Equipment

The purpose of mineral processing is to turn the raw ore from the mine into a marketable product. This chapter describes the steps involved in mineral processing.

3.1.1 Comminution

Comminution is an essential element of mineral processing. In comminution, the particle size of the ore is gradually reduced. This is necessary for many reasons:

- to liberate one or more valuable minerals from the gangue in an ore matrix;to achieve the desired size for later processing or handling;
- to expose a large surface area per unit mass of material, thus aiding some specific chemical reaction (e.g. leaching); and
- to satisfy market requirements relating to particle size specifications.

Comminution is composed of a sequence of crushing and grinding processes.

3.1.1.1 Crushing

Crushing is the first stage in the comminution process. Crushing is usually a dry operation, which involves breaking down the ore by compressing it against rigid surfaces or by impacting it against hard surfaces in a controlled motion flow. This process step prepares the ore for further size reduction (grinding) or for feeding directly to the classification and/or concentration separation stages. Crushing circuits include in-pit, primary, secondary, tertiary and quaternary crushing systems.

Typical types of crushers are:
- jaw crushers;
- gyratory crushers;
- cone crushers;
- roll crushers; and
- impact crushers.

3.1.1.2 Grinding

Grinding is the final stage in the comminution process and requires the most energy of all the mineral processing stages. Because of this, the tendency is to first blast (in the mine) or crush the ore as fine as possible to reduce the amount of larger materials sent to grinding, thereby reducing the overall energy consumption in grinding. If possible, grinding is performed 'wet' as this requires less energy, allowing energy savings of up to 30 % compared to dry grinding.
In grinding, the particles are usually reduced by a combination of impact and abrasion of the ore by the free motion of grinding bodies such as steel rods, balls or pebbles in the mill.
- Grinding circuits: Large autogenous grinding (AG) and semi-autogenous grinding (SAG) circuits, as well as rod and ball milling.
- Fine grinding: Tower mills, stirred mills and Isa mills for flotation concentrate re-grinding.

3.1.2 Screening

Screening can be defined as a mechanical operation which separates particles according to their sizes and their acceptance or rejection by openings of a screening face.
The most important reasons for screening in mineral processing are:
- to avoid undersized material from entering the crushers;
- to avoid oversized material passing to the later stages in the grinding process or in closed circuit fine crushing; and
- to produce material of controlled particle size, e.g. after quarrying.

3.1.3 Classification

Classification may be described as the separation of solid particles into two or more products according to their velocities when falling through a medium. The velocity of the particles depends on their size, density and shape. In mineral processing, classification is mostly carried out wet, with water being used as the fluid medium. Dry classification, using air as the medium, is used in several other applications (cement, limestone, coal). Classification is normally performed on minerals considered too fine to be separated effectively by screening.

3.1.4 Pre-concentration

Physical separation processes for use prior to flotation, upgrade flotation feed by making use of differences in the physical properties of ore and gangue minerals. These include:
- Dense-Media Separation (DMS)

- Gravity Separation

Spirals separators are used in conjunction with DMS for copper recovery and application of jigs to recover metal from slag.

3.1.5 Flotation and Dewatering

Flotation

During flotation, surface chemistry selectively recovers valuable minerals or rejects gangue materials. Types of flotation include:

- Flash Flotation- In circuits employing multiple stages of milling, flash flotation cells recover liberated mineral species after each stage, to prevent overgrinding.
- Conventional Flotation- Design of banks of conventional flotation cells, and supply of proprietary cells, in addition to design and installation services.
- Tank Cells.
- Column Cells.

Column and Jameson cells, include pumping of high air content froths associated with fine grinding of concentrates.

Dewatering

Dewatering is used to remove water from concentrated material. Dewatering methods include the use of:

- Thickeners- Conventional, high-rate, ultra-high rate and paste thickeners to dewater concentrate, residue and tailings streams.
- Vacuum Filters- Drum, disc and belt filters.

3.2 Key Sources of Air Emission and Contaminants

Every ore, whether metallic or non-metallic, is rarely mono-mineralised, but composed of a complex mineral mixture which likely contains many potential pollutants, in addition to the material being mined.

Moreover, industrial processing methods use chemical components, which may also create air emissions. These components are present in small quantities and are often organic, dissociating rapidly in other molecules. Since excavation and subsequent processing creates different conditions from those that exist where the ore occurs, the chemistry of the elements concerned must also be considered.

Table 3-1: Summary of common sources and air contaminants from mining sites below summarizes the most common sources and air contaminants from the mining sites.

Table 3-1: Summary of common sources and air contaminants from mining sites

Sources of air emissions	Type of mine	Common contaminants
Drilling, Blasting	Open pit	Suspended Particulate Matter(SPM), metals.
Diesel Equipment	-	SPM, SO_2, NO_x, Metals, VOC's.
Ventilation shafts	Underground	CO_2, CO, NO_x, SO_2, SPM, metals.
Mineral processing	Open pit /Underground	SPM, metals.

Sources of air emissions	Type of mine	Common contaminants
(physical processing only, e.g. crushing)		
Fugitive emissions from roads, storage and material handling (loading/unloading ore and non-ore bearing rock, conveyors), and tailings	Mostly Open pit/Underground	SPM, metals.

As described in the Introduction, the Mining Sites IS focuses on sources of metal air emissions from mining sites, including the physical processing of the ore and excluding heat processes or chemical transformation processes.

Figure 3-1: Contribution to TSP emissions of the activities involved in open pit mining for the case of coal production in Colombia during 2009 below shows, as an example, the sources contributing to suspended particulate matter (SPM) emissions in various open pit coalmines. For some facilities, the dominant source was the wind erosion, for others the roads (transportation) or material handling.

A similar analysis was conducted for the sources of SPM (metals are included in the SPM) in nickel-copper-zinc mines, which are in the scope of this proposed Mining Sites - Industry Standard and results are expected to be similar.

Figure 3-1: Contribution to TSP emissions of the activities involved in open pit mining for the case of coal production in Colombia during 2009

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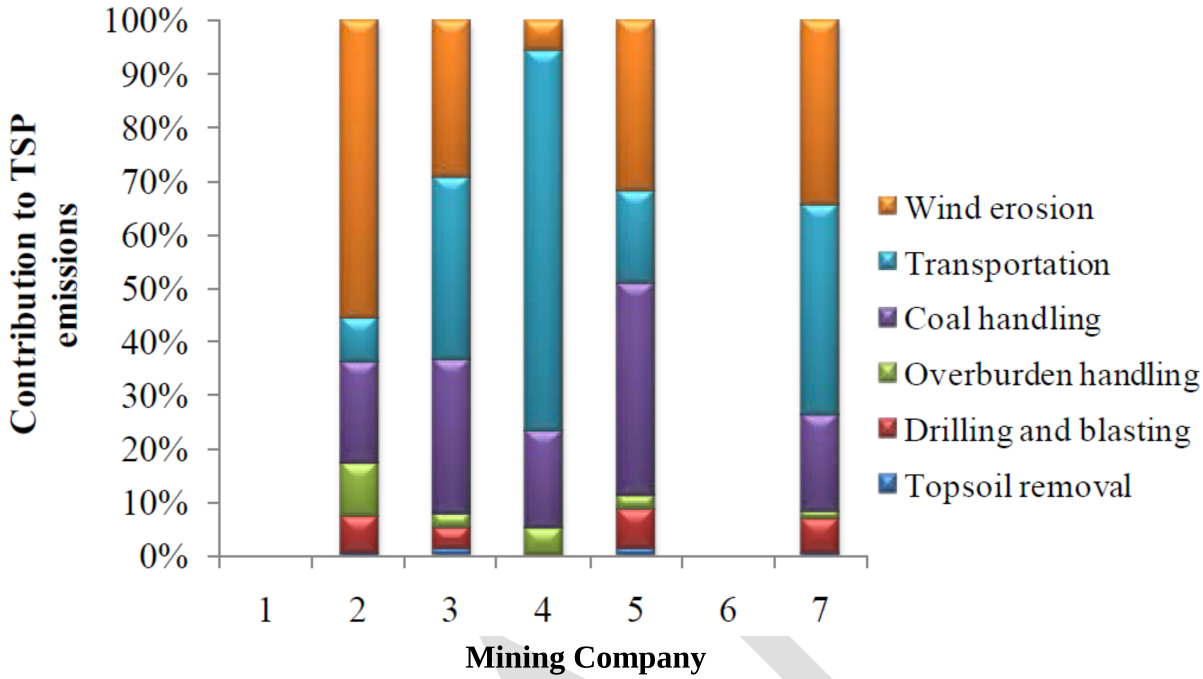

3.3 Dominant Source(s) Analysis for Nickel and Nickel Compounds Air Emissions

The purpose of this type of analysis is to identify the sources of emission that are the dominant contributors to off property point of impingement concentrations of a contaminant.

3.3.1. Dominant Source Analysis Methodology

The dominant source analysis approach used by the Ministry to assist in the development of this proposed Mining Sites – Industry Standard (Mining Sites IS) involved the following approach that was applied to all nickel-copper-zinc Ontario mines submitting information:

- Use the latest emission summary and dispersion modeling reports for each facility (including air dispersion modelling on an annual average basis for nickel) as a basis for the dominant source analysis.
- Run the air dispersion models (e.g., AERMOD) for a large suite of off-site receptors (e.g., greater than a thousand off-site receptors per each facility) to determine the contributions of point of impingement concentrations of each of the source groups.
- Document the results of the modelling in a spreadsheet including factors such as emission estimate data quality and parameters such as source group dispersion factor.
- Based upon the initial set of air dispersion modelling, identification of a sample of receptors that were distributed throughout the exceedence zone. Depending upon the extent of the exceedence zone at each facility, a sampling of between 25 and 50 exceedance zone receptors were identified.

- Run the atmospheric dispersion models a second time but only with the exceedence zone receptors.

- Document the results of the second set of modeling including source group contribution to the point of maximum concentration and average source group contribution to point of impingement concentrations to the group of receptors within the exceedence zone.

3.3.2 Summary of the Results of the Dominant Source Analysis for Nickel Air Emission Sources at Ontario Nickel-Copper Mines

The number of reported nickel emission sources varied between the mining sites.

i) In general, the analysis of dominant sources showed that either one or two of the source group categories contributed about two thirds of the nickel point of impingement concentrations within the exceedence zones for each facility. The type of site-specific source group categories that were dominant varied between the six facilities assessed. However, some trends and commonality between the facilities were identified.

ii) The return air raises (RAR) source group category was the major contributor at one facility and in the top two to three contributing categories for the majority of the facilities.

iii) The fugitive emissions from paved and unpaved roads source group category was within the top two contributing categories for most facilities and was the dominant source for some facilities.

iv) The ore processing (crushing/screening) and handling (loading/unloading, conveying) source group category was in the top three contributing categories for the majority of the facilities.

In summary, the air dispersion modelling results suggest that the return air raises, roads and ore processing and handling will be important source types to assess in terms of best available management methods for nickel air emissions.

In addition, fugitive sources, such as tailings, ore and ore-concentrate storage piles, will be source categories important to address. It is important to note that all these sources are assessed under controlled emissions conditions; any of these sources left uncontrolled or inefficiently controlled could become dominant.

Modelling emissions and impacts of the haul roads proved to be challenging for the modelling community. In 2009, the US EPA formed a Haul Road Workgroup, which studied AERMOD different options applied to roads, and produced in 2012 a Memorandum (Haul Road Workgroup Final Report Submission to EPA-OAQPS) which included recommendations.

The use of non-regulatory defaults in the model, such as depletion, implies a level of site-specificity, which is not compatible with the overarching scope of a technical standard.
Both the Ministry and the OMA agreed that roads are a key source of Suspended Particulate Matter and metals from a mine site and have been managed for many years.

Since roads are one of the dominant sources of emissions from this sector, the draft Mining Sites IS includes requirements for roads to ensure management methods prevent or reduce air emissions where possible. Further details on specifics of modelling roads may be obtained from the upcoming updated guideline (Air Dispersion Modelling Guidelines Ontario - ADMGO). This new guidance may help facilities determine whether they choose to register for this proposed technical standard.

Although the air standard for nickel and nickel compounds is based on an annual average, shorter averaging times of 1 hour and 24 hours were also assessed.
The 1 hour value was used to investigate concerns for acute effects of Ni. The Texas' value of 1.1ug/m3 was used for assessment purposes only.

4.0 JURISDICTIONAL REVIEW

This chapter will summarize how mining sites are regulated in Canada and other jurisdictions.

4.1 CANADA

Under the Canadian Environmental Assessment Act (CEAA) 2012, unless either the Agency has determined that an environmental assessment is not required or a decision statement has been issued and the proponent is acting in accordance with the conditions of that decision statement, the proponent is prohibited from carrying out any part of a designated project that will result in:

- effects on fish and fish habitat, shellfish and their habitat, crustaceans and their habitat, marine animals and their habitat, marine plants, migratory birds, and federal lands;
- effects that cross provincial or international boundaries; and
- a change in the environment that affects First Nations (Indigenous) peoples, such as their use of lands and resources for traditional purposes.

In addition, a federal authority is prohibited from issuing a permit or authorization for a designated project that requires an environmental assessment under the CEAA 2012 unless a decision statement has been issued for the project. The decision statement issued at the end of the environmental assessment includes enforceable conditions with which a proponent must comply. These enforceable provisions under CEAA 2012 are designed to ensure compliance with the requirements of the legislation.

Regulations Designating Physical Activities

Mining projects may be designated for an environmental assessment under Canadian Environmental Assessment Agency. The Minister of the Environment and Climate Change, pursuant to paragraphs 84(a) and (e) of the *Canadian Environmental Assessment Act, 2012* Footnote [a], made the annexed *Regulations Designating Physical Activities*. The following definitions were found:

"Area of mine operations" in relation to a mine, means the area at ground level occupied by any open pit or underground mine workings, mill complex or storage area for waste rock, tailings or ore.

"Physical Activities" SCHEDULE (Sections 2 to 4) regulated under Canadian Environmental Assessment Agency, are defined as :

1. The construction, operation, decommissioning and abandonment, in a wildlife area or migratory bird sanctuary, of a new:
   (a) electrical generating facility or electrical transmission line;
   (b) structure for the diversion of water, including a dam, dyke or reservoir;
   (c) oil or gas facility or oil and gas pipeline;
   (d) mine or mill;
   (e) industrial facility;
   (f) canal or lock;
   (g) marine terminal;
   (h) railway line or public highway;
   (i) aerodrome or runway; or
   (j) waste management facility.

16. The construction, operation, decommissioning and abandonment of a new:
   (a) metal mine, other than a rare earth element mine or gold mine, with an ore production capacity of 3 000 t/day or more;
   (b) metal mill with an ore input capacity of 4 000 t/day or more;
   (c) rare earth element mine or gold mine, other than a placer mine, with an ore production capacity of 600 t/day or more;
   (d) coal mine with a coal production capacity of 3 000 t/day or more;
   (e) diamond mine with an ore production capacity of 3 000 t/day or more;
   (f) apatite mine with an ore production capacity of 3 000 t/day or more; or
   (g) stone quarry or sand or gravel pit, with a production capacity of 1 000 000 t/year or more.

17. The expansion of an existing:
   (a) metal mine, other than a rare earth element mine or gold mine, that would result in an increase in the area of mine operations of 50% or more and a total ore production capacity of 3 000 t/day or more;
   (b) metal mill that would result in an increase in the area of mine operations of 50% or more and a total ore input capacity of 4 000 t/day or more;
   (c) rare earth element mine or gold mine, other than a placer mine, that would result in an increase in the area of mine operations of 50% or more and a total ore production capacity of 600 t/day or more;
   (d) coal mine that would result in an increase in the area of mine operations of 50% or more and a total coal production capacity of 3 000 t/day or more;
   (e) diamond mine that would result in an increase in the area of mine operations of 50% or more and a total ore production capacity of 3 000 t/day or more;
   (f) apatite mine that would result in an increase in the area of mine operations of 50% or more and a total ore production capacity of 3 000 t/day or more; or
   (g) stone quarry or sand or gravel pit that would result in an increase in the area of mine operations of 50% or more and a total production capacity of 1 000 000 t/year or more.

Environment Canada – Environmental Code of Practice for Metal Mines

The Federal Government has also developed an Environmental Code of Practice for Metal Mines.

Concerns Related to Air Quality

Air quality impacts from mining are mainly associated with the releases of airborne particulate matter. Operation of vehicles and generators can also lead to releases of greenhouse gases and various air contaminants, including sulphur oxides, nitrogen oxides, carbon monoxide and particulate matter.

Releases of airborne particulate matter can result from various activities, including blasting, crushing, loading, hauling, and transferring by conveyor. Open pits, non-ore bearing rock piles, tailings management facilities, and stockpiles are potential sources of wind-blown particulate matter.

Common methods to minimize releases of airborne particulate matter include:

- spraying water to maintain sufficient surface moisture;
- using environmentally acceptable chemical sprays to stabilize the surface;
- re-vegetating the parts of the mine site that will not be disturbed in the future;
- controlling dumping or transfer rates of materials;
- covering dump trucks or rail cars to minimize releases during the transportation of material;
- establishing speed limits on unpaved surfaces that are low enough to minimize dust from vehicle operations, considering local weather conditions;
- storing ore or concentrate in storage bins, hoppers or other buildings to eliminate dusting concerns and position the material for loading or transfer;
- covering or enclosing conveyor lines;
- using baghouses or precipitators for point sources of releases such as stacks from ore concentrate driers;
- covering stockpiles or other material that may be a source of releases; and
- temporarily ceasing operations if weather conditions are such that the risks of significant releases of airborne particulate matter are unacceptably high.

The Mining Association of Canada published in 1998 a “Guide to the Management of Tailings Facilities” and a follow up manual in 2003 entitled, “Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities”. This manual was developed to compliment the 1998 guide, focusing on the day to day operations of a tailings facility. The manual draws on sound industrial practice and procedures and was prepared by tailings experts within the Canadian mining community.

4.2 ONTARIO

Local Air Quality Regulation (O.Reg.419/05) under the Environmental Protection Act

Ontario protects air quality through a comprehensive air management framework that includes regulations, targeted programs and partnerships with other jurisdictions to address sources of air pollution.

Ontario’s local air quality regulation (O. Reg. 419/05: Air Pollution – Local Air Quality) works within the province’s air management framework by regulating air contaminants released into communities by various sources, including local industrial and commercial facilities. The regulation aims to limit exposure to substances released into air that can affect human health and the environment, while requiring industry to operate responsibly under a set of rules that are publicly transparent.

The regulation includes three compliance approaches for industry to demonstrate environmental performance and make improvements when required. Industry can:

- meet the general air standard
- request and meet a site-specific standard or
- register and meet the requirements under a sector-based technical standard (if available).

All three approaches are allowable under the regulation.

Provincial air standards are used to assess a facility's individual contribution of a contaminant to air. They are set based on science and may not be achievable by a facility or a sector due to unique technical or economic limitations. In these cases, industries or sectors look to technology and best practices to improve their environmental performance and comply with the regulation.

The regulation is based on five principles:

- Protection
- Science and Technology
- Continuous Improvement
- Transparency
- Flexibility

Protection

Ontario's local air quality regulation works within the province's air management framework by regulating air contaminants released by industrial and commercial facilities.

The regulation, along with the Environmental Protection Act, provides Ministry of the Environment and Climate Change staff with a range of tools that can be used to ensure facilities are operating responsibly and meeting their regulatory obligations.

The ministry works with industry to ensure that facilities are doing their best to manage air emissions and that industry applies the best available technology or best practices when they need to reduce emissions.

Science and Technology

Ontario uses science and technology as the foundation for building environmental policy under the regulation.

Ontario develops air standards by reviewing scientific information about the effects of contaminants on health and the environment, as well as approaches taken in setting air quality criteria by leading organizations such as the United States Environmental Protection Agency, World Health Organization, Health Canada, and various European agencies.

Ontario's general air standards are set based solely on science and therefore may not be achievable by a facility or a sector due to unique technical or economic limitations. Instead of making the air standard less stringent, the regulation allows facilities or sectors to exceed the air standard as long as they are working to reduce their air emissions as much as possible with technology-based solutions and best practices.

The Ministry of the Environment and Climate Change closely oversees their progress using a framework for managing risk that was developed in cooperation with public health units in

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Ontario and other stakeholders.

Continuous Improvement
Most facilities operate under the general air standards compliance approach. Some facilities or sectors may not be able to meet an air standard because of technical or economic limitations. Some facilities may never be able to meet the air standard. In these cases, industries or sectors need to reduce specific contaminants in their air emissions as much as possible by finding technology-based solutions. This is achieved by the site-specific and technical standards compliance approaches.

Science and technology continue to evolve with time. Ontario's local air quality regulation recognizes that significant investments may be needed to keep pace with these new or updated requirements.

The site-specific standard and technical standards compliance approaches allow facilities the time needed to develop and implement an action plan and to work towards improving their environmental performance when necessary. Site-specific standards are periodically reviewed, and technical standards may also be updated based on the availability of new technologies or updated science on a contaminant that suggests more controls are needed.

Emissions are reduced when industrial and commercial facilities invest in new technology solutions and implement best practices.

Although facilities operating under a site-specific standard or technical standard may not meet the general air standard, the focus is on reducing risks to local communities by managing the emissions that contribute most to local exposures.

Transparency
Transparency and public consultation are key requirements built into Ontario's local air quality regulation to ensure communities are informed about the actions facilities are taking to achieve compliance.

The regulatory framework takes into consideration the concerns of the public, businesses, public health and environmental non-government organizations and First Nations and Métis communities.

Through public meetings, consultations and the Environmental Registry, communities are informed about which compliance approach a facility is using and given the opportunity to provide input.

Ontario will continue to consult on how we propose to manage the release of contaminants to air, including decisions made about specific facilities and proposed new requirements for the regulation.

Flexibility
There are three acceptable compliance approaches that facilities can take to meet the provincial requirements for each contaminant emitted. Each approach has potentially different outcomes for the community but each is structured to demonstrate environmental performance or improve performance, as needed, over time.

The regulation allows industries or sectors to exceed the air standards so long as they reduce

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specific contaminants in their air emissions as much as possible by implementing technology-based solutions and best practices.

The approach taken by the United States has similar elements but relies more heavily on prescribed technology requirements for all regulated facilities. Ontario's approach allows us to focus on those facilities that need to take action, rather than prescribing technology requirements for all regulated facilities. The three acceptable compliance approaches are:

- Meet a general air standard by the date specified in the regulation.

  Request and meet a site-specific standard for an individual facility.
  When a facility cannot meet an air standard, it may be eligible to request a site-specific standard. Facilities eligible to request a site-specific standard are those facing technical or economic challenges in meeting a provincial air standard.

- A site-specific standard is an approved air concentration based on technology considerations.

  It is approved by a director of the Ministry of the Environment and Climate Change for an individual facility.

  This approach focuses on actions to reduce emissions to air as much as possible considering the technology that is available and best operational practices. Economic factors may also be considered.

  A facility that meets its site-specific standard is in compliance with the regulation.

  Site-specific standards can be approved for a period of five years to 10 years, upon which a facility may make a subsequent request.

- Register and meet the requirements under a sector-based technical standard, if available.

  Sometimes, two or more facilities in a sector may not be able to meet an air standard due to technical or economic issues. In this case, the regulation allows for sector-based technical standards to be developed.

  Sector-based technical standards set out technical and operational requirements for major sources of air emissions identified in a sector.

  A technical standard can be an industry standard applied to multiple facilities within one sector, or an equipment standard that addresses a source of contaminant in one or more industry sectors.

  A facility that meets its obligations under a technical standard is in compliance with the regulation.

  Technical standards do not expire, but can be updated based on the availability of newer technologies, updated science on a contaminant that suggests more controls are needed, or at the request of industry or community stakeholders.

Ontario Mining Act

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The Mining Act is the primary piece of legislation that establishes the general framework for the exploration and development of minerals in Ontario.
As the Mining Act dated back to the 19th century, to improve and modernize the mineral development process in Ontario, a piece of legislation, Bill 173 - An Act to Amend the Mining Act was introduced. After extensive review, the bill was passed which resulted in the Mining Amendment Act, 2009. The amendment received Royal Assent on October 28, 2009. Bill 173 was passed in 2009 to modernize the Mining Act and promote mineral exploration and development in a manner that recognizes Aboriginal and treaty rights, is more respectful of private landowners, and minimizes the impact of mineral exploration and development on the environment.

The purpose of the Mining Act is to encourage prospecting, staking and exploration for the development of mineral resources, in a manner consistent with the recognition and affirmation of existing First Nations (Indigenous) and treaty rights in section 35 of the Constitution Act, 1982, including the duty to consult, and to minimize the impact of these activities on public health and safety and the environment.

Ministry of Northern Development and Mines (MNDM) has taken a phased approach to implementing Mining Act Modernization and the changes introduced by Bill 173. The changes to the Act, regulations and operational policies, which largely focused on private landowners, (e.g. notice of staking, mining land tax exemption), took effect in 2011. Most of the remaining changes to the Act came into effect in November 2012; they included provisions for exploration plans and permits, clarification of Aboriginal consultation requirements, criteria for protection of sites of Aboriginal cultural significance (SOACS), and the Mining Act Awareness Program.

Ontario Occupational Health and Safety ActOntario's Occupational Health and Safety Act (OHSA) is cornerstone legislation for workplace health and safety. The main purpose of the Act is to protect workers from health and safety hazards on the job. It sets out duties for all workplace parties and rights for workers. It establishes procedures for dealing with workplace hazards and provides for enforcement of the law where compliance has not been achieved voluntarily. More information is available by the Ministry of Labour.

O. REGULATION 854, MINES AND MINING PLANTS is also relevant for this sector:

257. In an underground mine, clean water under pressure shall be made available for dust control purposes in a workplace where rock or ore is drilled, blasted,

loaded or transported. R.R.O. 1990, Reg. 854, s. 257.

258. In an underground mine, broken rock or ore shall be thoroughly wetted by water,

(a) during blasting operations or immediately thereafter; and

(b) when the ore or rock is being loaded or scraped. R.R.O. 1990, Reg. 854, s. 258.

259. Sections 257 and 258 do not apply at a salt mine or any other operation where the ore or rock is hygroscopic. R.R.O. 1990, Reg. 854, s. 259.

4.3 QUEBEC

Environment Quality Act, Clean Air Regulation (Gouvernement du Québec - 18 May 2011 R.S.Q., c. Q-2), DIVISION III: FUGITIVE PARTICLE EMISSION STANDARDS:

*12. Particle emissions from the transfer, fall or handling of materials including aggregates, ashes, grains, fertilizers, sawdust, wood chips, **mine tailings, ore, ore concentrate, ore slag,** coal, coke or iron concentrate pellets must not be visible more than 2 m from the emission point.*

4.4 EUROPEAN UNION

On July 16, 2008, the European Commission presented a series of proposals on sustainable consumption and production that will contribute to improving the environmental performance of products and increase the demand for more sustainable goods and production technologies. The proposals sought to encourage EU industry to take advantage of opportunities to innovate. The building blocks of the European Union's policy on sustainable consumption and production include Integrated Product Policy.
Integrated Product Policy is an approach pursuing the reduction of the environmental impacts of products throughout their life cycle (from the mining of raw materials to production, distribution, use and waste management). The intention is to address potential environmental impacts at each stage of the life cycle.

The EU's non-energy extractive industry is striving to remain competitive by supplying high quality materials. Increasing automation, particularly in deep mines, has resulted in a reduced work-force and higher productivity. The industry continues to make progress in environmental performance through the transfer of knowledge and the use of best available techniques. The implementation of environmental legislation, such as the Environmental Impact Assessment Directive, also requires the industry to be more knowledge based.

Metal mining occurs in many of the EU-27 countries, and mainly in the more northern and more southern countries, such as Sweden, Finland, Greece, Spain and Portugal. There is also substantial metal mining in Poland, Slovakia, Bulgaria and Romania. New mines continue to be developed, and provide employment and economic growth in regions which have difficulties attracting other forms of investment.

A comprehensive framework for the safe management of waste from extractive industries at EU level is now in place comprising:

- Directive 2006/21/EC on the management of waste from the extractive industries (the mining waste directive).
- a Best Available Techniques reference document for the management of tailings and waste-rock in mining activities; and
- an amendment of the Seveso II Directive to include in its scope mineral processing of ores and, in particular, tailings ponds or dams used in connection with such mineral processing.

Although not specifically for mining sector, the Non-Ferrous Metals BREF (Section 2.12.4 of the GC/EIPPCB/NFM_Final Draft, October 2014) and the Emissions from Storage BREF lists Best Available Technologies (BAT) for ore storage, handling and transportation.

4.5 UNITED STATES - SUMMARY OF FEDERAL STATUTES AND REGULATIONS

Clean Air Act

Under §111 of the CAA, New Source Performance Standards (NSPS) applicable to metallic mineral-processing plants have been established (40 CFR 60 Subpart LL). These standards regulate emissions of particulate matter in metal mining operations in crushers, conveyor belt transfer points, thermal dryers, product packaging stations, storage bins, truck loading and unloading stations, and rail car loading and unloading. Although all underground mining facilities are exempt from these provisions, fugitive dust emissions from mining activities may be regulated (usually by requiring dust suppression management activities) through State permit programs established to meet Federal National Ambient Air Quality Standards (NAAQSs).

For example, the Maximum Achievable Control Technology (MACT) for Iron Taconite Ore Crushing and Handling, is as follows:

The PM emissions limits for ore crushing and handling are 0.008 grains per dry standard cubic foot (gr/dscf) for existing sources and 0.005 gr/dscf for new sources. Compliance with the PM emissions limits for ore crushing and handling is determined based on the flow-weighted mean concentration of emissions for all ore crushing and handling units at the plant.

Industry-Specific Requirements
Three types of laws govern and/or regulate the mining of metal resources. The first type, (i.e., the Mining in National Parks Act and the Wild and Scenic Rivers Act), define areas that are off-limits to metal mining. The second type of law, (i.e., the General Mining Law of 1872), defines methods for allocating metal deposits for extraction. The third type of law, governs the extraction process and establishes restrictions on the types and amounts of wastes that may be generated.

Other Acts and regulations: Clean Water Act, Safe Drinking Water Act, Toxic Substances Control Act, National Environmental Policy Act (NEPA), Endangered Species Act, Resource Conservation and Recovery Act, Comprehensive Environmental Response, Compensation and Liability Act, Emergency Planning And Community Right-To-Know Act.

CALIFORNIA

AQMD Rule 403: South Coast Air Quality Management District (AQMD) is the regulatory agency for southern California. The rule, amended in 2005, applies to all activities capable of generating fugitive dust. The purpose of the rule is to: "*reduce the amount of particulate matter entrained in the ambient air as a result of anthropogenic (man-made) fugitive dust sources by requiring actions to prevent, reduce or mitigate fugitive dust emissions."*

Requirements (summary):
(1) No person shall cause or allow the emissions of fugitive dust from any active operation, open storage pile, or disturbed surface area such that:

> *(A) the dust remains visible in the atmosphere beyond the property line of the emission source; or*
> *(B) the dust emission exceeds 20 percent opacity (as determined by the appropriate test method included in the Rule 403 Implementation Handbook), if the dust emission is the result of movement of a motorized vehicle.*

The rule is not specific to mining, but contains rules for activities encountered at mining sites (soil disturbing, earth moving (material handling), stock piles, roads).

Mostly it refers to water spraying, chemical dust suppressants application, re-vegetation, PM10 sampling and monitoring.
Under Rule 403:

- fugitive dust emissions cannot remain visible in the atmosphere beyond the property line of the emission source;
- the dust emission cannot exceed 20 percent opacity if the dust emission is the result of movement of a motorized vehicle;
- active operations must apply the applicable best available control measures included in Tables of the Rule to minimize fugitive dust emissions from each fugitive dust source type within the active operation; and
- PM10 levels cannot exceed 50 micrograms per cubic meter when determined, by simultaneous sampling, as the difference between upwind and downwind samples collected on high-volume particulate matter samplers or other U.S. EPA-approved equivalent method.

Additional requirements for large operations include:
- implement the applicable actions specified in the Tables of the Rule, at all times;
- assign a dust control supervisor, who has completed the AQMD Fugitive Dust Control Class and has been issued a valid Certificate of Completion for the class, available on site within 30 minutes during working hours, who has the authority to expeditiously employ sufficient dust mitigation measures to ensure compliance with all Rule requirements;
- AQMD-approved dust control plan annually revised; and
- maintain daily records to document the specific dust control actions taken, maintain such records for a period of not less than three years; and make such records available to the Executive Officer upon request;

EKAPCD Rule 402- Eastern Kern Air Pollution Control District (California) 2015 proposed amendments
- Provisions of amended Rule 402 are applicable to specified outdoor fugitive dust producing activities, which include: handling, storage, and transport of bulk storage piles, construction, demolition, excavation, extraction, and other earthmoving activities, including, but not limited to, land clearing, grubbing, scraping, on-site travel including travel on access roads to and from the job site, and any other anthropogenic condition resulting in wind erosion.

ARIZONA

Arizona is home to many copper and copper-molybdenum mines. Mining facilities are required to:

- Report Excess Emissions;

- Report Permit Deviations;

- Operating the mining facilities is subject to Permit Limitations (“The Permittee shall not cause or permit the airborne diffusion of visible emissions, including fugitive dust, beyond the property boundary line within which the emissions become airborne. Within actual practice, the airborne diffusion of visible emissions across property lines shall be prevented by appropriately controlling the emissions at the point of discharge, or ceasing entirely the activity or operation which is causing or contributing to the emissions.”)

- Daily (or more often) visible emissions survey;

- PM10 emission limits per each source;

- Air pollution control requirements (crushers, transfer points/loading/unloading, general ventilation of stockpile building need to be controlled by a baghouse).

- Trucks required to be covered.

-Dust Control Plan

- Monitoring:
  - Within 90 days prior to the start-up of mine operations, the Permittee shall install, operate and maintain a continuous particulate matter monitor at the mining site to monitor ambient concentrations of PM10.
  - If the monitored daily average of PM10 is greater than 150 µg/m3, the Permittee shall notify the Director of the event by a FAX communication within 24 hours of discovery. The cause of the exceedance shall be included in the notification, if known. It shall be the responsibility of the Permittee to demonstrate to the satisfaction of the Director whether the exceedance was or was not primarily caused by the Permittee's operations.
  - If such concentrations are not shown to be primarily the result of emissions from a source or sources other than the Permittee, the Permittee shall implement immediate actions, including, but not limited to, a reduction in the level of operations, with the intention of avoiding a repeat of the exceedance. The immediate corrective actions shall be continued until the alternative control plan is implemented. The Permittee shall be required to develop an alternative control plan to eliminate the problem(s).

4.6 UNITED NATIONS

Because of the number of issues now considered to be "environmental" a wide range of specific laws and regulations may apply. All countries face the decision as to how much environmental legislation should be generic to all industries, and how much should be specific to the mining industry. The administrative arrangements for enforcement tend to be complex because the division of responsibilities between mining, environmental, health and water ministries (amongst others), and between national, provincial or state and local levels of government is seldom straightforward. There is unfortunately no ideal system, and each country needs to decide based on its own priorities and circumstances.

Fundamental Principles for the Mining Sector (taken from the Berlin Guidelines):

Governments, mining companies and the minerals industries should as a minimum:

1. Recognize environmental management as a high priority, notably during the licensing process and through the development and implementation of environmental management systems. These should include early and comprehensive environmental impact assessments, pollution control and other preventative and mitigative measures, monitoring and auditing activities, and emergency response procedures.

2. Establish environmental accountability in industry and government at the highest management and policy-making levels.

3. Encourage employed at all levels to recognise their responsibility for environmental management and ensure that adequate resources, staff, and requisite training is available to implement environmental plans.

4. Ensure the participation and dialogue with the affected community and other directly interested parties on the environmental aspects of all phases of mining activities.

5. Adopt best practices to minimise environmental degradation, notably in the absence of specific environmental regulations.

6. Adopt environmentally sound technologies in all phases of mining activities and increase the emphasis on the transfer of appropriate technologies which mitigate environmental impacts including those from small-scale mining operations.

7. Seek to provide additional funds and innovative financial arrangements to improve environmental performance of existing mining operations.

8. Adopt risk analysis and risk management in the development of regulation and in the design, operation, and decommissioning of mining activities, including the handling and disposal of hazardous mining and other wastes.

9. Reinforce the infrastructure, information systems service, training and skills in environmental management in relation to mining activities.

10. Avoid the use of such environmental regulations that act as unnecessary barriers to trade and investment.

11. Recognise the linkages between ecology, socio-cultural conditions and human health and safety, both within the workplace and the natural environment.

12. Evaluate and adopt, wherever appropriate, economic and administrative instruments such as tax incentive policies to encourage the reduction of pollutant emissions and the introduction of innovative technology.

13. Explore the feasibility of reciprocal agreements to reduce transboundary pollution.

14. Encourage long term mining investment by having clear environmental standards with stable and predictable environmental criteria and procedures.

4.6.1 UN Mining Legislation

Mining laws aim to regulate the sector in a variety of ways, and some environmental requirements such as waste disposal, occupational safety, control of water contamination are sometimes incorporated into such laws. While mining laws are rarely specific enough to allow for broad environmental programs, this approach is nevertheless a useful first step to environmental control in countries where the appropriate controls do not yet exist elsewhere, or where they are very specific to mining operations.

Some environmental matters that mining laws may incorporate into specific schedules or regulations include:

- safety of structures and operations (limiting exposure to chemicals; explosive hazards);
- establishment of wastewater retention and treatment techniques, safe management of contaminated runoff, and groundwater contamination;
- soil erosion control and re-vegetation procedures during the operation as well as afterwards;
- requirements to prepare plans for mine waste disposal; and
- reclamation and restoration of sites and disturbed areas, and removal of all unused structures and machinery.

4.6.2 UN Environmental Legislation

Environmental laws are used to address a wider range of ecological, conservation, pollution and health issues and have a much wider application than just mining. Due to the range of issues, these may be dealt with by separate laws, perhaps even administered by different agencies such as pollution, conservation and national parks bodies. Among the matters that may be covered by specific environmental legislation are:

- environmental impact assessment (EIA), or other environmental planning. Regulations may require that a formal assessment report be prepared for approval, but may also involve some form of project permit;
- nature conservation, protection of national parks, flora and fauna, endangered species and special scientific sites as well as cultural heritage and landscape features;
- water pollution laws to limit discharges into waterways of mine drainage, of wastewater and also polluted runoff;
- "clean air" laws to regulate air emissions, toxic gases or dusts from mining and refining operations; and
- soil contamination by waste and chemicals.

Other issues such as noise, waste disposal and chemicals control are also sometimes regulated by environmental laws where they do not appear under health or other legislation.

Where the same issues are also covered by mining laws, the environmental regulation usually takes precedence.

4.6.3 UN Environmental Quality Standards and Criteria

Environmental standards, criteria and norms are found in regulations subordinate to environmental legislation. Standards are a regulatory requirement that provide the numerical limits to which industrial operations must be designed and managed. They can include:

- air emissions, and/or workplace air quality;
- ambient water quality in streams, or effluent discharge standards;
- noise emissions, or exposure;
- waste disposal, especially waste materials allowed to be dumped; and
- human exposure to dust, toxic chemicals or radioactivity.

There are no international environmental standards which apply around the world; each country has its own needs and circumstances and must set its own standards accordingly.

The World Bank International Finance Corporation has developed a series of performance standards on social and environmental sustainability, as well as environmental, health and

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safety guidelines for mining and environmental, health, and safety general guidelines (general EHS guidelines), which are relevant to environmental and social monitoring and auditing.
In addition, an increasingly popular protocol is the Global Reporting Initiative (GRI), which was established by the United Nations in conjunction with governments and civic and industry groups specifically to facilitate consistency and transparency for sustainability reporting (GRI 2006). Although these protocols are essentially voluntary in nature, compliance is increasingly being expected as evidence of good corporate governance.

The GRI provides a framework for annual reporting of a wide range of information and data, with a view to demonstrating progress against sustainable development objectives. It includes qualitative or quantitative indicators covering human rights and economic, social, environmental and labour practices. The GRI has been widely adopted by most major mining companies. Although it could be perceived as standard practice for larger companies, it provides the opportunity to demonstrate a company's commitment to positive outcomes in various sustainability areas, such as water resource protection, biodiversity conservation, education and social investment. On the other hand, it allows a company to acknowledge problems and outline planned responses to resolve them.

4.7 AUSTRALIA

Australia mining regulations are controlled by individual states.

In Western Australia, the Department of Minerals and Energy (DME), through administering the Mining Act 1978, Mining Act Regulations 1981, Mines Safety and Inspection Act 1994 and Mine Safety and Inspection Regulations 1995, regulates safety and environmental aspects of tailings disposal in Western Australia (DME 2000).

In Victoria, the Minerals and Petroleum Division (MPD) of the Victorian Department of Primary Industries (DPI) is responsible for regulating the minerals, petroleum and extractive industries within Victoria and its offshore waters, including Commonwealth waters. The MPD manages the administration of the Mineral Resources Development Act 1990 and the Extractive Industry Development Act 1995 (DPI 2003).

In Queensland, tailings storage facilities are regulated under the Environmental Protection Act 1994 (Robinson 1999).

In Tasmania, a mining lease is required under the Mineral Resources Development Act 1995. Dam safety is handled under The Water Management Act 1999 which highlights in part 8, the regulations on dam construction maintenance and decommissioning. Mineral Resources Tasmania (MRT) impose rehabilitation bonds on tailings projects as they progress. Environmental management plans are required for mines and waste handling, rehabilitation and discharge are covered under this Act.

The DME in Western Australia have produced two guidance manuals to improve tailings management. The Guidelines on the Safe Design and Operating Standards for Tailings Storage (DME 1999), are intended to provide a common approach to the safe design, construction, operation and rehabilitation of a tailings facility, and to provide a systematic method of classifying their adequacy under normal and worst case operating conditions. For the operational stage of a tailings facility the DME requires a site-specific operating manual for every Tailings Management Facility (TMF). Each manual should be prepared in accordance with the Guidelines on the Development of an Operating Manual for Tailings Storage, and is required to be periodically reviewed, updated and audited.

The Australian mining industries (iron ore, bauxite, copper ore, gold ore, nickel ore, silver-lead-zinc ore, uranium ore and other metallic ores) are expected to report emissions of National Pollutant Inventory (NPI) substances to the NPI. The NPI has six different threshold categories (1, 1a, 1b, 2a, 2b and 3), and each NPI substance has at least one reporting threshold. If an NPI substance exceeds a threshold all emissions of that substance from the facility must be reported. In the case of mining operations: the tripping of substance thresholds is likely to result from:

- Materials contained in the raw ore and non-ore bearing rock.
- Materials used in the extraction of products from the ore.
- Fuel storage / usage.

Particulate emission standards are more commonly applied to the discharge of gaseous emissions containing dust, but specific regulatory standards for ambient environmental dust concentrations are not commonly used by the regulatory bodies in Australia. This is in part due to the wide variation in climatic regimes and the often remote locations of mine sites. Regulatory bodies generally accept that mine operators should apply all reasonable and practicable measures in the control of dust. The extent of these measures will differ depending primarily on location and the proximity of populated areas.
Despite the absence of fixed regulatory standards relating to dust emissions, it is common practice for companies using best environmental practices to use internal targets for dust control to achieve certain goals.

Other approaches in Australia

The primary role for pollution prevention and control is assumed by the states, like our provincial ministries of environment in Canada. The Australian Environmental Protection Authority uses several tools (instruments) which are used to minimise wastes, pollution, and environmental risks. These instruments include State Environment Protection Policy, Waste Management Policy, works approvals, licenses, pollution abatement notices, noise control notices, environment improvement plans and industry waste reduction agreements[34].

Table 4-1: Summary of the Protocol for Environmental Management (PEM) for Mining

	Close to residential areas or large urban areas Level 1	**Rural locations with residences in close proximity Level 2**	**Rural locations with no residences nearby Level 3**
Indicators to be Assessed	- PM_{10}, $PM_{2.5}$, respirable, crystalline silica, nuisance dust (dust deposition). - Arsenic (gold mining). - Emissions from combustion processes to be included in modelling. - Other indicators that might be considered on a case-by-case basis.	- PM_{10}, $PM_{2.5}$, respirable, crystalline silica, nuisance dust (dust deposition). - Arsenic (gold mining). - Emissions from combustion processes to be included in modelling. - Other indicators that might be considered on a case-by-case basis.	- PM_{10}, $PM_{2.5}$, respirable, crystalline silica, nuisance dust (dust deposition). - Arsenic (gold mining). - Emissions from combustion processes to be included in modelling. - Other indicators that might be considered on a case-by-case basis.
Monitoring/Modelling data needed for approvals	yes	yes	Modelling only

	Close to residential areas or large urban areas Level 1	**Rural locations with residences in close proximity Level 2**	**Rural locations with no residences nearby Level 3**
Dust control practices to be applied	- All emissions must be controlled by application of best practice. - For Class 3 indicators (respirable crystalline silica, arsenic), emissions must be controlled to the maximum extent achievable.	- All emissions must be controlled by application of best practice. - For Class 3 indicators (respirable crystalline silica, arsenic), emissions must be controlled to the maximum extent achievable.	- All emissions must be controlled by application of best practice. - For Class 3 indicators (respirable crystalline silica, arsenic), emissions must be controlled to the maximum extent achievable.
Operational practices	- Real-time continuous monitoring of PM_{10} and $PM_{2.5}$ and nearest sensitive locations linked to a reactive management strategy. - 12 months of 1 in 6 day sampling for respirable crystalline silica to confirm results of modelling.	- Real-time continuous monitoring of PM_{10} and $PM_{2.5}$ and nearest sensitive locations linked to a reactive management strategy. - 12 months of 1 in 6 day sampling for respirable crystalline silica to confirm results of modelling.	None required for off-site impacts. Occupational health and safety requirements to be met.

4.8 NEW ZEALAND

Good practice guide for assessing and managing the environmental effects of dust emissions[25]: “The key point to recognise with most fugitive dust sources is that nuisance effects will almost certainly occur if the sources are not adequately controlled.” It is more appropriate to put the effort into the design and development of effective dust control procedures. These procedures should be thoroughly documented in a dust management plan.

Under Resources Management Plan, regional and more specific district and site air quality management plans are required to be implemented and monitored.

In the absence of any current national guidelines for dust nuisance, it is appropriate to recommend trigger levels or control limits that could be applied to individual dust sources.

The impact of dust emissions may then be assessed regarding these limits, among other factors.

Table 4-2: Recommended trigger levels for deposited and suspended particulate

Dust type	**Trigger level**	**Preferred method**
Deposited dust	4 g/m^2/30 days (above background concentration) I	ISO DIS-4222.2
Total suspended particulate	80 $\mu g/m^3$ (24-hour average) – sensitive area	AS 3580.9.6-1990 (hi-volume sampler)
	100 $\mu g/m^3$ (24-hour average) – moderate sensitivity	
	120 $\mu g/m^3$ (24-hour average) – insensitive area	

The recommended trigger levels should only be considered in conjunction with the results of other assessments, including complaints surveys and community consultation.

DRAFT

Site-specific trigger levels that are acceptable to the local community should be developed in each case.

Other approaches in New Zealand

The Resource Management Act includes tools (instruments), such as land use planning, regional and district plans, and resource consents (discharge permits) to manage dust nuisance, although they need to take into account the nature of the environmental effects of dust emissions[25].

Examples of conditions in the approvals**:**

- *"No dust beyond the site boundary which causes an offensive or objectionable effect"* ***(***as determined by trained persons, such as council officers, according to clear criteria).
- Requirement that Management plans deemed acceptable (examples provided) to be implemented.
- Complaints records.
- Dust monitoring may be imposed where there is potential for significant adverse effects beyond the site boundary. It is important that the monitoring methods and program are carefully selected to ensure that meaningful results are received.
- In the absence of any current national guidelines for dust nuisance, it is appropriate to recommend trigger levels or control limits that could be applied to individual dust sources, as shown in Table 4-2.

All monitoring results should be summarized in an annual report, copies of which should be made available to the public, and to the relevant regional and district councils.

Example of conditions for open pit quarry within 100 m of residential area:

- No noxious, offensive or objectionable discharges beyond the property boundary, in the opinion of an enforcement officer.
- Ensuring discharges do not exceed concentrations of alert level 200 mg/m^3 or an absolute limit of 400 mg/m^3.
- A buffer zone with a width of 65 metres where the boundaries of the site adjoin residential areas.
- No uncovered stockpiles within 200m of the site boundary.
- Application of water prior to blasting at a rate equivalent to 20 kg/m2 fine mist sprays at the crushing plant and conveyors.
- Location of the crushing plant within a raised embankment.
- Dampening of haul roads with a water cart and fixed sprays, restriction of truck speed to 10 km/hr.
- Enclosing stockpiles of fine materials within a shed.
- Use of a drill for blasting with vacuum dust extraction and watering.
- Application of water to the rock excavation face.
- Removal of as little vegetation, overburden and soil as possible.
- Dust monitoring program as follows:
  - Dust deposition gauge network continues to be used to monitor long term (30 day) dust nuisance at the property boundary.
  - Suspended particulate monitoring using two real-time 'DataRam' monitors

located within the plant and near the site boundary. The monitors measure the suspended particulate concentration every five minutes and are connected to an on-site alarm and the quarry manager's cell phone. The alarm is triggered when concentrations exceed 200 mg/m^3 and 400 mg/m^3. Triggering at the lower level requires that immediate action be taken to control dust emissions, while triggering at the higher level requires that work cease until the cause of the discharge is identified and rectified.

4.7 SOUTH AFRICA

An evaluation and modelling methodology for truck generated fugitive dust emissions is developed as a basis for the comparative assessment of dust control strategies[75].

As a result of the large number of variables affecting the generation of dust, a visual classification system was developed for the 'degree' of dust defect based on the road user's experience from the point of view of a haul truck travelling at 40 km/h.

Table 4-3: Classification of the degree of haul road dust defect gives these descriptions, both as they relate to the measurements and practically to what the mine would visually experience. A Hund Tyndalometer (TM digital µP, Hund, 1991) was used to measure the dust generation profiles in 2 dimensions (time and dust reading in mg/m^3 of the PM10 dust fraction) of vehicles passing the measuring point. The instrument operates on the principle of light scattering and is commonly used for routine checking of dust levels associated with mining operations. Details of the measurement system adopted are more fully described by Thompson and Visser[75].

In general, the consensus was that a dust defect score of 2 would represent a typical dust defect intervention level (where some dust suppression activity would be initiated). This defect score was based primarily upon the visual effects (road safety and driver discomfort), rather than any perceived health impacts.

Table 4-3: Classification of the degree of haul road dust defect

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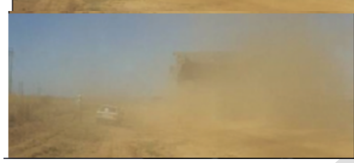
Typical dust defect photograph showing haul truck travelling past monitor point at 40 km/h descriptions	Dust defect degree and associated Hund peak dust levels (approx. mg/m³ for 10 µm dust per haul truck pass)	Qualitative dust defect degree descriptions
	Degree 1: <3.50	Minimal dustiness
	Degree 2: 3,51 to 23.50	Dust just visible behind vehicle
	Degree 3: 23.51 to 45,00	Dust visible, no oncoming vehicle driver discomfort, good visibility.
	Degree 4: 45,01 to 57,50	Notable amount of dust, windows closed in oncoming vehicle, visibility just acceptable, overtaking hazardous.
	Degree 5: >57.51	Significant amount of dust, window closed in oncoming vehicle, visibility poor and hazardous, overtaking not possible.

Silt content, is defined as particles that pass a 200-mesh screen, and is the finest particle size segment that can be separated reliably by conventional dry sieving. Silt content is expressed as % by weight. Silt loading is the silt content ratio to the surface where it was sampled and is expressed in units of mass per units of area.

4.8 Selection of Jurisdictional Requirements for Further Consideration

From the jurisdictional requirements assessed it was determined that further consideration to be given to approaches used in:

- Australia – the concept of differentiating the requirements to manage the particulate emissions based on the proximity of residences.
- New Zealand – developing particulate emission trigger levels, monitoring requirements, buffer zone between an open pit mine and nearest residences.
- US – legislative requirements in Arizona and California
- South Africa – the development of the concept of the road dust defect.

5. EXISTING METHODS AND CONTROLS TO MANAGE EMISSIONS

Dust, more precisely, suspended particulate matter, is part of a mine operation. Almost inevitable, it is visible, invasive and potentially hazardous. The metal(s) content is particularly relevant in the context of this proposed Mining Sites IS. Emission sources need to be acknowledged, assessed and managed/controlled to address their impact. The dominant sources analysis demonstrated the main nickel (and other metals coexisting in the ore) sources are: drilling and blasting, material handling (loading/unloading, stockpiling), crushing/screening (ore and non-ore bearing rock), transportation (roads), and wind erosion (tailings and ore/non-ore bearing rock storage piles).

The amount of contaminants generated, the way it gets dispersed and impacts the receptors depends on many factors including: the type of mine, local climate, topography, working methods and types of equipment used, the mineralogy of ores, and the inherent character and/or land use of the area around the mine.

The challenge for mining companies is to adopt a dust management system that recognizes and responds to the issue of dust emissions at all stages of mining from mine planning and operation through to mine closure. This includes systematically identifying sources, predicting contaminant levels, evaluating potential effects on human health and the environment, and incorporating prediction and control measures.

Community engagement and public transparency is also important.

5.1 Current International Recommended Practices

As presented in the Integrated Pollution Prevention and Control Reference Document on Best Available Techniques (BAT) on Emissions from Storage July 2006 – BREF for storage of solids[47]

5.1.1 Current Practices for Storage and Transfer

5.1.1.1 Open Storage

Best Available Technologies or Techniques (BAT) for material storage is to have enclosed storage (by using, for example, silos, bunkers, hoppers and containers) to eliminate the influence of wind and to prevent the entrainment of dust by wind as much as possible by primary measures. However, although large volume silos and sheds are available, for (very) large quantities of moderately drift sensitive and wet-able material, open storage might be the only option.

BAT for open storage is to carry out regular or continuous visual inspections to see if dust emissions occur and to check if preventive measures are in good working order. Following the weather forecast by, e.g., using meteorological instruments on site, will help to identify when the moistening of piles is necessary and will prevent unnecessary use of resources for moistening the open storage.

BAT for long-term open storage are one, or a proper combination, of the following techniques:

- Moistening the surface using durable dust-binding substances (impact sprinklers, pop-up rotors), as shown in Figure 5-1: Water sprinklers or pop-up rotors used to control storage piles.
- Covering the surface, e.g. with tarpaulins.
- Solidification of the surface.
- Grassing-over of the surface.

Figure 5-1: Water sprinklers or pop-up rotors used to control storage piles

BAT for short-term open storage are one, or a proper combination, of the following techniques:

- Moistening the surface using durable dust-binding substances.
- Moistening the surface with water.
- Covering the surface, e.g. with tarpaulins.

Additional measures to reduce dust emissions from both long and short-term open storage are:

- Placing longitudinal axis of the pile parallel with the prevailing wind.
- Applying protective plantings, windbreak fences or upwind mounds to lower the wind velocity.
- Applying only one pile instead of several piles as far as possible (with two piles storing the same amount as one, the free surface increases with 26 %).
- Applying storage with retaining walls reduces the free surface, leading to a reduction of diffuse dust emissions; this reduction is maximized if the wall is placed upwind of the pile.
- Placing retaining walls close together.

5.1.1.2 Enclosed Storage

BAT is to apply enclosed storage by using, for example, silos, bunkers, hoppers and containers. Where silos are not applicable, storage in sheds can be an alternative, as well as when batches need to be mixed.
BAT for silos is to apply a proper design to provide stability and prevent the silo from collapsing.

BAT for sheds is to apply proper designed ventilation and filtering systems and to keep the doors closed.

BAT is to apply dust abatement, the type of abatement technique should be decided on a case-by-case basis, depending on the nature/type of substance stored.

5.1.1.3 Transfer and handling of solids

General approaches to minimize dust from transfer and handling

BAT for transfer and handling is to prevent dust dispersion due to loading and unloading activities in the open air, by scheduling the transfer as much as possible when the wind speed is low. However, this type of measure cannot be generalized and local circumstances should be taken into account.

BAT is to make transport distances as short as possible and to apply, wherever possible, continuous transport modes. Discontinuous transport (e.g. shovel or truck) generally generates more dust emissions than continuous transport such as conveyors. For existing plants, this might be a very expensive measure.

When applying a mechanical shovel, BAT is to reduce the drop height and to choose the best position during discharging into a truck.

For loading/unloading activities, BAT is to minimize the speed of descent and the free fall height of the product.
Minimizing the speed of descent can be achieved by the following techniques that are BAT:

- installing baffles inside fill pipes,
- applying a loading head at the end of the pipe or tube to regulate the output speed,
- applying a cascade (e.g. cascade tube or hopper), and
- applying a minimum slope angle with, e.g. chutes.

To minimize the free fall height of the product, the outlet of the discharger should reach down onto the bottom of the cargo space or onto the material already piled up. Loading techniques that can achieve this, and that are BAT, are:

- height adjustable fill pipes,
- height adjustable fill tubes, and
- height adjustable cascade tubes.

Optimized discharged hoppers are available.

Transfer techniques

Grabs (grab-type excavator bucket)

For applying a grab (bucket), BAT is to follow the decision diagram and to leave the grab in the hopper for a sufficient time after the material discharge.
BAT for new grabs, is to apply grabs with the following properties:

- geometric shape and optimal load capacity,
- the grab volume is always higher than the volume that is given by the grab curve,
- the surface is smooth to avoid material adhering, and
- a good closure capacity during permanent operation.

Conveyors and transfer chutes

For all types of substances, BAT is to design conveyor to conveyor transfer chutes in such a way that spillage is reduced to a minimum. A modelling process is available to generate detailed designs for new and existing transfer points.

For non, or very slightly, drift sensitive products and moderately drift sensitive, wet-able products, BAT is to apply an open belt conveyor and additionally, depending on the local circumstances, one or a proper combination of the following techniques:

- lateral wind protection,
- spraying water and jet spraying at the transfer points, and/or
- belt cleaning.

The type of conveyor depends on the substance to be transported and on the location. This should be decided on a case-by-case basis.
The materials transported (ore, fine mining material, concentrate) are characterized by a drift sensitivity factor (S). For existing conventional conveyors, transporting highly drift sensitive products (S1 and S2) and moderately drift sensitive, not wet-able products (S3), BAT is to use enclosed conveyors.
Annex 8.4 of the BREF for Emissions from Storage lists the nickel-copper ore and concentrates drifting sensitivity as an S4, moderately drift –sensitive, wet-able.
The recommendation is that where it does not compromise product quality, plant safety, or water resources, BAT for loading/unloading drift sensitive, wet-able products S4, is to moisten the product. Risk of freezing of the product, risk of slippery situations because of ice forming or wet product on the road and shortage of water are examples when this BAT might not be applicable.

5.1.2 General approaches to minimize dust from roads/transportation

The amount of particulate matter generated by vehicles from an unpaved haul road is a function of the following factors:

- The road design.
- The road maintenance and management.
- Other dust control methods.

It is usually more cost effective to design and plan appropriately to control particulate matter emissions from the onset. A good haul road design is a fundamental component of particulate matter minimisation.

Figure 5-2: Road dust at a mining site

Roads Design

The design factors that are relevant to the minimisation of these emissions are[86]:

- Design of haul road cross section
  - The preparation of a suitable road sub-base.
  - The placement of materials within the cross section of the haul roads so the stiffest material is placed as close to the upper surface as possible.
  - The amount of compaction of material within the cross-sectional design.

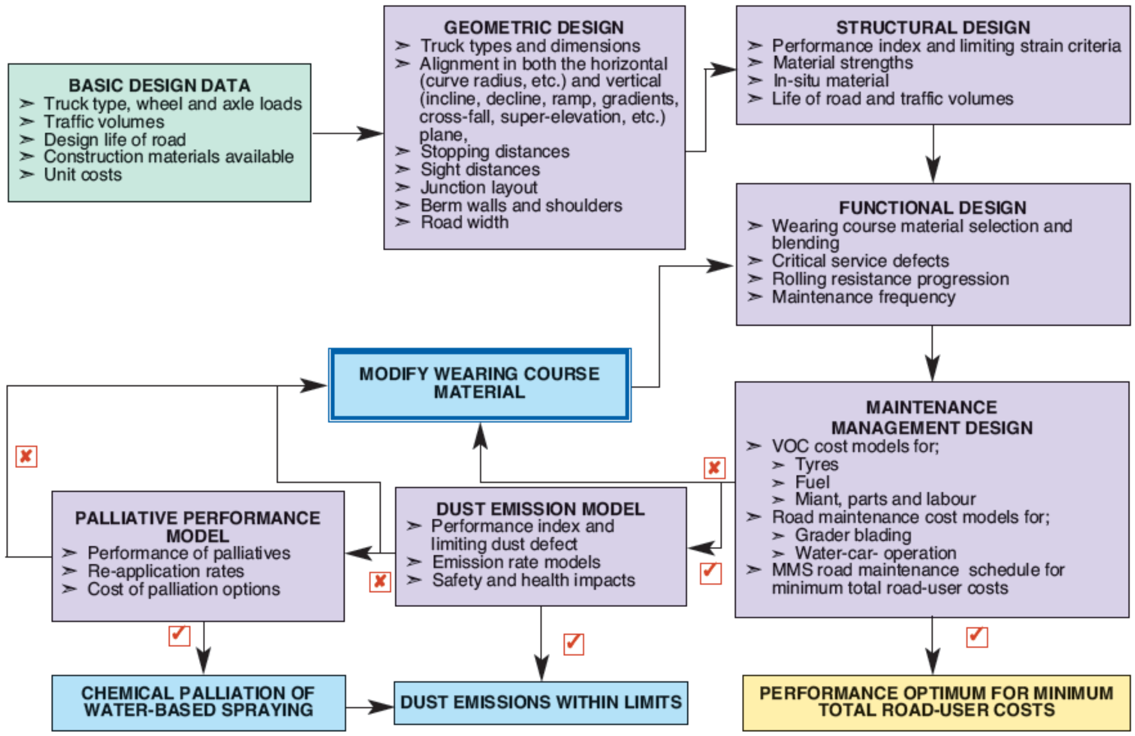
- Road construction materials
  - The surface material selected for haul road construction is most frequently gravel or crushed stone. This is mainly due to cost effectiveness of the material and availability. However, the actual cost effectiveness of this material may be poor over the longer term if a large amount of maintenance is required.
  - The type of aggregate used dictates the most suitable approaches to control particulate matter emissions. For example, for gravel road surfaces with minimal fines, chemical suppressants cannot compact the surface or form a new surface and therefore do not provide a substantial additional benefit from watering alone.
  - The durability of the material used for the road surface.

- Road surface
  - Particulate matter emissions are proportional to the silt content of the material used for the road (i.e. lower silt content will result in a lower emission rate of particulate matter). Silt content, is defined as particles that pass a 200-mesh screen, and is the finest particle size segment that can be separated reliably by conventional dry sieving. It is expressed as % by weight. The silt loading is the silt content ratio to the surface where it was sampled and is expressed in units of mass per units of area.
  - The silt content of the road surface will determine how successful suppressants may be. For example, at silt contents greater than 20-25% suppressants are unlikely to be effective.

- Haulage road planning and alignment
  - Particulate matter emissions are proportional to vehicle kilometers travelled (VKT) (i.e., lower VKT will result in a lower emission rate of particulate matter).
  - The amount of traffic and speed of vehicles on unpaved haul roads has been shown to be an effective mitigation technique.
  - Haul roads that are redundant should be shut down and re-vegetated as soon as practical.
  - Conveyors can be used in place of haul roads, particularly on high traffic routes that are relatively static during the mine life.

A well planned and designed haul road will allow for easier management and maintenance, increased productivity (i.e., becoming more cost effective) and minimise emissions of particulate matter. See Figure 5-3: Mine haul road integrated design components.

Figure 5-3: Mine haul road integrated design components



Roads Maintenance and Management

Methods of wind erosion control are based on two principles: (1) reducing the direct force of wind on erodible soil particles; and, (2) modifying the soil surface to resist wind action or limit particle movement.
In terms of the use and management of the road, there are three methods that have been demonstrated to be effective in controlling emissions of particulate matter from unpaved haul roads:

- Surface improvements.
- Surface treatments.
- Vehicle restrictions.

While driving, vehicles might re-entrain dust from solids spread on the ground, originated from track-out or spillage. BAT then is to adjust the speed of vehicles on-site to avoid or minimize dust re-entrainment.

Surface improvements

BAT for roads that are used by trucks and cars only, is applying hard surfaces to the roads, such as concrete or asphalt, because these can be cleaned easily to avoid dust re-entrainment. However, applying hard surfaces to the roads is not justified when the roads are used just for big shovel vehicles or when a road is temporary.

Cleaning of vehicle tires is BAT. The frequency of cleaning and type of cleaning facility applied should be decided on a case-by-case basis.

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An alternative to paving is the addition of lower silting materials, such as gravel or aggregate, to the surface of a road and the resurfacing of haul roads as part of haul road maintenance.

Surface Treatments

Watering

Watering roads is a standard practice in most mining facilities in the world, as it is an effective method to control emissions of particulate matter. See Figure 5-4: Water sprays along the loading/unloading points.

Figure 5-4: Water sprays along the loading/unloading points

However, where water supply is limited or costly, watering may not be an adequate or desirable solution. In addition, watering roads can result in a slippery surface and, in some cases, the addition of water can lead to the production of increasingly fine particles. The loss of fine particulates from the surface through run off and wind erosion can cause an increase in surface roughness and lead to the formation of potholes and a destruction of the road surface.

The selection of spray nozzles for an application should take into consideration the dust particle size distribution, because dust particles join with water droplets of the same size much more efficiently, as shown in the Figure 5-5: Dust particle – water drop interaction, below:

Figure 5-5: Dust particle – water drop interaction

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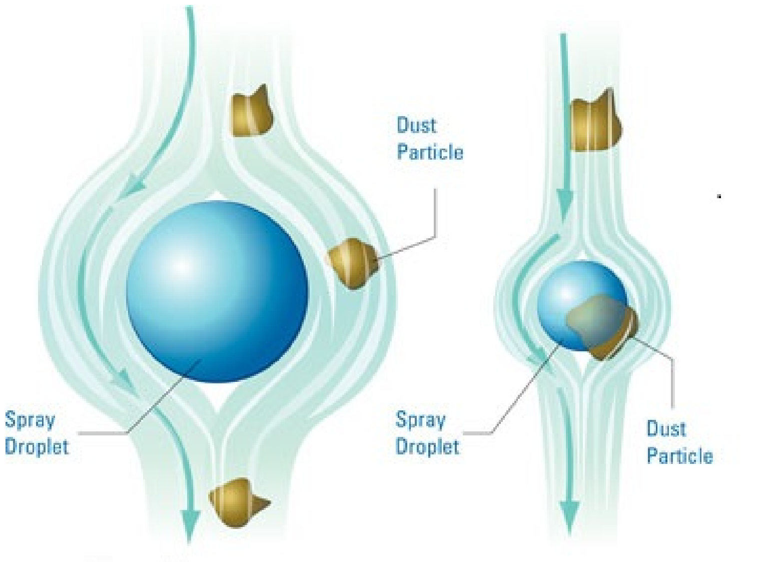

If the drop diameter is larger than the dust particle diameter, the dust particle will follow the air stream around the drop. (Shown left.) If the diameters of the drop and the dust particle are comparable, the dust particle will follow the air stream and collide with the drop. (Shown right.)

The following newer approaches in water truck technology achieve superior performance:
- Water sprayed as a function of ground speed versus motor speed for reduced water wastage.
- Finer mists from spray bars.
- Closer proximity of spray heads to the ground surface.
- Surfactants addition to improve water performance.
- GPS tracking of spray areas.

As an alternative to water trucks, an ultrasonic dry fogging system can apply watering using a compression system, with a water droplet size of 0.3-0.5 mm. The smaller the droplet size the larger surface area affinity for particles increases. This system can thereby agglomerate and suppress emissions of particulate matter at the source.

The control efficiency for water can be highly variable as it is highly dependent upon road material type, traffic, and weather conditions. Untreated plain water is commonly used for roadway dust control. The study by Rosbury and Zimmer [1983a,b][10,64,81] showed that watering once per hour resulted in a control efficiency of about 40%. Doubling the application rate increased the control effectiveness by about 15% to 55%.

The degree of dust mitigation achieved with watering is a function of:
- ➢ The amount of water applied per unit area of road surface
- ➢ The time between reapplications
- ➢ Traffic volumes
- ➢ Prevailing meteorological conditions
- ➢ The wearing course material
- ➢ Extent of water penetration in to the wearing course.

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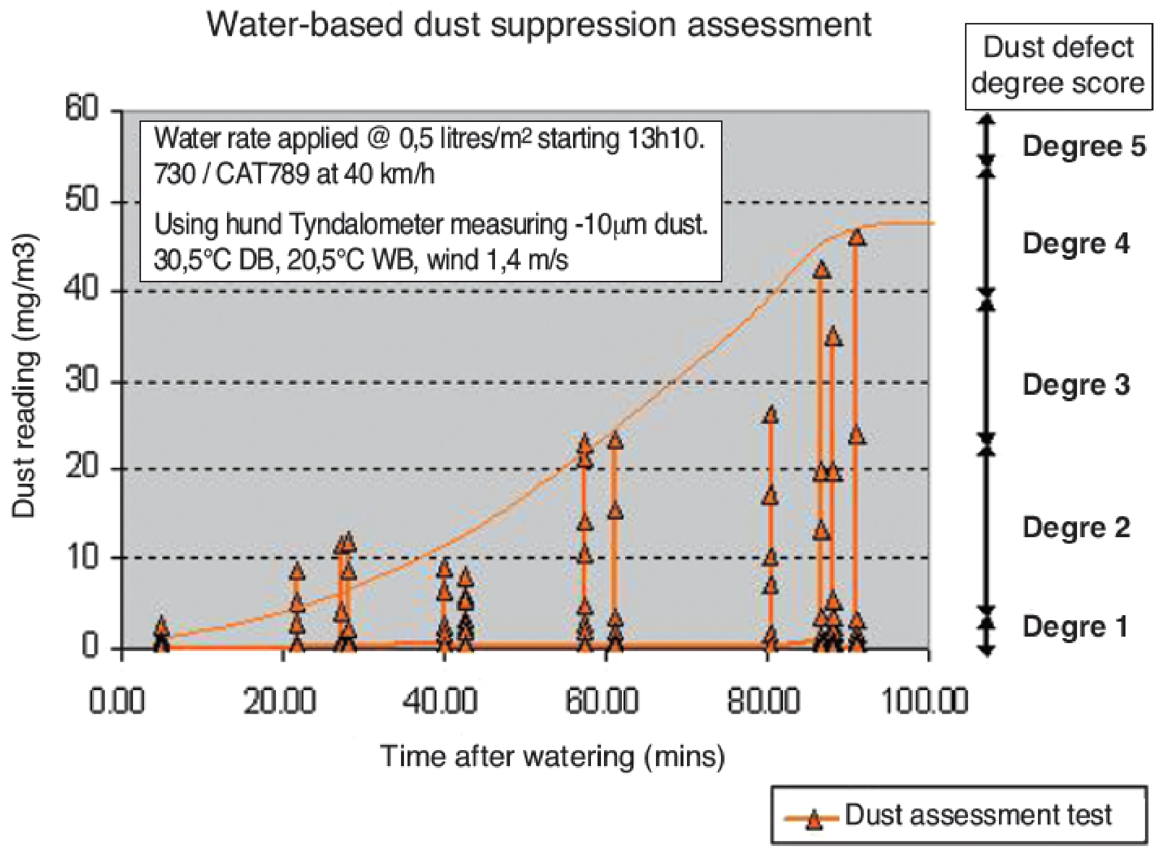
Figure 5-6: Rate of increase in dustiness following watering on a mine haul road below, illustrates a typical dust-time curve from a particular test site, showing how dustiness increases with each vehicle pass from dust defect degree 1 (immediately following spraying) to degree 4, 90 minutes after application.[75]

Figure 5-6: Rate of increase in dustiness following watering on a mine haul road



More recently, the US EPA has reported several test results of watering haul roads. An application of water at the rate of 0.13 gallons per square yard (gal/yd^2) had a control efficiency of 95 percent for TSP for 0.5 hours after application. Another test showed that an application of water at a rate of 0.46 gal/yd^2 had a control efficiency of 74 percent for TSP for the 3-4 hours following the application of water[81].

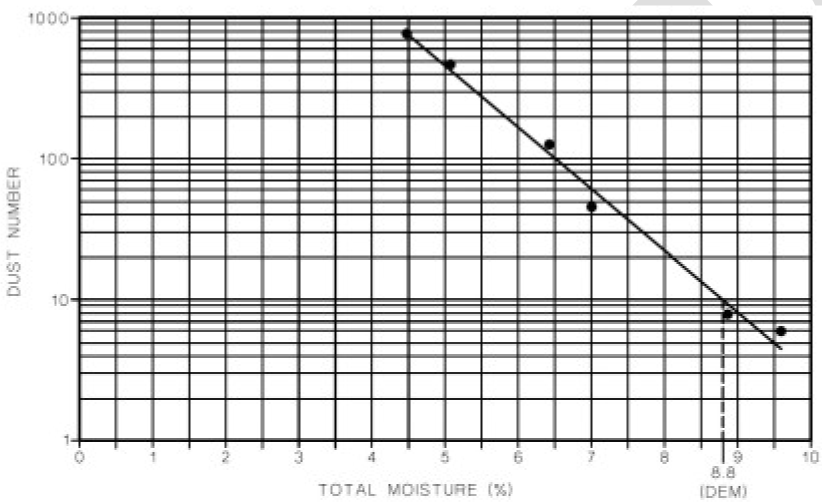
There are no published guidelines for the amount of water to use for dust control on haul roads. The optimal haul road moisture content for the best reduction of respirable dust was found to be approximately 2 percent in a study completed in Kansas[81].

Additionally, except for the application intervals previously mentioned, there are no published guidelines for determining optimum haul road watering intervals. Determining optimum haul road watering intervals would be dependent upon the amount of water applied to the road, the time between water applications, the traffic volume of the road, and the prevailing meteorological conditions[81].

To quantify the amount of moisture needed for dust mitigation, a method (AS 4156) was developed in Australia for coal mines, but it is noted that it is also applicable to other ore materials. It defines a Dust Extinction Moisture (DEM) level and it helps to determine the optimum amount of dust suppressant needed.

The Australian Standard (AS) AS4156[94] part 6 deals with the dust/moisture relationship in coal and was developed to optimise the amount of water used for dust suppression. The standard defines the moisture content, the DEM level, at which the dust/moisture relationship is “optimal”. In practice, this means minimal dust generation. The DEM is determined by plotting the dust number at different moisture contents on a log/linear graph as shown in Figure 5.7: Dust/moisture curve for a coal sample showing DEM = 8.8%. An exponential trend line is normally fitted to the data and used to determine the DEM for the material. The DEM is defined as the moisture content at which the dust number is 10. A dust number of 10 correlates to 0.01% in mass of dust collected from the sample.

Figure 5-7: Dust/moisture curve for a coal sample showing DEM = 8.8% (TAKEN FROM AS4156.6-2000)[94]



Chemical Suppressants

Chemical suppressants can either compact the surface or form a new surface. The control efficiencies of suppressants depend on:

- Dilution rate of the mixture.
- Application rate.
- Time between applications.
- Size, speed and volume of traffic.
- Meteorological conditions.
- Characteristics of the road.

Under identical operational conditions, dust deposition was 37% less following application of the suppressant compared with the application of water[74]

The following categories of suppressants are identified in the literature:

Hygroscopic salts - Hygroscopic compounds such as calcium chloride, magnesium chloride, hydrated lime, sodium silicates, etc. Salts increase roadway surface moisture by extracting moisture from the atmosphere.

Chlorides are the most commonly used products for haul road dust control. A study by Rosbury and Zimmer [1983][10, 64, 81] showed that the highest control efficiency measured for a chemical dust suppressant, 82%, was for calcium chloride 2 weeks after application. Average efficiencies ranged between 40% to 60% over the first 2 weeks after application, and then decreased with time. After the fifth week beyond application, the limited data show a control efficiency of less than 20%.

The effectiveness of chlorides is enhanced by good roadway preparation, that is, a good crown and good drainage at the shoulder. In addition, it is helpful to loosen at least 1-2 inches of the existing roadway surface. This allows the chloride to penetrate evenly into the gravel. To enhance dust control efficiency, the roadway surface should not be compacted before applying chlorides. It is important that the gravel be kept close to the optimum moisture just before applying chlorides. The product will thus be absorbed much more quickly and evenly into the gravel. Chloride should never be applied to dry gravel in that it will not be evenly absorbed and may show failure in spots. Also, rain on a freshly treated surface will leach out and dilute the chloride, causing it to run off the road. Therefore, application should be postponed if rain is forecast for that day.

Lignosulphonates (i.e., adhesives) - field testing of lignin sulfonate demonstrated control efficiencies ranging from 50 to 63 percent for up to 4 weeks after application, with the highest control efficiencies occurring directly after application [USBM 1983].

Petroleum (or sulphonated petroleum) - resins and tar and bitumen emulsion products form coherent surface layers that seal the road surface, thereby reducing the quantity of dust generated. Most petroleum resins do require a 24-hour period allowing the road surface to cure. Haul roads have been reported to be relatively dust free for a period of 3 to 4 weeks.

For petroleum emulsions, documented control efficiencies are highly variable. Testing reports showed control efficiencies up to 70 percent for up to 21 days after application, as well as 4 to 38 percent during a 4-week period after application at several surface coal mines [USBM 1983][10.64,81]. Differences in the variations of control efficiency could be due to the type of petroleum emulsion used, method of application, type of vehicle traffic, and measurement method.

Polymer emulsions, such as soaps and detergents, decrease the surface-tension of water, which allows the available moisture to wet more particles per volume unit. Polymers include acrylics and vinyls, which are chemical additives, mixed with water to form a diluted solution, then applied to the road surface topically. Only a few studies have documented their control efficiency. One study conducted on mine haul roads reported that a specific polymer had control efficiencies of 74 to 81 percent within 4 weeks of application, reducing to 3 to 14 percent after 5 weeks of application [USBM 1983][10,64,81]. Another study, conducted on a public dirt road, demonstrated control efficiencies of 94 to 100 percent within a week of application of the same specific polymer; the control efficiencies reduce to 37 - 65 percent at approximately 11 months after application. The efficiency of polymer emulsions is highly influenced by precipitations.

Road aggregate and dust control. Different types of road aggregate dictate different approaches to dust control. Recommendations based on specific road aggregate are:

- Gravel with few fines*.* In gravel road surfaces with not enough fines, only watering will be effective. Chemical dust suppressants can neither compact the surface (because of the poor size gradation) nor form a new surface, and water-soluble suppressants will thus leach.

- Sand. In compact sandy soils, bitumen, which are not water-soluble, are the most effective dust suppressant. Water-soluble suppressants such as salts, lignin-based products, and acrylics will leach from the upper road surface. However, in loose, medium, and fine sands, bearing capacity will not be adequate for the bitumen to maintain a new surface.

- Good gradation*.* In road surfaces with a good surface gradation, all chemical suppressant types offer potential for equally effective control.

- Silt. In road surfaces with too much silt (greater than about 20% to 25% as determined from a scoop sample, not a vacuum or swept sample), no dust suppression program is effective, and the road should be rebuilt.

- In high-silt locations, the chemical suppressants can make the road slippery and are not able to compact the surface or maintain a new road surface because of poor bearing capacity. Further, rutting under wet conditions requires that the road be graded, which destroys chemical dust suppressant effectiveness. If the road cannot be rebuilt, watering is the best program. If there is uncertainty about the gradation of the gravel or if there is doubt about the equipment and products to be applied, the process can be tried on a 150 to 300 metres test section of the road. If the process fails at the test section level, then only a small investment and time are lost.

Chemical dust suppressants, such as salts and lignin-based products can be more cost-effective than watering under some conditions. However, all chemical dust suppressants (with infrequent watering) share one common failing compared to frequent watering. Material spillage on roadways is very common, and the material spilled is subject to re-entrainment. With frequent watering, newly spilled material is moistened at close intervals. When chemicals are applied with infrequent watering, newly spilled material could go for long periods before being moistened. Therefore, in mines where spillage cannot be controlled, watering alone is better for dust control. In many instances, chemical suppressants have an advantage over plain water.

In locations where track-out from an unpaved road to a paved road creates a dust problem, chemical suppressants are a good choice. Watering aggravates the track-out problem with moisture and mud; chemical suppressants, particularly bitumen and adhesives, leave the road dry. Finally, some mines have a dust problem in winter when temperatures are subfreezing but little moisture is present. The case for chemical suppressants over water in such instances is clear.

Other Dust Control Methods for Roads

Load covers

Entrainment of material can occur when airflows coming in contact with the material exceed 13 mph (20 km/h) for small diameter material that is less than 0.10 mm in diameter; higher velocities are required for larger material [Chepil 1958][10]. However, loaded highway trucks and rail cars can exceed speeds where airflows contacting the loaded material exceed this threshold, resulting in dust emissions as the material becomes airborne. Therefore, covering with tarps or surface wetting of the loaded material should be done to prevent it from being windblown. Additionally, the truck or rail car should not be overloaded.

Figure 5-8: Dust-proof rail car system shows an Australian mining facility covering loads leaving the site, including using concentrate rail cars covered by a fully automated dust-proof wagon cover system.

Figure 5-8: Dust-proof rail car system

Speed Control

Reducing speed of the vehicles traveling on haul roads can be an effective method for dust control. However, this method may conflict with maximizing production since the haul trucks are designed to operate at an optimum speed; to lower the speed of the trucks would lower the production rate of the mine, which may not be desirable. Nevertheless, reducing the speed of vehicles has been shown to reduce the potential generation of dust particles (with diameters less than10 μm) by approximately 58% when speeds were reduced from 25 to 10 miles per hour, (40 to 16 km/h), and by 42% when speeds were reduced from 25 to 15 mph (40 to 24 km/h)) [Watson et al. 1996][10.64]. In another study, limiting speeds on unpaved roads to 25 mph (40km/h) demonstrated a control efficiency of 44 percent.[64,81]

Traffic Control

Maintaining a 20 second time interval between trucks, travelling on unpaved roads, has shown to reduce respirable dust exposure to the trailing driver; it also allows for the dust cloud generated from the lead truck to dissipate, reducing the possibility of an accident.

5.1.3 Current Practices for and Drilling and Blasting

Drilling

Blast hole drilling may also contribute to the dust generated from open pit or underground mining. To some extent, in the case of open pit mines, this is mitigated by dust retention effects of the pit. Other ways to control dust from drilling is either using wet drilling with a wet suppression system or, in case of dry drilling, dust collection devices, such as fabric filters or cyclones.

For underground mines, the most common method of dust control for drilling is using wet drilling techniques. Water is also important for controlling dust generated by blasting. The area surrounding the blast (e.g., walls, floor, and back) should be thoroughly sprayed beforehand. This precaution will prevent dust settled out during previous operations from becoming airborne. Sufficient ventilation is critical for the control of blasting dust since water alone is usually inadequate. Blasting dust and fumes are diluted quickly and exhausted to the surface via a return air raise (RAR).

Blasting

Blasting is used in both open pit and underground mines to fragment the rock being mined. This is an important step in industrial mineral production as it is required to break up the mineral product. Blasting dust is produced as a concentrated 'cloud' that is highly visible and potentially may affect near neighbours downwind of the blast. The blasting of near-surface weathered materials that contain a high proportion of fines often creates large dust emissions.

In Australia, at the Kalgoorlie Consolidated Gold Mines Pty. Ltd., a computer program was created to determine dust dispersion from blasting operations[87]. This program uses meteorology, bench height, blast design information, and rock density to predict the behavior of dust from blasting. It accounts for absorption of the dust on the pit walls and for reflection of the dust off the pit walls. The dust concentrations are calculated using settling velocities for different particle sizes and densities. The program is designed to determine if blasting will have an impact on a nearby town[87].

A report commissioned by the National Institute for Occupational Safety and Health (NIOSH) in 2005[87] presents the various dust dispersion models that have been developed specifically for the mining industry. The report first gives a brief background of the regulatory environment that helped to promote development of such models. It then presents an overview of the mathematical concepts used in this dispersion modeling. Finally, each of the various models developed for the mining industry are described, along with their associated mathematical algorithms and any field validation conducted on the different models.

There it is a mention of a study completed by Shearer stating that approximately one-third of the emissions from mining activities escape the open pit. This is a very simplistic model that is representative of the box model algorithm.

Multiphase computational fluid dynamics (CFD) showed that the best trapping scenario is done when the barriers are located near the blast, with better trapping in case of higher barriers[88]. Higher levels of suspended particulates were modelled 400-700 m from the open pit mining site in the predominant wind direction[89]. In an example of a blast management plan residences located within 2 km are considered when planning blasting events[90].

The options for controlling dust from blasting are somewhat limited. Watering of the blast area following the charging of blast holes with explosives may combat dust from certain ore types that have a high content of fine particles. Another method that can be effective in protecting areas adjacent to the mine from blasting dust involves delaying blasting under unfavourable wind and atmospheric conditions. This requires some flexibility in blasting schedules, but can be highly effective. Planning mining so that adequate buffer stocks of ore are available is required to accommodate delays in blasting. A knowledge of seasonal and daily wind patterns will give some degree of predictability to the likelihood and frequency of blast postponement.

An Australian open mining facility maintains a dust monitoring network of depositional and high volume air samplers surrounding the mine. In addition, also operates a real-time laser dust monitor, located between the residential areas and the mine which reads dust levels 24-hours a day. The real-time system offers a rapid feedback to the mine operators regarding current dust levels. Hence, it allows a rapid management response that is not possible using other dust monitoring methods, such as the standard high volume samplers or dust deposition gauges, where there may be a delay of days or weeks before the monitoring data is available for examination.

The real-time monitor operates in conjunction with a weather station. Dust and weather data is continually relayed via a radio link to the mine site. A general dust 'risk factor' is calculated by assessing weather conditions such as wind speed and direction, temperature, solar radiation and rainfall and existing dust levels. When the dust risk factor is high, alarms alert the mine personnel, allowing mine operations to be adjusted to reduce dust. The same monitoring system is used to provide environmental clearance prior to blasting.
The facility also operates a 24-hour environmental complaints 'hotline'. The hotline provides a quick response mechanism for the community to report dust incidents or other environmental aspects of the operation, which they believe, are creating a problem.
In New Zealand, suspended particulate monitoring is undertaken using two real-time ‘Data Ram’ monitors located within the plant and near the site boundary. The monitors measure the suspended particulate concentration every five minutes and are connected to an on-site alarm and the manager’s cell phone. The alarm is triggered when concentrations exceed 200 µg/m3 and 400 µg/m3. Triggering at the lower level requires that immediate action be taken to control dust emissions, while triggering at the higher level requires that work cease until the cause of the discharge is identified and rectified.

Monitoring and Auditing

A monitoring program should be closely tied to the environmental conditions as one of its functions is to ensure and demonstrate compliance with regulatory requirements. Monitoring should also include relevant process and operational parameters needed to ensure better oversight of the entire site. See Figure 5-9: Monitoring station at a mine site.

DRAFT

Figure 5-9: Monitoring station at a mine site

Environmental monitoring programs may initially appear as an expensive item for mining operations to implement. However, they are a sound financial investment, particularly when critical environmental constraints are identified. Planning can ensure that cost-effective mitigating measures are adopted, a clean, hazard-free operating environment is maintained and mine site rehabilitation is undertaken in a continuous, cost effective and satisfactory manner.

The schedule for a monitoring program should be set up so that it is simple to operate and will provide data that can be directly utilised by the company.

This is reflected in the program design, as described in the steps below:

- Identification of the scope of monitoring required.
- Definition of the objectives.
- Specification of how the data or information collected will be used in the decision-making process.
- Definition of the spatial boundaries for the monitoring work, and selection of sites for direct measurement, observation or sampling.
- Selection of the key indicators for direct measurement, observation or sampling.
- Definition of how the data will be analysed and interpreted, and how it will be presented in the monitoring report.
- Definition of the precision and accuracy required in the data.
- Evaluation of the compatibility of any data collected with historical data and with contemporary related data.

In many cases, monitoring results, and any actions triggered by these results, are summarised in an annual environmental report to the government authorities. This describes the current state of the environment on the mine site and details the environmental parameters monitored.

Regular reporting of monitoring results - especially any non-compliance or unusual incidents

DRAFT

- is now increasingly a feature (or even a condition) of company management systems. Where monitoring indicates that environmental parameters are exceeding statutory levels, a planned response should be determined and set in place to effectively control any adverse effects. Each monitored parameter should be linked to a contingency plan to enable corrective action to be taken.

Dust monitoring methods include the following:

- Dust deposition gauges.
- High volume samplers.
- Continuous particle monitors: Continuous particle monitors produce a continuous record of ambient dust levels. This is a significant advance over the standard high volume sampler in that it allows examination of short-term dust episodes. It can be a powerful management tool when matched to records of mining activity and continuous wind data. The system can also be set up to operate on-line.

Other dust monitoring methods:

- TEOM™- The Tapered Element Oscillating Microbalance (TEOM™), consists of an oscillating tapered tube with a filter on its free end. The change in mass of the filter and collected aerosol produces a shift in the oscillation frequency of the tapered tube that is directly related to mass.

- Beta gauge – The continuous particle analyser, is a beta attenuation sampler that uses a 30mCi Krypton-85 source and detector to determine the attenuation caused by deposited aerosols and particles on a filter. The filter medium is contained on a roll and advances automatically on a time sequence, or when a pre-set particle loading is reached.

- Directional dust monitoring – This can be used to identify specific dust sources. Systems are now available for linking dust samplers to a wind sensor, so that the monitor only operates when the wind is from a certain direction. Alternatively, there are directional dust gauges available in which the dust is collected through vertical slots, which can be lined up with the direction of interest.

- Time-lapse video – This provides a simple method for visual monitoring of dust-producing activities over extended periods of time. Its main application is in identifying which activities on a site need better dust control.

- Microscopic examination – This can be very useful in investigating complaints of dust fallout. Examination of dust samples under a microscope can often assist in identifying the source.

- Tracer analysis – Analysis of dust for specific tracer elements can also be useful in identifying dust sources. For example, dust from a secondary steel mill will have high levels of iron and other metals such as lead and zinc.

Auditing

As the size and complexity of mining operations increase, regulators are increasingly working

DRAFT

through new mechanisms such as environmental management systems, with auditing taking on a new dimension.

The internal and external auditing roles share many common functions, such as:

- Ensuring that compliance with regulations and standards is part of the corporate environmental policy.
- Observing if the company has set quantitative goals for emissions and discharges beyond compliance levels.
- Checking that goals are achieved, and if not, working out the reasons.
- Ensuring that the company's employees, organisational structure, system and resources enable it to implement the environmental management system or agreement.
- Confirming that an effective internal program of monitoring, reporting and auditing is in place.

There is a wide range of audits that may be undertaken. Definitions of "audit" vary widely, but several different types concerned with environmental performance may be distinguished:

- Environmental management systems (EMS) audit - For those companies with a formalised EMS in place. This type of audit can be conducted at three levels:
  - First party audit by the company itself (i.e. an internal audit).
  - Second party audit by one company on another (e.g. audit on a supplier by a customer).
  - Third party audit by an independent organisation against an appropriate standard.
- Compliance audits - To demonstrate compliance or otherwise with environmental legislation, regulation, licences, approvals and other documentation, including the corporate environmental policy, and commitment to industry codes, charters and principles that the company has signed.
- Technical or process audits - to determine whether a process or operation is having a detrimental effect on the environment. These audits may focus on energy, waste, pollution or site aspects.
- Environmental liability audit - as a prerequisite to insurance that covers both sudden and accidental pollution as well as gradual pollution.
- Environmental performance audits - to assess the environmental performance of ongoing activities.

Professional and business associations now produce a wide range of guidelines of how to undertake such audits effectively. It is also useful to periodically assess the actual impact of operations against the initial environmental impact statement (EIS) through a form of impact audit. This is made easier if the EIS is structured to include a table of "Whole of Mine Life Commitments", such as planned safeguards, environmental management criteria and site closure objectives. This table provides a focus for the ongoing environmental auditing programme that should improve reporting to the approving authority. This report may be made public upon request in the same way as the EIS. **In some cases, it is necessary or desirable to have standards specific to a particular site or sector.**

5.1.4 Mills

The second step in the base metals process, after mining the ore, is to send it to a mill where the ore is processed to start the first step in a long separation process that will separate the metals from the non-ore bearing rock. The ore is transported from the mine to the mill by truck, or by conveyor. The ore may be stored before processing, either indoors or outside, or taken directly into the plant.

The ore is first screened and crushed by primary and secondary crushers, then conveyed to be milled. Milling further reduces the size of the ore.

Rod, ball, semi-autogenous or other types of mills are used. Although dry grinding could be done, wet grinding is by far the most used method. It is a wet process and the metals are extracted from the slurry by magnetic separation, flotation and thickening steps. Nickel-copper or copper-zinc concentrates are normally treated to produce separate products or to remove unwanted minerals. The metal concentrates may be shipped as slurry or may be de-watered. The waste ("tailings") is commonly piped as a slurry to the wet tailings area. Tailings can also be de watered and dry stacked but since this is not an approach used in the Ontario copper-nickel-zinc mines this Mining Sites IS is not addressing the option of "dry stacking" of tailings. This may be addressed in the future if needed.

Tailings may also be processed to produce fill for underground mining and/or low-sulphur material for site rehabilitation.

Best practice for screening and crushing activities at a mill is to operate local exhaust ventilation with air treatment devices, such as baghouses and/or wet scrubbers. There are no significant metal emissions from the wet milling or flotation / separation processes. Most mill operations are indoors.

5.1.5 Tailings

Most of the documentation relating to Tailings Management Facilities (TMFs) deals with design and water management with less emphasis on air related issues.

Best Available Techniques (BAT) are included in the Reference Document on Best Available Techniques (BREF) for Management of Tailings and Waste-Rock in Mining Activities, January 2009[46] .

TECHNIQUES TO CONSIDER IN THE DETERMINATION OF BAT
For the tailings(TMF) and waste rock management facilities (WRMF) environmental problems and costs can be reduced if the total operation (including the mine, mill, tailings and non-ore bearing rock management facilities), is designed at the same time, taking into consideration the various chemical, physical and biological interactions due to the influence of the mining and the processing.[105]
The management of tailings and non-ore bearing rock, including water management, is usually an integral part of the entire life cycle of an operation, and is as fundamental as the extraction itself[28] .

The good management of tailings and non-ore bearing rock includes evaluating alternative options for:

- Minimizing the volume of tailings and non-ore bearing rock generated in the first place, by e.g. proper choice of mining method (open pit/underground, different underground mining methods).
- Maximizing opportunities for the alternative use of tailings and non-ore bearing rock, such as:
  - use as aggregate;
  - use in the restoration of other mine sites; and
  - use in backfilling.
- Conditioning the tailings and non-ore bearing rock within the process to minimise any environmental or safety hazard, such as
  - de-pyritisation; and
  - addition of buffering material.

The most efficient way of reducing the amount of non-ore bearing rock is to extract the ore using underground mining instead of an open pit. The open pit method though, may have economical advantages over underground mining, due to the possibility of using a much larger part of the ore body. However, there are many aspects to consider when deciding on the applied mining method, (e.g. open pit or underground mining or combinations of the two main alternatives). Non-ore bearing rock generation and management is one such aspect, whereas safety, working conditions, costs, optimization of resource use, stability, the geometrical form of and depth to the ore-body etc. are examples of other aspects that also influence the decision when evaluating mining methods. Whichever mining method used, it is not in the interest of the operator to generate more non-ore bearing rock than necessary as the non-ore bearing rock management is resource consuming and constitutes a cost to the mining company, with very little or no benefit.

Any tailings and non-ore bearing rock that cannot be avoided (due to accessibility to the ore body, safety reasons, etc.) and that are not suitable for alternative use (e.g. due to physical or chemical properties, transport costs, lack of market) require a suitable management strategy which aims to assure the:

- safe, stable and effective management of tailings and non-ore bearing rock, with a minimized risk for accidental discharges into the environment in the short, medium and long term;
- minimization of quantity and toxicity of any contaminated release/seepage from the management facility; and
- progressive reduction of risk over time.

If more than one type of tailings and non-ore bearing rock are generated, segregating them according to type would facilitate any future recovery for alternative use or re-processing; however, blending the different types of tailings and/or non-ore bearing rock might become a good environmental management option if, for example, acid rock drainage (ARD) minimization could be achieved.

Characterization of tailings and non-ore bearing rock

Proper management of tailings and non-ore bearing rock requires a good understanding of the characteristics of the material. The characterization results will determine how to manage the tailings and non-ore bearing rock during operation (deposition technique, protective measures, etc.) at closure (closure requirements and techniques) and in the post-closure phase (prediction of long-term behaviour).

Ideally, the tailings and non-ore bearing rock are properly characterized before the start of the operation and the results are fully incorporated into the design of the management facilities and the management plans. The characterization includes physical and chemical characteristics that allow for the prediction of the short, medium and long-term dissolution/weathering characteristics (release of elements) as well as its geotechnical behaviour. In this work, which often is done in phases according to the results obtained, a series of methodologies are used ranging from relatively simple analysis, to sophisticated leach experiments, and complex interpretation and predictive models.

The implementation of cost effective tailings and non-ore bearing rock management techniques requires the accurate prediction of the behaviour of these mineral residues in the natural environment.
Many test procedures and predictive tools are in use internationally to characterize mining material and to evaluate the potential for mine tailings and non-ore bearing rock to produce acidity and or metal contaminated effluents.

Tailings control and monitoring

A comprehensive control and monitoring plan needs to be developed, and should cover the full site life cycle regarding control of the emissions and impacts, and monitoring of the same.

Quality assurance/quality control (QA/QC) plan

It is good practice to maintain and have available the following information throughout the entire life of the mining project (construction, operation and closure):

- construction drawings and as-built construction records, including revisions;
- test results;
- construction photographs; and
- monitoring notes.

Construction control

Typical components of a construction management system include:

- planning and scheduling;
- survey control (e.g., layout, as-built records)
- grouting monitoring;
- foundation preparation monitoring;
- material quality control;
- compaction control;
- instrumentation monitoring and data synthesis;
- record keeping;
- construction safety; and
- construction environmental criteria.

Dust control

It is necessary to minimize dust releases from the tailings facility. This may involve keeping the

DRAFT

tailings wet and/or using short- or long-term chemical or organic covers. The methods discussed above for minimizing dust emission from ore and non-ore bearing rock transfer and handling (see previous chapters) including roads, also apply to tailings.

Particles tend to become trapped in the turbulent eddies that formed near the edges of the tailings. However, particles that travel further than 500 m from the tailings tend to deposit on regions of topographic upslope[91].

Topographic upslope is a measure of the ground slope as measured along a radial direction with the origin being the centre of the mine tailings. Positively sloped areas are defined as upslope and negatively sloped areas are defined as downslope. Modelled simulations demonstrated that up slopes (i.e., small topographic ridges) coincide with regions of higher deposition, while a reduction in deposition was observed in regions of downslope. Utilizing two fundamentally different aerosol transport models, discrete phase modelling (DPM) and species transport, it was shown that airborne particulate matter preferentially deposits in upslope regions.[91]

The piles of non-ore bearing rock are stored or disposed of in the mine area may cause emissions of mineral dust and emissions into water bodies. Non-ore bearing rock is usually stored as large rocks, which prevents significant dust emissions. However, there may be gaps between the rocks that contain finely ground mineral material, which easily rises as dust. The possible weathering of non-ore bearing rock, the lack of a layer of topsoil that would support vegetation and the considerable height of the piles of non-ore bearing rock increase the risk of wind erosions and the dust this causes.[92]

Dust prevention

The following are ways in which **solid** tailings are disposed and some prevention options.

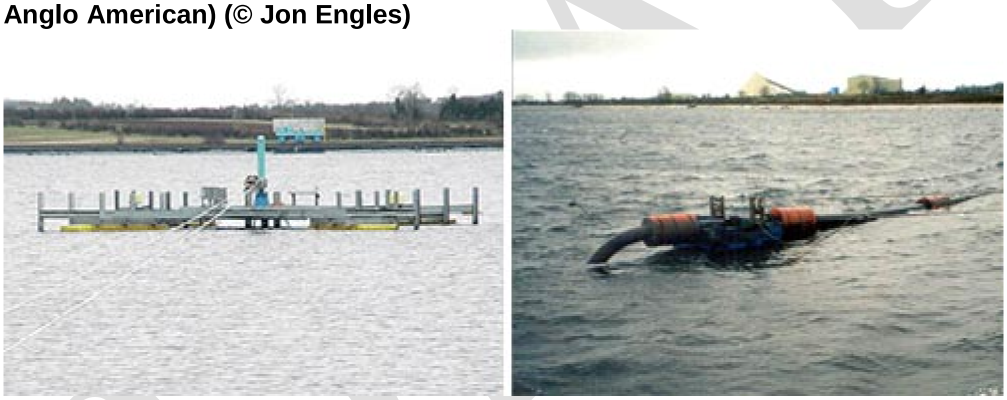
Deposition methods for tailings

- **Sub aerial deposition** – deposition of tailings above the water line is more common than subaqueous as it can form a beach above the water, sloping gently towards the supernatant pond (Figure 5-10: Sub aerial tailings discharge (left) and shallow low velocity braided streams on a tailings beach (right)). As the tailings discharge onto this beach they form shallow low velocity braided streams that allow the tailings to settle and segregate. Sub aerial deposition is generally practiced at tailings facilities that have multiple discharge points. This allows the deposition of tailings to be rotated between different locations around the facility to allow newly deposited tailings to bleed, dry and consolidate while tailings can continue to be discharged to other zones of the facility. The frequency of discharge point rotation and the number of deposition zones is dependent on the climate, tailings production rate, tailings drying characteristics and the tailings facility shape.

Figure 5-10: Sub aerial tailings discharge (left) and shallow low velocity braided streams on a tailings beach (right) (© Jon Engels)

- **Subaqueous deposition** is particularly suited to tailings that contain sulphides that are likely to oxidize and produce acid. Restricting oxygen to the tailings by permanently placing them underwater will prevent oxidation and minimize the environmental problems associated with the Acid Mine Drainage (AMD). See Figure 5-11: Subaqueous deposition within a conventional tailings impoundment.

Figure 5-11: Subaqueous deposition within a conventional tailings impoundment (Courtesy Anglo American) (© Jon Engles)



Prevention of Dust

Wind erosion to the surfaces of tailings or non-ore bearing rock management facility occurs from:
- crest of dam/pile;
- slopes of dams/piles; and
- surface of the beaches.

Prevention measures may include:
- dam crest and slopes may be treated for water erosion;
- surface may need wind breaks, water spraying, application of binding material, i.e. spraying with bituminous emulsion (dust suppressant), surface mulch, or lime slurry; and
- in some cases, tailings may be deposited under water;
- surface vegetation, either floating or on inactive areas; and

DRAFT

- frequent change of discharge points around perimeter to achieve constantly wetted surface.

Figure 5-12: Dust suppressant application on tailings

Tailing Beaches

In sub-aerial deposition, the exposed surface of the tailings between the point of discharge and the supernatant pond (where present) or towards the low point within the storage area, is referred to as the beach. Beach slope refers to the surface slope of the tailings after being hydraulically or mechanical deposited from a point of discharge. The tailings settle after being discharged from the end of a pipe at this slope. To minimize dusting from beaches, the surface is usually kept wet. For example, water spraying is applied when dusting conditions are imminent.

Example:

At a TMF site, sprinklers are distributed throughout the TMF and raised with the tailings level. Such a system can only be applied where tailings can be accessed by vehicles, i.e. for thickened tailings. Sprinkling of the beach in combination with the continuous management of the discharge point of the tailings onto the beach is normally satisfactory. Sprinkling is often applied in thickened tailings operations.

- **Advantages:**water from inside the TMF can be utilised; and,
- not expensive.

Disadvantages:
- problems in cold climates with freezing; and
- labour intensive.

Another method to avoid dust entrainment is to cover the beach with non-dusting material such as topsoil, lignin compounds, straw or bitumen.

Advantages:
- once the material is put in place the dust problem is solved for a long period.

Disadvantages:

DRAFT

- the beaches cannot be continuously raised;
- the non-dusting material might have to be removed when raising the dam; and
- the beach must be stable enough for machinery to work on it in order to spread the material, or application may be achieved by aircraft.

Examples[46]:

- At the tailings pond in the Legnica-Glogow copper basin in Poland, the water level inside the pond is kept at a distance of at least 200 m from the dam crest. The beach constitutes a considerable source of dust emissions, especially on windy days. To reduce this dust a water ‘curtain’ is installed on the crest. Additionally, to stabilize the surface in sections which are temporarily dry, an asphalt emulsion is sprinkled from a helicopter. Currently, additional water ‘curtains’ are being tested. These are installed inside the pond on the beach at a distance of 150 m, and are put into operation when a dry section (after removing the asphalt cover) is being utilized for dam construction.

- At Pyhäsalmi mine in Finland, spraying of lime slurry has been used to prevent the wind erosion of the fine particles of the tailings. Spraying has been done by equipment originally made for agricultural uses. This consists of a tank mounted onto a tractor and pump and hose system. This equipment has the capability to disperse the lime slurry into generally even layers to the desired areas. When drying, the lime forms a hard surface layer, which lasts throughout the dry summer period. Based on visual inspections, this technique has significantly decreased the effects of dusting. However, there is no reliable data demonstrating the achieved benefits. It should be noted that at Pyhäsalmi the lime slurry spraying is only done for the purpose of the mechanical and physical prevention of dusting and not to prevent any chemical purposes (i.e., neutralization of ARD). With better equipment the result could be more homogeneous and efficient. The costs of this technique has been around EUR 1500/ha, which is relatively high considering the demanded area (5 – 6 ha) and the need for spraying every year (spring time).

- The Lisheen mine in Ireland uses subaqueous deposition to control AMD. Part of their license to operate requires them to deposit all their tailings subaqueously with a minimum water depth of 1.3 m above the tailings in June and 1 m in October. The tailings are discharged from a mechanised floating head that is controlled by two railtrack mounted trucks on either side of the impoundment. The TMF is fully lined on the upstream embankment face as well as on the basin area.

  Discharging of tailings below water can create significantly steeper slopes than that of sub aerial deposition; for Lisheen the underwater tailings slope could be in excess of 10%. This means that if the distribution head or spigot is not regularly moved then differential settlement, slumping and squeezing can occur. It is essential for a lined impoundment using subaqueous deposition that the tailings are evenly distributed and that depth measurements are recorded at regular time intervals to establish dramatic elevation changes.
  Another, organizational way of dust reduction/prevention is to utilize a frequent change of discharge points around the perimeter to achieve constantly wetted surface or to constantly keep the tailings covered with water.

- Tailings as well as non-ore bearing rock deposits still contain metals. Below is an example from two Finnish facilities, a nickel mine (Hitura) and a copper-zinc mine (Pyhasalmi).

Table 5-1: Average metal concentrations in 2 Finnish TMFs (Hitura and Pyhäsalmi tailings)

Material	Cu, g/kg	Ni, mg/kg	Zn, mg/kg	Mg, g/kg	Mn, g/kg	Fe, g/kg
Hitura tailing	1.20	2775	70	41.60	1.27	111.00
Pyhäsalmi tailing A	1.56	25	2185	9.64	1.14	205.00
Pyhäsalmi tailing B	0.52	16	738	6.96	0.40	764.00

Slopes

Dusting can be prevented from the slopes of the dam by covering the slopes with coarsely crushed non-ore bearing rock.

Advantages:
- not expensive if the operation has an excess of non-ore bearing rock; and
- dam stability will be increased with the extra amount of weight from the non-ore bearing rock.

Disadvantages:
- additional cost for crushing and putting in place.

<u>Tailings Handling and Transport</u>

Tailings and non-ore bearing rock are usually transported by pipeline (only slurried tailings), conveyor belt or trucks. No dust emissions occur when slurried tailings are transported by pipeline.

The mechanical dewatering process compared to conventional slurry deposition increases costs. However, there are some advantages as well as disadvantages to using dry stacking of tailings.

Advantages:
- For cold climates, dry stacking prevents pipe freezes and frosting problems with conventional impoundments.
- Filtered tailings allow better recovery of dissolved metals and process chemicals.
- Easier to close and rehabilitate.
- Require a smaller footprint compared to other surface tailings storage options (i.e. higher density), can be utilized in steep terrain.
- Generate better regulator and public perceptions of tailings storage.

Disadvantages:

- High capital and operating costs associated with modern filtration technology (power, maintenance).
- Only really suited to low throughput operations.
- Surface contour management required to prevent accumulation and easy removal of surface water (i.e. precipitation events).
- Oxidation of sulphides in the tailings can create high concentrations (but low volume) of seepage water and dry deposition may not be practical for some ore types. Detailed geochemical testing is required.
- Dust generation is a common problem in arid climates and can occur relatively quickly after tailings disposal due to the low moisture content of the placed material.

Dewatering tailings to higher degrees than paste produces a filtered wet (saturated) or dry (unsaturated) cake (with a typical moisture content less than 20%) that can no longer be transported by pipeline due to its low moisture content. These filtered tailings are normally transported by conveyor or truck.

Tailings deposited by conveyor belt

Several types of approaches and dust reduction methods could be used where the tailings are transported on conveyor belts and discarded onto piles.

Primary approaches:

- choosing mineral processing equipment that generates as little fines as possible
- spraying the tailings

Secondary approaches:

- Organizational continuous processing;
- reducing the transport distances; and
- logistics of stacking areas.

Technical

- use of wind protection (e.g. covering of conveyor-belt);
- minimizing or reducing discharge heights;transverse/reverse conveyor-belt; and moistening of the solid tailings.
- use of wind protection (e.g. covering of conveyor-belt);
- minimizing or reducing discharge heights;

Tertiary approaches:

- Not depositing tailings during high wind speeds

Transfer stations are commonly enclosed in and the air cleaned in filters.

Tailings Loading/Unloading

Various methods of dust suppression are commonly used, including:

- spraying the shovel/bucket of the loader when loading;
- spraying the bucket of the truck;

DRAFT

- watering of the roads; spraying at unloading;
- direct water spraying of the trucks and/or sprinkling devices along the road; and
- establishing a speed limit of 30 km/h.

5.1.6 Underground Mines

The main sources of dust in an underground mine are:

- Drilling.
- Blasting.
- Transport.
- Crushing.

Machine-mounted water sprays and “scrubbers” are actually devices used to enhance the flow of fresh air in face areas (the end wall of the place where a miner works). Scrubbers are acting as "vacuum cleaners" which capture emissions before they are discharged to the air, while water sprays, when strategically located on machines, have been used successfully to act as a "booster fan" to re-direct airflow in certain directions in face areas.[

The risks associated with airborne dust are controlled by ventilation systems that protect the workers' health and address reduced visibility.

The risk of exposure to airborne dust in a mine is controlled by:

- Identification of likely sources.
- Reduction at the source:
  - Sharp cutting picks and drill bits.
  - Dust extraction and containment and redirection into return airways.
  - Scrubber fans.
  - Stopes, draw points exhaust to return.
  - Wetting of dust as it is generated.
- Adequate ventilation flow through areas where dust is generated:
  - Minimizing speed for roadways.
  - Very high velocities can raise dust into an airway.
- Design and documentation of ventilation flow paths.
- Working on the intake side of dust generating activity:
  - Remote operation of equipment.
- Homotropal (current of air traveling in the same direction as the flow of mineral out of a mine) ventilation of conveyor roadways.
- Prevention of unplanned recirculation.
- Inspections and monitoring.
- Reporting of ventilation system defects.
- Personal Protective Equipment.
- Air conditioned operator cabs.
- Procedures for:
  - re-entry after blasting;
  - starting and stopping fans;
  - restoration of ventilation after a disruption;
  - roadway maintenance, including watering; and
  - action to be taken when ventilation fails.

Airborne dust can be measured through static and personal samplers[26].

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Mine ventilation practice is heavily regulated in the world and various statutes dictate the volume of air required to dilute diesel emissions, blasting fumes, radiation, dusts, battery emissions, and many other contaminants. Air is necessary underground not only for breathing, but also to disperse chemical and physical contaminants. These practices are put in place to protect workers in underground (subsurface mine) operations.

In planning a ventilation system, the quantity of air required to be circulated to meet health and safety requirements must be decided at the outset. Once the quantity required has been fixed, the correct size of shafts, number of airways, and fans can be determined. As fresh air enters the system through the intake airshaft(s) or other connections to the surface, it flows along intake airways to the working areas where most pollutants are added to the air. These include dust (including metals present in the ore body) and a combination of many other potential hazards, such as toxic or flammable gases, heat, humidity, and radiation.

The contaminated air passes back through the system along return airways. In most cases, the concentration of contaminants is not allowed to exceed mandatory threshold limits imposed by Workplace Health and Safety Standard requirements. The return air (contaminated exhaust) eventually passes back to the surface via return airshaft(s), or through inclined or level drifts. This discharge of this air is through return air raises (RARs).

In the discussions with the internal committee the following details were provided[101].

Occupational hygiene monitoring is performed to monitor the performance of dust controls within the mines and to document worker exposure to particulate and metals. Occupational hygiene monitoring has been conducted in Sudbury mines since the 1920's. Gravimetric sampling became the sole method for occupational hygiene monitoring of particulates for the mines in approximately 1980.

Occupational hygiene and environmental particulate sampling methods and equipment are not equivalent. Occasionally occupational hygiene sampling methods and equipment for total particulate are used that would roughly correspond to the environmental sampling methods for SPM. These samples, however, are collected during specific work activities and analyzed by methods (e.g. assessment of oil mist exposure) that do not provide useful data for estimation of SPM emissions from RARs.

The majority of the occupational hygiene monitoring performed underground is performed using size-selective particulate sampling methods and equipment to measure either respirable or inhalable particulate. The criteria for size-selective particulate monitoring are described in guidelines and standards produced by the American Conference of Governmental Industrial Hygienists (ACGIH), the International Organization for Standardization (ISO) and the European Standardization Committee (CEN). The results of respirable particulate monitoring are not useful for comparison to SPM environmental standards.

Sampling and Analytical Method

The standard method used for sample collection and analysis of inhalable particulate is Methods for the Determination of Hazardous Substances (MDHS)14/3 published by the Health and Safety Executive in the United Kingdom. The sample collection method and equipment conform to the ACGIH, ISO and CEN standards for inhalable fraction.

Numerous publications since 1995 have compared the performance of inhalable and SPM occupational hygiene sampling equipment and methods. The consensus is that inhalable sampling collects more, often significantly more, particulate mass than SPM sampling. In an underground mining workplace, inhalable sampling would collect approximately 2.5 times more particulate mass than SPM sampling. The relationship varies considerably depending on workplace conditions and could be between 1 and >3.

Sampling Strategy
Occupational hygiene monitoring sampling strategy focuses upon those workers who are expected to have greater exposure to airborne particulate. The primary factor determining potential dust exposure is the performance of work that involves movement or disturbance of broken rock (i.e. the worker is at or near the point of particulate generation). A smaller number of samples are collected on workers who have lower potential exposure to airborne particulate. The overall result is that personal occupational hygiene monitoring should over-estimate average worker exposure and the concentration of airborne particulate in the general workplace.

Personal vs. Stationary Monitoring
Personal monitoring is conducted by mounting the monitoring equipment on a worker so that the sampling inlet is within the breathing zone. In mining and many other workplaces, personal monitoring is performed because it provides more meaningful and accurate measure of worker exposure. Measured concentrations from personal monitoring are typically 50%, or more, higher than that measured from stationary monitoring conducted even within 2 meters away. The result is that personal monitoring results significantly overestimate the concentration of airborne particulate that remains airborne within the mine airways.

Stationary area monitoring is normally performed during studies to evaluate the performance of dust control measures. These control efforts are also performed at locations where additional control is believed to be required.

Control of Airborne Particulate
There are numerous legislated requirements for dust control in underground mines. Primary dust control, the prevention of airborne dust, is normally achieved through wet methods such as the application of water to broken rock. Mines also apply water and/or dust suppressants to roadbeds to prevent the generation of dust from movement of vehicles underground.

Distance Between Particulate Generation and Emission
Ventilation is also provided in order to provide secondary control through dilution and displacement of airborne particulate. This is the source of any emissions to the environment when this air is exhausted from the mine through the RAR. In main airways, air velocity is sufficient to cause impaction of dust onto the walls of the tunnel and mines will wash walls to prevent this impacted dust from becoming re-entrained. Mines have also used water sprays or misters to increase humidity and promote settling or impaction of airborne particulate. Impaction also occurs during the passage of air upwards through the exhaust raise.

The mines in Sudbury are relatively deep. Mining depths vary between approximately 1150 metres (3750 feet) and 2475 metres (8110 feet) below surface. Horizontal distance between the mining activity and the RAR also varies but could be as much as several kilometres. The actual distance of air movement between the mining activity (particulate generation) and emission to the environment could be as little as 1.5 kilometres or as much as 10 kilometres for deeper mines with more complex mine ventilation designs.

5.2 Facility Level Practices Used in Ontario

Input on current practices was provided by members of the Technical Committee. The following Table 5-2: Facility Level Dust Mitigation Practices Used in Ontario summarizes the types of control measures for processes or activities that may generate metals emissions that are common for mining facilities in Ontario. The factors that are influenced for each type of control measure are highlighted and the measures are classified as either preventative or reactive. Facilities implement control measures as required depending on the relative risk of high emissions from each process or activity, which is dependent on site specific characteristics.

Table 5-2: Facility Level Dust Mitigation Practices Used in Ontario

Process/ Activity	***Factors Affected by Control Measures***	***Preventative measures***	***Preventative measures***	***Reactive measures***
		Design/ Installation	***Pre-op /Operation***	
Site Preparation	Material Silt Content	If possible, lay down coarser material over finer material to prevent wind erosion and excessive track-out	Be aware that sites with finer materials will require more control measures than sites with coarser materials	-
	Material moisture content	Make provisions to have water sprays on hand during site preparation	Wet material during dry conditions	-
	Wind conditions	Consider installation of temporary wind breaks if site contains fine materials	Do not schedule activities for days when there are high wind speeds, or persistent constant wind directions with above-average wind speeds forecasted if controls are not adequate to control the dust	Stop activities during times of unfavourable wind conditions
Open Pit Drilling and Blasting	Size of area blasted / number of holes drilled	- Design for smaller blast areas	- Maintain drilling equipment to avoid excessive vibration	—
	Material silt content	—	—	—
	Material moisture content	—	- Wet material during dry conditions	—
	Wind conditions	—	- Schedule drilling and blasting for days when there are low wind speeds forecasted	- Stop drilling activities in high wind speed conditions
Material Movement (conveyors, material loading and unloading)	Material silt content	—	—	—
	Material moisture content	- If possible, use spray bars when conveyors or drop points are not enclosed.		

Process/ Activity	***Factors Affected by Control Measures***	***Preventative measures*** ***Design/ Installation***	***Preventative measures*** ***Pre-op /Operation***	***Reactive measures***
		Pre-wet the material if possible.		
	Material density	—	—	—
	Wind conditions	- Consider historic data when choosing the equipment location to avoid areas with predominant wind from equipment towards sensitive areas - If possible, take advantage of natural wind breaks (trees, landscaping)	- Do not schedule activities for days when there are extremely high winds forecasted if controls are not adequate to control the dust	- Stop activities in high wind conditions
	Material transfer rate		- Reduce material throughput	
	Equipment characteristics	- Avoid transfer points by using longer conveyors, if possible - Set up equipment with longer axis parallel with prevailing wind direction - Construct wind barriers - Fully enclose conveyors and transfer points - Implement dust collection equipment	- Maintain all equipment accordingly to reduce vibration - Maintain good housekeeping in areas around equipment to avoid track-out	—
	Loading/unloading conditions (drop height, bucket load size, etc.)	- Minimize material drop heights - Segregate areas to handle each type of material; restrict vehicle movements to minimal working face to reduce track-out	- Maintain minimum drop heights - Maintain appropriate load sizes to ensure material do not unintentionally fall	—
Crushing and Screening	Material silt content (initial and final)	- Avoid over processing material, (i.e. only crush to largest size that is necessary)	- Only process enough material that will be used, avoid having to store finer materials in storage areas	—

Process/ Activity	***Factors Affected by Control Measures***	***Preventative measures*** ***Design/ Installation***	***Preventative measures*** ***Pre-op /Operation***	***Reactive measures***
	Material moisture content	- If possible, install spray bars when conveyors or drop points are not enclosed. Pre-wet the material if possible.	- Apply water on material if not enclosed, and if material is dry	—
	Wind conditions	- Consider historic data when choosing the equipment location to avoid areas with predominant wind from equipment towards sensitive areas - If possible, take advantage of natural wind breaks (trees, landscaping)	- Do not schedule activities for days when there are extremely high winds forecasted	- Stop activities in high wind conditions
	Material processing rate	—	- Schedule material processing rate appropriately on an as-needed basis	—
	Equipment characteristics (enclosures, spray bars, vibration, etc.)	- Set up equipment with longer axis parallel with predominant wind direction - Construct wind barriers - Fully enclose equipment - Implement dust collection equipment	- Maintain all equipment accordingly to reduce vibration - Maintain good housekeeping in areas around equipment to avoid track-out and wind erosion	—
	Loading/unloading conditions (drop size, bucket load size)	- Minimize material drop heights	- Maintain minimum drop heights - Maintain appropriate load sizes to ensure materials do not unintentionally fall	—
Paved Roadways	Silt loading on the roadway surface	—Follow accepted design practices, allowing for surface drainage	- Vacuum truck - Apply dust suppression on shoulders - Grade / contour shoulders to permit drainage	- Vacuum roads as needed

DRAFT

Process/ Activity	***Factors Affected by Control Measures***	***Preventative measures*** ***Design/ Installation***	***Preventative measures*** ***Pre-op /Operation***	***Reactive measures***
	Road surface moisture content	—	- Implement a water truck regularly	- Spray roads as needed
	Wind conditions	- Consider historic data when designing the road route to avoid high speed wind areas and areas with predominant wind from roadway towards sensitive areas - If possible, take advantage of natural wind breaks (trees, landscaping)	- Install wind fences in highly exposed areas, if required	- Stop activities in high wind conditions
	Vehicle speed	- Specify and post speed limits	- Enforce posted speed limits	—
	Vehicle weight	—	- Maintain appropriate load sizes so trucks are not over-loaded	—
	Number of vehicles	- Designate specified routes travel that avoid site roads adjacent to populated areas or sensitive receptors	- Maintain appropriate load sizes to reduce the number of truck trips	—
	Vehicle loads	-	- Maintain appropriate load sizes to ensure material do not unintentionally fall - Cover loads, if possible - Implement wheel washing stations and load wetting stations to avoid track-out	—
Unpaved Roadways	Road surface silt content	- Resurface roadway with larger aggregate - Pave the roadway	- Apply dust suppression chemical regularly	- Apply additional suppression as needed
	Road surface moisture content	—	- Implement a water truck regularly	- Spray roads as needed

Process/ Activity	Factors Affected by Control Measures	Preventative measures Design/ Installation	Preventative measures Pre-op /Operation	Reactive measures
	Wind conditions	- Consider historic data when designing the road route to avoid high speed wind areas and areas with predominant wind from roadway towards sensitive areas - If possible, take advantage of natural wind breaks (trees, landscaping)	- Install wind fences in highly exposed areas, if required	- Stop activities in high wind conditions
	Vehicle speed	- Specify and post speed limits	- Enforce posted speed limits	—
	Vehicle weight	—	- Maintain appropriate load sizes so trucks are not over-loaded	—
	Number of vehicles	- Designate specified routes travel that avoid site roads adjacent to populated areas or sensitive receptors	- Maintain appropriate load sizes to reduce the number of truck trips	—
	Vehicle loads	—	- Maintain appropriate load sizes to ensure material do not unintentionally fall - Cover loads, if possible - Implement wheel washing stations and load wetting stations to avoid track-out	—
Tailings Areas and Storage Piles (wind erosion)	Material silt content	- Cover/re-vegetate areas that are no longer in use	- If possible store coarser material on top of finer material - Apply chemical suppression regularly	- Apply additional suppression as needed
	Material moisture content	- Design for wet disposal of	- Maintain an appropriate	- Spray storage

Process/ Activity	***Factors Affected by Control Measures***	***Preventative measures*** ***Design/ Installation***	***Preventative measures*** ***Pre-op /Operation***	***Reactive measures***
		tailings if possible	moisture content of storage piles	areas/piles as needed
	Wind conditions	- Consider historic data when designing the storage area to avoid high speed wind areas and areas with predominant wind from the storage area towards sensitive areas - If possible, take advantage of natural wind breaks (trees, landscaping)	- Do not schedule material placement for days when there are extremely high winds forecasted - Install wind fences in highly exposed areas, if required or if practical	- Stop activities in high wind conditions
	Material placement (drop height, exposed surface area)	- Minimize material drop heights - Design working areas to avoid disturbance of materials as much as possible (work from inside to outside, set up storage piles near the equipment which uses the material if possible, etc.) - If possible maintain one larger pile rather than many small piles to reduce exposed surface area - If possible build piles with long axis parallel with predominant wind direction - Construct wind barriers - Construct storage domes /enclosures especially for finer materials	- Maintain minimum drop heights - Maintain good housekeeping in storage area to avoid track-out - Segregate activities, and designated minimal working faces, to minimize track-out	—
Underground mining (emissions are discharged	Material moisture content	- Install fixed / automatic water sprays, as required,	- Maintain appropriate moisture content of ore	- Spray muck piles, as required

Process/ Activity	***Factors Affected by Control Measures***	***Preventative measures*** ***Design/ Installation***	***Preventative measures*** ***Pre-op /Operation***	***Reactive measures***
through mine ventilation raises)		at fixed ore/waste handling equipment (e.g. crushers, rock-breakers, etc.)	and waste rock	- Wash walls, as required, to remove settled dust
	Material silt content (initial and final)	--	Avoid over processing material, (i.e. only crush to largest size that is necessary)	- --
	Material placement (drop height, etc.)	-	- Maintain material levels in ore passes, bins, chutes and stopes	- Additional measures when passes, etc become open
	Air flow (velocity and volume)	- Design and install controls for air flow velocity and volume	- Regularly perform air flow measurements (no less than legislated minimum) - Maintain and operate air flow controls, as directed	- Restore air flow controls following blasting or other disruption
	Removal of airborne dust	- Install dust collection equipment at fixed ore or waste processing equipment - Install automatic water sprays / atomizers	- Use manually operated water atomizers	- --
	Road surface silt content	- Resurface roadway with larger aggregate - Pave the roadway	- Regular application of dust suppression chemical - Regular vacuuming / sweeping of paved roads	- Apply additional suppression as needed
	Road surface moisture content	- Install automatic water sprays / atomizers	- Implement a water truck regularly	- Spray water on roads as needed
	Road maintenance (to minimize spillage)	-	- Regular grading of unpaved roadbeds	- Repair roadbeds
	Vehicle loads	- Install fixed loading equipment (chutes,	- Maintain appropriate load sizes to ensure	—

Process/ Activity	Factors Affected by Control Measures	Preventative measures Design/ Installation	Preventative measures Pre-op /Operation	Reactive measures
		draw-points, etc.) to control loading of haulage trucks and minimize spillage - Install conveyor belts	material does not spill	
	Location and orientation	- Design / install mine exhaust raises with consideration of historic wind data and points of impingement (where possible)	-	

The following methods to manage metal emissions from mining sites were discussed in detail at the meetings during the development of this document:

Methods for Open Pit Mines

Used in Ontario:

- Design/plan for smaller blast areas.
- Schedule drilling and blasting for days when there are low wind speeds forecasted / delay blasting under unfavourable wind and atmospheric conditions.
- Maintain drilling equipment to avoid excessive dusting (adequate sharp tools for cutting, drilling). Wet material during dry conditions.
- Stop drilling activities in high wind speed conditions.

The following methods were discussed and considered with the Technical Committee:

- Water the blast area following the charging of blast holes with explosives.
- Use the blasting mats to prevent fly rock and dust emissions.
- Acquire knowledge of seasonal and daily wind patterns.
- Use drilling rigs fitted with dust collection equipment.
- Install a dust monitoring network around the mine site.
- More frequent inspections and monitoring.

Methods for Underground Mines

Used in Ontario:

- Install fixed / automatic water sprays, at fixed ore/ non-ore bearing rock handling equipment (e.g. crushers, rock-breakers, etc.) to maintain appropriate moisture content of ore and non-ore bearing rock.
- Wash walls to remove settled dust.

- Avoid ore over processing and install dust collection equipment at fixed ore or non-ore bearing rock processing equipment.
- Maintain material levels in ore passes, bins, chutes and stopes.
- Control dust on underground roads (resurface, pave, manual or automatic water sprays, vacuuming, dust suppression)
- Install conveyor belts and maintain appropriate load sizes.
- Design / install mine exhaust RARs with consideration of historic wind data and max POI.

The following methods were discussed and considered with the Technical Committee:

- Adequate (sharp) tools for cutting and drilling.
- Set and enforce speed limits for the underground roads.
- Prevention of unplanned material recirculation.
- Adequate ventilation flow through areas where dust is generated.
- Inspections and monitoring/ reporting of ventilation system malfunctions.
- Well documented & implemented procedures for: starting /stopping fans, restarting ventilation after a disruption and underground roads maintenance.
- Design and install controls for air flow velocity and volume, regularly perform air flow measurements and maintenance.
- Install fixed loading equipment (chutes, draw-points) to control loading of haulage trucks and minimize spillage.

Methods for Common sources for underground and surface mines

Source: Storage piles (ore, non-ore bearing rock, concentrates)

Used in Ontario:

- Do not schedule activities for days with extremely high winds forecasted if controls are not adequate to control the dust and/or stop activities in high wind conditions.
- Use spray bars when conveyors or drop points are not enclosed and/or pre-wet the material.
- Consider historic data when choosing the equipment location: avoid areas where the predominant wind blows from the equipment towards sensitive areas and take advantage of natural wind breaks (trees, landscaping).

The following methods were discussed and considered with the Technical Committee:

- Use enclosed storage (domes): apply proper designed ventilation and filtering systems, and keep the doors closed.
- Automatic sprays (water or other dust-binding substance) around the perimeter of the stockpile activated when the wind speed or the pile moisture reaches a certain level.
- Stockpiles formed on “as needed” basis, loaded out within 24 hours.
- Limit the height and slope of the stockpiles and the drop heights from conveyors.
- Use of windbreaks and retaining walls.
- Cover the piles with tarps.
- Place longitudinal axis of the pile parallel with the prevailing wind.
- Create only one pile instead of several (with 2 piles storing the same amount as one, the free surface increases with 26 %).
- Re-vegetation (long term storage).

Source: Transfer/handling (ore, non-ore bearing rock, other materials)

Used in Ontario:

- Maintain good housekeeping in areas around equipment to avoid track-out / regular clean-up of spillages around transfer points.
- Avoid transfer points by using longer conveyors / restrict vehicle movements to minimal required.
- Use fully enclosed conveyors and transfer points, clean belts and implement dust collection equipment.
- Use spray bars when conveyors or drop points are not enclosed and pre-wet the material if possible.
- Set up equipment with longer axis parallel with prevailing wind direction.
- Construct wind barriers and/or use the natural existing ones.
- Segregate areas to handle each type of material.

The following methods were discussed and considered with the Technical Committee:

- Use of a reclaim tunnel at the product stockpile and an enclosed conveyor to transfer the product to the truck or rail car loader.
- Use of a retractable telescopic chute with curtains to load product into trucks or rail road cars, minimizing drop heights.
- Cover all loads leaving the site, including using concentrate rail cars covered by a fully automated dust-proof car cover system.
- Minimize transfer distances through appropriate site layout.
- Use of water sprays at each contact or transfer point along the conveyance system which have adjustable rates of application (low, medium and high) depending on dust levels.
- Hopper bin with automatic water sprays that produce a fine mist to suppress dust with sensors triggered when a truck enters the dump zone and activated until a set time following the departure of the truck.

Source: Transportation/roads

Used in Ontario

- Pave roads where appropriate, resurface road with larger aggregate; clean paved roads.
- Limit load size to avoid spillages, use wheel wash facilities, regular cleaning and control vehicle speed.
- Use the appropriate approach to control dust for the type of road.
- Follow accepted design practices: allow for surface drainage, design the road route to avoid high speed wind areas and take advantage of natural wind breaks (trees, landscaping).
- Implement a vacuum truck (vacuum as needed), apply dust suppression on shoulders, and grade / contour shoulders to permit drainage.
- Specify post and enforce speed limits.
- Maintain appropriate load sizes so trucks are not over-loaded or making unnecessary trips.
- Designate specified routes to avoid roads adjacent to populated areas or human receptors.

The following methods were discussed and considered with the Technical Committee:

- Cover loads.
- Minimize travel distances through appropriate layout.
- Implement wheel washing stations and load wetting stations to avoid track-out.
- Use of a global positioning system as a tool to track the locations of transport trucks and dust suppression equipment and cross-referencing this information with real-time weather monitoring to assist with dust control.
- Prepare the road and monitor weather for the best time to apply dust suppressant.
- Find the optimal dust suppressant (water, chemical solutions) and apply regularly/additional as determined is needed.

Source: Tailings

Used in Ontario:

- Deposit tailings under water.
- Surface vegetation, either floating or on inactive areas.
- If possible, store coarser material on top of finer material.
- Apply chemical suppression regularly/additional as needed.
- Stop activities in high wind conditions.

The following methods were discussed and considered with the Technical Committee:

- Design the TMF/WRMF operation to cover the full site life cycle, know the local layout, and choose proper location.
- Use the tailings as backfill for mine; recycle tailings as construction material.
- Reprocess tailings and non-ore bearing rock (further mineral extraction).
- Accurate prediction of the behaviour of mineral residues in the natural environment using tests procedures and predictive tools.
- Protect / surround tailings surface with wind breaks.
- Spray tailings' surface with water (water curtains) or other binding material.
- Apply mulch or lime slurry on tailings surface.
- Frequent change of discharge points around the perimeter to achieve constantly wet surface.
- Actively monitor dusting potential from dry/freeze-dried tailings.

Source: Ore processing

Used in Ontario and discussed:

- Avoid over processing material, (i.e. only crush to largest size that is necessary).
- Only process enough material that will be used and avoid storing finer materials in storage areas.
- If possible, install spray bars when conveyors or drop points are not enclosed.
- Pre-wet the material if possible.
- Apply water on material if not enclosed, and if material is dry.
- Consider historic data when choosing the equipment location to avoid areas with predominant wind from equipment towards sensitive areas.
- If possible, take advantage of natural wind breaks (trees, landscaping).
- Do not schedule activities for days when there are extremely high winds forecasted.

- Stop activities in high wind conditions.
- Schedule material processing rate appropriately on an as-needed basis
- Set up equipment with longer axis parallel with predominant wind direction
- Construct wind barriers.
- Fully enclose equipment.
- Implement dust collection equipment.
- Maintain good housekeeping in areas around equipment to avoid track-out and wind erosion.
- Maintain minimum drop heights.
- Maintain appropriate load sizes to ensure materials do not unintentionally fall.
- Minimize material drop heights.

Source: Mills

Used in Ontario and discussed:

- Historically the mills are built as enclosed buildings.
- Wet grinding
- Control equipment: baghouse / wet scrubber

The following methods were discussed and considered with the Technical Committee:

- Enclose and control the entire mill operation- refers to operations of secondary/tertiary crushing, screening, flotation, etc.
- Enclose and control loading / unloading points
- Enclose and control conveyors / feeders
- Use of filter presses for de-watering operation.
- Control equipment: baghouse / wet scrubber Indicate optimal operating parameters.

6.0 ASSESSMENT OF FEASIBLE MANAGEMENT METHODS FOR THE ONTARIO MINING SITES INDUSTRY STANDARD

6.1 Identification of Technically Feasible Methods

6.1.1 Material Substitution

Given the specific of the activity, where a product (the ore) is extracted from the natural environment, there are no considerations of material substitution.

6.1.2 Process changes

Although mining processes are well established and focused on extraction efficiency and workplace safety, care for ecological impact is increasing. An example where a well-known process can be changed to improve the environmental outcome is the use of water or chemical suppressants to minimize dust. Environmental impact can be reduced by changing the type of suppressant (either water or a chemical compound), the technology used to distribute it, and the frequency of treatments.

6.1.3 Add-on Controls

As discussed in the previous chapters, fugitive sources are the most significant sources considered in the proposed Mining Sites IS. When the source of contaminants is enclosed in a building, such as for mills, enclosed crushers, or concentrates ore storage buildings, an add-on control in the form of a baghouse or wet scrubber would be required.

6.2 Technically Feasible Management Method Options for Further Consideration

The objective of this technical standard is to address nickel and nickel compounds other metals and SPM emissions from designated mining sites. The technical standard will propose a set of requirements to ensure the best applicable methods are used to address these emissions.

We determined the emission sources and agreed that any of these sources left uncontrolled or less rigorously controlled would become a dominant source: processing (crushing, screening, etc.), material handling, RARs, roads, storage piles, tailings. For each of the significant sources considered in this Mining Sites IS, pollution control options were further considered for discussions with the Technical Committee with the goal to formulate a proposed set of requirements and to ensure the best applicable methods are used to address nickel, other metals, and SPM emissions.

Further in this chapter are listed methods discussed with the Technical Committee and assessed for general feasibility and applicability to Ontario (more specific Northern Ontario conditions). Some methods were adopted and included in the proposed Mining Sites IS, others were deemed impractical or too costly but are still listed here for documentation purposes.

Technically feasible management methods for further consideration for underground mines

For the underground mines, a significant source of nickel and other ore- contained metals are the RARs. As these are essential to mine worker safety, there are not many options to address the metal emissions from them.

For new mines and / or new / replacement installations it is proposed to take into account:

- The RAR should be oriented away from the property line and from receptors.
- Cleaning / particulate removal.
- Design / install mine exhaust RARs with consideration of the predominant wind direction.

Technically feasible management methods for further consideration for roads

Paved and unpaved roads are a critical part of mining sites and currently represent a significant source of contaminants (metals and suspended particulate).

Best management practices will be concentrated in areas which have the potential to cause the most impact on receptors; these areas will be known as “high risk roads” or shorter segments to be known as a “high risk road segments”

High risk roads would be assessed upon registration using the following considerations:

- Vehicle traffic (number of vehicle, weight of vehicle).
- Proximity to sensitive areas (1-2 km), with emissions potentially impacting human receptors.
- Silt content, and more specifically an increase in silt content as determined based on monitoring data and statistical analysis in comparison to a base line level.

- Number of complaints received by the mining facility about discharges of suspended particulate from that road segment.

Once a year the road classification could be reviewed since it may change, i.e. a low risk road could become high risk, or on the contrary, a high risk will become low risk due to changes in traffic, silt content, etc.

Requirements for high risk roads proposed for discussion during development of the Mining Sites IS:

- Specify, post and enforce a speed limit, no more than 20/40 km/h as recommended in literature.
- Post signs in a highly visible location (at least one sign in each direction) to direct people to call the facility if excessive dust emissions from the road are observed.
- Maintain appropriate load size (avoid spillage, avoid unnecessary trips).
- Cover or wet all the loads of material with less than 2 inches (approximate 5 cm) diameter that contain a registered contaminant.
- Any NEW roads that are within 1 or 2- km of human receptors must be paved.

Inspections and Maintenance for high-risk roads, proposed for discussion during development of the Mining Sites IS-:

- Once a month inspect roads for damage (holes, shoulder grade).
- Once per day and more often in dry, windy conditions visual inspection looking for road dust (spills, deposition).
- Maintain, grade and contour road and road shoulders to permit drainage.
- Develop road surface treatment practices consisting of:
  - Resurface the road with larger aggregates.
  - Find the best performing (optimal) dust suppressant for the type of the road based on amount of dust suppressant (water or chemical solutions), time between applications, traffic volume, meteorological conditions.
  - Document your findings.
  - Determine the mitigation efficiency and the required application frequency.
- Apply chemical dust suppression or water to road and road shoulders.
- Repair damage observed, resurface the road (if needed, with larger aggregates).
- Clean any deposited material observed (using a vacuum truck for paved roads).

Monitoring:

- Monitoring of high risk roads would consist of measuring the silt content / loading or measuring and recording the concentration SPM.
  Alternatively, the development of a “road defect score”[75] would have the advantage of creating a scale to evaluate the efficiency of the methods chosen for mitigation. However, this approach was not pursued.

Technically feasible management methods for further consideration for mills

- Enclose the entire mill operation and install dust collecting equipment (baghouses or wet scrubbers) to control all the emissions points (crushers, screens, grinders, conveyors, dryers, and loading points).

- Use only wet grinding.

- Use filter-presses for de-watering (applies to new facilities AND phase-in for existing facilities – timing in draft Mining Sites IS). Dewatering is a significant process in the mill and using the filter-presses appears to be the best available technology. The use of dryers would not be recommended, as they are much more energy consuming, and, if the temperatures are high enough, some components of the ore concentrate may be released (for example sulphur dioxide or metals with lower melting points). For existing facilities using dryers, they need to operate at lower temperatures, below 200 degrees Celsius.
- Maintain good housekeeping: regular clean-up of spillages around crushers, screeners, conveyors, and loading points.
- Store, handle and transport concentrates using enclosures.

Inspection and Maintenance
Bags damage, pressure drop in baghouse.

Monitoring:
- Monitoring of operational parameters of pollution control equipment should be done continuously.

Technically feasible management methods for further consideration for mine tailings

- All mine tailings must not be dry.

Different options to manage dust emissions from mine tailings include:
- Deposit tailings under water.
- Surface vegetation, either floating or on inactive areas.
- Apply chemical suppression or water regularly/additional as needed.
- Stop activities in high wind conditions.
- Protect/surround tailings surface with wind breaks if less than 2 km of human receptors.
- Cover tailings with: mulch, lime slurry, bio-solids, vegetation.

Inspections:
- At least once per day (more often in dry windy conditions) a visual inspection of tailings area for dusting events.
- Dedicate personnel for tailings area.
- Close circuit camera to remotely observe the tailings area and be able to intervene timely in case of dusting events.

Monitoring:
- As previously mentioned, tailings could be a source of fine particulate, metals and other contaminants. If situated within the trigger distance (2 km) from sensitive receptors, community monitors would be required.
- Regular inspections proposed.

Technically feasible management methods for further consideration for Storage/Handling/Processing

Processing (primary crushing, screening):
- Processing area protected by a natural or artificial wind barrier.
- Clean the area at least once/day

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- Clean wheels of vehicles (wash or wheel shaker) for new facilities; washing wheels timing April to November.
- Stop activities in unfavorable wind conditions
- Control the processing equipment either by dust collector (new facility) or water spray nozzles.

Conveyors:
- Should be enclosed, covered or equipped with water spray nozzles with adjustable water rate; special considerations are included for new or existing facilities, proximity to human receptors, and type of material transported.

Transfer / loading points:
- Use a retractable telescopic chute protected with curtains (new facility).
- Concentrate loading area to be controlled with a baghouse (phasing in for facilities less than 1-2 km from human receptors).
- Fine mining material loading areas to be controlled with water mist or a baghouse (phasing in for facilities less than 1-2 km from human receptors).

Storage:
- Different rules for mining material, fine mining material and concentrates, depending on location (1-2 km or less from human receptors) For example:
    - Storage piles of fine mining material and/or concentrates to be enclosed in a building controlled by dust collection equipment (new facilities or facilities less than 1-2 km from human receptors), in a 3 sides structure with a roof or a half-dome.
    - Storage piles of mining material to be wet (apply water) or coated with dust suppressant, protected from the wind, or 3-side enclosure.

Technically feasible management methods for further consideration for Open Pit Mines

- Schedule drilling and blasting for days when there are low wind speeds forecasted.
- Delay blasting under unfavourable wind and atmospheric conditions.
- Water the blast area following the charging of blast holes with explosives.
- Use wet drilling or drilling equipment with dust collection capabilities.
- Use blast mats.

Open pit mines closer than 2 km from human receptors (in addition to previous requirements) should:
- Design and plan for smaller blast areas.
- Create a water perimeter around active areas during blasting (phasing in for existing facilities).
- Surround the pit by berms and use blasting mats (new facilities only).

6.3 Consideration of Cost Effectiveness

The OMA members of the Technical Committee provided a document[106] which included~~s~~ Economic considerations. Typical costs (accurate as of 2003) associated with dust control were presented, however no detailed analysis was applied to a particular mine site.

7.0 PUBLIC CONSULTATION

7.1. Summary of Public Consultation Efforts to Date

The mining sector is comprised of both large and medium to small sized businesses that are mostly located in northern Ontario (Sudbury and Timmins area). Similar to other technical standards, the ministry used a technical committee with members from the OMA and ministry staff from various branches to engage the sector in technical discussions and questions regarding contaminants, processes and environmental methods to better control or manage emissions. The technical committee included representatives from mining facilities, consultants and MNDM staff. Meetings were held between 2012 and 2016.

The ministry also participates on the Air Standards/Local Air Quality External Working Group (EWG) which has members from various industry sectors, public health agencies, environmental non-governmental organizations and some members of First Nations. The EWG provides general feedback and recommendations to the ministry on a broad range of issues related to the Local Air Quality Regulation (O.Reg.419/05). Status updates have been given to the EWG regarding the development of the Mining Sites IS and more discussion will be offered during the public comment period. Input from the EWG will likely be at a general program level (as opposed to sector-specific technical issues).

Public Transparency
The Mining Sites IS proposal includes summaries that are to be made available to the public. This approach was developed during consultation on the Pulp and Paper – Industry Standard based on feedback from the Local Air Quality Regulation External Working Group for the need for more public transparency.

The proposal is that the same two annual reports are updated and made available to the public: the Implementation Summary Table and the Performance Summary Table. The implementation summary table includes a list of the requirements that apply to the registered facility, when the requirements phase-in and the date the facility implemented the requirements. The Performance Summary Table would include a listing of notifications made to the ministry, notices and orders issued by the ministry to the facility.

7.2 Consideration of Feedback from Public Consultation

To be completed after the EBR posting period.

7.3 First Nations Engagement

In July 2014, the ministry sent 57 letters to various First Nations (Indigenous) communities who may be located near existing and possible future Nickel- Copper mines (mostly the Sudbury and Timmins area). In September 2014, ministry staff attended the Northern Ontario First Nations Environmental Conference and hosted a booth for participants to find out more about the proposed technical standard compliance approach. At this conference, interested parties signed up to receive additional information. Ministry staff followed up in early 2015 to provide more information.

OMA members that were considering registration to the proposed technical standard also reached out to interested First Nations (Indigenous) groups in their communities.

Follow up communications are planned during the comment period. First Nations and other community members will also have an opportunity to provide comments if the facility applies to register to this technical standard compliance approach.

8.0 PROPOSED MINING SITES INDUSTRY STANDARD

8.1 Proposed Structure

The Mining Sites IS applies to NAICS codes 212232 and 212233 activities, namely Nickel-Copper Mines and Copper-Zinc Mines.

In order to prevent, reduce or minimize emissions of nickel and nickel compounds as well as the other metals that comprise the ore, the Mining Sites IS compliance approach includes specified technologies and methods that must be used, operational, monitoring, recordkeeping and reporting requirements.

The requirements are summarized as follows:

Part I: General Requirements
- Definitions
- Application

Part II to VIII: Technology Specifications
- Technology requirements for dominant sources:
  - Mining material and concentrate storage
  - Material handling and processing
  - Mills
  - Tailings
  - Return Air Raises
  - Open pit mines
  - Roads

Part IX: General Operation and Maintenance Practices
- Operating Parameter Summary Table
- Measurement of operating parameters
- Deviations from operating parameters
- Operational adjustments
- Inspections and Maintenance

Part X: Requirement to continue the use of management methods to manage emissions (no backsliding)
Part XI: Community Monitoring
Part XII: Site Plan and Best practices
Part XIII: Complaints, Annual Summary reports and Records
- Complaint Procedure
- Notifications
- Summary Reports
- Records

A general requirement for facilities is a requirement to continue using existing air pollution control devices to ensure "no backsliding" or degradation of air pollution controls that are in place at the time of registration.

Part XIV requirements are related to records, internal reports to be provided to the Highest Ranking Individual, external notifications to the ministry and the availability of certain information to the public. This approach is similar to parts of other Industry standards published (Pulp and Paper – Industry Standard, Metal Finishers – Industry Standard, etc.)

8.2 Rationale for Requirements and Timing

Specific rules are proposed to apply to new mining facilities and mining sites close to receptors listed in section 1(5) of the draft Mining Sites IS, with phasing-in provisions. The receptors listed in 1(5) of the draft Mining Sites IS would be defined to include places referred to in subsection 30(8) of O.Reg.419/05 and places used for recreational or social purposes (see draft Mining Sites – IS section 1(5)).

To trigger additional requirements the distance between the source and the property line of "the place" as defined in section 1(5) of the draft Mining Sites IS is proposed to be 1 km. Modelling exercises provided by the OMA members of the Technical Committee showed the concentrations of nickel (used as a surrogate for all the contaminants contained in the ore) drop significantly within 1km from the property line of the mining facility for the additional grid of receptors added to address the source. For example Figure 8-1: Graphical display of modelling of a typical mining facility has an example of a road situated at the mining site property line. Figure 8-2: Relationship between the maximum ground level concentrations of nickel and distance from the property line for various sources at typical mining facility and Figure 8-3: Relationship between the maximum ground level concentrations of nickel and distance from the property line for various sources at typical mining facility, with an additional grid of receptors. If there is a conflict between these details of this rationale document and the Mining Sites IS proposals the Mining Sites IS will prevail.

Figure 8-1: Graphical display of modelling of a typical mining facility

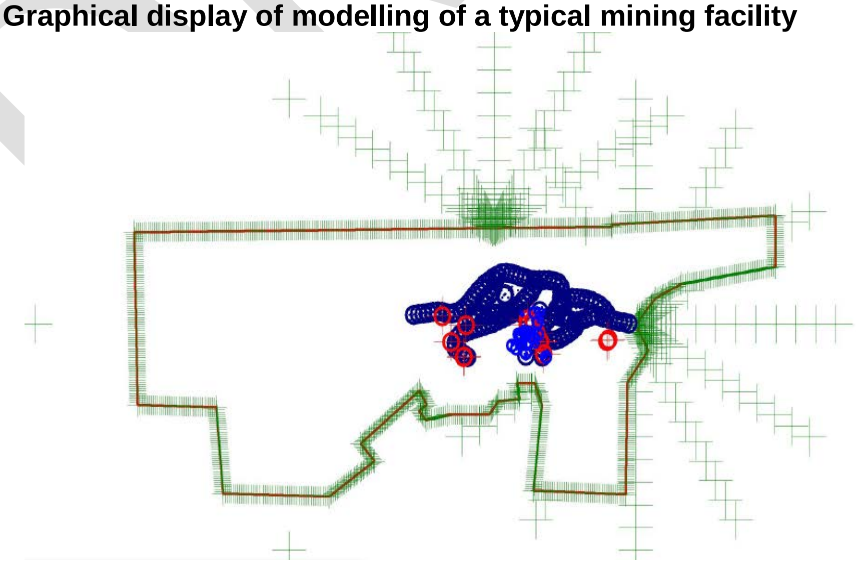
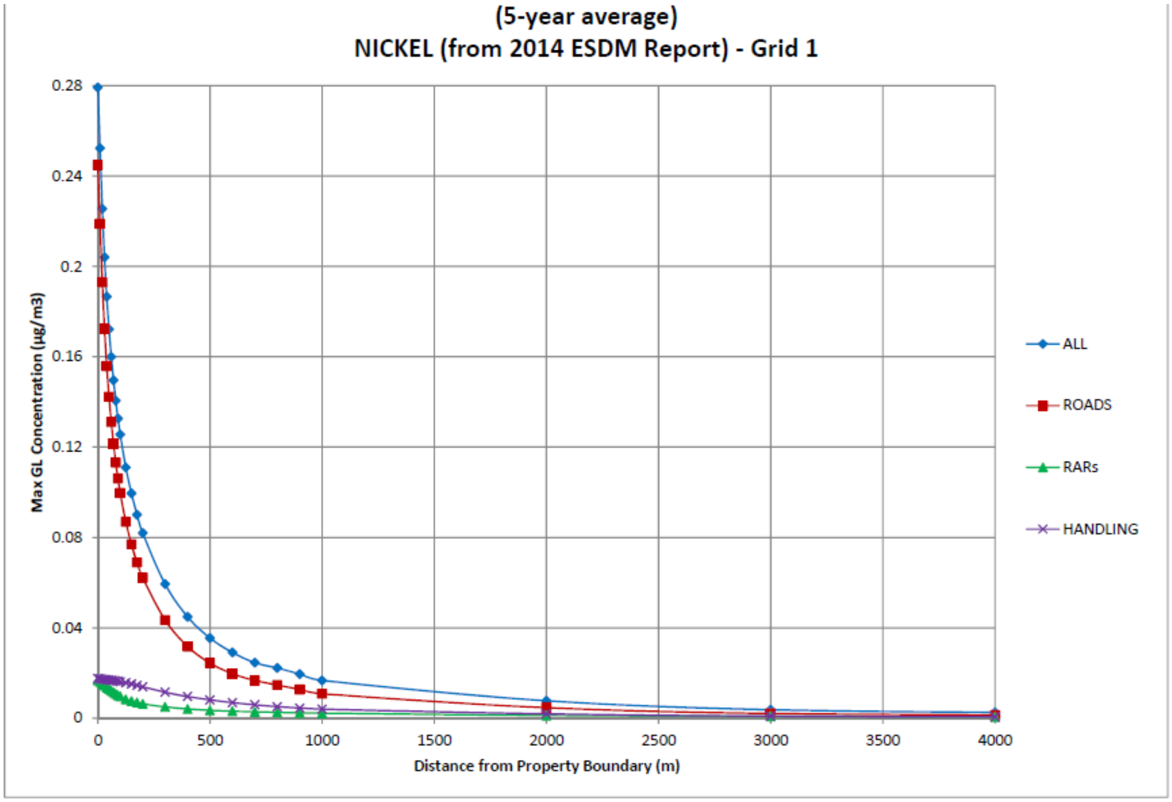


Figure 8-2: Relationship between the maximum ground level concentrations of nickel and distance from the property line for various sources at typical mining facility



A second grid of receptors was added with the focus of addressing the maximum point of impingement projected for nickel when the ensemble of all sources is considered.

Figure 8-3: Relationship between the maximum ground level concentrations of nickel and distance from the property line for various sources at typical mining facility, with an additional grid of receptors.

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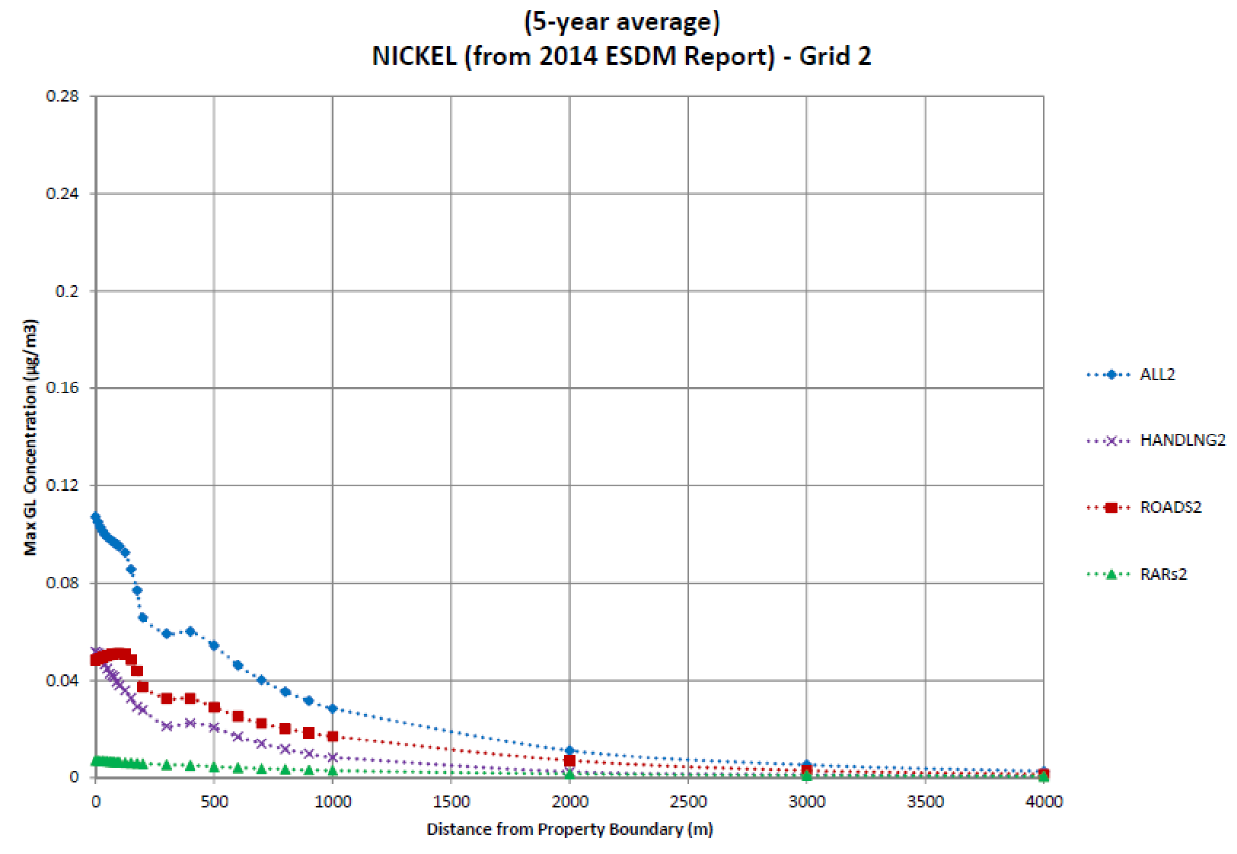

A significant part of the proposed Mining Sites IS will be represented by the tools to be included in order to demonstrate, in a transparent way, the efficiency of the methods selected, the need for adjustments and the environmental accountability.

If there is a conflict between these details of this rationale document and the Mining Sites IS proposals the Mining Sites IS will prevail.

Specific rules are proposed around the sources considered.

8.2.1 Proposed Rules for mining material and concentrate storage

The proposed Mining Sites IS recognizes mining material will be stored in different ways depending on dimensions and ore content. Terms as “fine mining material” (less than 2 inches) and “concentrates” are clearly defined in the proposed Mining Sites IS. The dominant sources analysis showed that this source (material storage) could become a significant one if left uncontrolled.

Proposed rules for fine mining material storage at an existing mining facility within 1 km of receptors listed in 1(5) of the draft Mining Sites IS include the requirement to store it inside a building, under a three-side enclosure with a roof or under a half dome. New mining facilities would be required to store fine mining material inside a building.

Proposed rules for mining material (larger size ore, non-ore bearing rocks) include: maintaining the surface wet or coating it with a dust suppressant and protecting it with from wind with one or more methods listed: a wind barrier (a fence, a line of trees, or a natural feature), placing below the grade in a pit, protecting with a three-sides wall enclosure and placing below the height of the lowest wall, or any other method that in the opinion of the Director would reduce the emissions. Facilities located within 1 km from the receptors listed in 1(5) of the draft Mining Sites IS would be required to apply two or more of these methods.

Concentrates would be required to be stored inside a building. The industry members of the Technical Committee mentioned that at least once a year, in spring, due to shipping restrictions in Quebec, overstock concentrates could be stored outside and covered by tarps. Since this situation seems to be repeating itself every year, the facilities could plan for it and in time (phase-in) build additional enclosed storage for overstock of concentrates.

8.2.2 Proposed Rules for tailings area

Tailings storage could be done under water, according to all relevant legislation and approvals. Other options of tailings disposal could be considered as long as the surface of tailings is not dry, coated with a dust suppressant or covered by different materials (mulch, lime slurry, straw, vegetation, snow).

Due to the potential of emitting very fine particulate, tailings facilities situated within 2 km of receptors listed in 1(5) of the draft Mining Sites IS would have to install a wind barrier between the receptor and the facility. As we recognize this would need time to be built this requirement would be phased-in.

Since the occurrence of freeze-dry dusting episodes was documented, the ministry proposes a requirement to treat the tailings with a dust suppressant before the winter temperatures settle and snow covers the area.

Tailings intended to be used as mine backfill will have to be controlled: either to ensure they contain sufficient moisture or to be coated with chemical dust suppressant.
The storage area of tailings material intended to be used as backfill has to be protected from wind by at least two methods referred to in the material storage section.

8.2.3 Proposed Rules for material handling and processing

Specific rules would apply to transfer points, material handling and material processing. Transfer points are defined as points where mining material or concentrate are loaded onto or off a conveyor, piece of equipment or vehicle. A first requirement would be to keep the area clean. The transfer point of concentrates, situated in a building, has to be controlled by a baghouse or wet scrubber. For transfer points where fine mining material is loaded on/off, at existing facilities within 1 km of receptors listed in 1(5) of the draft Mining Sites IS, control options would include: the use of a protective curtain, enclosing, or keeping the material wet.

Material handling would be expected to take place in an area surrounded by natural or artificial wind barrier(s), and to stop when the wind speed is greater than the value determined for that particular site and documented in the Best Practices Procedure record. Conveyors used to transport fine mining material at existing facilities would be required to be either enclosed in a building, equipped with a covered belt or curtain; or if the conveyor is located more than 1 km from receptors listed in 1(5) of the draft Mining Sites IS, it could be fitted with water spray nozzles to maintain the surface of the material moist. There would be provisions for phasing-in these requirements. If the facility is new, close to receptors listed in 1(5) of the draft Mining Sites

IS , or if the conveyor is used to transfer concentrates, water spray nozzles cannot be used. Water spray would not be used in winter months. New conveyors installed two years after the Industry Standard publication would have to be have adjustable speed and water application rate.

For new facilities, conveyors handling fine mining material are required to be enclosed in a building or to have a covered belt.

Mining material processing (crushing and screening) is expected to stop if the wind speed is higher than the value determined for that site and documented in the Best Practices Procedure record. New facilities and facilities close to receptors listed in 1(5) of the draft Mining Sites IS would be required to control these processing operations through the installation of pollution control equipment (baghouses). Existing facilities can use wind barriers and must keep the material that is being processed sufficiently moist.

8.2.4 Proposed Rules for mills

Mill operations are known to be significant sources of SPM and metals. For this reason, they are proposed to be enclosed in buildings. The main sources within a mill would be: the grinding circuit (crushers, screeners), the material handling inside the mill (conveyors), and the dryers. The proposed requirements include using wet grinding and capturing and controlling emissions from crushing/screening with a baghouse or wet scrubber.

For dewatering, the acceptable methods are to use thickeners or any type of filtration (vacuum or press filters). For the existing facilities currently using a thermal dryer they may continue to do so but on July 1, 2019 the proposal is that the dryer has to be operated at low temperature (max 200 degrees Celsius).

8.2.5 Proposed Rules for underground mines- Return Air Raises

Return air rises are a significant source of particulates, including metals that are exhausted from the underground operations. The health and safety requirements for the air quality underground make difficult for this source to be controlled.

Baffles or other similar equipment installed to reduce the velocity of the exhaust will also have the effect of dropping some of the particulates transported.

Therefore, the Mining Sites IS proposes that new RARs (phasing-in provision) have to be equipped with baffles and oriented away from receptors listed in 1(5) of the draft Mining Sites IS or prevailing wind direction.

Another way to minimize the particulate emission from this source is to apply water in the active work place as required by the Regulation 854 Mines and Mining plants made under Ontario Occupational Health and Safety Act.

8.2.6 Proposed Rules for Open Pit mines

Literature studies[84, 88] show that operations in open pit mines could impact nearby receptors in significant ways. A set of requirements is included in the proposed Mining Sites IS for open pit mines in general, with more stringent requests if a receptor listed in 1(5) of the draft Mining Sites IS is situated at or less than 2 km. It has been established that a distance of 2 km would allow the particulates to settle; in addition, existing facilities will have to use blasting mats or to ensure blasting initiation does not take place if wind speed is higher than the specific speed determined and documented for the site. Alternately, the surface of the material to be extracted has to be sufficiently wet to prevent the discharge of contaminants.

Facilities located less than 2 km from a receptor listed in 1(5) of the draft Mining Sites IS have to use blasting mats, the blasting area needs to be minimized, and a berm has to be erected between the pit and the receptor. These requirements will be phased in.
A new facility will have to use wet drilling or drilling equipment fitted with dust collection features. A blasting record has to be created and updated for each blasting activity as per the described details in the Mining Sites IS.

8.2.7 Proposed Rules for roads

Roads were determined to be a significant source of particulates (including metals), even the most significant source for some mining sites. Although it is important to maintain and clean all the roads, this proposed Mining Sites IS will focus only on the “high risk roads” or “high risk roads segments”.

Each facility will identify the high risk road segments based on criteria as: speed and volume of traffic, vehicles weight, the distance between that portion of the road and a receptor listed in 1(5) of the draft Mining Sites IS, and the silt content/loading.

Each facility will determine a maximum speed limit post signs and implement this requirement. A sign with the facility’s phone number has to be posted for public to address complains in case they witness dusting events.

Vehicles using high risk roads will be required to be loaded in a manner that no material shall be visible above the top portion; if carrying fine mining material or tailings intended to be used for fill the load in the vehicle needs to be covered or to contain sufficient moisture to prevent the discharge of particulate. Vehicles will be required to respect the posted maximum speed for the high risk road they travel on.

A newly constructed high risk road situated 1 km or less from a receptor listed in 1(5) of the draft Mining Sites IS would be required to be paved (phased in requirement). This requirement would not apply to roads (portions of roads) travelled by overweight vehicles (mine hauling trucks).

Road maintenance requirements will include vacuuming and washing paved roads, applying water or dust suppressant to unpaved roads and shoulders, grading, compacting and keeping updated records of the activities performed.

8.3 Assessment of Continuous Improvement

The proposed requirements include regular monitoring of operating parameters such as silt loading or content and monitors near dominant emission sources that will determine if best practices methods are effective.

A facility must track and self-correct if the operating parameter is not in the normal operating range. It would not be an offence to deviate from a normal operating range (unless there was an adverse effect). However, it is an offence if the monitoring was not conducted or if operational adjustments were not made.

In addition, facilities with sources located close to a receptor listed in subsection 1(5) of the draft Mining Sites IS are required to maintain a community monitor. The proposal includes a requirement to establish a three year baseline (on a monthly basis) that will then be compared to newer data to determine if things are improving. If the results show a degradation, there is a proposed notification requirement. This notification would help identify to the ministry any potential follow-up.

This type of continuous improvement cycle is common to management approaches used in industry such as the ISO (International Organization for Standardization) quality and environmental management systems and can allow for alignment with a facility's existing systems.

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REFERENCES

1. Mining Commodity Website

2. http://www.frontiermining.com/investors/Reports/110516_Wardell_Armstrong_Benkala_Study.pdf -

3. Wardell Armstrong International-Kazcopper-Open pit Design and Scheduling Study for Benkala deposit, 2011.

4. D. J. Brake - A protocol and standard for mine ventilation studies, *12th U.S./North American Mine Ventilation Symposium 2008 – Wallace (ed)*
ISBN 978-0-615-20009-5

5. Avanti Mining Inc. – Kitsault Mine project Environmental Assessment-Appendix 6.2-C Atmospheric Environment-Emission Sources and Air Quality Modelling.

6. Voysey Bay Enivironmental Effects Assessment

7. AMEC-Rainy River Project –Final Environmental Assessment-Appendix Q-1 Air Quality Modelling Report, June 2013.

8. Cowal (Barrick) Gold Mine E-42 Modification- Appendix C- Tailings and Waste Rock Geochemical Assessment, Geo-Environmental Management, 2009.

9.Chatten Cowherd, Jr., Mary Ann Grelinger and Dick L. Gebhart - Development of an Emission Reduction Term for Near-Source Depletion.

10. CDC- national Institute for Occupational Safety and health IC 9465/2003 – Handbook ANDBOOK FOR DUST CONTROL IN MINING.

11. Mining Magazine – January 2012, When the dust settles.

12. C. B. Arpacıoğlu & C. Er - Estimation of Fugitive Dust Impacts of Open-Pit Mines on Local Air Quality - A Case Study: Bellavista Gold Mine, Costa Rica- *18t" International Mining Congress and Exhibition of Turkey-IMCET 2003, © 2003, ISBN 975-395-605-3.*

13. http://www.mining-technology.com/projects/kemi/kemi1.html - Kemi, Finland

14. http://www.miningwatch.ca/two-million-tonnes-day-mine-waste-primer - 2010.

15. http://www.akaction.org/Publications/Mining/Mining_and_Toxic_Metals.pdf - Alaska Community Action on Toxics – Donlin Creek Mine, 2013.

16. Environmental Law Alliance Worldwide (ELAW), 2012- Guidebook for Evaluating Mining project EIAs.

17. B. Plante, M. Benzaazoua, B. Bussière , M.C. Biesinger , A.R. Pratt , 2010, Study of Ni sorption onto Tio mine waste rock surfaces.

18. Kevin Rolfe, Air Quality Implications of underground mining in the Golden Link Project Area, 2012.

19. Jose I. Huertas, Dumar A. Camacho, Maria E. Huertas - Standardized emissions inventory methodology for open pit mining areas - Environ Sci Pollut Res
DOI 10.1007/s11356-012-0778-3, 2012.

20. Golder Associates – 2013, Hammond Reef Gold Project, Appendix 3.1- Emissions.

21. EPA-450/3-81-009a, Emission Standards and Engineering Division- Metallic Mineral Processing Plants-Background information for proposed standrds, vol1, chapters1-9.

22. Environmental Sustainability Metrics for Nickel Sulphide Versus Nickel Laterite, A Jessup, G M Mudd, ***3rd International Conference on Sustainability Engineering & Science : Blueprints for Sustainable Infrastructure*** Auckland, New Zealand – 9-12 Dec. 2008

23. Ontario Mining Act

24. AQMD Rule 403: South Coast Air Quality Management District Profile of the Metal Mining Industry (September 1995) (EPA Office of Compliance Sector Notebook Project) US Department of the Interior (DOI)

25. Good practice guide for assessing and managing the environmental effects of dust emissions- New Zealand

26. Safe Work Australia- VENTILATION OF UNDERGROUND MINES- *Draft* Code of Practice.

27. “Canadian guide to the management of tailings facilities”, Mining Association of Canada, 1998

28. “Framework for mining waste management” [Euromines, 2002]

29. Comparison of chemical and biological leaching of sulfide tailings - Jari Arooma, Jarno Makinen, Henri Vepsalainen, Tommi Kaartinen, Margareta Wahlstrom, Olof Forsen.
http://www.minproc.pwr.wroc.pl/journal/pdf/ppmp49-2.607-620.pdf

30. First-Quantum Minerals Inc. Annual Information Form
http://www.first-quantum.com/files/doc_downloads/2014%20AIF%20-%20FINAL.pdf

31. Deposition Methods of Tailings - http://www.tailings.info/disposal/deposition.htm

32. http://www.industry.gov.au/resource/Documents/LPSDP/AirborneContaminantsNoiseVibrationHandbook_web.pdf

33. LEADING PRACTICE SUSTAINABLE DEVELOPMENT PROGRAM FOR THE MINING INDUSTRY
http://www.industry.gov.au/resource/Documents/LPSDP/EvaluatingPerformanceMonitoringAuditing_web.pdf

34. PROTOCOL FOR ENVIRONMENTAL MANAGEMENT: MINING AND EXTRACTIVE INDUSTRIES http://www.epa.vic.gov.au/~/media/Publications/1191.pdf

35. Live monitoring
http://www.porcupinegoldmines.ca/en/ouroperations/hollinger.asp?_mid_=3260

36. Tailings Management
http://www.industry.gov.au/resource/Documents/LPSDP/LPSDP-TailingsHandbook.pdf

37. Code of Practice for Tailings Storage Facilities
http://www.dmp.wa.gov.au/documents/Code_of_Practice/MSH_COP_TailingsStorageFacilities.pdf

38. Environment Canada- Environmental Code of Practice for Metal Mines
http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=CBE3CD59-1&offset=6&toc=show#s4_1_7

39. Good practice guide for assessing and managing the environmental effects of dust emissions, New Zealand Ministry of Environment, 2001.
http://www.mfe.govt.nz

40. http://www.epa.gov/scram001/reports/Haul_Road_Workgroup-Final_Report_Package-20120302.pdf US EPA Haul Road Workgroup Recommendations Memorandum, 2012.

41. United Nations Department of Economic and Social Affairs (UNDESA) and United Nations Environment Programme Industry and Environment (UNEP)- Environmental Guidelines for Mining Operations, 1998.

42. United Nations Department of Economic and Social Affairs (UNDESA) and United Nations Environment Programme Industry and Environment (UNEP)- Environmental Impact Assessment Training Resource Manual, 2002

43. The Mining Association of Canada - A Guide to the Management of Tailings Facilities *Second Edition, 2011*

44. Getting the deal through- Mining in 37 jurisdictions worldwide, 2012

45. *MANAGEMENT OF MINING, QUARRYINGAND ORE-PROCESSING WASTE IN THE EUROPEAN UNION*- Study made for DG Environment, European Commission Co-ordination by P. Charbonnier December 2001

46. European Commission - Reference Document on Best Available Techniques(BREF) for Management of Tailings and Waste-Rock in Mining Activities, January 2009

47. European Commission - Integrated Pollution Prevention and Control Reference Document on Best Available Techniques on Emissions from Storage, July 2006

48. Environment Australia – Overview of Best Practice Environmental Management in Mining – 2002

49. Environment Australia - Leading Practice Sustainable Development Program for the Mining Industry – Airborne contaminants, 2009

50. Environment Australia - Australian Minerals Industry First Code for Environmental Management, 1999

51. Environment Australia - Leading Practice Sustainable Development Program for the Mining Industry – Community Engagement and Development, 2006

52. Enduring Value – The Australian Minerals Industry Framework for Sustainable Development, 2005

53. Environment Australia - Leading Practice Sustainable Development Program for the Mining Industry – Evaluating Performance: Monitoring and Auditing, 2009

54. The Department of Environment, Climate Change and Water NSW Australia - The Strategic Environmental Compliance and Performance Review, 2009

55. Environment Australia - Leading Practice Sustainable Development Program for the Mining Industry – Mine Closure and Completion, 2006

56. Australia- National Pollutant Inventory – Emissions Estimation Technique Manual for Mining , Version 3.1, January 2012

57. *Australian Journal of Environmental Management*, Vol 7 No 2, June 2000, pp91-98- Fiona L Solomon- External Verification of the Australian Minerals Industry Code for Environmental Management: A Case Study

58. Department of Minerals and Energy Western Australia- Guidelines on the safe design and operating standards for tailings storage, 1999

59. www.epa.vic.gov.au – Protocol for Environmental Management: Mining and Extractive Industries, 2007

60. Environment Australia - Leading Practice Sustainable Development Program for the Mining Industry – Tailings management, 2007

61. Environment Australia - Leading Practice Sustainable Development Program for the Mining Industry – Stewardship, 2006

62. Environment Australia - Leading Practice Sustainable Development Program for the Mining Industry- Self Assessment Protocol, 2006

63. Federation of Canadian Municipalities and National Research Council – Dust Control for Unpaved Roads, 2005
64.CDC NIOSH – Handbook for Dust Control in Mining, 2003

65. Centre for Excellence in Mining Innovation – Literature review of current fugitive dust control practices within the mining industry, 2010

66. US EPA *Mining Industry Profile: Copper-* WASTES AND OTHER MATERIALS ASSOCIATED WITH COPPER EXTRACTION AND BENEFICIATION

67. www.epa.gov/oeca/sector - Sector notebook project Metal Mining

68. Japan Ministry of Environment - Environmental Performance Indicators Guideline for Organizations, 2003

69. http://www.cdsn.org/images/FugitiveDustGuide_v7_201_.pdf - Fugitive Dust- A Guide to the Control of Windblown Dust on Agricultural Lands in Nevada, Jan 2007

70. http://www.epa.nsw.gov.au/resources/air/KE1006953volumeI.pdf - NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining, Office of Environment and Heritage, Australia, June 2011

71. Cowal Gold Project – Dust Management Plan, Barrick Australia 2003

72. http://www.epa.gov/region9/air/phoenixpm/fip/method.html Tests methods for unpaved roads

73. Protocol for Environmental Management- State Environment Protection Policy (Air Quality Management) Mining and Extractive Industries EPA Victoria 40 City Road, Southbank Victoria 3006 Australia, December 2007, Publication 1191, ISBN 0 7306 7668 4 © EPA

74. NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining- Office of Environment and Heritage, Queensland, Australia, 2011

75. Selection, performance and economic evaluation of dust palliatives on surface mine haul roads by R.J. Thompson* and A.T. Visser†, *The Journal of The Southern African Institute of Mining and Metallurgy* **VOLUME 107 REFEREED PAPER** JULY 2007.

76. Foley, G., Cropley S., Giummarra G., 1996, Road Dust Control Techniques - Evaluation of Chemical Dust Suppressants. Performance. Special Report 54 to ARRB Transport Research Limited, Australia.

77. Long-Term Efficiencies of Dust Suppressants to Reduce PM10 Emissions from Unpaved Roads, John A. Gillies, John G. Watson, C. Fred Rogers, David DuBois, and Judith C. Chow
Desert Research Institute, University of Nevada System, Reno, Nevada Rodney Langston and James Sweet San Joaquin Valley Unified Air Pollution Control District, Fresno, California
http://www.midwestind.com/wp-content/uploads/2014/11/MW_PM10Emiss-Technical-Paper.pdf

78. Minerals, Metals and Sustainability: Meeting Future Material Needs
W. Rankin, 2011
https://books.google.ca/books?id=LTw0JJWGgvEC&pg=PA152&lpg=PA152&dq=metallurgical+engineer+manual,+copper+ore+beneficiation,+dry+concentrate&source=bl&ots=EGcuc5q0E7&sig=dGcfBxgEigfdrni9eQcFrbHikZI&hl=en&sa=X&ei=cZPsVN_pDuWxsASTzoLgBg&ved=0CBkQ6AEwATgK#v=onepage&q=

metallurgical%20engineer%20manual%2C%20copper%20ore%20beneficiation%2C%20dry%20concentrate&f=false

79. USGS 2011 Minerals Year Book – Nickel, published 2013
http://minerals.usgs.gov/minerals/pubs/commodity/nickel/myb1-2011-nicke.pdf

80. Processing of Complex Ores: Proceedings of the International Symposium on ...
edited by G. S. Dobby, S. R. Rao- Application of reverse pyrite flotation at Kidd Creek Mines, A.V.Kizilirmakli

81. Dust Control Handbook for Industrial Mineals Mining and Processing- 2012
http://www.cdc.gov/NIOSH/Mining/UserFiles/works/pdfs/2012-112.pdf

82. Measurement System Evaluation for Fugitive Dust Emissions Detection and Quantification, John G. Watson, Judith C. Chow, Li Chen, Xiaoliang Wang
Desert Research Institute, Reno, NV, USA, June 15, 2010
https://www.dri.edu/images/stories/editors/eafeditor/Watsonetal2010SCAQMDFugDustReport.pdf

83. Alternative methods for determining emissions for re-entrained road dust on transportation projects, Final Report- Prepared for The National Cooperative Highway Research Program, Transportation Research Council, National Research Council – prepared by Midwest Research Institute and Parsons Brinckerhoff, December 2008
http://environment.transportation.org/pdf/research_news/nchrp25-25_task42finalreport.pdf

84. Dust Control at Mining Operation-Vale Iron ore, Brazil
http://www.rainbird.ca/documents/turf/site_DustControl-long.pdf

85. TechnoMine Mining Technology
http://technology.infomine.com/reviews/mineroads/welcome.asp?view=full

86. Design of haul roads (master thesis)
http://www.collectionscanada.gc.ca/obj/s4/f2/dsk1/tape4/PQDD_0003/MQ59826.pdf

87. Significant Dust Dispersion Models for Mining Operations - DEPARTMENT OF HEALTH AND HUMAN SERVICES Centers for Disease Control and Prevention- National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Pittsburgh, PA, September 2005 https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2005-138.pdf

88. Dust barriers in open pit blasts. Multiphase Computational Fluid Dynamics (CFD) Simulations J. T. Alvarez, I. D. Alvarez & S. T. Lougedo *GIMOC, Mining Engineering and Civil Works Research Group,Oviedo School of Mines, University of Oviedo, Spain*
http://www.witpress.com/Secure/elibrary/papers/AIR08/AIR08010FU1.pdf

89. Harper Creek Mining Corporation – Air Quality Assessment
http://www.yellowheadmining.com/i/pdf/EIS/1)%20Main%20Report/09)%20Chapter%209.%20Air%20Quality.pdf

90. Environmental Management System – Vale Integra Coal Operations Pty Ltd- BLAST MANAGEMENT PLAN 2012 – 2015

http://www.vale.com/australia/EN/aboutvale/regulatory-reports/integra-complex-regulatory-information/Management%20Plans%20Draft/Integra%20Complex%20-%20Blast%20Management%20Plan.pdf

91. Modeling the emission, transport and deposition of contaminated dust from a mine tailing site
Michael Stovern,* Eric A. Betterton, A. Eduardo Sáez, Omar Ignacio Felix Villar, Kyle P. Rine, MacKenzie R. Russell, and Matt King, Rev Environ Health. Author manuscript; available in PMC 2014 May 7. Published in final edited form as:
Rev Environ Health. 2014; 29(0): 91–94.

92. Best Environmental Practices in Metal Ore Mining- Helsinki 2013 Finnish Environment Institute Päivi Kauppila, Marja Liisa Räisänen and Sari Myllyoja (eds)
https://helda.helsinki.fi/bitstream/handle/10138/40006/FE_29en_2011.pdf?sequence=4

93. Best Environmental Practices in the Mining Sector in the Barents Region International Conference 23–25 April 2013
http://www.barentsinfo.fi/beac/docs/Best_Environmental_Practices_23-25_April_2013_conference_publication_ENG.pdf

94. Settling the Dust- How Much is too Much, Australian Mine Safety Journal, May 2013, Authors: Leong Mar and Peter Wypych
http://www.amsj.com.au/news/settling-the-dust-how-much-is-too-much/

95. Freeze-dust prevention http://www.midwestind.com/blog/mine-tailings-case-study/

96. Simulation of windblown dust transport from a mine tailings impoundment using a computational fluid dynamics model
Michael Stovern,[a] Omar Felix,[b] Janae Csavina,[b] Kyle P. Rine,[a] MacKenzie R. Russell,[a] Robert M. Jones,[a] Matt King,[a] Eric A. Betterton,[a,b] and A. Eduardo Sáez[b,*]

97. Basics in Minerals Processing -

http://www.metso.com/miningandconstruction/MaTobox7.nsf/DocsByID/EAE6CA3B8E216295C2257E4B003FBBA6/$File/Basics-in-minerals-processing.pdf

98. Technical Support Document for Mobile Monitoring Technologies- C. Cowherd Midwest Research Institute January 9, 2009
https://www3.epa.gov/ttn/chief/ap42/ch13/related/Mobile_Monitoring_TSD_010909.pdf

99. TEOM-BASED MEASUREMENT OF INDUSTRIAL UNPAVED ROAD PM10, PM2.5, AND PM10-2.5 EMISSION FACTORS- John Hayden, CPG and John Richards, Ph., D., P.E- 2015
https://www3.epa.gov/ttnchie1/conference/ei14/session7/hayden.pdf

100. Mine ventilation Systems – Practical mine ventilation engineering
http://web.mst.edu/~tien/218/Lab8-Systems.pdf

101. Sudbury Mines Occupational Hygiene Data – February 2014

102. FATAL ACCIDENTS DUE TO FLYROCK AND LACK OF BLAST AREA SECURITY AND WORKING PRACTICES IN MINING
T. S. Bajpayee Mining Engineer Suresh K. Bhatt Mining Engineer Timothy R. Rehak General Engineer Gary L. Mowrey Electrical Engineer David K. Ingram Research Geologist National Institute for Occupational Safety and Health Pittsburgh, Pennsylvania, USA
https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/fadtf.pdf

103. Guidelines for spray nozzles selection
http://www.spray.com.au/pdf/dust_control_nozzle_selection.pdf

104. Dust Emissions from Landfill due to Deposition of Industrial Waste: a case study in Malmberget mine, Sweden
Qi Jin, Yi Huang, Nadhir Al-Ansari and Sven Knutsson- Civil, Mining, and Nature Resources Engineering of Lulea University of Technology.
http://www.ltu.se/cms_fs/1.85152!/file/3.3%20Dust%20from%20Landfill%202%200%20.pdf

105. Tailings.Info http://www.tailings.info/basics/tailings.htm

106. Literature Review of Current Dust Control Practices within the Mining Industry, Report submitted to The Centre for Excellence in Mining Innovation, Golder Associates, 2010.

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