National Pollutant Inventory

Emission Estimation Technique Manual

for
Mining and Processing
of
Non-Metallic Minerals

First published in November 1999

EMISSION ESTIMATION TECHNIQUES
FOR
MINING AND PROCESSING OF NON-METALLIC MINERALS

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1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial, and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in mining and processing of non-metallic minerals.

The activities covered in this Manual apply to facilities primarily engaged in the mining, extraction and processing of non metallic minerals such as perlite, diatomite, feldspars, phosphate rock and other minerals discussed below.

EET MANUAL:	Mining and Processing of Non-metallic Minerals
HANDBOOK:	Mining of Non-Metallic Minerals
ANZSIC CODES :	1411, 1419 & 1420

The NPI Unit of the Queensland Environmental Protection Agency drafted this Manual on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders.

Context and use of this manual

This NPI manual provides a "how to" guide for the application of various methods to estimate emissions as required by the NPI. It is recognised that the data that is generated in this process will have varying degrees of accuracy with respect to the actual emissions from facilities. In some cases there will necessarily be a large potential error due to inherent assumptions in the various emissions estimation techniques (EETs) and/or a lack of available information of chemical processes.

EETs should be considered as 'points of reference'

The EETs and generic emission factors presented in this manual should be seen as 'points of reference' for guidance purposes only. Each has associated error bands that are potentially quite large (eg. based on generic emission factors only); uncertainties of 100% are considered likely. Chapter 5 discusses the general reliability associated with the various methods. The potential errors associated with the different EET options should be considered on a case-by-case basis as to their suitability for a particular facility. Facilities may use EETs that are not outlined in this document. They must, however, seek the consent of their relevant environmental authority to determine whether any 'in house' EETs are suitable for meeting their NPI reporting requirements.

Hierarchical approach recommended in applying EETs

This manual presents a number of different EETs, each of which could be applied to the estimation of NPI substances. The range of available methods should be viewed as a hierarchy of available techniques in terms of the error associated with the estimate. Each substance needs to be considered in terms of the level of error that is acceptable or appropriate with the use of the various estimation techniques. Also the availability of pre-existing data and the effort required to decrease the error associated with the estimate will need to be considered. For example, if emissions of a substance are clearly very small no matter which EET is applied, then there would be little gained by applying an EET which required significant additional sampling.

The steps in meeting the reporting requirements of the NPI can be summarised as follows:

- for Category 1 and 1a substances identify which reportable NPI substances are used (or handled by way of their incidental presence in ore or materials, or exceeds the bulk storage capacity for 1a), and determine whether the amounts used or handled are above the "threshold" values and therefore trigger reporting requirements;
- for Category 2a and 2b substances determine the amount and rate of fuel (or waste) burnt each year, the annual power consumption and the maximum potential power consumption, and assess whether the threshold limits are exceeded;
- for Category 3 substances determine the annual emissions to water and assess whether the threshold limits are exceeded; and
- for those substances above the threshold values, examine the available range of EETs and determine emission estimates using the most appropriate EET.

Generally it will be appropriate to consider various EETs as alternative options whose suitability should be evaluated in terms of:

- the associated reliability or error bands; and
- the cost/benefit of using a more reliable method.

The accuracy of particular EETs is discussed in the section on emission factor ratings.

NPI emissions in the environmental context

It should be noted that the NPI reporting process generates emission estimates only. It does not attempt to relate emissions to potential environmental impacts, bioavailability of emissions, natural background levels etc.

Facilities may undertake 'Ancillary Activities', such as the production of substances, either as a process input or through processing of waste steams. When estimating emissions a facility should ensure that emissions are not 'double accounted' (see Section 4) and process maps should be used to minimise the potential for this.

This manual is structured to allow facilities to work through it addressing issues in a structured and coherent manner.

This approach has been adopted in order to demonstrate how an EET may be applied to estimating emissions of a substance and supported by other EETs. For example, facilities may choose to use a mass balance approach to their estimation of emissions. However the mass balance EET is likely to be supported by direct monitoring data and emission factors.

2.0 Processes and Emissions

Most of the non-metallic minerals are extracted by open-pit mining. Open-pit mining methods are used where an ore body lies at or near the surface. To uncover the ore body, the overburden (waste rock and soil lying over it) must be removed. The topsoil and waste rock are stockpiled, and may be used to restore the landscape when the deposit is mined out. In softer ground, machines simply rip up the soil and rock around the ore zone. In harder ground, drilling and blasting are issued to open up the pit.

Underground mining is used when the ore body extends far beneath the surface or where the form of the landscape would make it uneconomic to move large quantities of waste material to develop an open pit mine. For many years inclined or vertical shafts were exclusively used to reach deep ore bodies, however, spiralling decline shafts are now the most popular method of accessing underground mines, particularly those exploiting shallower mineral deposits.

For the mining aspect of the non-metallic minerals, similar emissions estimation techniques to those described in the *Emission Estimation Technique Manual for Mining* will apply. Relevant parts of the *EET Manual for Mining* have been extracted and included in Sections 4.1.1 to 4.1.6 of this Manual.

Processing of the non-metallic minerals on the mine site involves crushing and grinding of the ore, the separation of the valuable minerals from the matrix rock through various concentration steps; and at some operations, the drying, calcining, pellitising and packaging of concentrates to ease further handling or refining. In some cases chemical and physical methods such as magnetic separation, flotation, solvent extraction and leaching may be necessary to separate impurities or to change the physical or chemical nature of the product.

Emissions of particulate matter (PM) and particulate matter equal to or less than 10 micrometres in diameter (PM_{10}) result from mineral plant operations such as crushing and dry grinding ore, drying concentrates, storing and reclaiming ores and concentrates from storage bins, transferring materials, and loading final products for shipment. Fugitive emissions are also possible from roads and open stockpiles. Emissions from dryers and calciners include products of combustion, such as CO, carbon dioxide (CO_2), NO_x, SO_2 in addition to PM and PM_{10}. Emissions of SO_2 may not be an issue when low sulfur fuels such as natural gas are used. VOCs associated with the raw materials and the fuel may also be emitted from drying and calcining processes. Cyclones, wet scrubbers and fabric filters and occasionally electrostatic precipitators are used to control PM emissions from non-metallic minerals processing operations.

In the absence of Australian data, this manual has adopted where available, air emission factors for processing of non-metallic minerals from USEPA AP-42, Chapter 11 (1995). The USEPA emission factor rating for most non-metallic processing operations is category D (below average). Australia's non-metallic processing industries may differ from those in the US. The suitability of USEPA emission factors will depend on the degree of similarity between the equipment and process described by the USEPA document, and the equipment and process actually used on the Australian site.

2.1 Process Description

Australia's mineral industry is quite diverse and the following sections highlight some of the mining and processing operations in Australia.

2.1.1 Perlite

Perlite is a glassy volcanic rock that exhibits a pearl like lustre. In a typical sample, the composition of perlite is 71-75 per cent silicon dioxide, 12.5 - 18.0 per cent alumina, 4 to 5 per cent potassium oxide, 1 to 4 per cent sodium and calcium oxides and trace amounts of metal oxides. Perlite deposits in Australia are found primarily in New South Wales, Queensland and South Australia. Although not all deposits are exploited, there are operations in New South Wales and potential for further expansion in other areas. Figure 1 illustrates the basic flow diagram for the mining and processing of perlite ore.

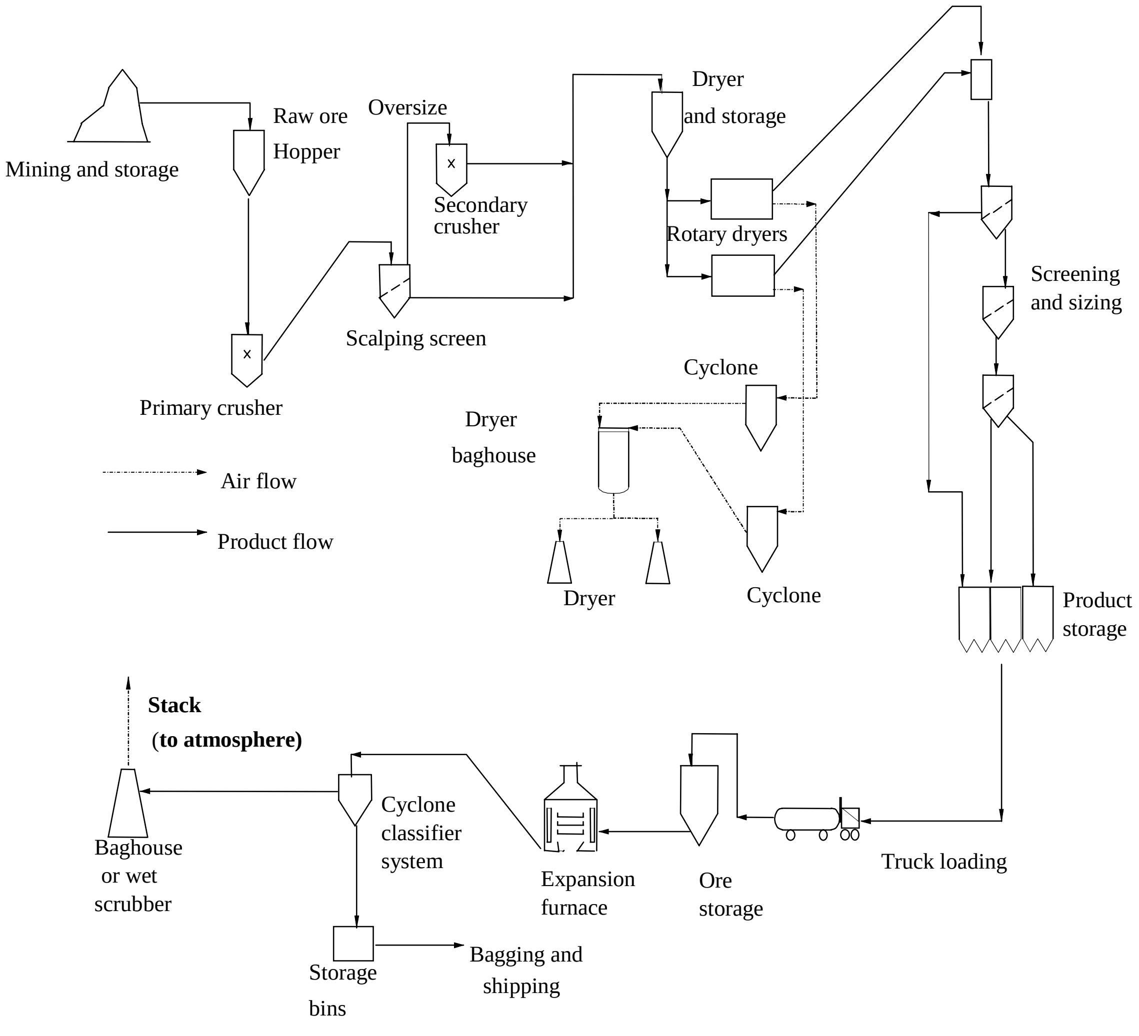

Figure 1- Basic Process Flow Diagram for Perlite Manufacturing
Source: USEPA AP-42 Section 11.30 (1995)

Industrial perlite is produced in two stages. Firstly, natural perlite is mined, crushed, dried and screened at the mine site to yield crude perlite. In the second stage, perlite is rapidly heated for a short time to temperatures between 800°C and 1000°C to yield expanded perlite, a sterile ultra lightweight aggregate. Bulk densities are typically 50-100 kg/m^3. Typical fuel usage in the drying and heating operations (furnaces) comprises of natural gas and possibly propane.

2.1.2 Feldspar

Feldspar minerals are a major component of igneous rocks. Feldspars are aluminosilicate minerals with varying amounts of potassium, sodium and calcium. The feldspar minerals include orthoclase ($K[AlSi_3O_8]$), albite ($Na[AlSi_3O_8]$), anorthite ($Ca[Al_2Si_2O_8]$) and celsian ($Ba[Al_2Si_2O_8]$).

The alkali feldspars are used in the manufacture of porcelain and pottery fibreglass, glazes, and opalescent glass.

The most economically viable deposits of feldspar occur in the Broken Hill region of NSW. Feldspar and feldspathic materials are principally used as a source of alumina and alkalis in glassmaking and the ceramic industry, with sodium-rich feldspar being preferred for glassmaking and potassium-rich feldspar for ceramic manufacture. Due to the availability of cheaper, alternative materials many Australian consumers have changed to substitutes such as calcined alumina and soda ash for glassmaking.

Feldspar can be extracted from high purity deposits in Australia by a simple process involving only mechanical separation and grinding. Feldspar is extracted using open cut mining and transported to a primary crusher where it is reduced to 150 mm. Lumps of quartz and mica are removed before transfer to a secondary crusher where the material is reduced to 40 mm in size. Further size reduction is achieved using a roll crusher or a pebble mill. The main commercial products are materials 1.2 mm and 53 micrometre in size.

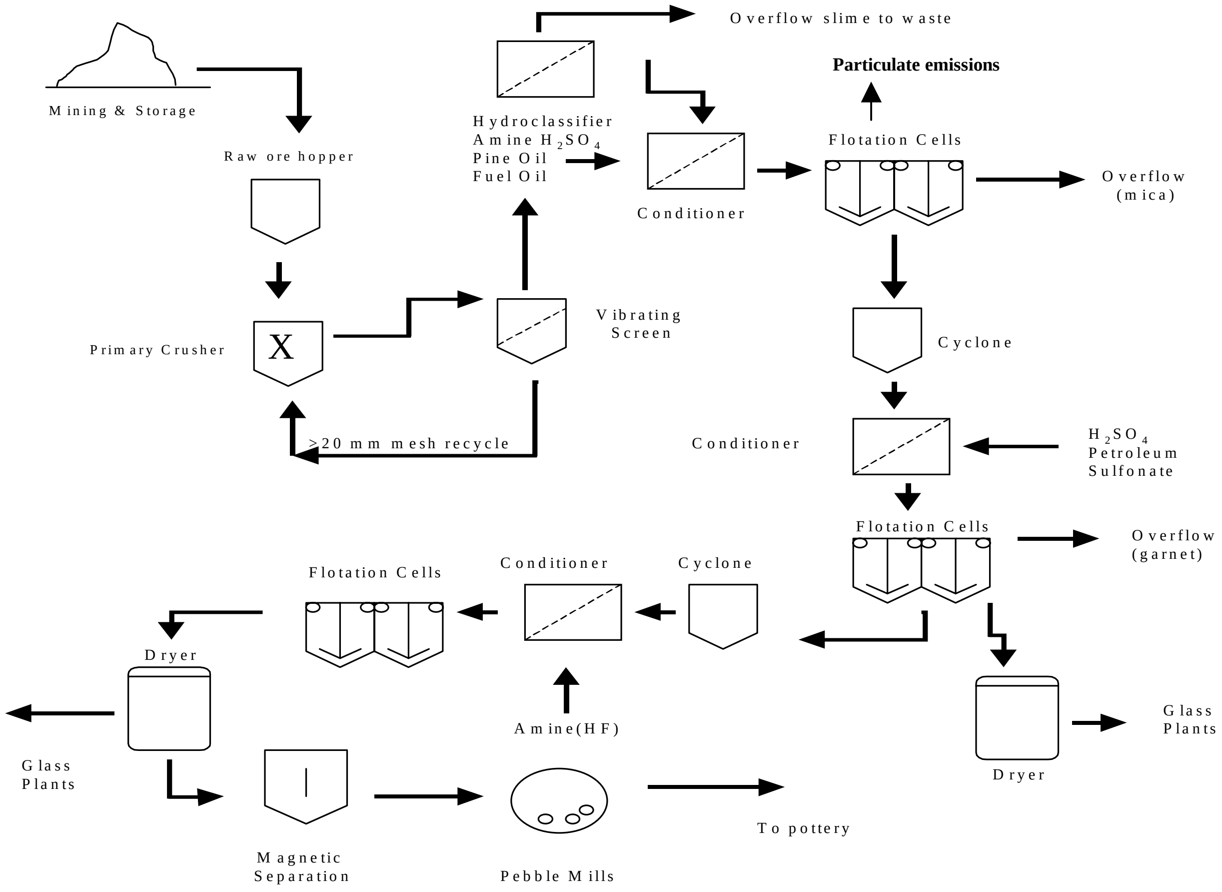

Figure 2 - Process Flow Diagram for Feldspar Processes
Source: USEPA AP-42 Section 11.27 (1995).

2.1.3 Phosphate Rock

The term phosphate rock is used to describe sedimentary rock containing a high percentage of minerals from the apatite group - $Ca_5(PO_4)_3(F,OH,Cl)$.

Australia has large phosphate rock resources, (eg. the Georgina Basin sediments in Queensland and the Northern Territory). Phosphate rock is the basic raw material for the commercial manufacture of phosphoric acid and single- and triple-super-phosphate fertiliser. Australian manufacturers of phosphate fertilisers currently use imported phosphate rock. A fertiliser project being developed by Western Mining Corporation in Queensland will change this situation by commencing production during 1999 of phosphate fertilisers from indigenous phosphate rock extracted from the Phosphate Hill mine and sulfuric acid derived from smelting operations at Mt Isa Mines Ltd.

The rock phosphate from Phosphate Hill is high grade and the only processing carried out at the mine site will be crushing and screening. Emissions of dust (including PM_{10}) will occur during excavation, transport, crushing, screening and stockpiling of the phosphate rock.

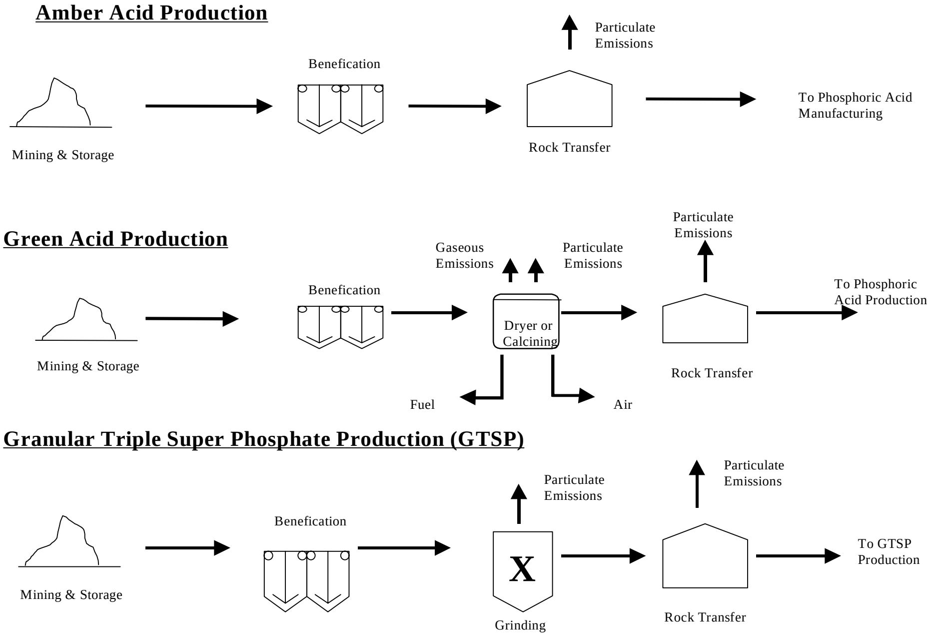

Figure 3 - Flow Diagram for Phosphate Rock Processing
Source: USEPA AP-42 (1995).

2.1.4 Clay

Clay

Clay is a natural, earthy, fine-grained material composed mostly of clay minerals with varying amounts of quartz, feldspar, micas and iron oxides. The clay minerals are crystalline hydrous aluminium silicates having the Si_4O_{10} sheet structure. Clay minerals may also contain appreciable quantities of iron, sodium, potassium, calcium and magnesium. Clay is usually formed by the mechanical and chemical breakdown of rocks. Clay may be formed in situ or transported and deposited as sediments. Shale is a laminated sedimentary rock that is formed by the consolidation of clay, mud, or silt. Common clay and shale are composed mainly of the clay minerals, illite or chlorite, but also may contain kaolin and montmorillonite.

Most clays, except bentonite and fuller’s earth, have the property of becoming plastic and capable of being moulded when wet and then becoming hard and rock-like when heated to a suitable temperature. Clays may be classified as structural or specialist clays. Structural clays are mined and mainly used for the manufacture of ceramics, bricks, clay tiles and pipes. Other clays such as kaolinite, bentonite and fuller’s earth are mined and processed for specialised uses.

Most domestic clay is mined by open-pit methods using various types of equipment, including drag-lines, power shovels, front-end loaders, backhoes, scraper-loaders, and shale planers. In addition, some kaolin is extracted by hydraulic mining and dredging.

Clays are usually transported by truck from the mine to the processing plants, many of which are located at or near the mine. For most applications, clays are processed by mechanical methods, such as crushing, grinding, and screening, which do not appreciably alter the chemical or mineralogical properties of the material. However, because clays are used in such a wide range of applications, it is often necessary to use other mechanical and chemical processes, such as drying, calcining, bleaching, blunging, and extruding to prepare the material for use.

Primary crushing reduces material size from as much as one metre to a few centimetres in diameter and is typically accomplished using jaw or gyratory crushers. Rotating pan crushers, cone crushers, smooth roll crushers, toothed roll crushers, and hammer mills are used for secondary crushing, which further reduces particle size to 3 mm or less. For some applications, tertiary size reduction is necessary and is accomplished by means of ball, rod, or pebble mills, which are often combined with air separators. Screening is typically carried out by means of two or more multi-deck sloping screens that are mechanically or electro-magnetically vibrated. Pug mills are used for blunging, and rotary, fluid bed, and vibrating grate dryers are used for drying clay materials. Flash, rotary or multiple hearth furnaces may be used to calcine clays.

The following paragraphs describe the various types of clay and procedures for processing them.

Kaolin

Kaolin is clay composed primarily of the hydrated aluminosilicate mineral kaolinite ($Al_2O_3.2SiO_2.2H_2O$) with minor amounts of quartz, feldspar, mica, chlorite and other clay minerals. It is distinguished from other clays by its softness, whiteness and ease of dispersion in water. Primary kaolin deposits were formed by the alteration of in-situ minerals such as feldspar and other aluminium silicates to kaolinite. Secondary deposits were laid down as sediments, usually in fresh water, far from the place of origin. Various types of secondary kaolins may be termed ball clays, fireclays or flint clays depending on their properties or use. Kaolin has applications as a filler and extender in paper, paints and plastics. Ball clay is a plastic, white-firing clay that is composed primarily of kaolinite and is used mainly to make ceramic pottery, tiles, insulators and refractories. Fire clays are composed primarily of kaolinite, but may also contain several other materials including diaspore, burley, burley-flint, ball clay, bauxitic clay and shale. Because of their ability to withstand temperatures of 1500°C or higher, fire clays generally are used for refractories or to raise vitrification temperatures in heavy clay products. Flint clay, a hard kaolinitic rock, is used mainly in refractories.

USEPA AP-42 Chapter 11.25 describes both dry- and wet-processes for kaolin. Flow diagrams for these processes are presented in Figure 4 and Figure 5. The dry process is simpler and produces a lower quality product than the wet process. Dry-processed kaolin is used mainly in the rubber industry, and to a lesser extent, for paper filling and to produce fibreglass and sanitary ware. Wet-processed kaolin is used extensively in the paper manufacturing industry.

In the dry process, the raw material is crushed to the desired size, dried in rotary dryers, pulverized and air-floated to remove most of the coarse grit.

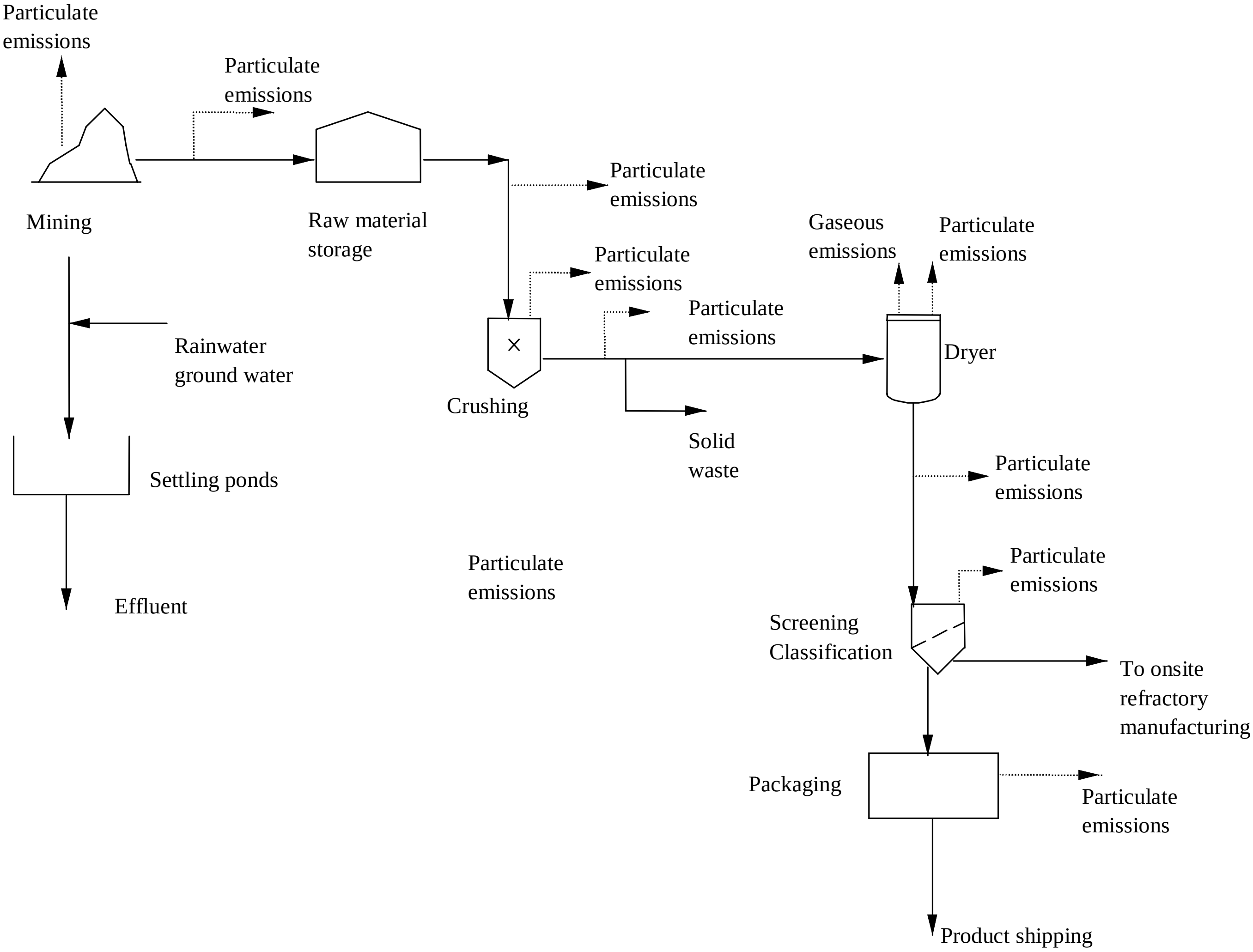

Figure 4 - Process Flow Diagram for Kaolin Mining and Dry Processing
Source: USEPA AP-42 (1995).

Wet processing of kaolin begins with blunging to produce a slurry, which then is fractionated into coarse and fine fractions using centrifuges, hydro-cyclones, or hydro-separators. At this step in the process, various chemical methods, such as bleaching, and physical and magnetic methods, may be used to refine the material. Chemical processing includes leaching with sulfuric acid, followed by the addition of a strong reducing agent such as hydrosulfite. Before drying, the slurry is filtered and de-watered by means of a filter press, centrifuge, rotary vacuum filter, or tube filter. The filtered de-watered slurry material may be shipped or further processed by drying in apron, rotary, or spray dryers. Following the drying step, the kaolin may be calcined, usually in a multiple hearth furnace, for use as filler or refractory material.

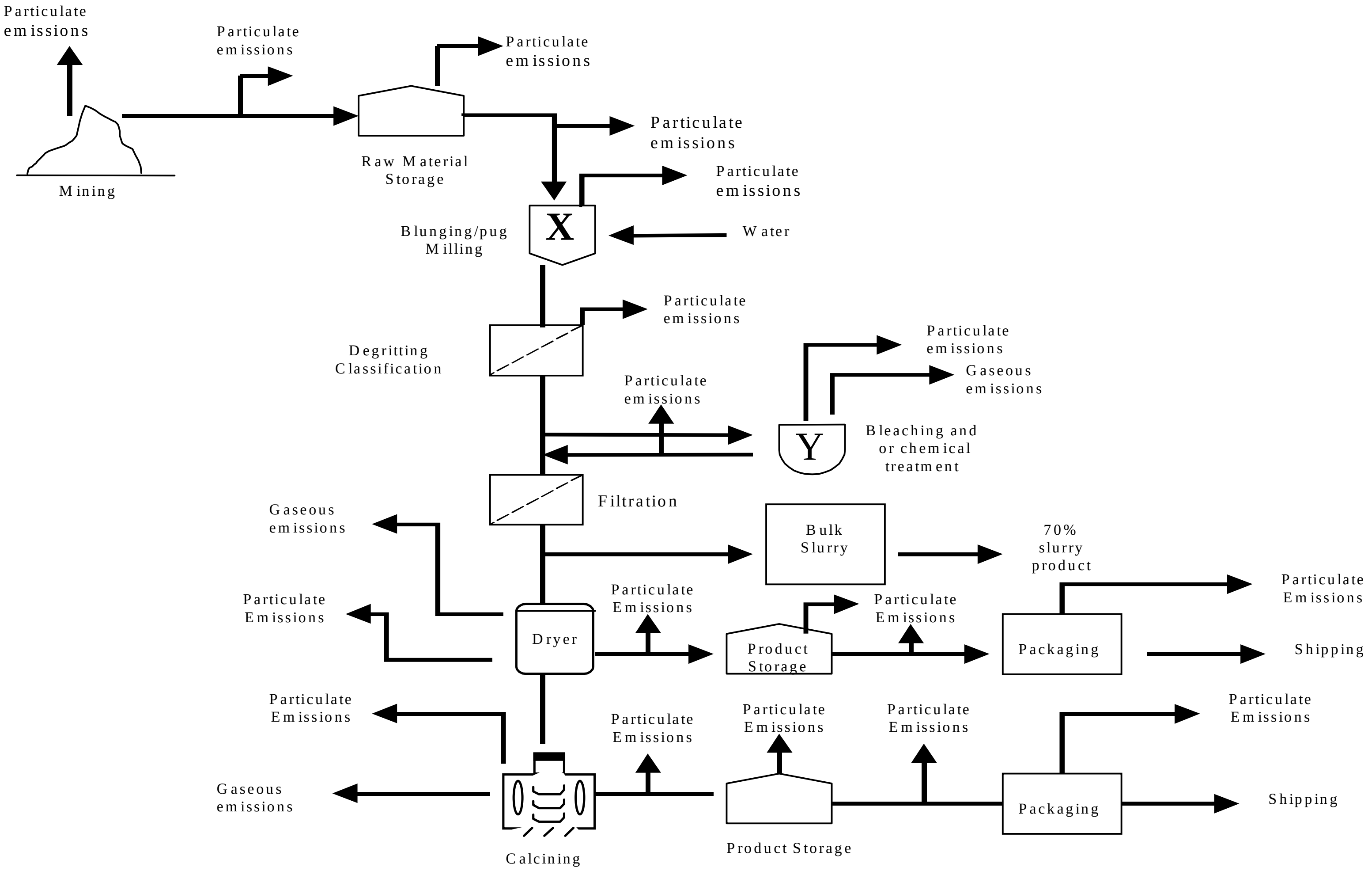

Figure 5 - Process Flow Diagram for Wet Process Kaolin for High Grade Products
Source: USEPA AP42 Section 11.25 (1995)

Ball Clay

Ball clay, which typically has a moisture content of approximately 28 per cent, is first stored in drying sheds until the moisture content decreases to 20 to 24 per cent. The clay then is shredded in a disintegrator into small pieces 1.3 to 2.5 centimetres (cm) thick. The shredded material then is either dried or ground in a hammer mill. Material exiting the hammer mill is mixed with water, and bulk loaded as a slurry for shipping. Figure 6 depicts the process flow for ball clay processing. Indirect rotary or vibrating grate dryers are used to dry ball clay. Combustion gases from the firebox pass through an air-to-air heat exchanger to heat the drying air to a temperature of approximately 300°C. The clay is dried to a moisture content of 8 to 10 percent. Following drying, the material is ground in a roller mill and shipped. The ground ball clay may also be mixed with water as a slurry for bulk shipping.

Fire Clay

Mined fire clay is first transported to the processing plant and stockpiled. In some cases, the crude clay is weathered for 6 to 12 months, depending on the type of fire clay. Weathering breaks the material up, resulting in smaller particles and improved plasticity. The material then is crushed and ground. At this stage in the process, the clay has a moisture content of 10 to 15 per cent. For certain applications, the clay is dried in mechanical dryers to reduce the moisture content of the material to 7 per cent or less. Rotary and vibrating grate dryers fired with natural gas or fuel oil are typically used for drying fire clay. To increase the refractoriness of the material, fire clay is often calcined. Calcining eliminates moisture and organic material and causes a chemical reaction between the alumina and silica in the clay, producing a material (mullite) that is harder, denser, and more easily crushed than uncalcined fire clay. After the clay is dried and/or calcined, the material is crushed, ground, and screened. After screening, the processed fire clay may be blended with other materials, such as organic binders, before being formed in the desired shapes and fired.

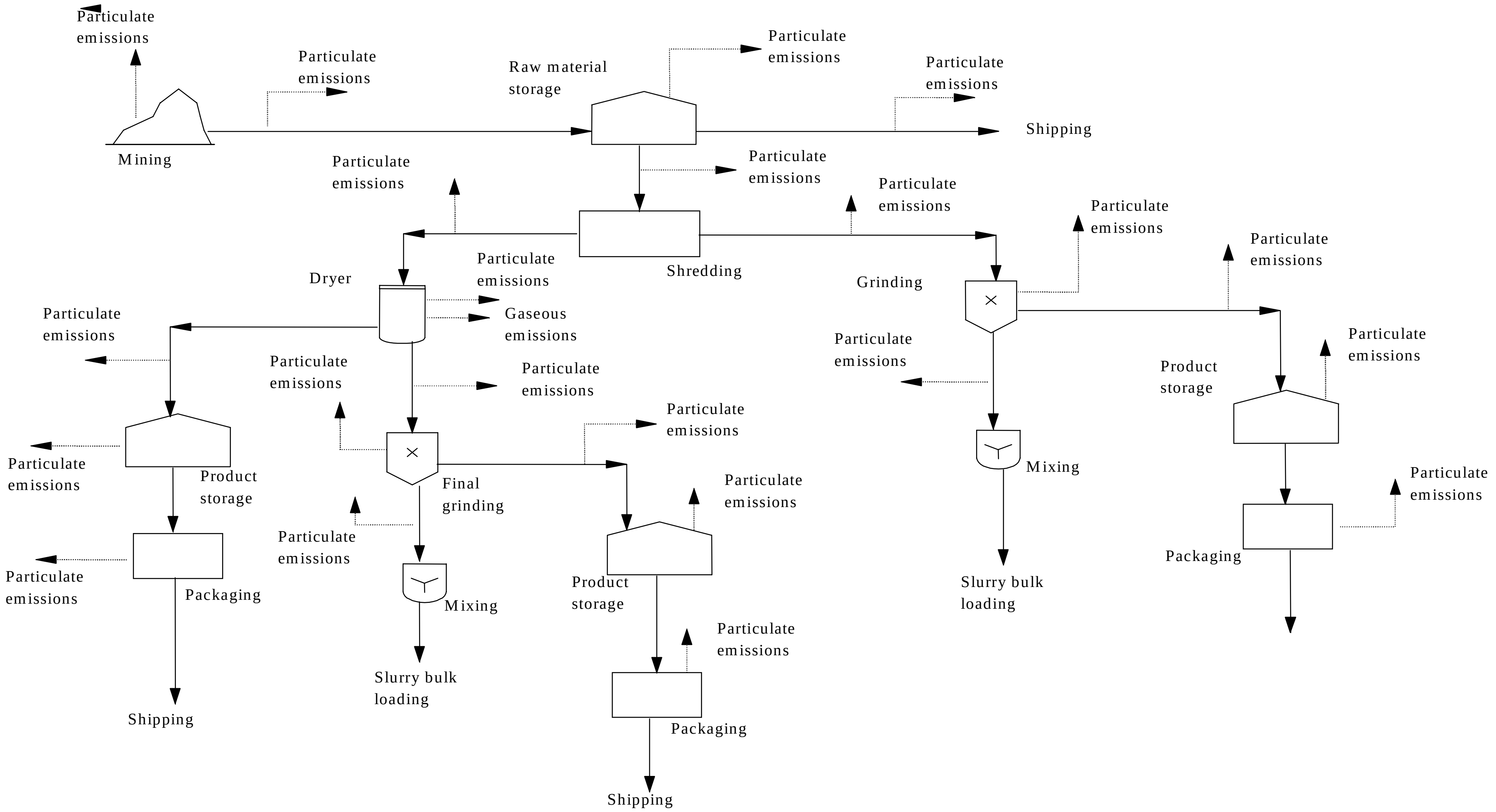

Figure 6 - Process Flow Diagram for Ball Clay Processing
Source: USEPA AP-42 Figure 11.25-3 (1995).

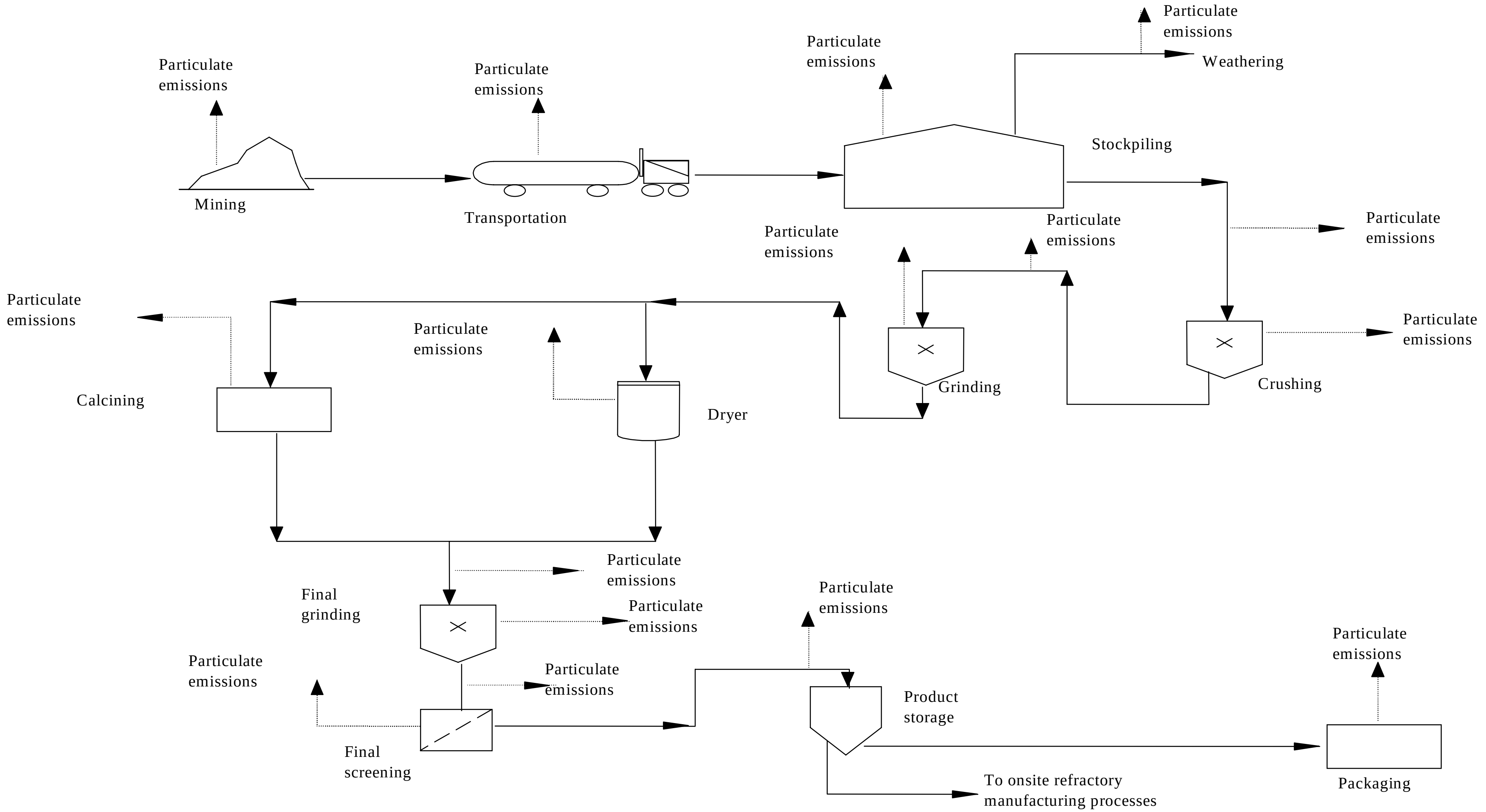

Figure 7 - Process Flow Diagram for Fire Clay Processing
Source: USEPA, AP-42, Section 11, (1995)

Bentonite

Bentonite consists predominantly of the swelling clay montmorillonite, a loosely bound sheet silicate with exchangeable sodium, calcium, and magnesium cations. The most useful properties of bentonite include its ability to exchange cations, its swelling and hydration capacity, its ability to act as a binder and its impermeability.

Applications are extensive as a result of the clay's different properties. Uses include drilling muds, civil engineering applications, foundry moulds, animal feed, pet litter, sealants, horticulture, wine making, absorbents, catalysts, binders, furnace linings, ceramics, pesticides, paints, purifying and de-colourising fats and oils, medical and pharmaceutical products. Specialised grades of bentonite are used in a wide range of industrial applications for domestic and export markets. Bentonite is a major component in foundry sand and drilling muds and it is widely used in the pelletisation of stockfeeds. Particular types are used to seal dams and for other civil engineering applications and as a moisture absorbent in pet litter. Acid activated bentonite is also used in refining oils, fats and solvents. Particular types have a high adsorbency for gaseous, liquid and solid industrial wastes, including heavy metal contaminants in solution and for oil spillages both on land and water. Bentonite is being used increasingly for environmental applications.

Figure 8 shows a flow diagram for bentonite processing. Mined bentonite first is transported to the processing plant and stockpiled. If the raw clay has a relatively high moisture content (30 to 35 per cent), the stockpiled material may be ploughed to facilitate air drying to a moisture content of 16 to 18 per cent. Stockpiled bentonite may also be blended with other grades of bentonite to produce a uniform material. The material then is passed through a grizzly and crusher to reduce the clay pieces to less than 2.5 cm in size. Next, the crushed bentonite is dried in rotary or fluid bed dryers fired with natural gas, oil, or coal to reduce the moisture content to 7 to 8 per cent. The temperatures in bentonite dryers generally range from 900°C at the inlet to 100 to 200°C at the outlet. The dried material is then ground by means of roller or hammer mills. At some facilities that produce specialised bentonite products, the material is passed through an air classifier after being ground. Soda ash also may be added to the processed material to improve the swelling properties of the clay.

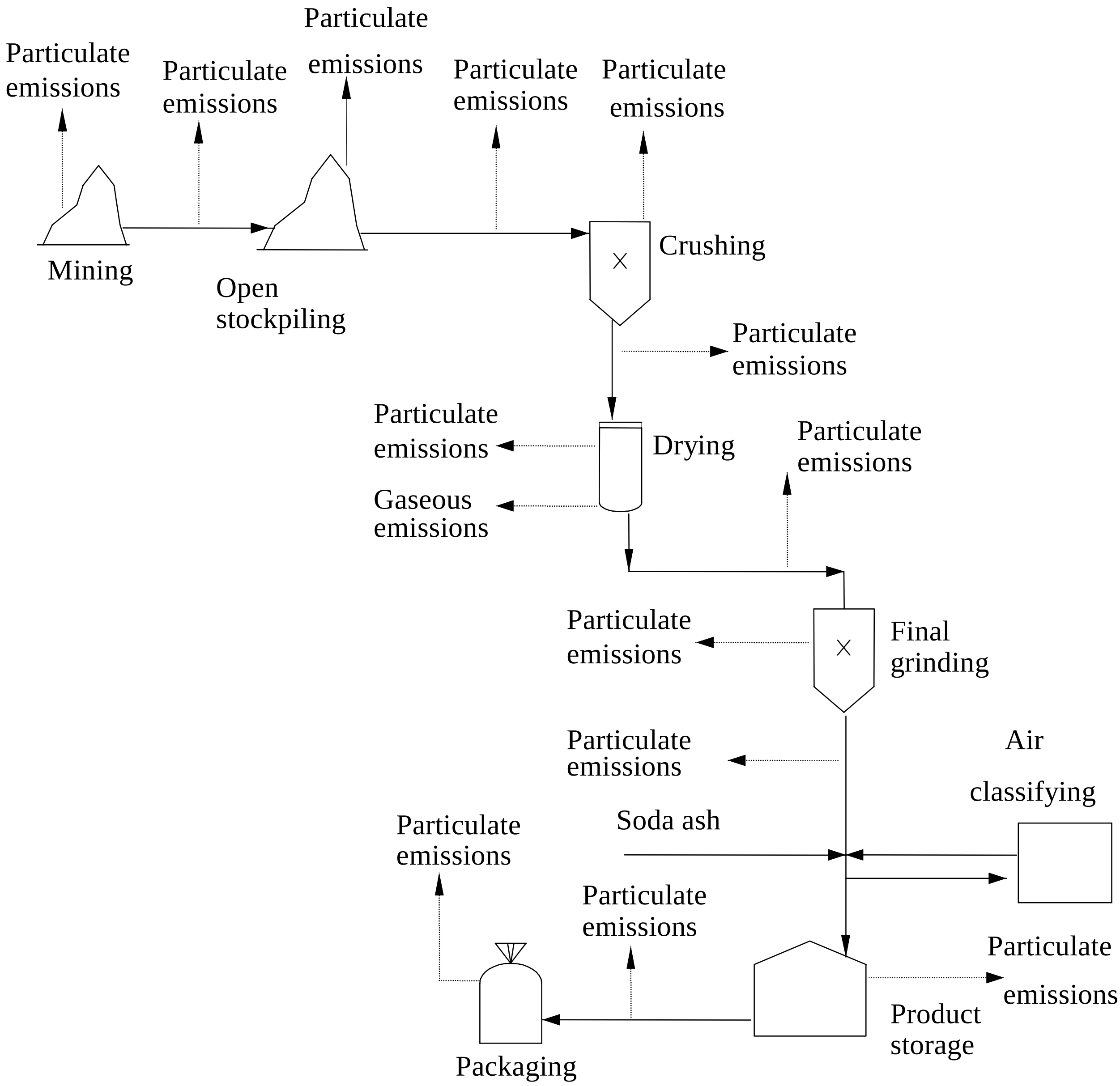

Figure 8 - Process Flow Diagram for Bentonite Processing
Source: USEPA AP42 Section 11.25 (1995)

Fuller's Earth

Fuller's Earth consists of montmorillonite and other hydrous aluminium silicate minerals. It is a non-plastic clay high in magnesium and has specialised decolourising and purifying properties. Fuller's earth has similar uses to bentonite as an absorbent of pet waste, oil, and grease.

Figure 9 presents a process flow diagram for fuller's earth. After being mined, fuller's earth is transported to the processing plant, crushed, ground, and stockpiled. Before drying, fuller's earth is fed into secondary grinders to reduce the size of the material further. At some plants, the crushed material is fed into a pug mill, mixed with water, and extruded to improve the properties needed for certain end products. The material then is dried in rotary or fluid bed dryers fired with natural gas or fuel oil. Drying reduces the moisture content from its initial moisture content of 40 to 50 per cent to 10 per cent or below. The temperatures in fuller's earth dryers depend on the end use of the product. For colloidal grades of fuller's earth, drying temperatures of approximately 150°C are used, and for absorbent grades, drying temperatures of 650°C are common. In some plants, fuller's earth is calcined rather than dried. In these cases, an operating temperature of approximately 675°C is used. The dried or calcined material then is ground by roller or hammer mills and screened.

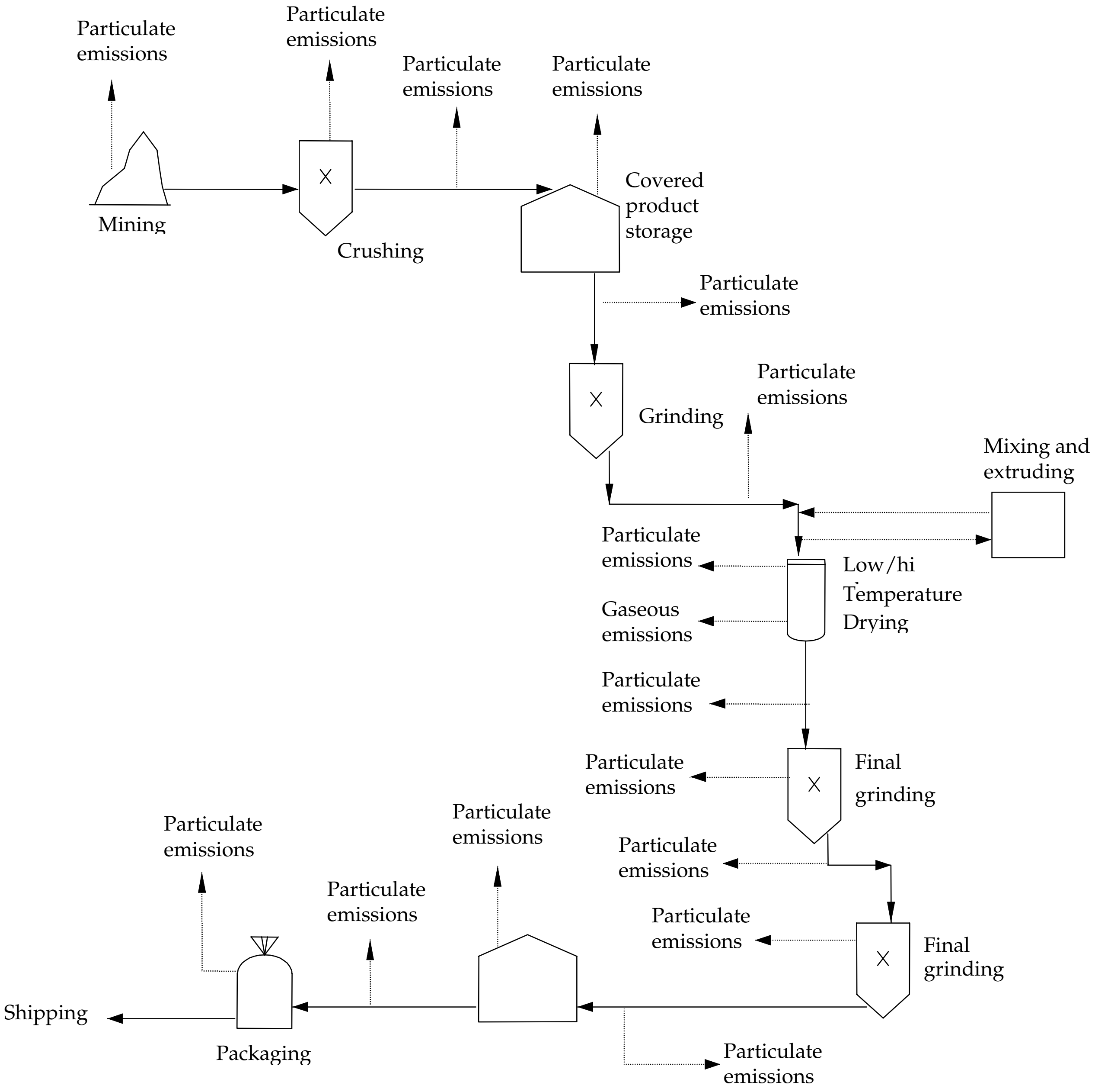

Figure 9 - Process Flow Diagram for Fuller's Earth Processing
Source: USEPA AP-42 Section 11.25 (1995)

Common clay and shale

Common clay is defined as a plastic clay or clay-like material with a vitrification point below 1100°C. Shale is a laminated sedimentary rock that is formed by the consolidation of clay, mud, or silt. Common clay and shale are composed mainly of illite or chlorite, but also may contain kaolin and montmorillonite.

Figure 10 depicts common clay and shale processing. Common clay and shale generally are mined, processed, formed, and fired at the same time to produce the end product. Processing generally begins with primary crushing and stockpiling. The material is then ground and screened. Oversize material may be further ground to produce particles of the desired size. For some applications, common clay and shale are dried to reduce the moisture content to desired levels. Further processing may include blunging or mixing with water in a pug mill, extruding and firing in a kiln, depending on the type of end product.

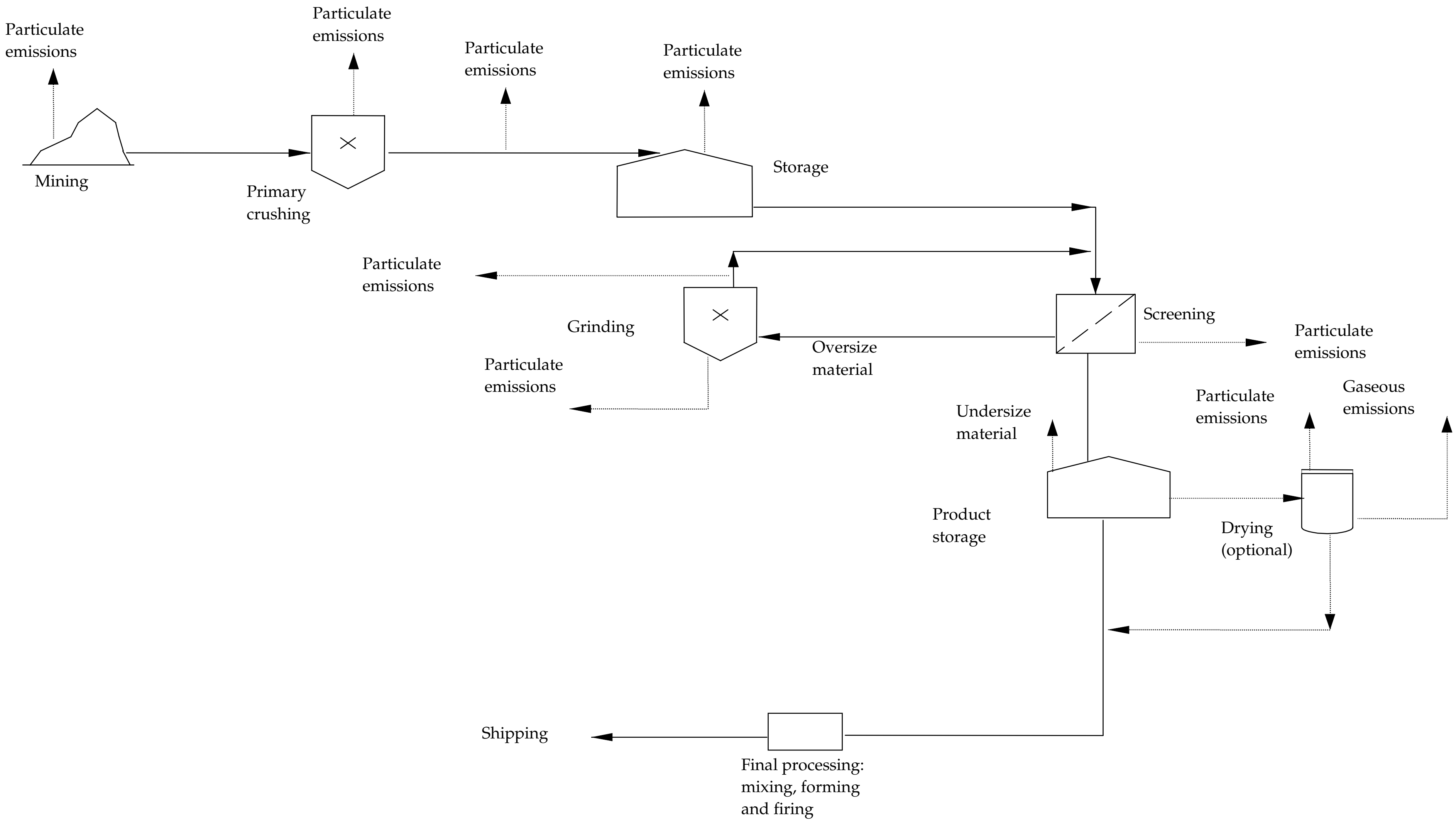

Figure 10 - Process Flow Diagram for Common Clay and Shale Processing
Source: USEPA AP42 Section 11.25 (1995)

2.1.5 Vermiculite

Vermiculite is a hydrous magnesium silicate. The mineral has a sheet structure resembling that of talc but with water molecules present in some of the sheets. When subjected to heat, vermiculite has the unusual property of exfoliating or expanding, due to the inter-laminar generation of steam.

Vermiculite is used for the production of insulating materials lightweight cements and plasters, for refractory purposes, a filler for paints, paper and rubber, and as an absorbent for nitro-glycerine

Vermiculite ore is mined using open-pit methods. Beneficiation includes screening, flotation, drying in rotary or fluid bed dryers, and expansion by exposure to high heat. Vermiculite is dried and sized at the mine site prior to exfoliation.

Figure 11 is a flow diagram for vermiculite processing. Crude ore from open-pit mines is brought to the mill by truck and is loaded onto outdoor stockpiles. Primary processing consists of screening the raw material to remove the waste rock greater than 1.6 centimetres (cm) and returning the raw ore to stockpiles. Blending is accomplished as material is removed from stockpiles and conveyed to the mill feed bin. The blended ore is fed to the mill, where it is separated into fractions by wet screening and then concentrated by gravity. All concentrates are collected, de-watered, and dried in either a fluidised bed or rotary dryer. Drying reduces the moisture content of the vermiculite concentrate from approximately 15 to 20 per cent to approximately 2 to 6 per cent. At most facilities, the dryer products are transported by bucket elevators to vibrating screens, where the material is classified. The dryer exhaust is generally ducted to a cyclone for recovering the finer grades of vermiculite concentrate. The classified concentrate is then stored in bins or silos for later shipment or exfoliation.

The rotary dryer is the more common dryer type used in the industry, although fluidised bed dryers also are used. Drying temperatures are 120°C to 480°C, and fuel oil is the most commonly used fuel. Natural gas and propane also are used to fuel dryers.

After being transported to the exfoliation plant, the vermiculite concentrate is stored. The ore concentrate is then conveyed by bucket elevator or other means and is dropped continuously through a gas- or oil-fired vertical furnace. Exfoliation occurs after a residence time of less than 8 seconds in the furnace, and immediate removal of the expanded material from the furnace prevents damage to the structure of the vermiculite particle. Flame temperatures of more than 540°C are used for exfoliation. Proper exfoliation requires both a high rate of heat transfer and a rapid generation of steam within the vermiculite particles. The expanded product falls through the furnace and is air-conveyed to a classifier system, which collects the vermiculite product and removes excessive fines. The furnace exhaust is generally ducted through a product recovery cyclone, followed by an emission control device. At some facilities, the exfoliated material is ground in a pulveriser prior to being classified. Finally, the material is packaged and stored for shipment.

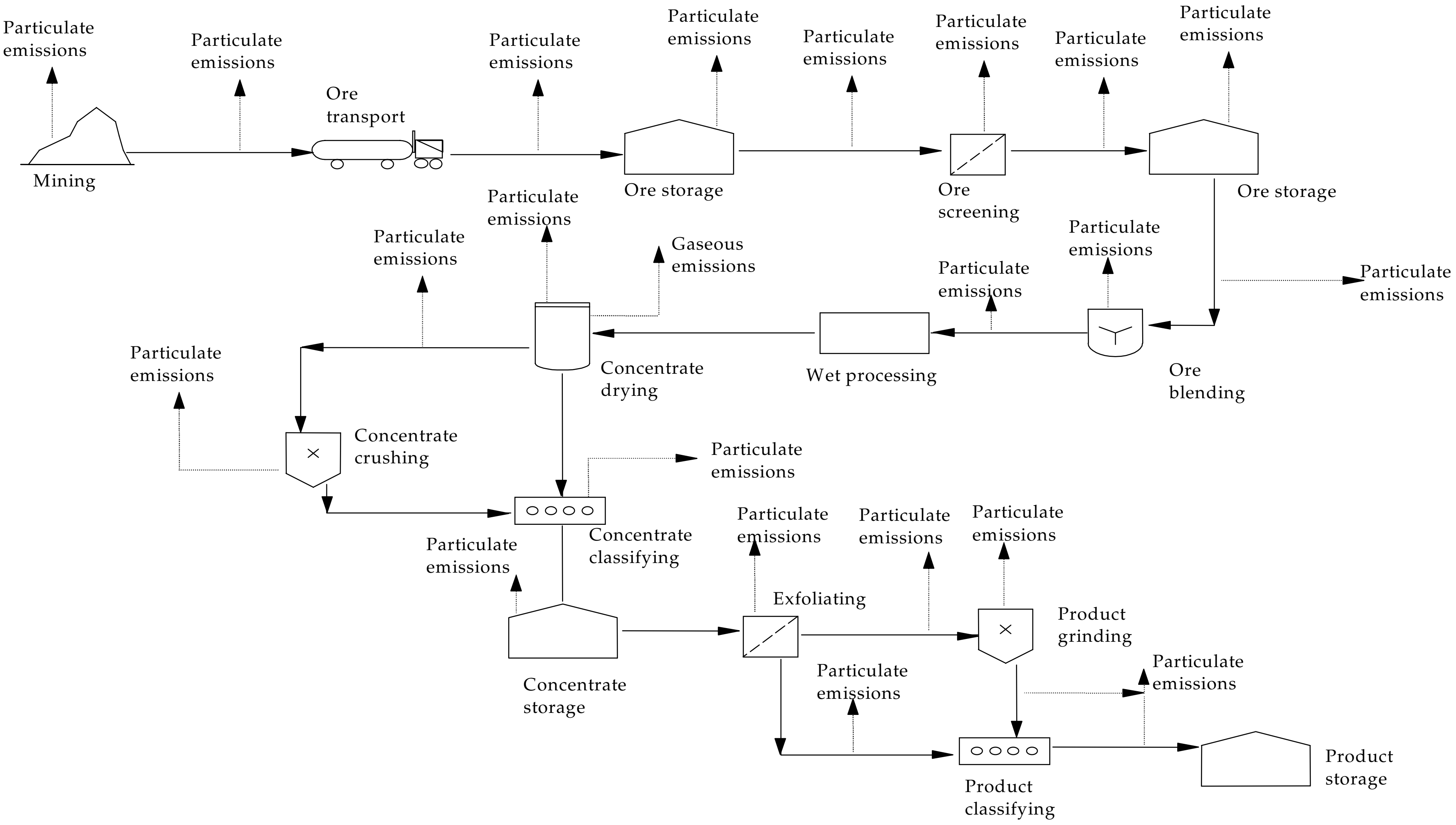

Figure 11 - Process Flow Diagram for Vermiculite Processing
Source: USEPA AP42 Section 11.28 (1995)

2.1.6 Diatomite

Diatomite is a chalky, sedimentary rock consisting of the skeletons of siliceous organisms, algae and diatoms. The skeletons are essentially amorphous hydrated or opaline silica occasionally with some alumina. Diatomite is used for polishing powder, filtering medium and in cement glazes pigments.

Most diatomite deposits are found at or near the earth's surface and can be mined by open pit methods or quarrying normally using some combination of bulldozers, scraper-carriers, power shovels, and trucks to remove overburden and the crude material. In most cases, fragmentation by drilling and blasting is not necessary. The crude diatomite is loaded on trucks and transported to the mill or to stockpiles.

The processing of uncalcined or natural-grade diatomite consists of crushing and drying. Crude diatomite commonly contains as much as 40 per cent moisture, in many cases over 60 per cent. Primary crushing to aggregate size (normally done by a hammer-mill) is followed by simultaneous milling and drying, in which suspended particles of diatomite are carried in a stream of hot gases. Flash and rotary dryers are used to dry the material to a powder of approximately 15 per cent moisture. Typical flash dryer operating temperatures range from 70°C to 430°C. The suspended particles exiting the dryer pass through a series of fans, cyclones, and separators to a baghouse. These sequential operations separate the powder into various sizes, remove waste impurities, and expel the absorbed water. These natural-milled diatomite products are then bagged or handled in bulk without additional processing.

For filtration uses, natural grade diatomite is calcined by heat treatment in gas- or fuel oil-fired rotary calciners, with or without a fluxing agent. Typical calciner operating temperatures range from 650°C to 1200°C. For straight-calcined grades, the powder is heated in large rotary calciners to the point of incipient fusion, and thus, in the strict technical sense, the process is one of sintering rather than calcining. The material exiting the kiln then is further milled and classified. Straight calcining is used for adjusting the particle-size distribution for use as a medium flow-rate filter aid. The product of straight calcining has a pink colour from the oxidation of iron in the raw material, which is more intense with increasing iron oxide content.

Further particle size adjustment is brought about by the addition of a flux, usually soda ash, before the calcining step. Added fluxing agent sinters the diatomite particles and increases the particle size, thereby allowing increased flow rate during liquid filtration. The resulting products are called "flux-calcined". Flux-calcining produces a white product, believed to be coloured by the conversion of iron to complex sodium-aluminium-iron silicates rather than to the oxide. Further milling and classifying follow calcining. Figure 12 shows a typical process flow diagram for diatomite processing.

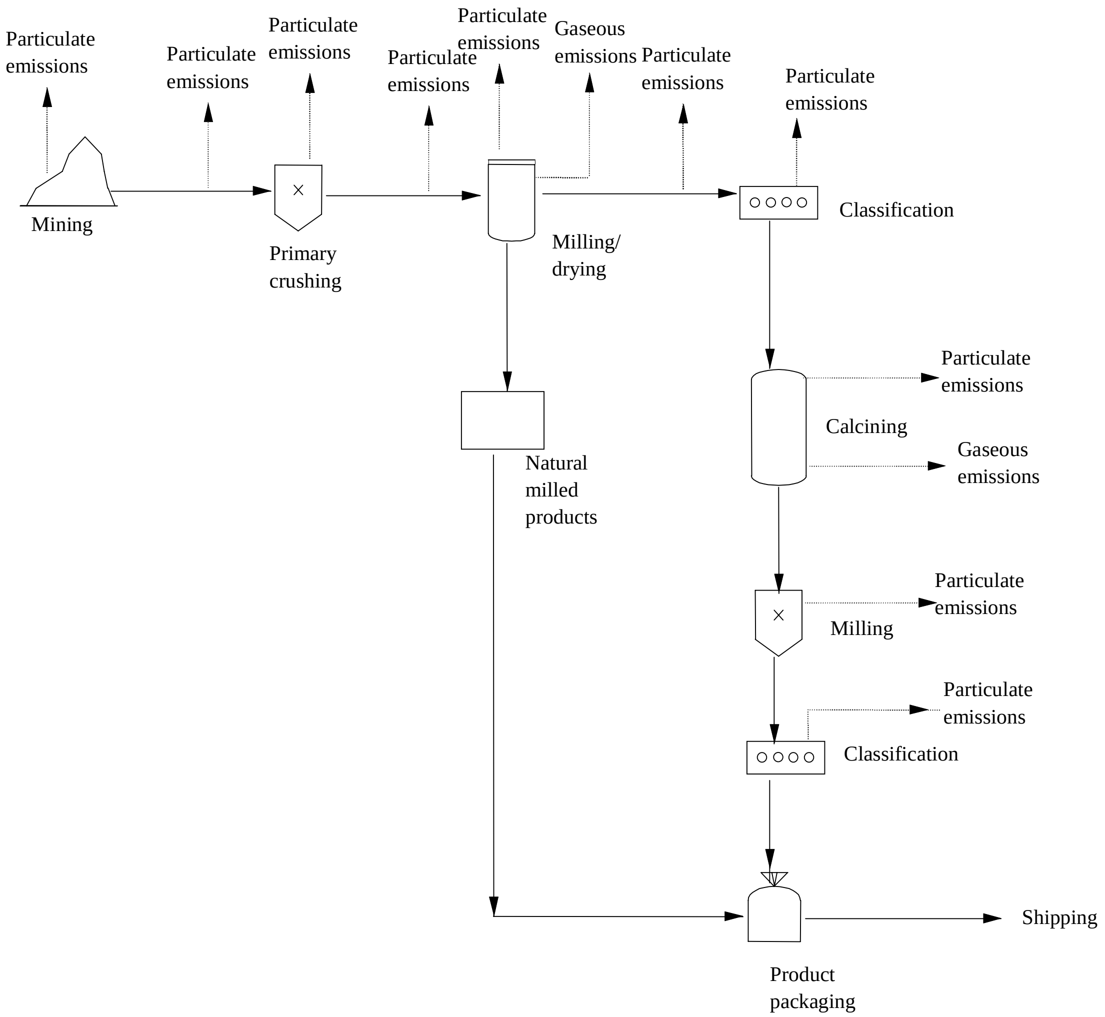

Figure 12 - Typical Process Flow Diagram for Diatomite Processing
Source: USEPA AP42 Section 11.22 (1995)

Particulate matter is emitted from crushing, drying, calcining, classifying, and materials handling, and transfer operations. Emissions from dryers and calciners include products of combustion, such as carbon oxides, nitrogen oxides, sulfur oxides and PM_{10}.

2.1.7 Talc

Talc is a hydrous magnesium silicate used in a wide range of industries including the manufacture of ceramics, paints and paper.

Figure 13 gives a process flow diagram for a typical talc plant. Talc ore generally is hauled to the plant by truck from a nearby mine. The ore is crushed, typically in a jaw crusher, and screened. The coarse (oversize) material then is returned to the crusher. Rotary dryers may be used to dry the material. Secondary grinding is achieved with pebble mills or roller mills, producing a product that is 44 to 149 micrometres in size. Some roller mills are designed to use heated air to dry the material as it is being ground. Hammer mills, steam or compressed air-powered jet mills may be used to produce additional final products. Air classifiers (separators), generally in closed circuit with the mills, separate the material into coarse, coarse-plus-fine, and fine fractions. The coarse and coarse-plus-fine fractions are then stored as products. The fines may be concentrated using a shaking table (tabling process) to separate product containing small quantities of nickel, iron, cobalt or other minerals and may then undergo a one-step flotation process. The resultant talc slurry is de-watered and filtered prior to passing through a flash dryer. The flash-dried product is then stored for shipment, unless it needs further grinding to meet customer specifications. The classified material also may be pelletised prior to packaging for specific applications. In the pelletising step, processed talc is mixed with water to form a paste and then is extruded as pellets.

Talc deposits containing organic impurities must be calcined prior to additional processing to yield a product with uniform chemical and physical properties. Prior to calcining, the mined ore passes through a crusher and is ground to a specified screen size. After calcining in a rotary kiln, the material passes through a rotary cooler. The cooled calcined talc (0 per cent free water) is then either stored for shipment or further processed. Calcined talc may be mixed with dried talc from other product lines and passed through a roller mill prior to bulk shipping.

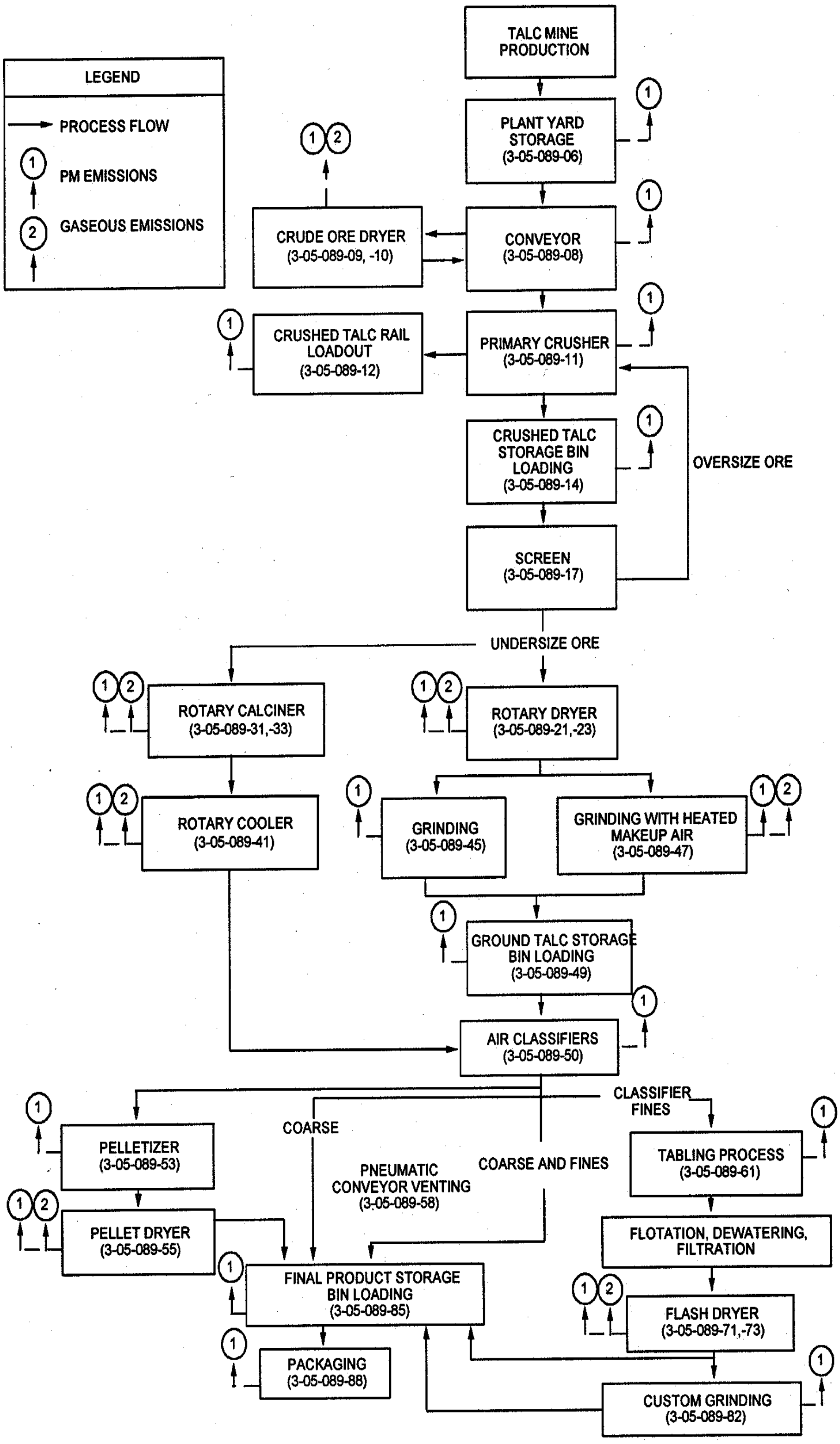

Figure 13 - Process Flow Diagram for Talc Processing
Source: USEPA AP42 Section 11.26 (1995)

The primary pollutant of concern in talc processing is particulate matter. Particulate matter is emitted from drilling, blasting, crushing, screening, grinding, drying, classifying, materials handling, transfer operations, packaging and storage.

2.1.8 Limestone

The term limestone is used to describe sedimentary rocks containing calcium carbonate, which is present as the minerals calcite and aragonite. Limestone may contain varying amounts of dolomite (calcium-magnesium carbonate) as well as silica and alumina. Limestone is mainly used for manufacturing Portland cement and lime, as a flux in steel making, in copper and lead smelting, in glass manufacturing, alumina refining and in agriculture. Most consumers of limestone rely on being able to obtain raw material that meets certain specifications in terms of physical properties (crystal size) or chemical content. Special grades of high-quality white calcium oxide are used for paper coating. Calcium oxide (quick lime) is derived from limestone by calcining to expel carbon dioxide. Cement clinker is produced by burning a slurry of limestone, clay, sand, iron stone and water in a kiln. The clinker is then ground with gypsum to make cement.

Mining and processing of limestone typically involves removal of overburden, blasting, shovelling and transport by truck to the crushing and blending plant.

2.1.9 Magnesite

Magnesite is a mineral composed of magnesium carbonate, ($MgCO_3$). A large resource of high quality magnesite occurs at Kunwarara in Queensland. After removal of overburden, magnesite is extracted by open-pit mining and crushed, screened, washed and sorted at the mine site. Raw magnesite is used in paints, and as a filler in plastics and paper. It is used for surface coatings, landscaping, ceramics and as a fire retardant. It can also be mixed with limestone to form a synthetic dolomite for use an agricultural fertiliser.

Magnesite is the most important source mineral for producing magnesia (MgO). Raw magnesia is converted to calcined magnesia (MgO) by heating to 700°C - 1000°C. Calcined (or caustic magnesia) is used in the manufacture of paints, paper, plastics, rubber, oil, pharmaceutical products, fertiliser and animal feed. It is also used in building materials, as a fire retardant, and for acid neutralisation.

With further processing, calcined magnesia is made into pellets and heated to 1500°C - 2000°C in shaft kilns forming dead-burned magnesia. Dead-burned magnesia, also known as sintered magnesia or clinker, is used to make refractory bricks to line steel making furnaces. When calcined magnesia is heated to 2750°C - 3000°C in electric furnaces, electro-fused magnesia is produced. Electro-fused magnesia has higher strength, abrasion resistance, and chemical inertness than dead-burned magnesia. It is used for premium grade refractory bricks, electrical substrates, high temperature insulators, and ceramics. Electro-fused magnesia is also used for special refractory applications in the nuclear and space industries.

Magnesite can also be used to produce magnesium metal by the electrolytic reduction of magnesium chloride, or by the reduction of magnesium compounds with ferrosilicon.

(PM), (PM_{10}) and combustion gases from machinery used in the mining process are the major air pollutants emitted from the mining and beneficiation of magnesite. Combustion gases from the heating processes become an important consideration in the production of calcined magnesia, dead-burned magnesia and electro-fused magnesia but these processes are not usually carried out at the mine site.

2.1.10 Silica Sand

The mineral silica (SiO_2) occurs in abundance as sand, sandstone, quartz, quartzite, and quartz gravel.

In Australia, high-grade industrial silica is mined from surface deposits (dunes). High quality silica is used for the manufacture of glass, refractories, cement, foundry sand, metallurgical flux, for silicon metal and other silicon containing products.

Sand is scooped up from surface deposits, transferred by conveyer to an up-grading plant where it is sieved wet, the water is drained using a drier belt and the product is stock-piled and then transferred to ships. The sand deposits at Cape Flattery contain less than 0.01 per cent of fine particles less than 50 microns in diameter and the processed product is 99.8 percent pure silica.

2.1.11 Sand and Gravel

Sand & gravel processing

Sand and gravel are siliceous and calcareous products of the weathering of rock and stone. Deposits of sand and gravel are generally found in near-surface alluvial deposits and in subterranean and subaqueous beds. Construction sand and gravel are typically mined in a moist or wet condition by open pit excavation or by dredging. Open pit excavation is carried out with power shovels, drag lines, front-end loaders, and bucket wheel excavators. Mining by dredging involves mounting the equipment on boats or barges and removing the sand and gravel from the bottom of a body of water by suction or bucket type dredges. After mining, the materials are transported to the processing plant by suction pump, earthmover, barge, truck, belt conveyers or other means.

The processing of sand and gravel for a specific market involves the use of different combinations of washers, screens, and classifiers to segregate particle sizes; crushers to reduce oversized material; and storage and loading facilities.

Industrial Sand and Gravel

Industrial sand and gravel typically are mined from open pits of naturally-occurring-quartz-rich sand and sandstone. Mining methods depend primarily on the degree of cementation of the rock. After mining, the rock is crushed in several stages. Gyratory crushers, jaw crushers, roll crushers, and impact mills are used for primary and secondary crushing. The size of the material is further reduced to 50 microns (µm) or smaller by grinding, using smooth rolls, media mills, autogenous mills, hammer mills, or jet mills. The ground material then is classified by wet screening, dry screening, or air classification. Impurities may be removed by washing or froth flotation. The final product is dried, classified and stored.

Emissions from the production of sand and gravel consist primarily of (PM) and (PM_{10}), which are emitted by many operations at sand and gravel processing plants, such as conveying, screening, crushing, and storing operations. Generally, the materials are wet or moist when handled, and process emissions are often negligible. A substantial portion of the emissions may consist of heavy particles that settle out within the plant.

Emissions from dryers include PM and PM_{10}, as well as typical combustion products including CO, CO_2, and NO_x. In addition, dryers may be sources of VOCs or sulfur oxides (SO_2) emissions, depending on the type of fuel used to fire the dryer.

2.1.12 Crushed Stone Processing

Major rock types processed by the rock and crushed stone industry include limestone, granite, dolomite, sandstone, quartz, and quartzite. Rock and crushed stone products generally are loosened by drilling and blasting, then are loaded by power shovel or front-end loader into large haul trucks that transport the material to the processing operations. Techniques used for extraction vary with the nature and location of the deposit.

Processing operations may include crushing, screening, size classification, material handling, and storage operations. All of these processes can be significant sources of PM and PM_{10} emissions if uncontrolled. A substantial portion of these emissions consists of heavy particles that may settle out within the plant. Typical size classifications that occur as a result of crushing and screening processes are:

Primary crushing	7.5 to 30 cm
Secondary crushing	2.5 to 10 cm
Tertiary crushing	0.5 to 2.5 cm
Fines screening	< 0.5 cm
Fines crushing	< 0.5 cm

Crushed stone emission sources may be categorised as either process sources or fugitive dust sources. Process sources include those for which emissions are amenable to capture and subsequent control. Fugitive dust sources generally involve the re-entrainment of settled dust by wind or machine movement. Emissions from process sources should be considered fugitive unless the sources are vented to a bag-house or are contained in an enclosure with a forced-air vent or stack. Factors affecting emissions from either source category include the stone size distribution and surface moisture content of the stone processed; the process throughput rate; the type of equipment and operating practices used; and topographical and climatic factors. Fugitive emissions typically increase at higher wind speeds. Both fugitive and process emissions may increase with lower moisture content of the material processed.

A variety of material, equipment, and operating factors can influence emissions from crushing. These factors include:

(1) stone type;
(2) feed size and distribution;
(3) moisture content;
(4) throughput rate;
(5) crusher type;
(6) size reduction ratio; and
(7) fines content.

Insufficient data is available to present a matrix of rock crushing emission factors detailing the above classifications and variables.

2.1.13 Gemstones

Gemstones mined in Australia include opal, sapphire, diamond, chrysoprase, garnet and zircon.

Sapphire is a variety of the mineral corundum, which consists of aluminium oxide. The presence of small amounts of oxides of iron, titanium and chromium can impart a wide range of colours to the mineral. Sapphire occurs in alluvial deposits. Mining of sapphires varies from simple hand mining of surface and shallow wash through digging shafts in deeper ground to large-scale open cuts operations involving heavy machinery.

Opal is a hydrated form of silica in which water is chemically bonded. There are two main forms of opal: precious opal and common opal. Precious opal exhibits the characteristic play of spectral colours and is comparatively rare. Common opal shows no play of colours. It may be colourless or coloured and can be transparent to opaque. Opal is mined from underground shafts but the larger mines are open-cut operations. Ironstone boulders are carefully removed from the ground for processing.

Garnet comprises a group of complex aluminium silicate minerals, some varieties are used as a gemstone. Garnet is being increasingly used as a high quality abrasive for sandpaper, in sand blasting, on non-skid surfaces and as a filtration medium. Mining involves drilling and blasting. The material is reduced in size using two-stage crushing and rolling to produce 3 mm size material. The material is then dried. Magnetic separation gives a 99 percent pure product.

2.1.14 Gypsum

The mineral gypsum is composed of calcium sulfate $CaSO_4.2H_2O$. In its natural state, gypsum is generally associated with impurities such as sand, clay and limestone. South Australia, with deposits located close to ports, is the major producer of gypsum. Gypsum is used as a soil conditioner, while calcined gypsum is used widely for plaster sheets and finishings in the building industry.

Most of the gypsum used for plasterboard manufacture in Australia is mined at Lake Macdonnell in South Australia. The gypsum that occurs as sedimentary deposits together with salt is excavated and pushed up into stockpiles. After natural rainfall has leached the salt from the stockpiles, the gypsum is crushed to size and shipped to plasterboard manufacturing plants located in the major population centres.

2.1.15 Zeolite

Zeolite is a calcium aluminium silicate mineral derived from volcanic ash, which has been highly compressed by the weight of sedimentary layers and coal deposits. Deposits of zeolite may be lifted to the surface by earthquake activity over geological time scales of hundreds of millions of years. The most important deposits are at Wirra NSW and Emerald in Queensland. Zeolite is used as a cation exchanger, an absorbent for odours, a flocculant for wastewater and a soil conditioner. Zeolite is extracted from surface deposits by drilling and blasting. The product is crushed to various sizes and packaged in 20 kg and one tonne quantities. A powdered form (50 micrometres) which may be transported by tanker is also produced using a ball mill.

2.1.16 Barite

The mineral barite (barytes) is a soft dense mineral consisting of barium sulfate. It is used primarily as a weighting agent in oil drilling muds, as a filler and extender in paint and plastics, as a flux in glassmaking and as a source material for barium chemicals.

2.1.17 Dimension Stone

Dimension stone is natural stone that has been cut or shaped to a specific size for a particular building or decorative application. The term encompasses a large variety of rock types; the most popular of which are granite, sandstone, marble and slate.

Dimension stone is usually obtained from surface quarries. In many cases, overburden is removed using bulldozers or other earth moving equipment. The stone is then cut into blocks by drilling, cutting or blasting. Large blocks are then cut into sheets using gang saws. These sheets are then trimmed to the required size and shape. Depending on the application, the stone is then given a surface finish, which may range from a rough non-slip texture to a polished mirror surface.

2.1.18 Serpentine and Rhyolite

Serpentine is a rock composed largely of serpentine, a magnesium-rich silicate mineral associated with ultrabasic igneous rocks. Its prime use is as a flux for steel making.

Rhyolite is a fine-grained volcanic rock consisting mainly of quartz and feldspar minerals. It is typically used as a fluxing agent in ceramic manufacture.

3.0 Emission Estimation Techniques

Estimates of emissions of NPI-listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in *The NPI Guide* at the front of this Handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility.

The four types described in *The NPI Guide* are:

- sampling or direct measurement
- mass balance
- fuel analysis or other engineering calculations
- emission factors

Select the EET, (or mix of EETs), that is most appropriate for your purposes. For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

If you estimate your emission by using any of these EETs, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of EETs that are not outlined in this handbook, your data will also be displayed as being of 'acceptable reliability'.

This Manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to this industry. However, the absence of an EET for a substance in this handbook does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if your company has developed site-specific emission factors, you may use these if approved by your relevant environmental authority.

You should note that the EETs presented in this manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg. spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, ie. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

The **usage**[a] of each of the substances listed as Category 1 and 1a under the NPI must be estimated to determine whether the 10 tonnes (or 25 tonnes for VOCs) reporting threshold is exceeded. If the threshold is exceeded, **emissions** of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero.

[a] Usage is defined as meaning the handling, manufacture, import, processing, coincidental production or other uses of the substances.

3.1 Direct Measurement

You may wish to undertake direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. However, the NPI does not require you to undertake additional sampling and measurement. To be adequate, sampling data used for NPI reporting purposes would need to be collected over a period of time representative of the whole year.

3.1.1 Sampling Data

Stack sampling test reports often provide emissions data in terms of kg/hr or g/m^3 (dry). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (ie. normal) operating conditions. You should be aware that some tests undertaken for a State or Territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

3.1.2 Continuous Emission Monitoring System (CEMS) Data

A continuous emission monitoring system provides a continuous record of emissions over time, usually by reporting pollutant concentration.

Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas or liquid flow rate of that pollutant.

It is important to note that prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies your relevant environmental authority's requirement for NPI emissions estimations.

3.2 Mass Balance

A mass balance identifies the quantity of substance going in and out of an entire facility, process, or piece of equipment. Emissions can be calculated as the difference between input and output of each listed substance. Accumulation or depletion of the substance within the equipment should be accounted for in your calculation.

3.3 Engineering Calculations

An engineering calculation is an estimation method based on physical/chemical properties (eg. vapour pressure) of the substance and mathematical relationships (eg. ideal gas law).

3.3.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation and can be used to predict SO_2 and metal emissions based on application of conservation laws, if fuel rate is measured. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur, which may be converted into other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is the following:

Equation 1

$$E_{kpy,i} = Q_f * C_i/100 * (MW_p/EW_f) * OpHrs$$

where:

$E_{kpy,i}$ = annual emissions of pollutant i, kg/yr
Q_f = fuel use, kg/hr
OpHrs = operating hours, hr/yr
MW_p = molecular weight of pollutant emitted, kg/kg-mole
EW_f = elemental weight of pollutant in fuel, kg/kg-mole
C_i = concentration of pollutant i in fuel, weight percent, %

For instance, SO_2 emissions from oil combustion can be calculated based on the concentration of sulfur in the oil. This approach assumes complete conversion of sulfur to SO_2. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO_2 (MW = 64) are emitted. The application of this EET is shown in Example 1.

Example 1 - Using Fuel Analysis

This example illustrates how SO_2 emissions can be calculated from oil combustion based on fuel analysis results and the fuel flow information. The facility is assumed to operate 1500 hours per year.

E_{SO2} = may be calculated using Equation 1:

Fuel flow	=	2000 kg/hr
Weight percent sulfur in fuel	=	1.17 %
OpHrs	=	1500 hr/yr

$$\begin{aligned} E_{kpy,SO2} &= Q_f * C_i/100 * (MW_p/EW_f) * OpHrs \\ &= (2000) * (1.17 / 100) * (64 / 32) * 1500 \\ &= 46.8 kg/hr * 1500 hr/yr \\ &= 70\ 200 kg/yr \end{aligned}$$

3.4 Emission Factors

An emission factor is a tool that is used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source to a common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources. They are usually expressed as the weight of a substance emitted, divided by the unit weight, volume, distance, or duration of the activity emitting the substance (eg. kilograms of particulate matter emitted per tonne of perlite, expanded using a furnace with cyclone and baghouse).

Emission factors are used to estimate a facility's emissions by the general equation:

Equation 2

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$

where :

$E_{kpy,i}$ = emission rate of pollutant i, kg/yr
A = activity rate, t/hr
OpHrs = operating hours hr/yr
EF_i = uncontrolled emission factor of pollutant i, kg/t
CE_i = overall control efficiency for pollutant i, %.

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. Should a company have several processes of similar operation and size with emissions measured from one process source, an emission factor could be developed and applied to similar sources. You are required to have the emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

In most cases, fugitive emissions can be estimated using emission factor equations. These equations are used with process-specific information (eg. the silt and moisture content of material being handled, or the silt loading and moisture level on a road), to estimate an emission factor, which can be applied to the particular operation being analysed.

Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted multiplied by the unit weight, volume, distance, or duration of the activity emitting the substance (eg. kilograms of TSP emitted per tonne of overburden loaded).

Most of the work in developing emission factor equations for fugitive emissions has been undertaken in the United States (see US EPA 1998). Some work has also been undertaken in Australia (see SPCC 1986 and NERDDC 1988). Although the Australian work is not nearly as comprehensive as the US work, it is useful in that it confirms that the US emission factors are relevant for Australian conditions provided appropriate variables are used and it highlights those emission factors that are not appropriate for particular operations.

Appendix A of the *Emission Estimation Technique Manual for Mining* includes guidance on the application to Australian conditions, of the emission factors presented in Table 1 and Table 2.

Finally it is worth pointing out that the US EPA emission factors are published in a large number of references, which are often referred to in different ways. The most comprehensive compilation of emission factors is that in the US EPA document referred to as AP-42. Chapters from AP-42 are updated periodically and are available from the US EPA's web site (http://www.epa.gov/ttn/chief/ap42.html). Often the date of the reference will be given as the date of the re-formatting of the AP-42 chapter. Different chapters have been reformatted in different years. This can be confusing. For the current document for example reference is made to US EPA (1998). This is taken from a version of AP-42 Chapter 11 that was re-formatted in 1995. Some authors will reference this as US EPA (1995). This chapter of AP-42 includes work done in the late 1970s and the 1980s.

4.0 Estimating Emissions from Mining and Processing of Non-Metallic Minerals

4.1 Emissions to Air

4.1.1 Background

Mining Emissions:

The main emissions to the air environment consist of wind-borne dust and the products of combustion from mine transportation, mine power generation (if any) and blasting. Trace metals in mined materials could also lead to the reporting requirements of the NPI being triggered and so these emissions in the dust would need to be considered.

Process Emissions:

Emissions from any processing and beneficiation of the mineral carried out at the mine-site after mining - crushing, grinding, sizing, drying, calcining etc. would need to be considered.

4.1.2 Overview of Air Emission Sources

Air emissions from mining and processing may be categorised as fugitive or point source emissions depending on the processing and ventilation system.

4.1.2.1 Fugitive Emissions

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from vats, open vessels, or spills and materials handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs are the usual method for determining losses through fugitive emissions.

The major fugitive emission from mining is dust. Dust emissions are classified according to the size range of the component particles. Total suspended particulate matter (TSP) refers to the mass loading of airborne particles determined gravimetrically by a high volume air sampler. (PM_{10}) is the mass loading of airborne particles that pass through a size selective inlet with a 50% efficiency cut-off at 10μm aerodynamic diameter. The term particulate matter (PM) given without reference to particle size is usually taken to be the same. For fugitive emissions from mining operations the PM_{10} component is reportable as part of the NPI. In addition, trace elements (such as lead, manganese, and selenium) which are also reportable may be a component of both the PM_{10} and TSP fugitive emissions. It may therefore be necessary to estimate TSP emissions as well as PM_{10} emissions in order to estimate trace metal emissions. Emission Estimation Techniques for PM_{10} and TSP are presented in Section 4.1.3.

The use of organic solvents in the beneficiation process (in a solvent extraction process) or in workshops where emissions can arise through the use of volatile solvents for equipment servicing and cleaning and from fuel storage facilities, would result in fugitive emissions of volatile organic compounds. If the amount of solvent used triggers the reporting threshold, emissions can be estimated on the basis of the net solvent consumption, taking account of any recovery procedures.

It should be noted that the process emissions could be either Point Source or Fugitive emissions, depending on the process and ventilation system.

Vehicle Exhaust Emissions:

Emissions from vehicle exhaust are fugitive emissions Diesel vehicles will emit particulate matter, which can be considered to be 100 per cent PM_{10}, CO, NO_x and VOCs. The US EPA (1985) publish emission factors for these vehicles in terms of grams of pollutant emitted per litre of fuel consumed by each type of vehicle in the following classes:

1. Track-type tractor;
2. Wheeled tractor;
3. Wheeled dozer;
4. Scraper;
5. Grader;
6. Off-highway truck;
7. Wheeled loader; and
8. Track type loader

Emission factors are presented in Section 4.1.4.

4.1.2.2 Point Source Emissions

These emissions are exhausted into a vent (excluding roof vents) or stack and emitted through a single point source into the atmosphere. Air emission control technologies, such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers, are commonly installed to reduce the concentration of substances in venting air streams prior to emission. Where such emission abatement equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimation, the collection efficiency of the abatement equipment needs to be considered. Emission factors for power generation at mine sites may be found in the Combustion Engines Manual. Section 4.1.6 of this manual includes emission factors for the processing on non-metallic minerals sourced from the USEPA AP-42 (1995).

With regards to emission controls for PM_{10}, in the absence of measured data, or knowledge of the collection efficiency for a particular piece of equipment, an efficiency of 90% should be used in the emission factor equation to calculate actual mass emissions. This default should only be used if there is no other available control efficiency.

4.1.3 Dust Emissions from Mining of Non-Metallic Minerals

For the NPI, only the PM_{10} fraction of dust emissions is reportable. This is triggered by the fuel usage or power requirements. When there are activities in common with coal mines and metalliferous mines, the emission factors and equations given in Table 1 and Table 2 can be used. Mining operations can be considered as unit operations, for example dragline operations, shovel operations, truck haulage of materials. For each of these unit operations there is an equation that can be used to estimate the TSP and PM_{10} components of the fugitive emission.

If the fuel usage or power requirements exceed the triggering threshold, some metals need to be reported in addition to those that may need to be reported via other trigger mechanisms.

Table 2 presents emissions factors for high-moisture ores and low moisture content ores. Both TSP and PM_{10} emission factors and equations are listed, together with the Emission Factor Rating (EFR) for each factor.

All factors are for uncontrolled emissions. Section 4.1.6 provides information on the efficiency of control methods and this information can be incorporated into the calculation of emissions.

Metal emissions can be estimated as a fraction of the TSP emissions, based on available assay data. Default concentrations of NPI-listed substances are provided in Table B2. Where assay data is not available and no site-specific information is available for metals in TSP emissions (eg. for the overburden), the concentrations in Table B2 should be used as a default to estimate metal emissions.

Table 1 - Emission Estimation Equations and Default Emission Factors for Various Operations at Coal Mines[a]

Operation/Activity	TSP Equation	PM_{10} Equation	TSP Emission Factor	PM_{10} Emission Factor	PM_{10}/TSP Ratio based on Emission Factors	Units	Emission Factor Rating
Draglines	$E = 0.0046 \times \frac{d^{1.1}}{M^{0.3}}$	$E = 0.0022 \times \frac{d^{0.7}}{M^{0.3}}$	0.06	0.026	0.43	kg/m^3	B
Excavators/Shovels /Front-end loaders (on overburden)	$E = k \times 0.0016 \left(\frac{U}{2.2}\right)^{1.3} \left(\frac{M}{2}\right)^{-1.4}$ using k=0.74	As for TSP, using k=0.35	0.025	0.012	0.47	kg/t	C
Excavators/Shovels /Front-end loaders (on coal)	$E = k \times \frac{0.0596}{M^{0.9}}$ using k=1.56	As for TSP, using k=0.75	0.029	0.014	0.48	kg/t	C
Bulldozers on coal	$E = 35.6 \times \frac{s^{12}}{M^{1.4}}$	$E = 6.33 \times \frac{s^{1.5}}{M^{1.4}}$	101	32	0.32	kg/hr	B
Bulldozer on material other than coal	$E = 2.6 \times \frac{s^{1.2}}{M^{1.3}}$	$E = 0.34 \times \frac{s^{1.5}}{M^{1.4}}$	17	4	0.24	kg/hr	B
Trucks (dumping overburden)			0.012	0.0043	0.36	kg/t	
Trucks (dumping coal)			0.010	0.0042	0.42	kg/t	
Drilling	--	--	0.59	0.31	0.52	kg/hole	B
Blasting	$E = 0.008 \times A^{1.5}$	As for TSP, multiplying by 0.52	--	--	0.52	kg/blast	C
Wheel and bucket			--	--			

Table 1 - Emission Estimation Equations and Default Emission Factors for Various Operations at Coal Mines cont'

Operation/Activity	TSP Equation	PM_{10} Equation	TSP Emission Factor	PM_{10} Emission Factor	PM_{10}/TSP Ratio based on Emission Factors	Units	Emission Factor Rating
Wheel Generated Dust	$E = 0.0019\ w^{3.4} * L^{0.2}$	$E = 0.00084 * w^{3.5}$	2	0.4	0.2	kg/VKT	
Scrapers	$E = 9.6 * 10^{-6} * s^{1.3}\ W^{2.4}$	$E = 1.32 * 10^{-6} * s^{1.4}\ W^{2.5}$	2	0.5	0.25	kg/VKT	A
Graders	$E = 0.0034 * S^{2.5}$	$E = 0.0034 * S^{2.0}$				kg/VKT	B
Loading stockpiles			0.004	0.0017	0.42	kg/t	
Unloading from stockpiles			0.03	0.013	0.42	kg/t	
Loading to trains			0.0004	0.00017	0.42	kg/t	
Miscellaneous transfer points			0.00032	0.00015	0.47	kg/t	
Wind erosion			0.4	0.2	0.50	kg/ha/hr	

[a] This includes combustion generated PM_{10} also.

d = drop distance in metres;
M = moisture content in %;
U = mean wind speed in m/s;
A = area blasted in m^2;
D = depth of blast holes in metres;
s = silt content in %;
k = 0.74 for particle less than 30 micrometres;
k = 0.35 for particle less than 10 micrometres;
W = vehicle gross mass in tonnes;
S = mean vehicle speed in km/hr;
L= road surface silt loading in g/m^2;
w = number of wheels;
t = tonne;
VKT = vehicle kilometres travelled;
■ = negligible.

Table 2 - Default Emission Factors for Various Operations at Mines[a]

Operation/Activity	TSP Emission Factor	PM_{10} Emission Factor	PM_{10}/TSP Ratio	TSP Emission Factor	PM_{10} Emission Factor	PM_{10}/TSP Ratio	Units	Emission Factor Rating
	High Moisture content ores			Low moisture content ores				
Primary crushing	0.01	0.004	0.4	0.2	0.02	0.1	kg/t	C
Secondary crushing	0.03	0.012	0.4	0.6	ND		kg/t	D
Tertiary crushing	0.03	0.01	0.33	1.4	0.08	0.06	kg/t	E
Wet grinding (milling)	0	0		0	0		kg/t	
Dry grinding with air conveying or classification	14.4	13	0.9	14.4	13	0.9	kg/t	C
Dry grinding without air conveying or classification	1.2	0.16	0.13	1.2	0.16	0.13	kg/t	D
Drying (all minerals except titanium / zirconium sands)	9.8	5.9	0.6	9.8	5.9	0.6	kg/t	C
Handling transferring and conveying (except bauxite)	0.005	0.002	0.4	0.06	0.03	0.5	kg/t	C
Drying titanium/zirconium with cyclones	0.3	ND	_	0.3	ND	_	kg/t	C

[a] This includes combustion generated PM_{10} also.

Note: Generally a high-moisture ore is taken to be one which either naturally, or as a result of additional moisture at the primary crusher (usually), has a moisture content of more than 4% by weight. However, important exceptions apply. For Bauxite, the high moisture ore threshold is 15–18%. For ores at Broken Hill a site-specific definition should be used. These definitions will need to be used with local knowledge.

ND - No data available

Example 2 - Estimating Emissions

PM_{10} and Total Solid Particulate (TSP) emissions from the primary crushing of a high-moisture content ore can be calculated using the emission factor from Table 2, Equation 2 and the following data.

For PM_{10} emissions
Given:

A = 30 tonnes/hr
$OpHrs$ = 1500 hr/yr
EF_i = 0.004 kg/tonne
CE_i = 90%

$$E_{kpy,PM10} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$
$$= [30 \text{ t/hr} * 1500 \text{ hr/yr}] * 0.004 \text{ kg/t} * [1 - (90/100)]$$
$$= 18 \text{ kg/yr of } PM_{10} \text{ emissions}$$

For TSP Emissions
Given:

A = 30 tonnes/hr
$OpHrs$ = 1500 hr/yr
EF_i = 0.01 kg/tonne
CE_i = 90%

$$E_{kpy,TSP} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$
$$= [30 \text{ t/hr} * 1500 \text{ hr/yr}] * 0.01 \text{ kg/t} * [1 - (90/100)]$$
$$= 45 \text{ kg/yr of TSP emissions}$$

To speciate the metals from the dust emissions, Table B2 can be used to obtain the concentration of the metal in the material. For example, using Table B2, the arsenic emissions can be calculated.

Given:

$C_{\text{Arsenic in soil}}$ = 6mg/kg TSP
$E_{kpy,TSP}$ = 45 kg TSP/yr
10^{-6} = kg/mg conversion

$$E_{kpy,Arsenic} = 6 * 45 * 10^{-6} \text{ kg}_{\text{Arsenic}}/\text{yr}$$
$$= 2.7 * 10^{-4} \text{ kg}_{\text{Arsenic}}/\text{yr}$$

4.1.3.1 Control Technologies

There are a number of ways in which mine operators can control dust emission from the mine. Most involve the use of water sprays to keep surfaces damp, but there are also other methods. Different control measures will reduce emissions by varying amounts. Table 3 summarises the methods used and the effect they have on reducing the dust emission from the mine (Holmes Air Sciences, 1998). These are drawn from control factors documented in AP42 and Buonicore and Davis (1992, see Table 3 page 794).

Table 3 - Estimated Control Factors for Various Operations at Mines

Operation / Activity	Control method and emission reduction [a]
Coal Mines	
Scrapers on topsoil	50% control is done when soil is naturally or artificially moist
Dozers on coal or other material	No control
Drilling	99% for fabric filters 70% for water sprays
Blasting coal or overburden	No control
Loading trucks	No control
Hauling	50% for level 1 watering (2 litres/m^2/hr) 75% for level 2 watering (> 2 litres/m^2/hr)
Unloading trucks	70% for water sprays
Draglines	Control dust by minimising drop height
Loading stockpiles	50% for water sprays 25% for variable height stacker 75% for telescopic chute with water sprays 99% for total enclosure
Unloading from stockpiles	50% for water sprays (unless underground recovery then no controls needed)
Wind erosion from stockpiles	50% for water sprays 30% for wind breaks 99% for re-vegetation (overburden only) or total enclosure
Loading to trains	70% for enclosure 99% for enclosure and use of fabric filters
Miscellaneous transfer and conveying	90% control allowed for water sprays with chemicals 70% for enclosure 99% for enclosure and use of fabric filters
Metalliferous Mines	
All activities listed in Table 4.	30% for windbreaks 50% water sprays to keep ore wet 65% for hooding with cyclones 75% for hooding with scrubbers 83% for hooding with fabric filters 100% enclosed or underground

Source: Holmes Air Sciences (1998).

[a] Controls are multiplicative. For example, water sprays used in conjunction with wind breaks give an emission which is 0.5 * 0.7 = 0.35 of the uncontrolled emission (ie. 50% of 70% of the total uncontrolled emissions).

4.1.4 Vehicle Exhaust Emissions

Diesel vehicles will emit particulate matter that can be considered to be 100 per cent PM_{10}, CO, NO_x and VOCs. Table 3 shows US EPA emission factors for vehicle exhaust in terms of kilograms of pollutant per 1000 litres of fuel consumed by each type of vehicle.

Table 4 - USEPA Emission Factors for Various Classes of Mining Equipment (kg/1000L fuel) [a,b]

	PM_{10} [a]	CO	NO_x	SO_x (as SO_2)	VOCs (exhaust)	Emission Factor Rating
Track type tractor	3.03	9.4	34.16	3.73	3.31	C
Wheeled tractor	5.57	32.19	52.35	3.73	7.74	C
Wheeled dozer	17.7	14.73	34.29	3.74	1.58	C
Scraper	3.27	10.16	30.99	3.74	2.28	C
Grader	2.66	6.55	30.41	3.73	1.53	C
Off-highway truck	17.7	14.73	34.29	3.73	1.58	C
Wheeled loader	3.51	11.79	38.5	3.74	5.17	C
Track type loader	2.88	9.93	30.73	3.74	4.85	C

Source: USEPA (1998).

[a] It should be noted that the emission factors for mining activities have been derived from measurements that cover all PM_{10} emissions associated with a unit operation, including exhaust emissions. To add the exhaust PM_{10} emissions to the fugitive emissions would involve some measure of double counting for those activities. However, if there are vehicle emission sources that are independent of the activities listed in Table 1 and Table 2, the factors in this table should be used to characterise emissions from these sources.

[b] This Table provides emissions from combustion sources only

Using these emission factors, and knowledge of diesel fuel, emission estimates of particulate matter, carbon monoxide, nitrogen oxides, sulfur oxides (as sulfur dioxide) and volatile organic compounds from diesel powered equipment can be made.

Emissions of a pollutant can be estimated by applying Equation 3, and the relevant emission factor from Table 3.

Equation 3

$$E_{kpy,i} = A * EF_i$$

where:

$E_{kpy,i}$ = emissions of pollutant i, kg/yr
A = amount of fuel used, 1000 L /yr
EF_i = emission factor from Table 4, kg/1000 L fuel

Example 3 - Estimating Pollutant Emissions from Mining Equipment

Emissions of NO_x from a grader can be calculated using Equation 3 and Table 4.

$$
\begin{aligned}
EF_{NOx} &= 30.41\ kg/kL \\
A &= 5000\ L/yr \\
&= 5\ kL/yr \\
\\
E_{kpy,\ NOx} &= EF_{NOx} * A \\
&= 30.41 * 5 \\
&= 152\ (kg\ NO_x/yr)
\end{aligned}
$$

Emissions from mining equipment can be calculated based on the fuel usage data. Diesel would be used by mining operations in a variety of sources (such as those listed above) and emissions should be calculated following the general calculation process below:

1. Determine diesel consumed at site from fuel usage data.
2. Estimate proportion used in each of the activities listed.
3. For each activity, work out emissions for each pollutant.
4. Calculate total emission from the sum of the emissions of each activity.

The US EPA provides emission factors for sulfur dioxide, however, these will be dependent on the percentage of sulfur in the fuel (The sulfur content of Australian diesel fuel is approximately 0.2% depending on the crude stock and the refinery. Emissions can be estimated assuming all sulfur is converted to sulfur dioxide, ie. for every 1000 litres of diesel fuel consumed, 3.4 kg of sulfur dioxide is produced, less than half the US EPA factor (calculation assumes that the density of diesel is 842 g/L (15°C) and that 1 g of sulfur converts to 2 g of sulfur dioxide).

Note: The PM_{10} *component of these calculations may be included in the* PM_{10} *inventory, but it should be noted that the emission factors for mining activities have been derived from measurements which cover all* PM_{10} *emissions associated with a unit operation, including exhaust emissions.*

4.1.5 Volatile Organic Compounds Emissions

In addition to VOCs emitted from vehicle exhausts, there will also be emissions of volatile chemicals used on site in workshops and from fuel storage (see the *EET Manual for Fuel and Organic Liquid Storage*). In some instances volatile substances may be released during mining processes.

Emissions of volatile solvents can be estimated on the basis of annual usage, assuming that all solvents are volatilised. Any vapour recovery system should be accounted for in controls.

4.1.6 Emission from Processing of Non-Metallic Minerals

The Tables in this section have been extracted from US EPA (1998), AP-42, Chapter 11. They present emission factors for some aspects of the processing of various non-metallic minerals.

The Tables give emissions factors for filterable PM and condensable PM. These terms originate from the USEPA emissions test method 5 for emissions of particulate matter from stacks. The terms refer to particulate matter collected in the heated and cooled parts respectively, of the sampling train. The factors do not allow emissions of the PM_{10} fraction to be calculated directly unless data on particle size distribution is also available. US EPA (1988) provides particle size distribution data for filterable PM for phosphate rock dryers and calciners and the processing of bentonite and fire clay. This information is included in Table 10, Table 14 and Table 16 of this manual. USEPA AP-42, Appendix B2 (1995) provides information on generic particle size distributions and typical control efficiencies for various particle control devices. This information may be applied to estimate PM_{10} emissions from some of the non-metallic minerals processes.

Some of the tables include emission factors for combustion gases for drying and calcining processes. Information on emission factors for external combustion sources, but not specifically for non-metallic minerals processing, is available from USEPA, AP-42, Chapter 1 (1998) and from the *Combustion in Boilers EET Manual*. The tables in this section provide only a rough guide for estimating emissions from Australian processes unless similarity of materials and processing plant can be established.

Perlite

Table 5 - Emission Factors for Perlite Processing[a]

Process	Filterable PM[b]	
	kg/t Perlite Expanded	Emission Factor Rating
Expansion furnace	ND	D
Expansion furnace with wet cyclone	1.1	D
Expansion furnace with cyclone and baghouse	0.15	D
Dryer	ND	D
Dryer with baghouse	0.64	D
Dryer with cyclones and baghouses	0.139	D

ND = No Data

Source: USEPA AP-42 Table 11.30-1 (1995)

a All emission factors represent controlled emissions.

b Filterable PM is that PM collected on or prior to the filter of an USEPA Method 5 (or equivalent) sampling train.

Feldspar

Table 6 - Emission Factors for Feldspar Processing - Filterable Particulate Matter

Process	Filterable Particulate	
	kg/t Feldspar Dried	Emission Factor Rating
Dryer with scrubber and demisters	0.60	D
Dryer with mechanical collector and scrubber	0.041	D

Source: USEPA AP-42 Table 11.27-1 (1995).

Phosphate Rock

Table 7 - Emission Factors for Phosphate Rock Processing - Combustion Gases [a]

Process	$S0_2$	CO	Emission Factor Rating
	kg/t of Total Feed	kg/t of Total Feed	
Dryer	ND	0.17	D
Calciner with scrubber	0.0034	ND	D

ND = No Data
Source: USEPA AP-42 Table 11.21-2 (1995)
a Factors represent uncontrolled emissions unless otherwise noted.

Table 8 - Emission Factors for Phosphate Rock Processing[a]

Process	Filterable PM[b]				Condensable PM[c]			
	PM		PM_{10}		Inorganic		Organic	
	kg/t of Total Feed	Emission Factor Rating	kg/t of Total Feed	Emission Factor Rating	kg/t of Total Feed	Emission Factor Rating	kg/t of Total Feed	Emission Factor Rating
Dryer	2.9	D	2.4	E	ND		ND	
Dryer with scrubber	0.035	D	ND		0.015	D	ND	
Dryer with ESP	0.016	D	ND		0.004	D	ND	
Grinder	0.8	C	ND		ND		ND	
Grinder with fabric filter	0.0022	D	ND		0.0011	D	ND	
Calciner	7.7	D	7.4	E	ND		ND	
Calciner with scrubber	0.10	C	ND		0.0079	C	0.044	D
Transfer and storage	2	E	ND		ND		ND	

ND = No Data

Source: USEPA AP-42 Table 11.21-3 (1995)

a Factors represent uncontrolled emissions unless otherwise stated.

b Filterable PM is that PM collected on or prior to the filter of an USEPA Method 5 (or equivalent) sampling train. PM_{10} values are based on cascade impaction particle size distribution.

c Condensible PM is that PM collected in the impinger portion of a PM sampling train.

Table 9 - Emission Factors for Phosphate Rock Processing - Fluoride [a]

Process	Fluoride, H_20-Soluble		Fluoride, Total	
	kg/t of Total Feed	Emission Factor Rating	kg/t of Total Feed	Emission Factor Rating
Dryer Dryer with scrubber	0.00085 0.00048	D D	0.037 0.0048	D D
Grinder Grinder with fabric filter	ND ND		ND ND	
Calciner with scrubber	ND		0.00081	D

ND = No Data

Source: USEPA AP-42, Section 11.21, Table 11.21-6 (1995)

[a] Factors represent uncontrolled emission unless otherwise noted.

Table 10 - Particle Size Distribution of Filterable Particulate Emissions from Phosphate Rock - Dryers and Calciners

Diameter, µm	Percent Less Than Size	
	Dryers	Calciners
10	82	96
5	60	81
2	27	52
1	11	26
0.8	7	10
0.5	3	5

Emission Factor Rating: E

Kaolin

Table 11 - Emission Factors for Kaolin Processing[a]

Source	Filterable PM[b]	Filterable PM_{10}[c]	Emission Factor Rating
Spray dryer with fabric filter	0. 12	ND	D
Apron dryer	0.62	ND	D
Multiple hearth furnace	17	8.2	D
Multiple hearth furnace with venturi scrubber	0.12	ND	D
Flash calciner	550	280	D
Flash calciner with fabric filter	0.028	0.023	D

ND = No Data

a Factors are kg/t produced. Emissions are uncontrolled unless noted.

b Filterable PM is that PM collected on or before the filter of an USEPA Method 5 (or equivalent) sampling train.

c Based on filterable PM emission factor and particle size data.

Source: USEPA AP-42, Section 11.25, Table 11.25-2 (1995)

Ball Clay

Table 12 - Emission Factor Rating for Ball Clay Processing

Source	Filterable PM kg/t	Emission Factor Rating
Vibrating grate dryer with fabric filter	0.071	D

Source: USEPA AP-42 Section 25, Table 11.25-5 (1995)

[a] Factors are kg/t of ball clay processed.

[b] Filterable PM is that PM collected on or before the filter of an USEPA Method 5 (or equivalent) sampling train.

Fire Clay

Table 13 - Emission Factors for Fire Clay Processing

Process	$S0_2$	NO_x	PM	Filterable PM_{10}	Emission Factor Rating
Rotary dryer	ND	ND	33	8.1	D
Rotary dryer with cyclone	ND	ND	5.6	2.6	D
Rotary dryer with cyclone and wet scrubbers	ND	ND	0.052	ND	D
Rotary calciner	ND	ND	62	14	D
Rotary calciner with multiclone	ND	ND	31	ND	D
Rotary calciner with multiclone and wet scrubber	3.8	0.87	0.15	0.03	D

ND = No Data

a Factors are kg/t of raw material feed. Emissions are uncontrolled, unless noted.

b Filterable PM is that PM collected on or before the filter of an USEPA Method 5 (or equivalent) sampling train, PM_{10} values are based on cascade impaction particle size distribution.

Source: USEPA AP-42, Section 11.25, Table 11.25-6 (1995)

Table 14 - Particle Size Distributions for Fire Clay Processing

Diameter (µm)	Uncontrolled	Multiclone Controlled	Cyclone Controlled	Cyclone/Scrubber Controlled
	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter	Cumulative % Less Than Diameter
Rotary Dryers (SCC 3-05-043-30)				
2.5	2.5	ND	14	ND
6.0	10	ND	31	ND
10.0	24	ND	46	ND
15.0	37	ND	60	ND
20.0	51	ND	68	ND
Rotary Calciners (SCC 3-05-43-40)				
1.0	3.1	13	ND	31
1.25	4.1	14	ND	43
2.5	6.9	23	ND	46
6.0	17	39	ND	55
10.0	34	50	ND	69
15.0	50	63	ND	81
20.0	62	81	ND	91

[a] For filterable PM only. Emission Factor Rating: D

ND = No Data

Source: USEPA Table 11.25-8

Bentonite

Table 15 - Emission Factors for Bentonite Processing[a]

Source	Filterable PM[b]	Emission Factor Rating	PM_{10}[c]	Emission Factor Rating
Rotary dryer	140	D	10	D
Rotary dryer with fabric filter	0.050	D	0.037	D
Rotary dryer with ESP	0.016	E	ND	

Source: USEPA AP-42, Section 11.25, Table 11.25-9

[a] Factors are kg/t produced. Emissions are uncontrolled unless noted.

[b] Filterable PM is that PM collected on or before the filter of an USEPA Method 5 (or equivalent) sampling train.

[c] Based on filterable PM emission factor and particle size data.

Table 16 - Particle Size Distributions for Bentonite Processing

Particle Size, µm	Cumulative Percent Less Than Size	
	Rotary Dryer, Uncontrolled	Rotary Dryer With Fabric Filter
1.0	0.2	2.5
1.25	0.3	3.0
2.5	0.8	12
6.0	2.2	44
10.0	7.0	74
15.0	12	92
20.0	25	97

Source: USEPA Table 11.25-8

Table 17 - Emission Factors for Vermiculite Processing[a]

Process	Filterable PM[b] kg/t	Condensible organic PM[c] kg/t	Total PM kg/t	Emission Factor Rating
Rotary dryer, with wet collector	0.29[d]	ND	ND	
Concentrate screening, with cyclone	0.30[e]	NA	0.30[e]	D
Concentrate conveyor transfer, with cyclone	0.013[e]	NA	0.013[e]	D
Exfoliation - gas-fired vertical furnace, with fabric filter	0.32	0.18[f]	0.50[g]	D
Product grinding, with fabric filter	0.18	NA	0.18	D

ND = No Data

NA = Not Applicable

Source: USEPA AP-42 Ch 11.28, Table 11.28-1 (1995)

[a] Factors represent uncontrolled emissions unless noted. Emission factor units are kg/t of material fed; emission factor units for other processes are kg/t of product.

[b] Filterable PM is that PM collected on or prior to the filter of an USEPA method 5 (or equivalent) sampling train.

[c] Condensible PM is that PM collected in the impinger portion of a PM sampling train. Condensible organic PM is the organic fraction of the condensible PM.

[d] Emission Factor Rating E.

[e] For dried ore concentrate.

[f] Emissions may be largely from volatilisation of oil used in ore beneficiation.

[g] Sum of factors for filterable PM and condensible inorganic PM; does not include condensible inorganic PM.

Talc

Table 18 - Emission Factors for Talc Processing[a]

Process	Total PM kg/t[b]	Emission Factor Rating
Natural gas-fired crude ore drying with fabric filter[c]	0.0020	D
Primary crushing with fabric filter	0.00074	D
Crushed talc railcar loading	0.00049	D
Screening with fabric filter[d]	0.0043	D
Grinding with fabric filter	0.022	D
Grinding with heated makeup air, with fabric filter	0.022	D
Classifying, with fabric filter[e]	0.00077	D
Pellet drying, with fabric filter[f]	0.032	E
Pneumatic conveyor venting, with fabric filter[g]	0.0018	D
Packaging, with fabric filter	0.0090	D
Crushed tale storage bin loading, with fabric filter[h]	0.0036	D
Ground talc storage bin loading, with fabric filter[i]	0.0016	D
Final product storage bin loading, with fabric filter[h]	0.0035	D

Source: USEPA AP-42 Ch 11.26, Table 11.26-1 (1995)

[a] Units are kg/t of production unless noted.

[b] Total PM includes the PM collected in the front half and the inorganic PM caught in the back half (impingers) of an USEPA Method 5 sampling train.

[c] Filterable PM faction is 60%, and condensible inorganic fraction is 40%.

[d] For crushed talc ore.

[e] For ground talc.

[f] Filterable PM fraction is 56%, and condensible inorganic fraction is 44%.

[g] For final product. Units are kg/t of material conveyed.

[h] Units are kg/t of material loaded into storage bin.

[i] Units are kg/t of material loaded into storage bin.

Table 19 gives emission factors for NPI substance emissions, while Table 20 gives emission factors for organic pollutants emissions, from industrial sand and gravel processing. Table 19 and Table 20 were adapted from USEPA, AP-42, Chapter 11 (1995). In the absence of other data, the emission factors presented in Table 21 for “crushed stone processing” can be used to estimate emissions from corresponding sand and gravel processing sources. The emission factors presented in Table 19 for industrial sand and gravel processing are not recommended as surrogates for construction sand and gravel processing as these materials are processed at much higher moisture contents.

Table 19 - Emission Factors for Industrial Sand and Gravel Processing[a]

Source	Total PM kg/t	NO_x kg/t	Emission Factor Rating
Sand dryer	0.98[b]	0.016	E
Sand dryer with wet scrubber	0.019[b]	[c]	C
	0.0053[b]	[c]	D
Sand dryer with fabric filter	0.00064[d]	ND	D
Sand handling, transfer, and storage with wet scrubber	0.0042[e]	ND	D
Sand screening with venturi scrubber			

Source: USEPA AP-42 Ch 11.19.1, Table 11.19.1 (1995)
ND = No data

[a] Factors represent uncontrolled emissions unless noted. Dryer emission factors in units of kg/t of dried material produced; other factors in units of kg/t of material stored or screened.

[b] Factors are for filterable PM only. Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 sampling train. Condensible organic and inorganic PM emission factors are not available. Factors can be considered a conservative underestimate of total PM.

[c] Control device ahs no effect on emissions. See factor for uncontrolled emissions.

[d] For dried sand.

[e] Screening of dried sand.

Table 20 - Emission Factors for Industrial Sand and Gravel Processing - Organic Pollutants [a]

Source	Pollutant		Emission Factor kg/tonne	Emission Factor Rating
	CASR [b]	Name		
Diesel-fired rotary sand dryer with fabric filter (SCC 3-05-027-22)	50-00-0	Formaldehyde	0.0021	D
	206-44-0	Fluoranthene	$3.0 * 10^{-6}$	D
	91-20-3	Naphthalene	$2.9 * 10^{-5}$	D
	85-01-8	Phenanthrene	$7.5 * 10^{-6}$	D

Source: USEPA AP-42, Section 11.19.1, Table 11.19-2

[a] Factors represent uncontrolled emissions unless noted. Dryer emission factors in units of kg/tonne of material dried. SCC = Source Classification Code.

[b] Chemical Abstract Service Registry Number

As PM_{10} emissions from limestone and granite processing operations are similar, the emission factors developed from the emission data gathered at limestone and granite processing facilities are considered to be representative of typical crushed stone processing operations. Emission factors for filterable PM and PM_{10} emissions from crushed stone processing operations are presented in Table 21, adapted from USEPA, AP-42, Chapter 11, (1995).

Table 21 - Emission Factors for Crushed Stone Processing Operations[a]

Source[b]	Total Particulate Matter	Emission Factor Rating	Total PM_{10}	Emission Factor Rating
Screening			0.0076	C
Screening (controlled)			0.00042	C
Primary crushing	0.00035	E	ND[c]	
Secondary crushing	ND		ND[c]	
Tertiary crushing	-		0.0012	C
Primary crushing (controlled)	ND		ND[c]	NA
Secondary crushing (controlled)	ND		ND[c]	NA
Tertiary crushing (controlled)	-		0.00029	C
Fines crushing	-		0.0075	E
Fines crushing (controlled)	-		0.0010	E
Fines screening	-		0.036	E
Fines screening (controlled)	-		0.0011	E
Conveyor transfer point	-		0.00072	D
Conveyor transfer point (controlled)	-		$2.4 * 10^{-5}$	D
Wet drilling: unfragmented stone	ND		$4.0 * 10^{-5}$	E
Truck unloading: fragmented stone	ND		$8.0 * 10^{-6}$	E
Truck loading: conveyor: crushed stone	ND		$5.0 * 10^{-5}$	E

Source: USEPA AP-42 Ch11.19.2, Table 11.19.2-1 (1995)

ND = No data

[a] Emission factors represent uncontrolled emissions unless noted. Emission factors in kg/t of material throughput.

[b] Controlled sources (with wet suppression) are those that are part of the processing plant that employs current wet suppression technology similar to the study group. The moisture content of the study group without wet suppression systems operating (uncontrolled) ranged from 0.21 to 1.3 percent and the same facilities operating wet suppression systems (controlled) ranged from 0.55 to 2.88 percent. Due to carry over or the small amount of moisture required, it has been shown that each source, with the exception of crushers, does not need to employ direct water sprays. Although the moisture content was the only variable measured, other process features may have as much influence on emissions from a given source. Visual observations from each source under normal operating conditions are probably the best indicator of which emission factor is most appropriate. Plants that employ sub-standard control measures as indicated by visual observations should use the uncontrolled factor with an appropriate control efficiency that best reflects the effectiveness of the controls employed.

[c] No data available, but emission factors for PM_{10} emission factors for tertiary crushing can be used as an upper limit for primary and secondary crushing.

4.2 Emissions to Water

4.2.1 Background

Emissions of substances to water can be categorised as discharges of all reportable substances to:

- Surface waters (eg. lakes, rivers, dams, and estuaries);
- Coastal or marine waters; and
- Stormwater.

- irrespective of whether these occur within or outside the mining lease or tenement.

Because of the significant environmental hazards posed by emitting toxic substances to water, most facilities emitting NPI-listed substances to waterways are required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This existing sampling data can be used to calculate annual emissions.

If no wastewater monitoring data exists, emissions to water can be calculated based on a mass balance or using emission factors.

The discharge of listed substances to a sewer or tailings dam does not require you to report to the NPI (See also Section Three of *the NPI Guide*).

The distinction between emissions and transfers is illustrated by reference to the activities in Table 1 that commonly occur at mines.

Table 22 - Transfers vs. Emissions

TRANSFER	EMISSION
• Tailings placement and retention in a pit or tailings storage facility	• Overflow of waters with or without suspended solids from a tailings storage facility to a water course
• Retention of run off water from infrastructure areas in anti-pollution pond	• Overflow of water / suspended solids from anti pollution pond to a water course
• Placement of waste rock in pits or in pit dumps	• Run off/leachate from a waste dump / haul road directly to a water course
• Retention of run off/leachate from waste dumps in pits or purpose built storages	• Seepage of pit water to regional groundwaters[a]

Table 22 - Transfers vs. Emissions cont'

• Treatment/neutralisation of leachate within a facility • Sale of concentrate or other mine product / by product • Sale of a waste rock or other waste material for commercial / industrial use, eg. as a road base or as a raw product for manufacture of a saleable product	• Injection of waste waters to groundwaters[a] (except where dewatering of groundwater seepage is reinjected and chemistry remains unchanged)

[a] Emissions to groundwater are categorised as emissions to land

It is suggested that facilities relate their potential emissions to the mine's water management practices. Information on the facility's catchment segregation, water balance, water storage capacity, volume of water used and volume of water discharged may be used to define the transfers which occur at the facility and to refine the sources of emissions.

With regard to emissions and transfers, it is recognised that actual emissions may depend on the weather conditions over the reporting period. For example, a system may be designed and operated to contain run-off from rainfall with a 1 in 5 - 20 year return period, and in that situation, estimation and reporting of emissions will be required only where overflows are recorded to have occurred. Therefore, where overflow or seepage do not occur, reporting is not necessary.

The estimation of emissions should involve the sequential consideration of the following matters:

1. Reporting criteria applicable to the actual use / production and / or consumption of reportable substances at the facility.
2. On-site management practices in relation to all reportable substances to determine emissions as distinct from transfers within the facility.

Estimation will require the input of relevant site-specific data that may need to be complemented by estimations of variables that are not routinely monitored. It is recognised that facility personnel understand the particular situations at their facilities and the data that is commonly available. This Manual intends to provide a guide on how data may be manipulated to estimate the reportable emissions. It should be noted that facilities may use alternative approaches which complement both their facilities and the available data for the estimation of reportable emissions.

4.2.2 Overview of Water Emission Sources

Emissions include all reportable substances either dissolved in water or as suspended solids, including colloids. The following activities potentially lead to reportable emissions under the NPI.

Process Waters from Mining

Most process water used in mining will be associated with transfers. For example:

1. process water in open cut mines routinely used for dust suppression, which will be applied to active working areas in pits and in surface areas such as haul roads and hardstands; and
2. process water in underground mines routinely used for dust suppression, cooling of equipment such as drills, continuous miners and tunnel boring machines. Excess wastewater from these activities is pumped to the surface.

Emissions will be associated with overflows and/or discharges of excess mine process waters from the site to surface waters or coastal/marine waters or groundwater (an emission to land).

Process Waters from Beneficiation

Water may be used in crushing and flotation and also to transport slurries (30-40 percent solids) within the plant and to wastes and tailings impoundments as appropriate.

Consumption of water will depend on the characteristics of the process. In most cases water is recycled (depending on the tailings storage facility design).

Residues would normally be considered as part of the tailings and/or product streams and their associated process waters. In these cases, residues would be transfers rather than emissions. Emissions will be confined to process waters discharged from the facility to surface waters and coastal/marine waters or groundwater (emission to land).

Surface Water Run-Off

Surface water run-off is that which leaves the operational area of the facility, such as run - off from haul roads, waste dumps, and administration areas. Run-off from un-worked areas of the mine may, in most cases, be regarded as natural run-off.

Depending on the characteristics of the facility, natural run-off in mineralised areas may contain elevated concentrations of reportable metal compounds and any emissions will need to be reported if the NPI threshold is exceeded. Catchment segregation will limit the volumes of such run-off.

Leachate from Stockpiles, Overburden, Waste Rocks and Tailings to Surface Waters

Leachate will occur from elevated features such as stockpiles, waste rock and overburden materials as a result of seepage of excess processing water and infiltration of rainfall run-off. It may also occur in pits as a result of leaching of waste rock material placed in the pit.

Where not fully contained in suitable structures, leachates that discharge from the facility should be regarded as emissions to water (eg. surface waters) or emissions to land (eg. groundwater).

4.2.3 Emission Estimation Methods

The following steps should be taken to determine what emissions need to be estimated:

1. identify and list all reportable substances associated with the mining operation that have triggered the threshold;
2. identify and list all sources of waters used in the mine and their quality with regard to reportable substances and management to establish whether the particular water use is associated with transfers or emissions;
3. identify and list all emissions to water over the reporting period. In above average rainfall years the number of emission sources and soil erosion may be expected to increase; and
4. identify and list the data available on the facility to estimate the reportable emissions. These would include total flows and flow rates after various rainfall/run-off events, suspended solids concentrations, concentrations of trace metals in various materials on the facility, and erosion rates. Also supplementary information such as rainfall and rainfall patterns over the reporting period may be required to complement other information. All data may not be available at all facilities and emissions should be estimated from the data available.

4.2.3.1 Direct Monitoring - Water Quality and Volume

Data which may be routinely available to help estimate emissions include, but is not limited to, the following:

1. Water quality on mines would be routinely monitored with the variables analysed being dependent on site-specific circumstances including the requirements of relevant licences and permits.
2. Water flows and flow rates from specific catchments as a result of direct monitoring or from estimations based on calibrated models or engineering calculations, eg. Australian Rainfall and Run-off, where appropriate and possible.
3. Quantities of reportable substances produced, consumed and/or used at the facility over the reporting period.
4. Typical quantities or concentrations of relevant consumables and process variables in the beneficiation plant.
5. Mineral composition/properties of relevant ores, concentrates, waste rock, spoils, tailings, soils, adjacent weathered rock, including reportable substances present in trace quantities. Trace metal composition of some waste materials may be available from specific studies undertaken at the facility, eg. geological modelling and analyses of surface materials to assess their suitability as growing media for rehabilitation.
6. Survey information that can be used to identify relevant matters such as mining blocks, areas/dimensions of waste rock dumps, catchments, sub-catchments and all areas from which emissions could occur.
7. Typical erosion rates from the mine area that may be obtained by monitoring, or interpretation of suitable models calibrated for the facility.

This data may be used directly to provide estimates of emissions. For example, the flow volume in a discharge multiplied by the concentration of a substance in the flow water will give a reliable estimate of the emission for that substance.

In many cases all data required will not be available and emission estimates will be based on combinations of data and information and data manipulation to estimate the emission. For example:

- flows may be known and survey data may be used to apportion part of the measured flow to run off from mine operational areas; and
- trace metal concentrations of water emissions may not be known and would need to be estimated from other site data.

4.2.3.2 Estimation Methods for Non-Monitored Substances

Where a reportable substance is not monitored, then default concentrations will need to be inferred or developed to provide an estimate of emissions. This would apply to trace metals and elements in a large tailings storage facility, especially after significant dilution. Where trace element concentration data is not available, estimates, using the assumed concentrations listed in Table B 1 as defaults, should be calculated.

4.2.3.3 Mass Balance Calculations

In summary, mass balance calculations depend on the conservation of matter and may be used to estimate unknown data and variables. If sufficient data is present, it may be used to check the general validity of estimated and/or assumed data. Details on mass balance are provided in Appendix B1.4.

In their simplest form, mass balances are straightforward additions. For example, on a dry mass basis, the mass of product will be the total quantity mined, less the quantities of waste (eg. Waste rock and tailings) produced. Similarly a catchment area will be equal to the sum of the areas of its particular sub-catchments. Water losses at a plant will be the total water consumed less the water entrained in the waste and product streams, water recycled to the plant and evaporation.

4.2.3.4 Estimation Methods for Leachate-Borne Emissions

These will generally be insignificant except in specific cases where water soluble reportable substances are present in locations where they may be discharged from the facility. Leachate emissions to groundwater are emissions to land.

The estimation of emissions will need to take site-specific circumstances and conditions into account, particularly the site water balance, rainfall infiltration and leachate volumes and flow rates, metal/substance concentrations in leachate waters and relevant properties of the leachate source materials, eg. host rock / tailings materials.

Acid Drainage (AD)

Sulfuric acid may be produced when soil or rock containing sulfide minerals is exposed to the atmosphere. AD formation is dependent on many inter related variables, including reactivity of the sulfide species present, water and oxygen availability and the neutralising capacity of the host and adjacent rocks. Reliable estimates of AD generation cannot be obtained from the application of general data in isolation. Thus the estimation of sulfuric acid generation must be determined after taking site-specific management and local environmental factors into account. These should be based on determination of the acid generating potential and neutralising capacity of all materials including ores, waste and associated rocks and tailings and the availability of rock materials to contribute to the acid-base reactions.

- For the purposes of calculating releases to the environment for NPI reporting substances, facilities should consider the pH of the discharge water. If the pH of these waters is less than 4, AD emissions will need to be estimated and reported.
- Where data is not available, it should be assumed that sulfuric acid is generated at a rate of 240 kg/hectare of exposed pyritic material - based on the oxidation of host rock containing 1% pyrite with no neutralising capacity.

4.2.4 Emissions to Waters from Site Operations

For reportable substances that have triggered the reporting threshold, the following approach should be used for each of the sources to estimate emissions.

Open Cut Mining Operations

- Estimate run-off from contaminated waters used for activities such as road watering and general dust suppression.
- Estimate run-off volumes from waste rock dumps that transport suspended solids.
- Estimate leachate emissions and where appropriate, include where leachate carries a suspended solids loading.

Data for these sources may not be directly available and other measures will be required to estimate emissions, eg. data on erosion and from downstream monitoring.

Direct emissions should be estimated from available data that may include pumping rates, eg. pumping of excess water from a pit. The facility should nominate appropriate and realistic pumping rates that take head losses, leaks and availability into account. Where pumping rates have not been determined, it should be assumed that the rate is 80 percent of the rated capacity for the particular pump and that the availability is equal to the operating hours for that pump.

Workshop and Maintenance Operations

Identify reportable substances and quantities of substances used from inventories and hazardous substance registers. The quantities of substances used will provide an estimate of the total transfers and environmental emissions. In most cases, these would be associated with air emissions and the assignment of emissions to waters would occur infrequently. If emissions of these substances to water occur, estimate the portion of water emissions.

Underground Mining Operations

Water from underground will be pumped to specific points from where it may be discharged, retained, recycled in the beneficiation plant or used for road watering.

- Identify the emissions and transfers; and
- Estimate emissions from available data (eg. pumping rates).

The facility should nominate appropriate and realistic pumping rates that take head losses, leaks and availability into account. Where pumping rates have not been determined, it should be assumed that the rate is 80% of the rated capacity for the particular pump and that the availability is equal to the operating hours for that pump.

Beneficiation Operations

Beneficiation operations are generally designed and operated to crush the ores/run-off mine (ROM) material and maximise the separation and recovery of specific target minerals from the ores/ROM. In addition to the mineralogical properties of the materials, the quality and availability of water and related facility-specific matters are taken into account.

Process water management and the location and operation of facilities such as ROM and product storage and tailings storage facilities will be dependent on site-specific factors including location of the ore body with respect to infrastructure areas and catchment/sub-catchment areas within the lease.

The occurrence of reportable substances in all materials handled in the plant will usually be known from mine and process monitoring. Similarly the flotation reagents used and their rates of consumption should be known from process management and monitoring.

The estimation of emissions from the beneficiation plant may be determined from monitoring data and/or should have regard to the following matters:

- Definition of the transfers and actual emissions for the facility;
- Flows, volumes, and water balances for all aspects of the operation with particular emphasis on water losses to the environment, eg. leachate and overflows from tailings storage facilities and discharges from the plant site;
- The composition of target and trace metals in all materials handled, particularly in run-off waters;
- Relevant water quality monitoring data;
- The quantities of materials lost from the plant. These would mainly be tailings and wastes and may also include spillages of materials, eg. concentrate, tailings, overflows of process waters as a result of operational problems;
- Losses of reportable substances should be estimated directly or from mass balances involving the quantities of solids and liquids treated and their composition;.
- Mass balances of materials treated and flotation substances used based on plant throughput, details of the particular plant and water circuit and average composition and/or concentration of all materials handled; and
- Certain reportable substances will be converted as part of the beneficiation process. These should be regarded as transfers and/or emissions as appropriate.

4.3 Emissions to Land

Emissions of substances to land include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids and may contain listed substances. These emission sources can be broadly categorised as:

- surface impoundments of liquids and slurries;
- unintentional leaks and spills; and
- emissions to groundwaters.

4.3.1 Background

Most activities such as placement of waste rock and tailings dams result in transfers. Emissions to land generally relate to those situations where reportable substances are not effectively contained within the containment facility and are discharged to land. Transfers within the operation are not regarded as land emissions under the NPI. However, facilities are expected to consider all such sources to determine if emissions do occur. If so, the EETs are provided below.

4.3.2 Land Emission Sources

Sources of emissions to groundwater

Groundwater are commonly associated with surface alluvia in watercourses and natural and established groundwater pathways such as faults, permeable strata and other openings established through mining, (eg. shaft construction and rock fracturing after blasting). The permeable media may reduce the levels of suspended solids by deposition and filtering.

Waste Rock and Spoil Dumps

These are regarded as transfers and would not be associated with an emission except in specific circumstances, eg. where AD generation has resulted in the formation of a contaminated leachate, which in turn discharges to an aquifer (groundwater).

In mineralised areas, waste rock may contain sub-economic quantities of reportable metal compounds and the excavation and placement of these materials in surface and in pit dumps may be regarded as emissions to land where releases to aquifers of leachates containing reportable compounds occur.

Surface Impoundments of Liquids and Slurries

Mine and process waters, and contaminated surface water run off, may be routinely contained in pits and/or purpose built structures such as tailings and environmental dams. This constitutes a transfer while the reportable substances are contained within the particular site facilities.

Discharges to aquifers are land emissions. Overflows are regarded as emissions to land except when the discharge is to a natural water body.

Agricultural Application of Substances to Land/Irrigation

In general these may occur where direct discharges of waters are not possible or permitted and excess water is used for flood or spray irrigation or is confined in evaporation ponds. Also, it would include incorporation of sewage sludge into land.

Flood or spray irrigation of effluent or process waters to land would be regarded as an emission to land. The emissions of reportable substances can be calculated by the percent content of reportable substance in the total volume irrigated.

Unintentional Leaks, Seepages and Spills

Under the NPI, spills, leaks and seepage are required to be reported as emissions to land. To calculate the emission, report the difference between the release/spill and collected material. The difference is the emission to land.

5.0 Emission Estimation Techniques: Acceptable Reliability and Uncertainty

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the National Pollutant Inventory does not favour one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with regards to accuracy

Several techniques are available for calculating emissions from mining and processing of non-metallic minerals. The technique chosen is dependent on available data, available resources, and the degree of accuracy sought by the facility in undertaking the estimate. In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data, such as the emission factors presented in Section 3.7 of this Manual.

5.1 Direct Measurement

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from mining and processing of non-metallic minerals. However, collection and analysis of samples from facilities can be very expensive and especially complicated where a variety of NPI-listed substances are emitted and where most of these emissions are fugitive in nature. Sampling data from a specific process may not be representative of the entire manufacturing operation and may provide only one example of the facility's emissions.

To be representative, sampling data used for NPI reporting purposes needs to be collected over a period of time, and cover all aspects of mining and processing of non metallic minerals.

In the case of CEMS, instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

5.2 Mass Balance

Calculating emissions from mining and processing of non-metallic minerals using mass balance appears to be a straightforward approach to emission estimation. However, it is likely that few Australian facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking, or other activities inherent in each material handling stage, can result in large deviations for total facility emissions. Because emissions from specific materials are typically below 2 per cent significantly skew emission estimations.

5.3 Engineering Calculations

Theoretical and complex equations or *models* can be used for estimating emissions from mining and processing of non-metallic minerals. EET equations available for emissions from the mining and processing of non-metallic minerals are described in Section 5 of this Manual.

Use of emission equations to estimate emissions from mining and processing of non-metallic minerals is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions.

5.4 Emission Factors

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Handbooks. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in Section 6 of this Manual. The emission factor ratings will not form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows:

A - Excellent
B - Above Average
C - Average
D - Below Average
E - Poor
U - Unrated

6.0 References

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The following EET Manuals are available at the NPI Homepage (http://www.environment.gov.au/npi.html), and from your local Environmental Protection Authority:

- *EET Manual for Combustion in Boilers;* and
- *EET Manual for Mining.*

7.0 APPENDICES - EMISSION ESTIMATION TECHNIQUES

7.1 Appendix A - Air - Emission Factor Equations for Mining

This Appendix provides information on how the Emission Factors in Table 1 and Table 2 were selected. Most of the equations and factors have been drawn from AP42 (US EPA 1985 and 1998) and the NERDDC (NERDDC 1998) and SPCC (SPCC 1986) studies in the Hunter Valley. When information from both sources (ie. USA and Australia) are available the two factors have been compared and where possible reconciled. Emission factors for TSP and PM_{10} are provided.

7.1.1 General Comments

Most non-metallic minerals are obtained from surface or open cut mining. There is little data available on which to develop emission factors for the mining and processing of non-metallic minerals in Australia. Emission factors for coal and metallic minerals mines may be adapted and used for non-metallic minerals mines in some cases where operations and materials are similar. USEPA AP-42 Chapter 11 (1955) gives some emission factors for processing of specific non-metallic minerals. These may be adapted for processes carried out in Australia in some cases where the equipment and materials are similar.

Mining of non-metallic minerals may have some of the following activities in common with mining of coal and metallic minerals:

- topsoil removal by scraper;
- bulldozers;
- drilling;
- blasting;
- haul truck traffic on premises;
- light/medium traffic on sealed roads;
- graders;
- wind erosion from stockpiles;
- truck loading;
- truck unloading (rear dump truck);
- primary ore crushing;
- secondary ore crushing;
- tertiary crushing;
- wet grinding;
- dry grinding with air conveying or classifying;
- dry grinding without air conveying or classifying;
- drying;
- emissions from integrated de-dusting systems; and
- miscellaneous handling, transfer and conveying.

7.1.2 Other Processing Steps

Processing of non-metallic minerals may have some of the following activities in common with processing of metallic minerals:

- primary ore crushing;
- secondary ore crushing;
- tertiary crushing;
- wet grinding;
- dry grinding - with air conveying;
- dry grinding without air conveying;
- drying; and
- emissions from integrated dust removing systems.

Emission factors from these activities are drawn from the US EPA (1995) AP-42 document, Section 11.24. Although these are specific for metallic minerals processing, some may be adapted for estimating emissions from non-metallic minerals processing. Emission factors for specific non-metallic minerals processing are given in other sections of Chapter 11 USEPA AP-42 (1995).

When considering emissions, it is useful to note that any ore (except bauxite) with a moisture greater than 4 per cent by weight, either naturally or by virtue of added water, is considered as a "high moisture" ore. If an ore is "high moisture" at the primary crusher, then it will remain so unless it is dried during the process. Also emission factors apply to all operations typically associated with the process. Thus emissions from a primary crushing activity include emissions from the screens, the crusher, the surge bin, the apron feeder and conveyor belt transfer points that are integral with the crusher.

7.2 Appendix B - Emission Estimation Techniques - Water & Land

7.2.1 Tables

Table B1 - Important Elements (Based on atomic weight of carbon 12)

Element	Symbol	Atomic Weight (Rounded)	Element	Symbol [a]	Atomic Weight (Rounded) [b, c]
Aluminium	Al	27	Iron	Fe	56
Antimony	Sb	122	Lead	Pb	207
Arsenic	As	75	Magnesium	Mg	24
Barium	Ba	137	Manganese	Mn	55
Beryllium	Be	9	Mercury	Hg	201
Bismuth	Bi	209	Molybdenum	Mo	96
Boron	B	11	Nickel	Ni	59
Cadmium	Cd	112	Nitrogen	N	14
Calcium	Ca	40	Oxygen	O	16
Carbon	C	12	Phosphorus	P	31
Chlorine	Cl	35	Selenium	Se	79
Chromium	Cr	52	Silicon	Si	28
Cobalt	Co	59	Silver	Ag	108
Copper	Cu	64	Sulfur	S	32
Fluorine	F	19	Tin	Sn	119
Gold	Au	197	Zinc	Zn	65
Hydrogen	H	1	Zirconium	Zr	91

[a] It should be noted that the following are not NPI-listed substances: aluminium, barium, bismuth, calcium, gold, iron, molybdenum, oxygen, silicon, silver and zirconium. Some of the other substances listed are reportable only in certain forms (eg. carbon disulfide). The information has been provided for the purposes of assisting you to calculate the proportion of NPI-listed substances in compounds/minerals found at your facility.

[b] Based on atomic weight of carbon 12.

[c] Atomic weights may be used to calculate the weight of a reportable metal in minerals. For example the chemical formula of chalcopyrite is $CuFeS_2$ and its molecular weight will be 64 + 56 + 2 * 32 = 184. A tonne of mineral will therefore contain about 0.34 (64/184) tonnes of copper.

Table B2 - Concentration of NPI-Listed Substances in Various Materials

Element	Symbol	Basalt	Granite	Coal	Soil	Earth's Crust	Marine Clays	Marine Carbonates	Shale	Limestone	Sandstone	Sediment
Antimony	Sb	0.69	0.2	3.5	1	0.2	1	0.05	1.5	0.3	0.05	1.2
Arsenic	As	1.5	1.5	6.5	6	1.5	13	1	13	1	1	7.7
Beryllium	Be	0.3	5	1	0.3	2.6	2.6		3	<1	<1	2
Boron	B	8	12	70	20	10	230	55	130	20	30	100
Cadmium	Cd	0.13	0.09	0.2	0.35	0.11	0.21	0.23	0.22	0.028	0.05	0.17
Chromium	Cr	200	4	20	70	100	90	11	90	11	35	72
Cobalt	Co	35	1	5.4	8	20	74	7	19	0.1	0.3	14
Copper	Cu	90	13	15	30	50	25	30	39	5.5	30	33
Fluorine	F	510	1400	-	200	950	730	550	800	220	180	640
Lead	Pb	3	24	30	35	14	80	17	23	5.7	10	19
Manganese	Mn	1500	400	41	1000	950	6700	1000	850	620	460	770
Mercury	Hg	0.12	0.08	0.23	0.06	0.05	0.08	0.46	0.18	0.16	0.29	0.19
Nickel	Ni	150	0.5	15	50	80	225	30	68	7	9	52
Selenium	Se	0.05	0.05	2.9	7	0.05	0.17	0.17	0.5	0.03	<0.01	0.42
Zinc	Zn	150	240	31	90	190	150	20	160	20	220	150

Note:

1. All figures in mg/kg (or g/tonne)
2. Extracted and adapted from Bowen, H.J.M. 1979. *Environmental Chemistry of the Elements*, Academic Press and generally checked against Berkman, D.A. 1989 *Field Geologists Manual*, The Australasian Institute of Mining and Metallurgy.
3. The figures listed above are average or median concentrations of the particular element within the rock or material specified.
4. The NPI requires the reporting of emissions of the elements listed in this Table and their compounds. As noted in the body of the manual, it is recognised that trace metal analyses are not routinely undertaken for mining operations. In these situations, it is likely that the trace metal concentrations would be average to below average. Thus, where data on particular elements is not available, the average concentrations listed above for the particular material type should be used. In most cases, it would be expected that a low reliability would be attached to the emission estimate.
5. Further to Note 3, trace metal concentrations will be significantly greater than average where the reportable metal occurs at the site. For example, at a silver, lead and zinc mine, the concentrations of lead, zinc and probably cadmium in waste rocks, tailings and soils will be significantly greater than the average concentrations listed in the above Table. It is expected that where it is necessary to use an assumed trace metal concentration to estimate emissions from a site, the facility will nominate a credible figure that can be justified to the administering authority. The reliability attached to the estimate will generally depend on the data sets available from which the estimate has been calculated.

7.2.2 General Assumptions for Emission Estimation Techniques

The methods and techniques outlined in the handbook for the estimation of emissions from mine sites take the following matters and/or assumptions into account:

1. Routine monitoring is directed to ensuring that environmental performance standards are met, and to meeting license and permit requirements. In general, monitoring will be directed to actual and perceived environmental issues which are significant for the particular mine.
2. Reportable emissions are confined to those materials that are not directed to, and contained by purpose built receiving facilities. All such purpose built facilities are to have the approval of the State or Territory Environmental Authority for the reception of the listed substances. Materials retained in tailings storage facilities, sediment from disturbed areas which is held in ponds or pits and waste rock/spoil dumps are examples of transfers.
3. Emissions of reportable volatile substances used on mines such as chlorinated solvents and volatile organic compounds are assumed to discharge to the atmosphere. Thus in most cases, there should be no reportable emissions to water for these substances.
4. Actual emissions from mines depend on a number of variables including handling and management of relevant substances used and/or produced, physical and chemical properties of the facility's waste and soil materials, local topography and climate, including climatic extremes, slope, vegetation cover, moisture infiltration and related matters. These will vary from facility to facility and it may not be possible in some instances to use generic equations and methodologies, which will have general application across the mining industry. Thus it is recognised that the estimation of emissions requires the application of techniques and methods which are appropriate to the facility. This section of the handbook provides guidance on nominating quantities, which may be used when data from definitive monitoring is not available.
5. It is not the intention of the NPI to require facilities to extend or expand monitoring of trace metals beyond those currently being conducted. In these situations it is considered acceptable to use figures based on the average concentration of trace metals in the various materials identified in Table B2.
6. The heterogeneous distribution of minerals, including trace elements across and within mine sites requires detailed and rigorous sampling to determine the concentrations of these minerals and substances within various areas of the mine operation. Also actual emissions will similarly vary. Emission estimations that directly use monitoring data and take the distribution of substances and their emissions into account will generally give reliable figures. Where assumptions and/or general terms or figures are used inherent errors will be introduced into the determination and the reliability of the estimates is decreased. Where there are several steps and a number of assumptions required to estimate emissions, the reliability of the estimate is significantly reduced.
7. Metal and trace element analyses are usually reported as the total concentration of the particular variable in the sample. In many situations the actual chemical or mineral forms of the element may be generally known from geological/mineralogical information on the site and the chemical form of the substance and/or the minerals likely to be present in the emission should be noted in the reporting. It is recognised that the relative proportions of minerals across the site will not be known with any certainty, particularly in areas outside of the defined economic limits of the deposit.

8. Most metals occur as sulfide or silicate minerals, which typically have solubility coefficients of $<10^{-20}$ g/L. In these circumstances losses of dissolved substances with low solubility would fall within the range of general estimation errors and therefore need not be reported. (For example, total losses of dissolved metals where flows are $> 10^{10}$ litres per annum would be measured in grams while emissions as suspended solids may be in kilogram to tonne quantities, +/- 10%. As the maximum possible dissolved metal emission, say 10 grams, falls well within the total emission, say 100 kg +/- 10 kg, it is not valid to report the emission as 100.01 kg.)
9. The observed suspended solids concentration at a particular point, eg. the lease boundary, will be associated with sediment transport from all upstream areas of the catchment. Erosion models may be used to determine sediment losses but these must be calibrated for the site. General indications on sediment losses from mining areas may be obtained from the difference between suspended solids concentrations of waters entering and leaving the lease. However, this method cannot be used directly unless the mine catchment has been properly calibrated. (The fallacy from use of such data can be shown in sites/areas where there is a net deposition on the site, that is suspended solids concentrations of waters entering the lease are greater than those leaving the lease. There will be emissions associated with the mine and this case illustrates the importance of ensuring that methods and techniques used to estimate emissions are appropriate for the facility.)
10. Where site-specific estimates of erosion are not available, general figures may be used. Erosion of <u>40 tonnes per hectare per annum</u> may occur in areas with dispersive or loose soils with poor vegetation cover and rainfall of about 900 mm per annum. This may be used as a representative figure for "high erosion rate" and should be used for those situations, including direct erosion of tailings type materials. Erosion from well vegetated sites and areas dominated by competent rock may be less than <u>1 tonne per hectare per annum</u> under similar rainfall conditions and this may be regarded as "low erosion rate". Where erosion data are not available, a figure of <u>20 tonnes per hectare per annum</u> may be assumed for the NPI emission reporting. (This figure may be applied to areas disturbed by the mining operation including waste dumps, cleared land and infrastructure.)
11. Facilities may use a more appropriate figure based on local conditions and experience and details should be noted in reporting. The figures to be used for emission estimation are summarised in the following table. It should be noted that these figures generally relate to average rainfall conditions and should be adjusted to reflect actual rainfall over the reporting period. Where rainfall is below average and up to 1.3 times normal average rainfall, a pro-rata adjustment to the erosion rate should be made. Where rainfall is over 1.3 times annual rainfall the pro-rata adjustment should be increased by 40% to fully account for the additional erosion which would be expected from the higher rainfall. The intensity of the rainfall, that is, annual rainfall divided by the number of rainfall days would be a better predictor of erosion rates.

Table B3 - Erosion Rates and Guidelines

Erosion Rate	Guideline
40 tonnes per hectare per annum	Exposed soils, vegetation cover <25%, dispersive material with high silt/clay content including tailings and similar materials
20 tonnes per hectare per annum	All other cases
Mine nominated erosion rate	Where site-specific data is available from monitoring or modelling

Reference: Personal Communication, C. Carroll, Department of Natural Resources, Emerald, Queensland (unpublished Thesis).

Note: Where sediment control structures are installed, the sediment estimates may be derived from filterable residues from dam discharges instead of run-off values.

12. Determination of sulfuric acid (AD) generation from pyrite oxidation is a complex matter and should be determined on a site by site basis. AD generated will be neutralised by naturally occurring alkaline materials and pH and sulfate concentrations cannot be used in isolation to estimate sulfuric acid generation and emissions. If the pH is above 4 at the facility boundary, it should be assumed that sulfuric acid is not present and that the AD generation and neutralisation is a transfer within the system.

13. Where the pH is below 4 at the discharge point from the facility, sulfuric acid emissions must be estimated, preferably from site-specific data. Where this is not available, it should be assumed that sulfuric acid generation is 240 kg per hectare of exposed acid generating material. (Oxidation of material with a 1% pyrite content and no neutralising capacity will result in the generation of about 16 kg sulfuric acid per tonne of acid generating rock. Erosion / exposure of 1 mm of this material equates to 10 cubic metres per hectare which at a density of 1.5 would have a mass of 15 tonnes per hectare, hence 240 (15 * 16) kg per hectare).

Data that is usually available at facilities relates to process control and to specific environmental management. Examples are provided below.

Fugitive Emissions

Dust

Drop in metres for draglines	Generally not available (from on-site estimates)
Moisture content of soil	Available most sites
Mean wind speed in m/s	Available most sites
Area blasted in square metres	Available
Depth of blast holes	Available most mines
Number of wheels for haul road traffic	Available
Silt content of soil	Generally not available
Vehicle gross mass	Available
Mean vehicle speed	Available (estimates)
Average level of reportable substances in overburden	Generally not available
Average level of reportable substances in waste rock	Generally not available
Average level of reportable substances in ore	Available some sites (parameters limited)

Metals

Assay data if available	Limited data only
type tractor, wheeled tractor, scraper, grader, off-highway track)	Available some sites
Water balance information	Generally not available
Reportable substances leaving the site either dissolved in water or as suspended solids	Very limited
Content in process waters	Available some sites
Content in surface water run-off	Available some sites
Leachate from stockpiles, overburden, waste rocks and tailings to surface waters	Available some sites
Emissions to ground-waters	Not available

Emissions to Waters

Concentration of reportable substances	Very limited
Flow rate	Very limited
Quantities of reportable substances used in Workshops and maintenance operations	Generally available
Flows, volumes and water balances (leachate from tailings storage facilities & waste rock dumps)	Very limited
Composition of target and trace metals in all materials handled and in run-off waters	Available some sites
Water quality monitoring data	Limited parameters
Quantities of materials lost in any way from plant (tailings, coarse rejects, spillages)	Available some sites

The following sections set out ways and means of manipulating process and environmental monitoring data to achieve the NPI reporting objectives.

7.2.3 Use of Monitoring and Flow Data

Monitoring and flow data may be used to estimate dissolved and suspended sediment emissions from specific catchments. Where complete data sets are obtained or available, for example, real time stream monitoring of flows and average metal concentrations in water from known sources determined from specific monitoring, mass emission estimates would be relatively reliable. Where there are several catchments contributing to a measured flow, eg. monitoring downstream of a lease where water quality is influenced by natural run-off from undisturbed catchments plus run-off from areas affected by the mining operation, errors will be introduced in allocating a proportion of the flow to the contaminant source or sources. Similarly if complete data is not available, an “average” concentration of the reportable substance calculated from an incomplete data set will probably incorporate errors. Thus the reliability of the estimate will be significantly reduced and should be noted in reporting.

Data Required/Available and Qualifications/Errors

The data that may be available, and relevant comments on that data, is set out in the following table. It is recognised that certain data may be available from monitoring at different locations at the facility.

Table B4 - Data Comments

Variable / Unit	Comment
Water Balance,	The water balance for the facility may describe water management practices under general and extreme rainfall conditions. Run-off over the reporting period may be estimated from site data including water consumption, production losses and rainfall.
Flow and Flow Rate Data Flow - litres, $m^{3,}$ ML; Flow Rate - L/s, cumecs (m^3/s)	May be directly monitored and total flows can be reported for each rainfall event. May be estimated from the cross sectional area of the water course and flow rates. (Inherent errors due to differences in flow rates within watercourses, eg. centre flows faster than the sides and bottom.) May be estimated from Australian Rainfall and Run-off and calibration. (Will be errors when applied to small catchments.)
Rainfall - mm	Actual rainfall will vary significantly over large sites, particularly when storm events provide a high proportion of total rainfall. Site rainfall data should be used where appropriate or alternatively data from the nearest meteorological station should be used.
Rainfall Run-off	Actual emissions will depend on run-off from the site which will depend on matters such as slopes, soil/rock types and properties, vegetation cover, soil permeability and moisture content, total rainfall, rainfall intensity, water use. Significant variations will occur between sites and from year to year at the same site. Where flow data is not available, guidance on run-off as a proportion of total rainfall may be obtained from personnel within regional offices of State Government Primary Industry and/or water resources departments.
Water Quality Data - mg/L or ppm	The data will depend on the samples taken, the variables analysed and analytical methods. Electrical conductivity, pH, suspended solids and other variables are commonly monitored by automatic samplers and readings continually recorded. Samples containing suspended solids may be filtered to determine suspended solids and analysis of the filtrate will give dissolved metal/element concentration. Analysis of the total sample that involves an acid digest step will give the total metal/element concentration in the sample - dissolved plus suspended solid material. As most metal species are insoluble a relatively high metal concentration would suggest an acid digest. If data on concentrations of total metals is available, it may not be necessary to estimate these from other information sources
Suspended Solids - mg/L or ppm	Obtained from gravimetric techniques from sampling or direct monitoring. It gives the total sediment loadings in waters only. That usually does not include trace element concentrations.
Survey Information - hectares (ha)	Mine surveys will give accurate data on all areas of interest, eg. all sections of the mine, stockpiles, infrastructure, tailings and environmental dams, cleared and undisturbed areas. While catchment areas of each feature can be measured accurately, their run-off/infiltration and sediment transport characteristics will vary. Without calibration for the site, any emission estimates based on sub-catchment areas will introduce errors. (See comment on run-off).
Trace element data on solids, eg. waste rock, concentrate, tailings - mg/kg	Trace metal / element concentration may be routinely available from process monitoring, eg. of concentrates and tailings. Trace metals will be present in waste rocks and especially sub-economic ore and data may be available from geological modelling of the deposit. If representative data is not available for all waste rock types, estimates from incomplete data will introduce errors.
Relevant Background Data - mg/L or mg/kg	Background data may be available from monitoring and environmental studies, eg. water quality data, trace element concentration in soils, suspended solids loadings.

Emission Estimation

In summary, where reliable flow and water chemistry data is available, losses of reportable substances and trace elements can be readily determined, particularly if the water analyses involved determination of total concentration of the reportable substance and reporting of all relevant trace elements. The reportable emissions should be calculated from the product of the flows and the trace element concentrations for those flows. Care should be taken to ensure that appropriate units are being used and the emissions should be reported as kilograms per annum. As noted above the chemical substances and/or minerals known or considered likely to be present should be noted in the reporting.

Specific points that should be noted are outlined below:

- Flow rate, water quality, rainfall run-off and suspended solids data should be appropriately integrated to obtain useable figures on flows and trace metal / element concentrations. It is recognised that site-specific factors will influence manipulation of available data.
- Corrections for natural occurrence of the trace elements should be made where appropriate. For example where the flows include natural run-off from mineralised areas outside of the mine area. The difference between the trace element concentration of waters leaving the lease or mine catchment compared to waters entering the lease and/or relevant catchment can be attributed to mine processing activities within the lease and/or catchment. Where data to make corrections is not available, this fact should be noted in the reporting.

Mass balance calculations can be used to estimate emissions if suspended solids data is only available from monitoring, and data is available on metal concentrations in materials. (See following section.)

7.2.4 Use of Mass Balance Calculations

In summary, mass balance calculations depend on the conservation of matter and may be used to estimate unknown data and variables. If sufficient data is present they may be used to check the general validity of estimated and/or assumed data.

In their simplest form, mass balances are straightforward additions. For example, on a dry mass basis, the mass of product will be the total quantity mined less the quantities of waste, (eg. waste rock and tailings), produced. Similarly a catchment area will be equal to the sum of the areas of its particular sub-catchments. Water losses at a plant will be the total water consumed less the water entrained in the waste and product streams, water recycled to the plant and evaporation. In summary, the total (T) will comprise the sum of its parts, (A, B, C, D). That is:

$$T = A + B + C + D$$

If the proportions or concentrations of a variable within a system are known, this can be linked with the arithmetic sum. For example if the concentration or proportion in the Total is t and in the parts a, b, c, d, then:

$$T * t = A * a + B * b + C * c + D * d$$

As a practical example if a run of mine ore has a grade of t% metal and the grades of concentrate and tailings are a% and b% respectively and the tonnes of ore treated are (T), the tonnes of concentrate (A) and the tonnes of waste (B), then:

$$T * t = A * a + B * b.$$

These equations may be used to estimate figures and/or check the validity of measured or assumed data. Thus if one variable is not known, eg. metal grade or concentration in tailings (b), it may be estimated, - ($b = (T * t - A * a)/B$), and if all variables are known they can be generally checked. (Some differences should be expected from inherent errors.)

If there are known losses from the system, eg. $T >> A + B$, the losses which may be leaks from pipes or material washed from the concentrator during cleaning and which may enter the environment may be aggregated as "C" while the average concentration of this material would be "c". This would give the following expression, which may be useful in the estimation of emissions:

$$T * t = A * a + B * b + C * c$$

Also trace element concentrations in emissions may be estimated provided the quantities of all of the various materials present and the concentration of the particular trace element in those materials are known. For example estimates in process water flows may be made from mass balance equations if the volumes of water used and/or lost in various elements of the process and the dissolved and/or suspended solid concentrations for those waters are known. If certain data is not available, the unknown variables may be expressed in terms of other unknowns. However, this may not be very useful and assumed or estimated values may need to be substituted in the equation or equations to allow an estimation to be made. This would introduce potential for significant errors.

Catchment area data may be manipulated to generate emissions estimates and/or figures, which could be used further to provide estimates. For example if flows from a catchment are known, then, as a first pass, the discharge flow from contaminated areas could be estimated from the proportion of those areas in the total catchment. This takes no account of the factors, which will influence sediment transport and ideally, as noted above, estimations should be calibrated for the particular facility. However if the total catchment area is large and the areas from which contaminated waters originate are small in comparison with the catchment area, <5%, the proportion may be used to estimate flow and the reliability of the estimate calculated appropriately qualified.

7.2.5 Use of Site-Specific Water Emission Factors

Water emission factors may be derived for each facility. Once obtained they would be useful for future emission estimation. For example, if an erosion rate can be estimated from characteristics of the site to give an erosion figure for the reporting period, which would normally be expressed as tonnes per hectare per annum, this figure can be used in conjunction with estimates of the metal concentration in the materials lost from the site, and the areas involved, to determine a mass emission.

Provided information on the areas and/or quantities of the relevant materials and trace element concentration data are available, mass balance calculations could be used to obtain a concentration for the particular element. Gaps in the data will introduce errors and assumptions would be required on the trace element concentration of the materials. For example, a waste rock dump may contain 90% waste rock and 10% sub-economic ore. If only the trace element concentration of the sub economic ore was known, it would be incorrect to assume that same concentration applied to the waste rock and any emission estimates would be significantly over stated and reliability would be low. Thus if emission factors are developed all gaps in the data record should be identified and appropriately covered.

With infrastructure areas such as the plant and tailings storage facility which do not change significantly over time, process water volumes and properties and data on the quantities and properties of the material treated may be used to define substance movements which in turn may be related to emissions. These may be developed into emission factors which when used with variables such as rainfall and flows off the lease could be used to estimate emissions.