BEST PRACTICE ENVIRONMENTAL MANAGEMENT IN MINING

Dust Control

Environment Australia
Department of the Environment

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The series illustration of the Koalas by Christer Eriksson, commissioned by BHP Transport 1998. Reproduced courtesy of BHP Transport.

Cover photo: BHP Iron Ore, Port Hedland, Western Australia. High volume samplers..
Photo: BHP Iron Ore.

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FOREWORD

Environment protection is a significant priority for our society. A major role for government is setting environment standards and ensuring that individuals and organisations meet them. Increasingly, however, government, industry and community organisations are working as partners in protecting our environment for present and future generations.

Representatives of the minerals industry in Australia and Environment Australia, (the environment arm of the Federal Government), are working together to collect and present information on a variety of topics that illustrate and explain best practice environmental management in Australia's minerals industry. This publication is one of a series of booklets aimed at assisting all sectors of the minerals industry—minerals, coal, oil and gas—to protect the environment and to reduce the impacts of minerals production by following the principles of ecologically sustainable development.

These booklets include examples of current best practice in environmental management in mining from some of the recognised leaders in the Australian industry. They are practical, cost-effective approaches to environment protection that exceed the requirements set by regulation.

Australia's better-performing minerals companies have achieved environmental protection of world standard for effectiveness and efficiency—a standard we want to encourage throughout the industry in Australia and internationally.

These best practice booklets integrate environmental issues and community concerns through all phases of mineral production from exploration through construction, operation and eventual closure. The concept of best practice is simply the best way of doing things for a given site.

The case studies included in these booklets demonstrate how best practice can be applied in diverse environments across Australia, while allowing flexibility for specific sites. Each booklet addresses key issues by presenting:

- basic principles, guidance and advice;
- case studies from leading Australian companies; and
- useful references and checklists.

Mine managers and environmental officers are encouraged to take up the challenge to continually improve their performance in achieving environment protection and resource management and to apply the principles outlined in these booklets to their mining operations.

Stewart Needham
Co-Chair, Steering Committee
Assistant Secretary
Supervising Scientist Group
Environment Australia

Denis Brooks
Co-Chair, Steering Committee

EXECUTIVE SUMMARY

Dust is an inevitable problem for almost all forms of mining.

It is one of the most visible, invasive and potentially irritating impacts, and it's visibility often raises concerns which are not necessarily in direct proportion to its impact on human health and the environment. However, many dusts do contain metals which are potentially hazardous, and certain types of dust particles are known to cause particular diseases. It has the potential to severely effect flora and fauna near the mine and to impact on the health of mine workers. Clearly dust requires special attention.

Dust results from blasting, handling, processing or transporting soil and rock or can arise from bare or poorly vegetated areas in combination with air movements. The level of dust generated, its behaviour (travel distance), and types of health and environmental risks depend on many factors including mine type, local climate, topography, working methods and types of equipment used, the mineralogy and metallurgical characteristics of some ores, and the inherent character and/or landuse of the area around the mine.

The control of dust must be a fundamental part of any environmental management plan because of the increasing public awareness of human health issues and expectations of environmental performance, and the duty of care required of mine operators by government and the community.

The challenge for mining companies is to adopt a dust management system which recognises and responds to the issue of dust emissions at all stages of mining from mine planning and operation through to mine closure. This includes systematically identifying sources, predicting dust levels, evaluating potential effects on human health and the environment, and incorporating prediction and control measures. Implementing an effective community consultation process is essential.

Such a 'whole of mine life' dust management system has benefits for the mining company and the wider community. It can result in cost savings, increased profits, and improved government and community relations, as well as easier access to resources and financial support in the future.

Case studies in this booklet have been chosen to demonstrate best management principles in action. Best practice in dust management uses new techniques in monitoring and control, and encourages a pro-active, educative, community consultation approach to dust issues. It uses predictive technology, such as dust modelling coupled with robust climatic and real time data, to identify and mitigate likely dust events.

Dust does not need to be an occupational or environmental hazard as it is within the operator's scope to manage. The success of best practice dust management depends on a joint commitment by management and workers to adopt dust control techniques which recognise and respond to the potential health and environmental impacts, and are sympathetic to the concerns of neighbouring communities.

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INTRODUCTION

1.1 WHAT IS MINE DUST AND WHY DOES IT NEED TO BE CONTROLLED?

Dust is a generic term used to describe fine particles that are suspended in the atmosphere. The term is non-specific with respect to the size, shape and chemical make-up of the particles. Particles as small as a few nanometres and as large as 100 microns (µm) have been measured in the atmosphere. Dust is formed when fine particles become entrained in the atmosphere by the turbulent action of wind, by the mechanical disturbance of fine materials, or through the release of particulate-rich gaseous emissions. The concentration of particles in the atmosphere can range from a few micrograms to hundreds of micrograms per cubic metre ($\mu g/m^3$) in highly polluted areas.

Dust associated with mining activity usually occurs as a result of the disturbance of fine particles derived from soil or rock. Dust formation is initiated by the disturbance of particles through mechanical action eg blasting, handling, transporting, in combination with air movement. Where particles are small and light, with a high surface area relative to their mass, the upward forces exerted on particles by air movement may exceed downward gravitational forces, leading to the formation of dust.

Depending on factors such as climate, geology and the method of mining, the potential exists for greatly increased dust levels in the environment surrounding a mine. Modern methods of open cut mining often involve the mining, transport and handling of huge tonnages of material, increasing the potential for dust to be produced. The consequences may include visible plumes and haze, the staining and soiling of surfaces, aesthetic or chemical contamination of water bodies or vegetation and, effects on personal comfort, amenity and health.

Photo: Westralian Sands Ltd

Westralian Sands Limited, Capel, Western Australia. Replacement of the manual handling of mineral by vacuuming.

Mine dust may be qualitatively quite different to other types of dust. In an urban environment, dust commonly includes sources from industry, transport, land clearing and wood smoke. Mine dust is typically less complex in its make-up, consisting mainly of particles from exposed soil and rock.

Mine dust can result in a serious nuisance and loss of amenity for populations living in the vicinity of a mine. This may be exacerbated by certain types of dust, such as coal and iron ore dust, that are highly visual and may result in a prominent and unsightly coating over surfaces. History has recorded numerous examples of dust problems created by mining operations, particularly those close to historical mining centres in arid climates, where, until recent times, dust control was rarely considered. Notable examples include Broken Hill, Kalgoorlie-Boulder and Port Hedland, where dust problems have been a major issue in the community, and where action in recent times has successfully addressed the problems (see Case Studies 1 and 2).

Fortunately dust rarely presents a serious threat to the wider environment. Dust concentrations, and hence deposition rates and potential impacts, tend to decrease rapidly away from the source. In the majority of situations dust produced by mining operations is chemically inert, although exceptions may occur where dust particles contain phytotoxic substances such as cement dusts or fluorides. Damage to vegetation and agriculture is possible through mechanisms such as the blocking of leaf stomata (and the inhibition of gas exchange), or reduced photosynthesis due to smothered surfaces (or in extreme cases lower ambient light levels). While such effects on vegetation are likely to be localised and reversible, they can contribute to negative public perceptions of the mining operation's environmental performance.

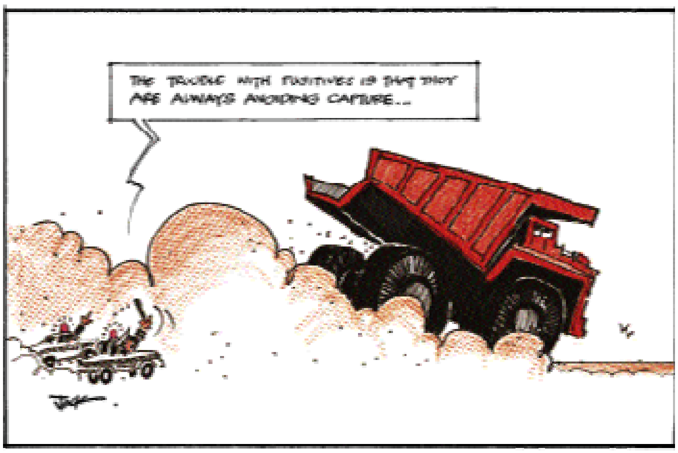
Nevertheless, there does exist the potential for harmful and more persistent contamination of the wider environment from certain types of material that may be exposed by mining. Dust derived from ore types containing asbestos, radioactive materials or heavy metals, for example, are in this category.

This booklet discusses principles and provides examples of best practice environmental management of dust in the Australian mining industry. While it focuses primarily on the mining industry, the principles outlined are also applicable to the quarrying industry, where dust control is particularly important given quarries are often located in heavily populated areas.

1.2 THE TERMINOLOGY OF DUST

Common terminology used to describe different classes of dust includes:

- **Nuisance dust**
  Nuisance dust is a term generally used to describe dust which reduces environmental amenity without necessarily resulting in material environmental harm. Nuisance dust comprises particles with diameters nominally from about 1 mm up to 50 µm. This generally equates with 'total suspended particulates' (TSP). The TSP range of dust particles is broad, and may be produced from sources such as industrial and mining processes, agricultural practices and, from wind erosion of the natural environment. Impacts of mine dust on near neighbours is most often due to nuisance dust.
- **Fugitive dust**
  Fugitive dust refers to dust derived from a mixture or not easily defined sources. Examples of fugitive dust include dust generated from vehicular traffic on unpaved roads, materials transport and handling, and unvegetated soils and surfaces. Mine dust commonly is derived from such non-point sources.



- **Inhalable dust**
  The inhalable fraction is that mass fraction of total airborne particles which is inhaled through the nose and mouth. These particles are usually less than 10 mm in diameter and approximately 80% of these particles are between 2.5 and 10 mm in diameter. When inhaled these particles are deposited in the trachea and bronchia section of the lung.

- **Respirable dust**
  The respirable fraction is that mass fraction of inhaled particles which penetrates to the lung's unciliated airways. Respirable dust represents those particles with diameters less than 2.5 mm that lodge in the alveolar region of the human lung.

The above two categories may have health implications, particularly for mine workers who may experience prolonged exposure to these types of dust (see Section 1.4). There is some divergence of opinion of the precise size fraction that is allocated against 'inhalable' and 'respirable' particle fractions. The International Organisation for Standardisation (ISO) criteria (ISO, 1995) is widely adopted:

'inhalable fraction'—the mass fraction of total airborne particles which is inhaled through the nose and mouth.

'respirable fraction'—the mass fraction of inhaled particles which penetrates to the unciliated airways.

Figure 1 provides an indication of the various particle size ranges that may be allocated to 'inhalable' and 'respiratory' categories.

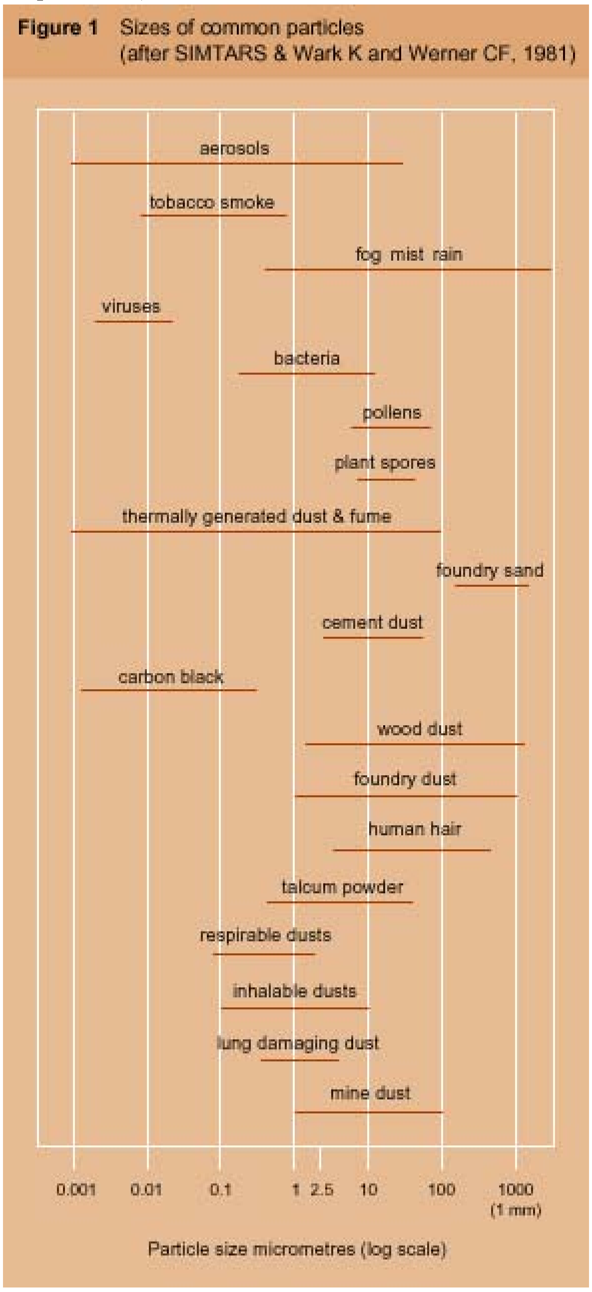
In air quality monitoring, various size fractions of dust are used to categorise dust, including:

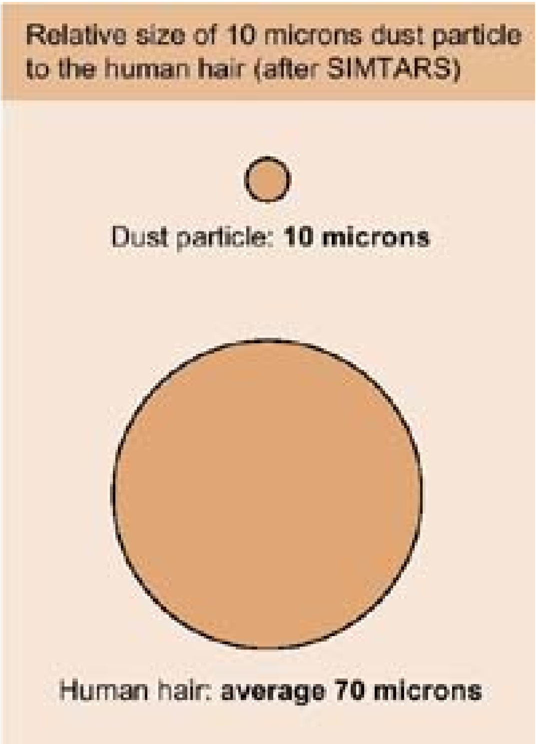
- **Total suspended particulates (TSP)**
  The nominal size of this fraction has particles with a diameter up to 50 microns. The monitoring program for TSP follows AS 2724.3—1987. This enables a determination of dust concentrations in units of mass (usually micrograms) per cubic metre.
- **Particulate matter less than 10 microns in size (PM_{10}) or 2.5 microns ($PM_{2.5}$)**
  This dust fraction includes particles with a diameter up to 10 microns or 2.5 microns, respectively. Measurements are also expressed in units of mass (usually micrograms) per cubic metre. The monitoring program for PM_{10} follows AS 3580.9.6—1990. PM_{10}. There is no Australian Standard for measuring $PM_{2.5}$, and this unit is not commonly applied in measuring ambient dust associated with mining.
- **Deposited matter**
  This term describes any particulate matter that falls out from suspension in the

atmosphere. The monitoring program follows AS 3580.10.1—1991. This measurement is usually expressed in units of mass per area per time. It is the least commonly used of the Australian Standards in determining dust concentrations. There is no direct method of conversion between deposited matter and TSP or PM_{10}.

The size ranges of some common forms of particles are indicated in Figure 1. Mine dust typically occupies the 1 to 100 µm size range.

Figure 1 Sizes of common particles (after SIMTARS & Wark K and Werner CF, 1981)





Relative size of 10 microns dust particle to the human hair (after SIMTARS)

Photo: Department of Minerals and Energy, WA

Kalgoorlie, Western Australia. Dust blowing from old tailings dams, at the southern end of the Golden Mile.

1.3 THE ORIGIN OF DUST IN MINING

By their very nature, mining activities are likely to produce dust. In open cut and strip mining the process of accessing the ore body involves the removal of the natural land surface. This stable soil and vegetative layer normally provides an important seal against dust generation. Open cut mining also creates new, unvegetated surfaces in the form of pits, overburden dumps and tailings disposal areas. A number of the historical mining centres in Australia, such as Kalgoorlie-Boulder and Broken Hill, have experienced severe dust problems in the past due primarily to the presence of bare, disturbed land and unvegetated tailings dumps.

A wide range of mining activities can generate dust. Dust sources may be localised, from blasting, truck loading, and ore crushing and conveyor transfer within the process plant. These sources are usually visible and readily identifiable. They are most often a direct result of mining and processing activities involving some form of ground disturbance or mechanical handling of the mined materials. Other sources of dust around the mine site are more diffuse, typically arising from relatively large areas such as waste rock dumps, pits, tailings impoundments and miscellaneous areas of disturbed and bare ground in and around the site. Linear dust sources are another category, with haul roads being a common example. All of the above are categorised as 'fugitive' dust emissions sources, in contrast to point source emissions from a stationary vent stack. Mining activities produce predominantly fugitive dust.

A typical open cut coal mine of 3 million tonnes per annum produces about 10 tonnes of dust per day (NSWSPCC 1983). Large open cut mines in arid areas can be expected to produce significantly greater amounts. This can be compared to typical dust (stack) emissions from a large coal-fired power station of 5 tonnes per day and 1 tonne per day for an aluminium smelter.

1.4 DUST AS A HEALTH ISSUE FOR MINE WORKERS

Health risks posed by inhaled dust particles are influenced by both the penetration and deposition of particles in the various regions of the respiratory tract and the biological responses to these deposited materials. The smaller the particles, the further they penetrate the respiratory tract. The largest particles are deposited predominantly in the nasal passages and throat. Much smaller particles, nominally less than 2.5 µm ($PM_{2.5}$), reach the deepest portion of the lungs.

Many epidemiological studies have linked levels of ambient particulate matter with a variety of human health problems, including mortality, increased hospital admissions and changes to the respiratory system. These effects have been observed through both short term (usually days) and long term (usually years) exposure.

Certain types of dust particles are known to cause particular diseases. Silica dust has been a widespread problem in the past for workers in mining and quarrying industries. Silica dust refers to silicon and its compounds that are very common in the rocks forming the earth's crust. Silica is non-toxic and safe except where specific crystalline forms of silica occur in dust. Long term inhalation of silica dust may lead to the formation of scar tissue in the lungs and can result in 'silicosis', a serious and life threatening lung disease.

Many dusts containing metals are potentially hazardous. Toxic metals include arsenic, antimony, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, selenium, vanadium, zinc and their compounds. Dusts containing mercury, arsenic or cadmium are particularly hazardous. Lead has a much lower toxicity but is a common constituent of dust in certain locations (see Case Study 1).

Asbestos dust, a recognised human carcinogen, is a product of the mining and processing of asbestiform minerals. Four minerals types are well known, namely chrysotile, amosite, crocidolite and anthophyllite. Serpentine bands may host asbestos minerals and are common geologic intrusions in mines and quarries. Asbestos is chemically inert, yet can induce a severe reaction within the lungs. The term 'asbestosis' is used to indicate the (non-malignant) scarring of the upper lobes of the human lungs which can result in reduced lung function. 'Mesothelioma' refers to cancer of the lining of the human lungs caused by exposure to asbestos.

Photo: Newcrest Mining Ltd

Newcrest Mining Ltd, Cadia, near Orange, New South Wales. Rural setting of the planned Cadia mine.

1.5 BEST PRACTICE PRINCIPLES IN PLANNING, IDENTIFYING, AND CONTROLLING DUST

'Best Practice' can be defined as the most practical and effective methodology that is currently in use or otherwise available. Best practice dust management can be achieved by appropriate planning in the case of new or expanding mining operations, and by identifying and controlling dust sources during the active phases of all mining operations.

Planning

Best practice planning involves:

- a systematic identification of the potential sources of dust;
- prediction of the dust levels likely to occur near the mine site;
- evaluating the potential for dust particles to effect human health and the environment; and
- incorporating dust predictions and control measures into mine planning and design.

Identifying

Best practice identification of sources involves:

- **Observation:** Existing dust sources, particularly point sources, can be readily identified by visual observation. In many cases this is all that is required to confirm the existence of problems that require attention. Around a process plant, visual inspection by an experienced operator is often the most effective means to identify and rank dust sources.
- **Dust emission rates:** The identification of diffuse dust sources, and the task of assessing the relative contributions of all sources to total dust levels, is more problematic. Nevertheless, techniques exist that produce quantitative estimates of dust emission rates from different classes of mining activity and land surface types eg blasting, haul road traffic, waste dump surfaces etc. The attraction of this approach lies in the ability to objectively rank the various dust sources, and, using that information, apply control efforts in a systematic manner.
- **Models:** Models that predict ambient dust concentrations or deposition rates are commonly used in mine planning. The models use source dust emission rates in conjunction with meteorological data to produce 'contour' maps of dust concentrations.

Controlling

Best practice principles applied to controlling dust involve:

- workforce awareness;
- integrating dust control provisions into operations planning e.g. construction, topsoil stripping, blasting, rehabilitation programs;
- integrating dust control provisions into work practices;
- monitoring and feedback mechanisms;
- using observational and quantitative assessments to guide control efforts;
- awareness of current methods and technology.

Useful references to establish best practice approaches in management and control of dust emissions are provided by Robertson and Wei (1998) and the Scottish Office Development Department (1998).

1.6 LINKAGE WITH OTHER BOOKLETS

Planning and prediction, source assessment and control and the concerns of local communities are key issues which must be thoroughly addressed if dust on mine sites is to be properly managed. Many of the principles that apply to other aspects of best practice environmental management in mining are also relevant to managing dust. Other booklets in this series include:

- Environmental Impact Assessment
- Mine Planning and Environment Protection
- Community Consultation and Involvement
- Environmental Monitoring and Performance
- Management of Atmospheric Emissions (in preparation).

Table 1 A dozen ways to deal with dust

Planning and Prevention

- study the climate, wind conditions and related factors for the site in detail (e.g. what is the best season for certain operations);
- identify potential dust sources systematically and incorporate details and potential control measures in planning;
- predict the dust levels likely to occur near the mine site; and
- evaluate the potential for dust particles to affect human health and the environment.

Identifying the problem

- observe existing dust sources, and particularly point sources, visually;
- estimate emission rates from different classes of mining activity and land surface types e.g. blasting, haul road traffic, waste dump surfaces etc; and
- model source dust emission rates and meteorological data to map concentrations.

Controlling Dust

- plan operations e.g. construction, topsoil stripping, blasting, rehabilitation programs, to integrate dust control;
- plan work practices to integrate remedial measures (e.g. chemical additives in dust suppression, dust collection);
- establish waste dump final surfaces early;
- monitor dust and feedback mechanisms provided; and
- continuing assessments using observational and quantitative data to improve control efforts.

Taking the long view

A long term view of dust control has proven consistently cost effective. Mine planning has a particularly important role to play in dust control. Applying controls after problems arise is often difficult, impractical or costly. Once established in the 'wrong' place in terms of prevailing winds and neighbours, a dust problem may be very difficult to rectify and be an irritating factor with surrounding residents.

Photo: Pasminco Broken Hill Mine Pty Ltd

Pasminco Broken Hill Mine, New South Wales. Well maintained and serviced roads are an effective method in reducing dust generation.

1.7 THE IMPORTANCE OF MINE PLANNING

Mine planning has a particularly important role to play in dust control. The application of dust controls after problems arise is often difficult, impractical or costly. The location of items such as process plants or haul roads may be flexible at the planning stage. Once established in the 'wrong' place in terms of prevailing winds and neighbours, a dust problem may be very difficult to rectify.

A thorough examination of wind and climate, geology and other factors that will effect dust generation and dispersion can be undertaken at the planning stage. Models can be constructed and run that will provide predictive contours of dust levels around the mine. To the degree that it is possible, modifications to the mine layout at the planning stage will avoid future problems.

1.8 WHAT ARE THE DUST CHARACTERISTICS FOR DIFFERENT MINING OPERATIONS?

The amount of dust produced by different mines can vary greatly. At underground mines and loadout facilities, stockpiles are usually the main source of dust. Open pit and strip mines include additional dust sources such as blasting, loading, haulage and clearing. Because of these differences, dust emission rates must be determined by the sum of the emission rates for various mining activities rather than on the basis of mine production rates.

The particular characteristics of dust are variable, depending largely on the mineralogy of the ore body and associated rocks and soils. In open cut and strip mining, soil, overburden and waste rock removal and transport may be the major contributor to dust emissions (Table 2), and the characteristics of dust will reflect this. The characteristics of particle size, shape, chemical composition and concentration may be an important consideration when developing management and control strategies.

The range of characteristics is well illustrated by the examples of coal, iron ore and talc. Differences in their properties include:

- colour—black and brown for coal, many shades of red and brown for iron ore and off-white for talc; and
- considerable variation in physical properties, particularly hardness (iron ore hard and talc soft), specific gravity (iron ore high and talc low), and shape and cleavage (i.e. the way the minerals split along internal planes).

These latter attributes affect both the amount of dust that is generated from the mine site, and the distance that it is transported. The colour of dust can be an important factor influencing its nuisance impact on the community.

Dust particle size is generally presumed to be an important factor influencing its dispersion and transport in the atmosphere, the formation of haze, and its potential effects on human health. A survey of fugitive dust from coal mines in the United States found that emitted dust had a median size of 24 µm, and that the particle size distribution of dust produced from a number of different mining activities was very consistent. (New South Wales State Pollution Control Commission [NSWSPCC], 1983) Also from the NSWSPCC document,—Figure 3, page 10—provides composite size/distribution curves for major mine emission sources. The numbers are based on typical size distributions up to about 65 mm in diameter. It also shows as a percentage of the total mass, the particle sizes less than 10 mm (the PM_{10} component) comprised about 11—23% of emissions from a variety of activites. These are based on measurements taken up to 100 m from the source (NSW SPCC 1983, page 8).

1.9 LEGISLATION AND REGULATORY STANDARDS

Australia has strong environmental legislation covering the mining industry. This legislation requires Australia's environmental protection authorities to assess the impact of mining proposals on the environment. Dust control issues can therefore be assessed at the project planning stage. Ongoing licence and permit requirements may subsequently be placed on the project that relate to dust control during the mine operational phase. Commonwealth and State occupational health legislation also applies to dust management in the mining industry.

Environmental Legislation

Legislation is usually related to the impact of dust emissions from any part of the mine's activities on any part or portion of the surrounding environment, including natural ecosystems. It also considers the loss of personal amenity of any nearby communities from nuisance dust emissions.

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

Despite the absence of fixed regulatory standards relating to dust emissions, it is common practice for companies using best environmental practices to use internal targets for dust control in order to achieve certain goals (e.g. Alcoa Australia Ltd utilises a 24-hour target value of 120 $\mu g/m^3$ TSP at its Pinjarra alumina refinery, see Case Study 6).

Table 2 Dust emissions from typical coal strip-mining operations (from NSW State Pollution Control Commission, 1983)		
Sources	**Truck and shovel operation % of total dust emission**	**Dragline operation % of total dust emission**
Dragline	n.a	27
Haul roads		
Overburden	35	-
Coal	7	42
Loading		
Overburden	12	-
Coal	4	5
Drilling		
(Overburden and coal)	1	2
Blasting		
(Overburden and coal)	5	1
Truck dumping	7	5
Topsoil removal	18	10
Exposed areas	6	7
Haul-road repairs	5	1
Total	**100**	**100**

These may be more stringent than the regulatory guideline in order to trigger remedial action well before dust emissions approach levels where they may be considered unacceptable to the public or regulatory authorities.

In February 1998, the National Environment Protection Council established a National Environment Protection Measure relating to the National Pollutant Inventory (NPI).

Local communities will now have access to comprehensive information on the pollutants released into the environment by industry including the mining industry in their area. From 1 July 1998, larger Australian industrial facilities will be required to estimate and report annually on their emissions of the chemicals listed on the NPI including dust as a fugitive emission.

An Emission Estimation Technique Manual for Mining is being developed by the NSW Environment Protection Authority, with funding from Environment Australia. This manual has standard estimation techniques for emissions to air, water and land which are reportable under the NPI. The air emissions section includes dust and metal species. The latest details on the NPI and its relationship to mining are on the NEPC homepage (www.nepc.gov.au).

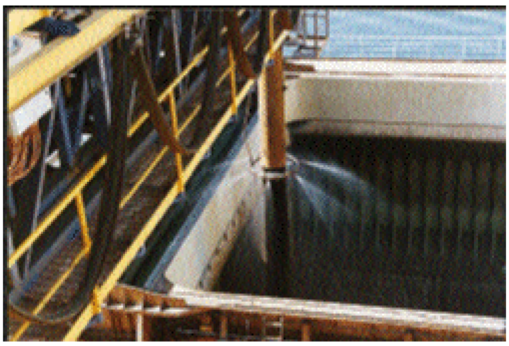


Photo: Esperance Port Authority

Esperance Port Western Australia. An ore discharge chute with ring sprays provides a blanket of water that effectively controls dust carried upward by the air displaced from the hold.

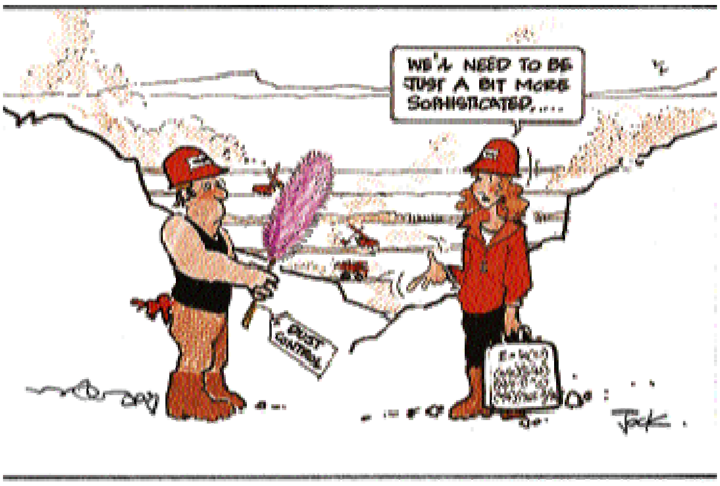
Occupational Health Legislation

This legislation addresses the physical health and welfare of mine workers. It normally imposes a 'duty of care' upon the industry for all personnel under its management. The relevant standards and codes of practice provide information regarding acceptable respirable dust levels for dangerous materials.

General guidelines for maximum ambient dust concentrations have been adopted by the National Health and Medical Research Council (NHMRC) and the Victorian Environmental Protection Authority (EPA) (see Table 3). There has been a recent trend towards a greater reliance on PM_{10} standards, reflecting the importance of human health issues.

Table 3 Examples of guidelines used by regulatory bodies in considering ambient dust concentrations

TSP	PM_{10}	$PM_{2.5}$	Deposition	Averaging Period	Source
90 µg/m^3				Annual	NHMRC (1986)
40 µg/m^3				Annual	WHO (1987)
260 µg/m^3				Annual	USEPA (superseded by PM_{10} standard)
	50 µg/m^3	15 µg/m^3		Annual	USEPA (1997)
	150 µg/m^3	65 µmg/m^3		24-hour	USEPA (1997)
	120 µg/m^3			24-hour	Victorian EPA (proposed)
	40 µg/m^3			Annual	Victorian EPA
	30 µg/m^3	To be developed		(Long term) annual reporting goal	NSW EPA(1998)
	50 µg/m^3	To be developed		24-hour	NSW EPA(1998)
			4g/m^2/month		NSW EPA



2 MODELLING AND PREDICTION

2.1 THE IMPORTANCE OF MODELS

Dust control planning tools for mine sites have in the past been quite limited, falling well short of what would normally be available in predicting impacts from other factors such as gaseous emissions or noise. In part this was due to complexities in the prediction and measurement of dust emissions and the array of potential sources, most of which are diffuse and highly variable. In addition, dust dispersion models needed to account for gravitational settling and other deposition processes as well as all the normal factors associated with gaseous dispersion. Despite these hurdles, dust dispersion modelling methods have developed significantly in the past decade, to the extent that dust modelling is now a commonly used tool at the mine planning stage.

Predictive models exist that allow the inclusion of both point and non-point dust sources, and algorithms are available that estimate dust contributions from a variety of sources. By combining these sources and local meteorological data, the models build a picture of dust deposition rates over the area surrounding the mine. The major contributing sources can be highlighted at the planning stage, allowing various mine configurations and control options to be tested and incorporated.

2.2 MODELLING AND THE USE OF MODELS

Dispersion modelling of dust is a process where a physical system is represented by a series of mathematical procedures in a computer program. For the outputs to be useful, the model must represent as realistically as possible the physical processes that are taking place. These include the generation of the dust, the transport of the dust by the wind, the deposition of dust from the plume by gravitational settling, other deposition processes, and the trapping of dust within an open pit. Computer modelling of the transport and diffusion of particulate matter can be achieved with standard Gaussian dispersion models that have been appropriately modified to recognise plume depletion through particulate fall-out.

Climatic factors such as rainfall, temperature and winds can have a very large influence on the levels of dust produced at a particular mine. As a result similar mines in different climatic regimes may generate very different levels of dust. By taking into account climatic factors such as wind speed and direction and the moisture content of dust source materials, models are able to accommodate these important locational factors.

The results of a number of validation studies indicate that modelling studies using properly constructed emissions inventories and an appropriate model and meteorological data will provide reasonably accurate predictions of annual average deposition rates. For example analysis of data presented in two studies (CSR, 1984; Holmes and Richmond, 1983) assessing the performance of the DUSTGLC model shows that, using an emissions inventory for a year of operation and meteorological data collected off-site, 70% of predictions made for 16 dust deposition gauges fell within the measured value of annual average +/- 40%.

The second study, which was a blind test of the DUSTGLC model, was made using meteorological and emissions data provided by the NSW SPCC (now EPA). This study showed that 80% of predictions fell within +/- 40% of the annual average measurements available from 10 deposition gauge sites. Other studies, for example those by the SPCC (1983), suggest that other models give similar accuracy for estimates of long-term deposition rates.

Clearly modelling can make a useful contribution to air quality impact assessments. However the science could benefit from further work in estimating short-term dust concentration and deposition rates under 'worst-case' conditions, and in developing amenity-based air quality goals for use in assessing the significance of exposures to short-term episodic dust.

2.3 EMISSION FACTORS AND EMISSION INVENTORIES

Emissions inventories represent a collection of the various separate emission factors that together account for all of the significant dust emission from a mine. The inventory is usually developed by analysing the mine plan to establish potential dust sources, and by estimating the level of dust-producing activity associated with each source. Emission factors relate dust generation to some quantifiable activity or aspect of the mine, e.g. vehicle size and distance travelled on haul roads.

Typically the information required to produce an emissions inventory will include:

- the length of haul routes, vehicle-kilometres travelled and vehicle types;
- the quantities of material to be mined;
- the size and number of blasts and number of blast holes drilled; and
- the area of exposed land surfaces associated with pre-stripping, waste dumps, stockpiles and other areas susceptible to dust from wind erosion.

Other information required to estimate dust emissions includes the physical properties of material being handled and the surfaces that will be subject to wind erosion. Moisture and silt content is of particular importance. Operational information, such as truck capacities, the bucket size of shovels and draglines, the distance which material is dropped during its handling, and climatic factors such as wind speed and the number of rain days. In finalising an emissions inventory, the estimates need to be modified to account for any controls, such as watering, applied to reduce emissions. The rate at which dust is deposited will be strongly dependent on particle size. The emissions inventory may be calculated for a number of particle size ranges. TSP and PM_{10} are commonly utilised.

The following empirical expression (USEPA, 1995) is an example of an emission factor for haulage to estimate the quantity of size-specific particulate emissions from an unpaved road, per vehicle kilometre travelled (VKT) or vehicle mile travelled (VMT):

$$E=k(1.7)(s/12)(S/48)(W/2.7)^{0.7}(w/4)((365-p)/365)$$

where:

E = emission factor
k = particle size multiplier (dimensionless)
s = silt content of road surface material (%)
S = mean vehicle speed, kilometres per hour (km/hr)
W = mean vehicle weight, megagrams (Mg) (ton)
w = mean number of wheels
p = number of days with at least 0.254 mm (0.01 in.) of precipitation per year (see discussion below about the effect of precipitation.)

The particle size multiplier in the equation, k, varies with aerodynamic particle size range as follows:

Aerodynamic Particle Size Multiplier (k) For Equation 1

a	=	all particles	<30μm	<15μm	<10μm	<5μm	<2.5μm
k	=	1.0	0.80	0.50	0.36	0.20	0.095

where a = is the Stokes diameter.

Unpaved roads have a hard, generally nonporous surface that usually dries quickly after a rainfall. The temporary reduction in emissions caused by precipitation may be accounted for by not considering emissions on 'wet' days —more than 0.254 millimetres (mm), 0.01 inches (in.) of precipitation.

Clearly there are a number of uncertainties in assigning quantitative entries in emission inventories. Errors can arise when compiling an emission inventory because of averaging and the possibility of missing sources. For example, the above emission factor relates only to tyre action on the road. It does not account for factors such as wind action on the load or spillage and pulverisation along the road.

A common point of reference for emission inventories with international acceptance is the US Environmental Protection Agency's (USEPA) compilation of air pollutant emission factors for stationary, point and area sources (USEPA, 1995). This document provides a wide reference source across a variety of industries.

Case Study 9, provides an example of an emissions summary developed from various emission factors for a large open cut gold mine in arid Western Australia.

Emission inventories should be seen as a valuable tool to the overall strategies developed for dust management and control. It will be a guide through which different scenarios can be investigated. Applying a model from an emissions inventory will nevertheless have some level of uncertainty without field verification.

2.4 LIMITATIONS AND NEED FOR VERIFICATION

Models rely on key inputs whose accuracy strongly affects the validity of the model prediction: dust emission factors, wind data, topography and dust entrainment, dispersion and fall-out characteristics. In most model applications, the greatest uncertainty is likely to surround the accuracy of emission factors. The real emission rates will tend to be strongly site-specific, being affected by local conditions including climate, geology and the type of mobile plant and materials handling equipment and techniques that are in use.

While 'standard' emission factors are available (and are widely applied) for various mining activities, caution must be exercised in applying such factors. An error or inaccuracy in developing a key emission factor will produce erroneous model results.

Much development work to determine fugitive dust emission factors from surface mines has been carried out in the United States. The US emission factor algorithms have been used for a number of Australian mines and it is worth noting that algorithm validation under local conditions is generally lacking. However, studies have been undertaken within the coal mining regions of New South Wales aimed at testing the validity of such emission factors (NSW Coal Association and SPCC, 1989).

Empirically determined emission factors, using high-volume dust samplers, were derived for various activities including truck and shovel loading of coal, dragline handling of overburden, and truck transport of coal and overburden. Reasonable concurrence with emission factors derived using the USEPA method was demonstrated, giving some degree of confidence that these factors are broadly applicable.

Regardless of algorithm validity, it must still be applied correctly. Inaccurate estimates of the variables involved, e.g. the moisture content or fine particle content of a dust source, could render the resultant model useless. It is therefore important that due consideration is given to local conditions in deriving the emission factors.

3 COMMUNITY RELATIONS MEASURES

The best practice principles for good community relations that are applied to other environmental issues are no different to those in respect of mining dust issues. These principles are detailed in the Community Consultation booklet in this series, which also presents recommendations on how best to plan and undertake the community consultation process. Community consultation is best begun early in the mine planning stages so that issues can be identified and resolved while designs and plans are still flexible.

Dust issues can be particularly important in community relations because the extent of any impacts is generally less easily defined and demonstrated than are other environmental effects of the mine. Nevertheless, demonstrating sound dust modelling and prediction methodology, coupled with appropriate dust controls and management programs, are important in reassuring neighbours and the public that dust issues are being adequately addressed.

The community view may be strongly influenced by perception. The 'visibility' of dust plumes and dust sources is often a significant factor affecting the public perception of mine dust. Public consultation and complaints registers usually target highly visible sources of dust and short-term episodes of high emissions, e.g. from blasting. In such cases there is clearly a need to consider the application of controls, even though an objective model may indicate that such dust sources may be quite minor contributors to dust levels overall (see Case Study 8).

Case Study 5 is an example of mechanisms to detect and respond to short-term dust events, including a public complaints 'hotline'. A weather station and real-time dust monitor located between the mine and residential areas can match dust events to both complaints and activities on the mine site. This is potentially a powerful tool both for checking the validity of complaints and managing mining activities to avoid creating nuisance dust. Complaints registers commonly record the details of public complaints directed at mine sites. To better assess the information these provide, details of time and location must be able to be matched with meteorological data and preferably with data on ambient dust levels.

Best practice in dust management is increasingly using complex technical methods, such as dust modelling and new technology. Examples in Case Studies 5, 6, and 8 show how on-line weather data and associated computer software can aid dust prediction and management. These aspects of management are technically complex and not easily communicated to the public. There is often a large variety of contributing dust sources, not only on the minesite but in adjacent urban and agricultural land. Providing an adequate public explanation that is accurate without being overly technical is a challenge.

Potential health risks posed by dust are another technically complex area where public concern is at times influenced by limited or inaccurate information. Pro-active education and community consultation (and preferably involvement), is an effective means of ensuring the wider community can see the complexity of the issues and be better informed.

Community consultation on dust issues often occurs at the public consultation stage of the mining project approval process. Environmental impact statements typically present predicted impacts on dust levels in surrounding communities and address any health issues. Examples of active community involvement are less common, notably in dust monitoring programs at Kalgoorlie and Broken Hill. These programs have been successful in promoting a more realistic picture of the causes of dust, and have encouraging a 'whole-of-community' approach to solutions.

4 PLANNING FOR DUST CONTROL

4.1 IDENTIFICATION OF PURPOSE

In planning for dust control, it is important to first ask some fundamental questions about objectives. The issues to consider will relate to community and workforce health, the potential for impacts from nuisance dust and the potential for impact on the surrounding environment. The nature of the material being mined and the properties of the resultant dust need to be evaluated, including the potential for dust to contain hazardous materials. Detailed information on the geology and composition of the materials to be mined should be available as part of the normal mine planning process.

Site-specific aspects need to be considered. For example, blasting may need to be planned to avoid unfavourable winds that could deposit dust on neighbouring houses; in areas remote from towns this would not be an issue.

4.2 Planning Process

The planning process involves the following steps:

- determine goals and targets;
- identify all potential sources;
- define locations and frequency e.g. a stockpile surface has a fixed location, with continuous potential emissions, truck movements will occur along a defined route at certain frequencies;
- develop an emissions inventory;
- collect or otherwise obtain relevant meteorological data;
- model dust deposition (surrounding environment);
- estimate localised peaks (occupational health);
- compare with goals, objectives, regulatory standards;
- test alternative siting and control options;
- continue this iterative process until the desired levels are achieved; and
- plan for monitoring (feedback and verification) and contingencies.

4.3 CONTROL ISSUES

The emissions inventory and model will assist to define and rank the major dust sources and their contributions to dust levels. Information about the climate (e.g. rainfall, wind strengths and patterns) needs to be added to the model. Systematic controls can then be applied.

For example, Case Studies 6 and 8 demonstrate how predictions using weather information can trigger dust control activities before a problem arises. These applications may involve the use of water over stockpiles, tailings or other dust producing surfaces, or postponing activities (such as blasting) that may carry dust to sensitive areas.

5 DUST EMISSION SOURCES AND CONTROL OPTIONS

5.1 LAND CLEARING, TOPSOIL REMOVAL

In the surface mining process, overburden and topsoil will be stripped and relocated. Mining, loading, transport and dumping can all produce dust. The options for control are limited to a certain extent. Clearly the location of the ore body is fixed, but the siting of transport routes and waste dumps and stockpiles may offer opportunities to limit the impact of dust on sensitive adjacent areas. Locating such activities away from sensitive areas is desirable.

Control options during mining, loading and dumping of topsoil and overburden are generally limited to dust suppression watering. Water trucks and truck mounted water cannons are commonly used. Scheduling these activities to coincide with favourable winds and weather conditions may be an option. Topsoil stripping commonly involves the use of scrapers that are able to efficiently remove the upper soil layers. A high degree of soil disturbance occurs, however, with the potential for associated dust problems. This may be exacerbated when topsoil stripping occurs during drier weather. There may be advantages in scheduling this activity to occur during periods when soil moisture can be expected to be optimal.

However, a number of potentially opposing factors have to be considered in planning topsoil stripping operations. Restrictions on the seasonal timing of topsoil stripping may mean that topsoil may need to be stripped earlier than would otherwise occur, increasing both total area disturbed and the period of topsoil storage—both of which are undesirable outcomes. Also, if topsoil handling occurs when the soil is too wet, the soil structure may be compromised (see booklet on Rehabilitation and Revegetation). Decisions on timing topsoil stripping require balancing these various aspects.

The application of water during topsoil stripping may be necessary. The quality of the water also needs to be considered. In the Goldfields region of Western Australia, for example, fresh water supplies are often very limited and/or expensive, and groundwater may be highly saline. While saline water is an effective dust suppressant, if used as a dust suppressant on topsoil, it will render the topsoil saline and sterile for a number of years. In such situations, the optional seasonal timing of topsoil stripping is critical.

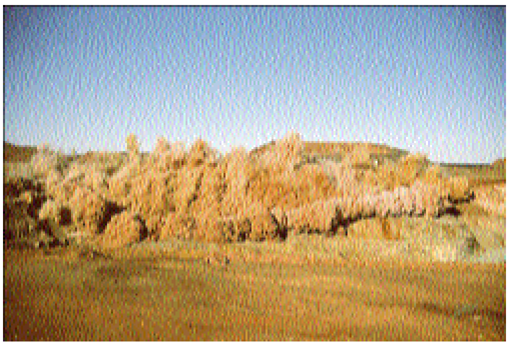


Photo: Kalgoorlie Consolidated Gold Mines Pty Ltd

Kalgoorlie Consolidated Gold Mines, Kalgoorlie, Western Australia. Open pit blast showing associated dust.

5.2 BLASTING AND DRILLING

The initial removal of ore and surrounding waste rock involves drilling and blasting. Blasting is usually a relatively minor contributor to total dust emissions (Case Study 9). However, blasting dust is produced as a concentrated 'cloud' that is highly visible and potentially may effect near neighbours downwind of the blast. The blasting of near-surface weathered materials that contain a high proportion of fines often creates large dust emissions. The options for controlling dust from blasting are somewhat limited. Watering of the blast area following the charging of blast holes with explosives may assist. This practice is sometimes utilised to combat dust from certain ore types that have a high content of fine particles.

Another method that can be effective in protecting areas adjacent to the mine from blasting dust involves delaying blasting under unfavourable wind and atmospheric conditions. This requires some flexibility in blasting schedules, but can be highly effective. Planning mining so that adequate buffer stocks of ore are available is required to accommodate delays in blasting. A knowledge of seasonal and daily wind patterns will give some degree of predicability to the likelihood and frequency of blast postponement. Case study 8 describes an innovative predictive tool developed by Kalgoorlie Consolidated Gold Mines Pty Ltd and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) that utilises blast properties and real-time meteorological data to predict the dust impact on residential areas of Kalgoorlie-Boulder adjacent to the mine.

This type of tool has potentially wide application as it could be applied to any dust source, or combination of sources, to predict dust dispersion. By linking the model to 'live' weather station data, the model provides a real-time prediction of dust concentrations.

Blast hole drilling may also contribute to the dust generated from open pit mining. To some extent this is mitigated by dust retention effects of the pit and the fact that (modern) drilling rigs are fitted with dust collection apparatus. Dust generated from drilling operations appears to be a minor contributor to overall dust emissions in comparison to other sources (see Table 2, Section 1.9).

5.3 Transportation

Loading material into haul trucks usually occurs within the pit, trucks then transport the waste rock and ore to its next destination along designated haul routes. Fugitive dust emissions are produced by the contact of tyres with the unsealed road surface and are affected by the total distance travelled, the silt and moisture content of the road surface and any control practices in use. Each stage of material transfer involves loading, transport and unloading, generating fugitive dust emissions.

Control strategies usually involve applying water, or a mixture of water and chemical dust suppressants for transport, and water sprays and/or enclosures for loading and unloading procedures.

5.4 PROCESSING, CRUSHING AND SCREENING

Dust generated when processing mined materials, primarily occurs as a result of the mechanical handling of ore. At the ore processing plant the mineral is extracted through a variety of processes that usually involve particle size reduction.

The main points which produce dust are the:

- dump hopper;
- primary crusher;
- transfer points;
- discharge points;
- stockpiles (open and enclosed);
- dry screens;
- dry loading areas; and
- return strand of conveyer belts.

Detailed analysis of various minerals process operations (including large and small scale operations employing a comprehensive mix of crushing, screening and conveyor systems, see Table 4) indicates the key contributors to overall dust volumes. It is important to note that dust collection equipment already serves most crushing and screening plants and the emissions indicated below reflect the effectiveness or otherwise of these systems.

Crushing	1—15%
Screening	5—10%
Stockpiling	10—30%
Reclaiming	0—10%
Belt Conveyor Systems	30—60%

In analysing how much airborne particulate any process plant creates, it is vital that an assessment recognises and addresses the processes and mechanisms which induce air movements through the entire process and entrain finer process particulates. The audit process, (by suitably accredited bulk materials handling design specialists) must embrace both the individual and collective characteristics of each plant component in the process. In some cases a review of mineralogy and metallurgical characteristics of some ores may be needed to gauge their suitability to various forms of process control minimising spillage and airborne particulates. In short all emissions are process and ore-type dependent, and best practice at the design stage should identify material spillages, process circuit dust generators and quantify air movements.

Table 4: Dust Sources (% of total) from Mineral Processing Operations

Sources	**Gold Mine A**	**Gold Mine B**	**Gold Mine C**	**Gold Mine D**	**Coal Mine**	**Coal Loading Terminal**	**Iron Ore Mine A**	**Iron Ore Mine B**	**Iron Ore Mine C**	**Iron Ore Loading Terminal**	**Iron Ore Loading Terminal**
Crushing	8.4	28.0	36.0	37.0	4.5	—	12.0	11.0		3.0	13.0
Screening	10.7	33.0	29.0	30.0	28.5	—	14.0	15.0	20.0	6.0	18.0
Stockpiling	37.7	4.0	3.0	3.0	24.5	9.9	23.0	20.0	22.0	13.0	14.0
Reclaiming	1.0	1.0	1.0	2.0	1.5	16.1	1.0	1.0	2.0	8.0	12.0
Belt Conveyor Systems	42.2	34.0	31.0	28.0	41.0	69.3	50.0	53.0	56.0	57.0	40.0
Other (traffic, rail car unloading etc)	NA	NA	NA	NA	NA	4.7	NA	NA	NA	13.0	3.0

NA: Not assessed at this location

Unfortunately, dust control in new plants is usually left till last in the design, after the process has been defined and detailed. More often it is simply treated as a vendor related issue and ignored. Best practice requires reviewing designs once a materials handling process has been determined minimising induced air movements and material spillage.

Table 5 provides a list of measures that can be used to control dust in ore processing.

Chemical additives generally do not significantly reduce the amount of water required, however they may increase the effectiveness of dust suppression and reduce the frequency of applications. Additives available include electrolytes (including reducing agents to bond chemically), polyelectrolytes (holding dust particles together electrostatically), surfactants (wetting agents), and polymeric films that form a crust.

The dust control method for dump hoppers (Table 5) is just one of the available options. Another useful way to control fugitive emissions differs from the conventional use of fogging and atomisation sprays, which require compressed air and/or high pressure pumps to generate fog particles.

This method creates a dominant controlled air stream within the dump hopper while simultaneously generating an active homogenous fog that completely fills the hopper void without using compressed air and high pressure water.

When ore is dumped, its falling ore stream expands and takes up the active mass of fog laden air. When this 'wet air' is expelled on impact from the collapsing ore stream, at very high velocities, it maximises agglomeration of the airborne dust and fog mist particles with the majority of the heavier homogenised particles settling within the dump hopper. Any displaced air from ore dumping is deflected inward by the high-velocity, fog-laden control air stream which minimises fugitive emissions.

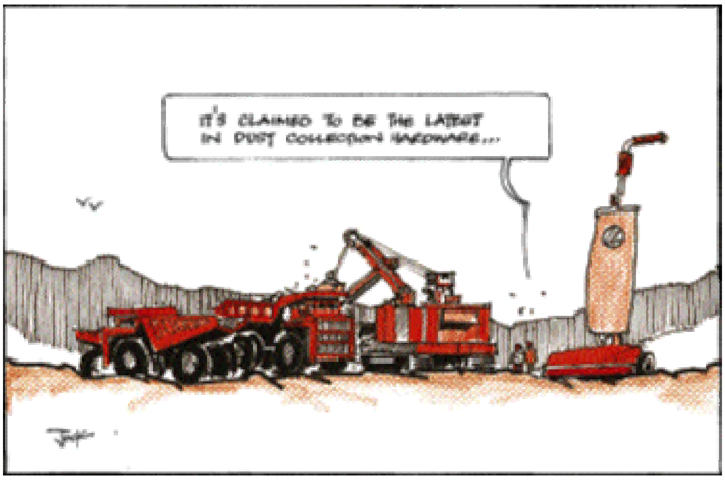
This method can give greater control over fugitive dust emissions from larger ROM (run of mine) dump hoppers and is also suited to smaller hoppers. As this method only requires a small positive head of water (gravity is sufficient), does not use compressed air, small orifice nozzles, filtration equipment or any type of pump, it has major capital and operating cost advantages.

Current best design practice for conveyor transfers incorporates controls to inhibit both excess air entering and rogue air movements.

Table 5 Dust control methods utilised in ore processing

Source	Dust control	Dust suppression
Whole plant	Enclosures/barriers	
Plant equipment	Dust proofing	
Enclosure structures	Regular maintenance	
Dump hopper		Three-sided, roofed sheds for truck dumping, with low volume high pressure adjustable water atomising sprays actuated at the time of dumping. If hoppers are open, fogger sprays at a higher level coupled with atomisers at dumping level will increase fall out rates and prevent dust surges due to the up-flow of displaced air. Wind breaks are also recommended.
Conveyors	Side wind guards,covers on high and steep conveyors, belt cleaning, dust collection systems, clean-up program, maintenance of enclosures.	Sprays at transfer points to wet dust and particles and prevent liberation, mist / fog systems to increase fall out rates. Belt cleaning sprays in opposite direction to travel.
Stockpiles—discharge		Minimising discharge heights and conveyor speeds, use of rill tower, enclosure of stockpile, atomising water sprays to wet falling stream. Drainage often required at stockpile base and foundations.
Stockpiles—storage		Fixed water cannons, or vehicular based sprays for small

		stockpiles. Drainage often required at stockpile base and foundations.



5.5 MATERIALS HANDLING

Ore surge piles and stockpiles used to transfer ore to processing facilities are frequently disturbed and may be considered as active disturbance areas. Stockpiles of crushed ore that are disturbed more or less continually are often enclosed by some form of partial cover. Finely crushed ore is usually held in fully enclosed bins.

Run-of-mine ore stockpiles contain fewer fines, but can be very large in size. These stockpiles are rarely enclosed. Where dust control on these larger stockpiles is necessary, regular watering is the commonly used method. Stockpile dust suppression can be expensive to install and operate due to the volumes of water required to cover large areas and the associated plumbing and pumping costs.

5.6 DUST COLLECTION

Centralised dust collection systems are used to capture, transport and separate dust emitted around the processing and materials handling areas. Dust collection generally provides the most effective means of controlling respirable dust emissions, while mist or fog sprays are effective in suppressing visible dust.

Dust can be separated from the airstream using the following methods:

- gravitational settling chambers;
- baghouses (cotton, glass fibre or synthetic fabric filter systems);
- insertable filters;
- cyclones (standard and high efficiency);
- wet scrubbers;
- electrostatic precipitator;
- viscous media (oil) filters; and
- high energy venturi scrubbers.

The collection system choice depends on the mining application. For example, wet collection systems are preferred in nickel operations due to hazardous materials concerns. In this situation, pay attention to the proper containment and management of the wet scrubber product.

5.7 WASTE ROCK DUMPS: OPEN AND RESIDUE DISPOSAL AREAS

Waste rock dumps and tailings present exposed surfaces that may be prone to wind erosion. It is desirable to plan the waste dump rehabilitation to occur as early as possible in the life of the mine. Establishing the final faces of waste dumps early and revegetating these surfaces will significantly reduce wind erosion. The same principle applies to open areas, ie areas cleared of vegetation in advance of mining, waste dumps etc. Mine planning should aim to minimise open areas and clear vegetation only when necessary for the upcoming mining program. The early rehabilitation of open areas no longer required for operational purposes will also minimise dust generation. Such areas can be significant contributors to the total mine dust load.

Tailings are distinct in silt and moisture content from both ore and waste rock, and differ in their potential for particulate emissions from wind erosion. Tailings contain a high proportion of fines, but are usually deposited as a wet slurry. While the tailings remain wet, there is little likelihood of dust problems occurring. Should the exposed surfaces of tailings dry out, however, wind erosion is likely to become a significant problem (see Case Study 6). Apart from creating nuisance dust, dry tailings surfaces may produce dust containing reactive salts or high metal content. Dry exposed tailings can be a problem in climates with strong seasonal rainfall, such as Northern Australia near the end of the dry season, or where tailings impoundments must be left to dry out to allow machinery access prior to final rehabilitation. Best practice here involves appropriate planning and design of the impoundment and the associated water circuit in order to accommodate both seasonal events and the decommissioning phase.

In most mining situations, tailings surface treatments at decommissioning are undertaken with the aim of stabilising them. Revegetating tailings surfaces may be possible, depending on the ability of the tailings material to support vegetation. Current regulatory guidelines and community expectations relating to the decommissioning of tailings storage areas generally favour placing a cover of rock and/or soil over the surface of the tailings and establishing vegetation. As this approach can incur very high costs, appropriate provision must be built into financial planning for the mine. Alternative methods which still offer long term dust mitigation and may meet community expectations in less populated regions include the in situ inducement of permanent crusts that are resistant to erosion.

6 MONITORING

Photo: BHP Iron Ore

BHP Iron Ore, Port Hedland, Western Australia. Installing a filter in a high volume sampler, Port Hedland, BHP.

6.1 ESTABLISHING A BASELINE FOR DUST LEVELS

Best practice management of dust emissions requires some measure of the level of impact of mining activities on dust levels in the surrounding environment, and the effectiveness of the controls that may be applied. Dust monitoring programs are designed to provide quantitative information on ambient dust levels and, providing they are well planned, should also provide information on background dust levels i.e. dust levels that would be expected in the absence of any influence from the mine. Two methods are commonly used to determine background dust levels:

- **Baseline sampling**—this generally refers to sampling at the prospective site of the mine prior to mining. This is useful in providing data on the pre-existing dust environment but, due to seasonal and annual variability in dust levels, may require sampling over a number of years in order to provide a 'baseline' data set that adequately describes natural variability. This type of long lead time for baseline data gathering is in reality rarely available.
- **Control site sampling**—another approach aimed at determining typical dust levels in the area in the absence of an influence from mining is using 'control' sites. This involves concurrent sampling near the mine and at sites far enough away to be outside the zone of influence of the mine, but still representative of the local environment. Using control sites has the advantage of allowing comparison of control and near-mine samples collected concurrently under similar weather conditions.

There is no standard method for determining the spatial arrangement of monitoring equipment or the optimal number of samplers that should be employed. Cost, access to potential sampling sites and the availability of power may limit the options. Monitors located on a grid pattern or cardinal directions should normally provide good spatial coverage. Consider siting dust samplers that will adequately monitor both short-term events such as blasting as well as the long impacts of the mining operation. It is advisable to establish a parallel monitoring system for wind speed and direction in the vicinity of the mine in order to interpret dust events in relation to local winds.

A range of dust monitoring equipment is available to measure concentrations and deposition of dust, ranging from a very simple deposit gauge through to the sophisticated real-time monitors that have only recently become available.

Dust monitoring methods include the following:

- **Dust deposition gauges**
  A deposition gauge is the most simple yet effective form of dust monitor available. It relies on the passive deposition and capture of dust within a funnel and bottle arrangement. It can be deployed in remote areas, does not require power and can be left in the field for long periods of time. The deposition gauge provides basic data on dust deposition rates (usually as g/m^2/month) and the relative 'dustiness' of sampling locations. It does not, however, provide information on dust concentrations, nor does it relate dust levels to wind direction or particular events.

- **High volume samplers**
  The TSP high volume sampler has remained essentially unchanged since 1971 when it was identified and referenced as a particle sampling devise in the US Code of Federal Register, 1971. Only minor technical updates have been incorporated in commercially available units, such as sequence and elapsed timers, flow and microprocessor controllers.

  The typical high volume sampler collects particles, with aerodynamic diameters exceeding 40 mm, by drawing a constant flow rate of ambient air through a filter medium. A determination of the net weight of the filter and a knowledge of the total air flow through the filter provides an average concentration of TSP in grams per cubic metre.

  When operated according to the relevant Australian Standard, the high volume sampler collects a sample over a period of 24-hours. An average dust concentration is produced. This type of sampling does not carry any information on short-term dust events. It is used to provide quantitative information on the dust levels encountered in a particular environment, but does not provide information regarding the actual source of the dust.

  A variation on the high volume sampler is available, which can be coupled to a wind direction vane so the sampler is only triggered while the wind is blowing in some defined wind arc. This type of sampler provides 'downwind' information and can be used to target dust from a specific source.

- **Continuous particle monitors**
  Continuous particle monitors produce a continuous record of ambient dust levels. This is a significant advance over the standard high volume sampler in that it allows examination of short-term dust episodes. It can be a powerful management tool when matched to records of mining activity and continuous wind data. The system can also be set up so as to operate on-line (see Case Study 5). Two examples of continuous monitors are: TEOM™ and Beta gauges.

  TEOM™
  The Tapered Element Oscillating Microbalance (TEOM™) consists of an oscillating tapered tube with a filter on its free end. The change in mass of the filter and collected aerosol produces a shift in the oscillation frequency of the tapered tube that is directly related to mass. The TEOM™ can be fitted with various cyclone heads which facilitates the continuous analysis of particles at PM_{50}, PM_{10} and $PM_{2.5}$.

Beta gauge

Another continuous particle analyser is the beta attenuation sampler that uses a 30mCi Krypton-85 source and detector to determine the attenuation caused by deposited aerosols and particles on a filter. The filter medium is contained on a roll and advances automatically on a time sequence, or when a preset particle loading is reached. The beta gauge can be fitted with various inlet samplers such as PM_{10} that provides continuous monitoring of particles.

- **Size selective inlets**

  Size selective inlets may be fitted to high volume samplers or continuous particle monitors. The inlets define the particle size fraction being sampled. Air is drawn through these inlets to remove particles that exceed a specified aerodynamic diameter before deposition on a filter medium. The sampler operates by passing particles of known diameter through the inlet and measuring the concentration before and after passage through the inlet.

  A typical example of this monitoring technique is the use of a size selective inlet for assessing the 10 mm (PM_{10}) fraction of particles in the atmosphere. The size selective inlet is usually mounted on a high volume sampler as an attachment.

- **Personal exposure samplers**

  The application of microcircuitry and miniaturisation has enabled the development of personal exposure monitors worn on the body to estimate exposure. Some personal exposure monitors can be fitted with size selective inlets that provide an average personal exposure concentration over variable time periods. The data is stored within the monitor and can be downloaded when convenient, e.g. between work shifts. These monitors have general acceptance across a wide range of industrial activity.

Monitoring methods need to be standardised to ensure reliable results and to assist valid comparison with standards and across different studies.

Standards Australia has developed the following standards applying to dust monitoring methodology:

- AS 2724.3
  Determination of Total Suspended Particulates (TSP)
- AS 2922
  Ambient Air — Guide for the Siting of Sampling Units
- AS 2985
  Workplace Atmospheres — Methods of Sampling Respirable Dust
- AS 3542
  Use of Standard Ringelmann and A5 Miniature Smoke Charts
- AS 3580.9.6
  PM10 High Volume Sampler with Size Selective Inlet — Gravimetric Method
- AS 3580.10.1
  Deposited Matter — Gravimetric Method
- AS 3640
  Workplace Atmospheres — Methods of Sampling Inspirable Dust

Photo: Pasminco Broken Hill Mine Pty Ltd

Pasminco Broken Hill Mine, Broken Hill. A Portal Exit Wash Bay is used to remove soil and dust as vehicles leave the underground workings.

CONCLUSION

The nature of mining involves disturbing the ground, removing and handling soil and rock, and the subsequent transport, dumping, crushing and processing of this material. At all stages there is some potential to produce dust. Best practice environmental management requires considering this issue during mine planning, operations and at mine closure.

The dual concerns of occupational health and the air quality near the mine require careful management. For mines located in dry or windy environments, the issue becomes more challenging.

In some situations the dust produced during mining may contain hazardous substances and this clearly requires special consideration. Even where dust does not contain harmful constituents, it may still represent a potential threat to the health of mine workers if concentrations in the work environment are allowed to exceed certain levels. From the standpoint of environmental impact, the main concern is the potential of dust to be released off-site and to affect the surrounding environment and general environmental amenity. The impact on environmental amenity is the most common issue relating to dust generated from mining operations.

In recent years, tools have become widely available that can greatly assist in the control and management of dust. Modelling techniques can predict dust impacts at the planning stage. The various mine dust emission sources can be estimated quantitatively, thus allowing control efforts to be applied systematically.

Technological developments in monitoring techniques have provided the means to accurately measure ambient dust levels. So-called 'real-time' dust monitors are able to supply rapid feedback on dust levels to the mine operators. This information can alert mine personnel to high dust events in a timely manner, allowing adjustments to mine operations. Such information can also be directly linked to wind information, giving an indication of contributing dust sources .

Clearly, the level of effort and expense that is applied in the control of dust will vary depending on circumstances. Each mine will have a unique set of conditions, and the appropriate solutions are not necessarily available 'off the shelf'. Nevertheless, success can be achieved using a wide range of methods, and the range of available of dust control techniques continues to develop and improve.

Photo: Alcoa of Australia Ltd

Alcoa, Pinjarra, Western Australia. Bitumen spray truck using an adjustable boom to apply bitumen emulsion.

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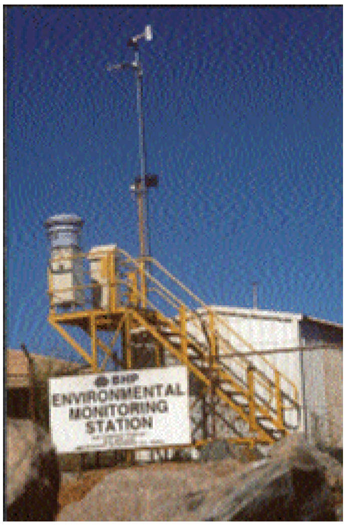


Photo: BHP Iron Ore

BHP Iron Ore, Port Hedland, Western Australia. Dust monitoring station. Two high volume samplers are located on the raised platform in the foreground. The sampler on the left has a particle size-selective head fitted. The shed houses a 'real-time' beta gauge sampler, whose intake can be seen above the shed roof.

CASE STUDY 1

PASMINCO BROKEN HILL MINE, NEW SOUTH WALES - CONTAINMENT OF DUST AT SOURCE

Pasminco Broken Hill Mine (PBHM) is situated in the semi-arid far west of New South Wales. Pasminco processes 2.7 million tonnes per annum of ore to produce 370,000 tonnes of zinc concentrate and 200,000 tonnes of lead concentrate. The dry climate of the region and seasonal winds create potential dust problems.

The mining operations are situated within the Broken Hill city boundary. The 'Line of Lode' outcropping is in the centre of the city, close to residential areas. The lead content in dust is a potential community health issue and consequently dust is one of the major environmental management issues for the site.

The primary focus of the dust management program is to contain dust at the emission source, and secondly to monitor community dust and lead levels. Monitoring is undertaken by the Department of Mineral Resources (DMR), the Environmental Lead Centre (a joint state Government agency of the Health Service and the Environment Protection Authority), Broken Hill City Council, Normandy Mining Investments and Pasminco Broken Hill Mine.

Dust management efforts at the mine generally aim to minimise dust emissions at their source. Methods used to achieve this include:

- covering all loads leaving the lease site, including concentrate rail wagons covered by a fully automated dust-proof wagon cover system;
- sealing all permanent haul roads and major traffic areas with bitumen;
- using chemical sealants on tailing surfaces and temporary roads;
- using two mobile tankers with pumps and water sprays on site to water roads, and where necessary, spray stockpiles and tailings areas;
- a road sweeper on site to clean spills and trafficable areas;
- vehicle wash down facilities to ensure vehicles leave the site clean;
- a variety of control mechanisms on crushing and conveying infrastructure, including dust extraction filters, mist sprays and enclosing conveyors with cover systems; and
- revegetating all disturbed areas wherever practical and minimising disturbance to stabilised areas. Rock armouring is used in addition to revegetation as a dust mitigation measure on tailings dams.

Photo: Pasminco Broken Hill Mine Pty Ltd

Applying chemical sealant to stabilise the surface of tailings.

By implementing these measures on site, dust emissions are effectively contained. A workplace dust monitoring program is routinely undertaken across the site to ensure worker dust exposure levels are contained well within prescribed limits. A laundry facility for work clothes is also provided on site.

A further check on dust prevention measures is provided by the ambient dust monitoring network established in the Broken Hill community. Dust and lead in dust are monitored in the city of Broken Hill by an extensive network of Deposit Gauges and High Volume Air Samplers (HVAS).

PBHM maintains 20 community deposit gauges and the Environmental Lead Centre and Broken Hill City Council maintain 13 and 12 gauges, respectively. Deposit gauges are operated to Australian Standards AS 2922—1987 and AS 3580.10.1—1991, and are analysed monthly for particulates and lead.

In addition, five HVAS are operated to AS 7274.3—1984 with four being serviced by PBHM and one by Normandy Mining Investments.

Dust monitoring results are pooled between the participants and each year a Collaborative Dust Monitoring Report details network results. This is discussed at an annual meeting chaired by DMR, which provides an open process of evaluating monitoring data and determining appropriate solutions for problem areas.

Environment Protection Authority Guidelines for dust deposition rates to protect community amenity are achieved for 89% of the network of deposit gauges. To date, all National Health and Medical Research Council guidelines for both total suspended particulates (TSP) and lead in dust have been readily achieved at the HVAS monitoring stations.

Photo: Pasminco Broken Hill Mine Pty Ltd

Concentrate load out facility utilising rail wagon covers to contain the potential for dust from rail wagons during transport.

A cooperative approach between Pasminco and the community to monitoring dust in Broken Hill has enabled dust mitigation and remediation activities to be identified and prioritised to meet community expectations. Input from the various stakeholders and a 'transparent' dust monitoring program ensures that the wider community is well informed and helps achieve lower community dust levels.

CASE STUDY 2

BHP, PORT HEDLAND, WESTERN AUSTRALIA - DUST MANAGEMENT IMPROVEMENT

The Port Hedland iron ore port facilities of Nelson Point and Finucane Island have been operational for approximately 30 years. The port facilities currently ship more than 62 million tonnes of iron ore a year.

Given the semi-arid environment and the proximity of port facilities to the town, dust has been a significant environmental issue for Port Hedland. Historically, high volume (24-hour TSP) dust monitoring has confirmed that residential dust levels adjacent to the port facilities were significantly higher than background levels.

Dust management for the port facilities has focussed on stockpiles, material handling, traffic and open areas. The review and upgrading of this management formed the basis for the recent Dust Management Performance Improvement Programme (Dust MPIP) a major three year program started in mid 1994 to:

- identify and evaluate site dust sources/emissions and associated public amenity issues;
- develop and implement a management plan to upgrade operational dust management and improve residential dust levels;
- develop and implement an ongoing management system based around performance monitoring and continual improvement; and
- assess the potential for dust related environmental health and ecological impacts.

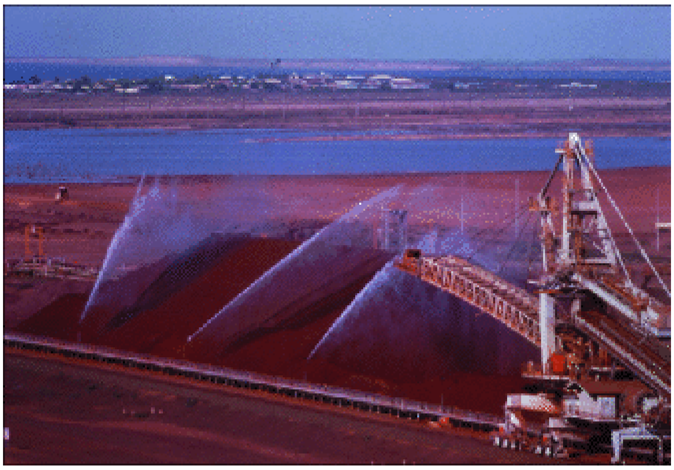


Photo: BHP Iron Ore

Dust suppression of iron ore stockpiles at Port Hedland using water sprays

Program evaluation continued through to early 1995. It involved identifying, assessing and ranking all operational dust sources, based on source severity, frequency and potential for residential impacts. Of the total dust sources identified, 81% were attributable to materials handling, 6% to vehicle movements, 5% to mobile plant and 4% each to windblown and other sources.

An integrated management plan and upgrade program addressed the ranked dust sources in order of priority. It addressed areas such as:

- dust control engineering standards;
- plant upgrades to the developed standards;
- programmed maintenance of dust suppression equipment;
- stockpile dust suppression;
- rationalising and land sealing of open areas;

- road definition sealing and traffic management; and
- dust suppression operating practices.

The upgrade program began in mid 1995 and was recently completed at a cost of approximately $14 million.

The performance monitoring and management system component of the program involved:

- community consultation and maintaining a community complaints register;
- maintaining a residential high volume dust monitoring network;
- developing and implementing a continuous operational dust monitoring network to identify operational dust events and non-operational/external events (weather or third party activities);
- establishing performance criteria and targets responsive to community complaints and residential dust levels;
- establishing a benchmarking process for BHP Iron Ore developments, and
- the ongoing review of dust management technology.

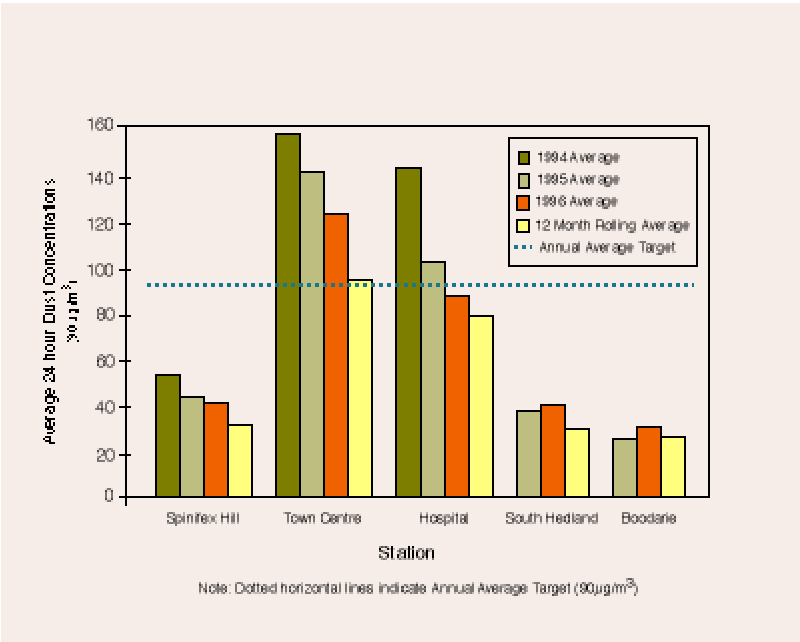
The program is meeting the established targets, with reductions of 45% in residential dust levels since 1994 and a 70% fall in community complaints.

To assess the potential for dust related health and ecological impacts, the following monitoring programs have been implemented:

- occupational dust exposure;
- residential/environmental health (through PM_{10} high volume dust monitoring); and
- vegetation dust loading(through depositional dust monitoring and associated vegetation monitoring).

Monitoring has shown there is a negligible potential for significant dust impacts in these areas.

Finally, as a component of the Dust MPIP implementation, the whole program underwent formal Department of Environmental Protection (WA) assessment in the form of an Consultative Environmental Review. This resulted in a formalised public review during the second half of 1996. The public response was favourable, with Ministerial approval for the program at the end of 1996.



Annual averages high volume dust monitoring from 1994 to 1996.

CASE STUDY 3

WESTRALIAN SANDS LTD, CAPEL, WESTERN AUSTRALIA - DUST SUPPRESSION, MITIGATION AND MONITORING

Westralian Sands Limited undertakes mineral sands mining and processing at Capel in south-western Australia. Deposits are mined using scrapers and the ore is processed, through wet gravitational separation plants on mine sites, to extract heavy minerals concentrate (HMC). The latter is subsequently processed in a dry separation mill to produce individual heavy minerals.

Land clearing and topsoil or overburden removal during mining operations can generate dust, as well as the dry electrostatic and magnetic separation of HMC into ilmenite, zircon and monazite. The naturally occurring radioactivity in minerals, and especially in monazite, means airborne dust is potentially a significant occupational health issue at the mill. Consequently, controlling dust levels in the mill has high priority. Dust control management methods include a combination of dust suppression, mitigation and monitoring as illustrated on page 16.

Dust monitoring methodology uses personal and positional (area) monitoring strategies and is of a 'grab sampling' type. Personal dust sampling forms the basis for personal radiation dose assessments from exposure to radioactive dust. Positional dust sampling serves to measure the performance of mill dust controls, and the long-term trends of ambient dust levels.

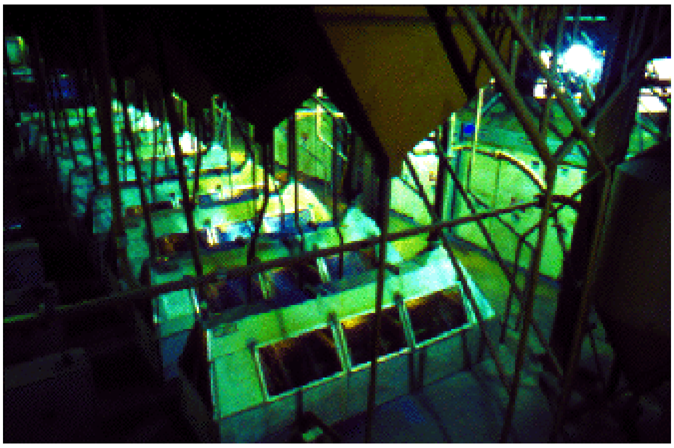


Photo: Westralian Sands Ltd

Interior of the dry plant showing overhead dust control systems on the dry separators.

The following dust monitoring tools are being used.

- personal inspirable dust sampling sets. Each set (see photo below) composes of a sampling head attached to the worker's torso and connected via tubing to a battery operated constant flow personal pump worn by the worker. Each measurement is carried out over an approximately eleven hour session, and measurements on each individual are repeated several times per year;
- positional dust sampling sets which are identical to the personal sampling sets but are used as stationary samplers located in designated points throughout the mill; and
- personal cascade impactors (Marple Mod 290), used to measure particle size distribution of airborne dust. An impactor is attached to the worker's torso and connected via tubing to a battery operated constant flow personal pump worn by the worker.

Photo: Westralian Sands Ltd

Personal inspirable dust sampling sets worn by mill personnel (see text).

For the purpose of radiation dose assessment the workforce is classified into radiation work categories. Workers within the same category are likely to be exposed to similar radioactive dust conditions due to performing similar work duties. Consequently, individual dust monitoring results are being pooled within each work category.

Engineering, process and work practice methods applied to control dust inside the Capel dry separation mill.

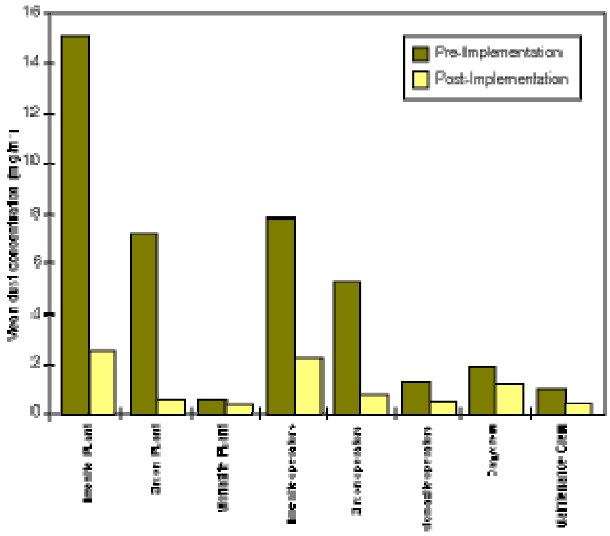
Control type	Methods	Status/Effectiveness
Engineering	Enclosing dry separators	Implemented / Highly successful*
	Enclosing transfer, feed and collection systems for processed minerals	Implemented / Highly successful*
	Ducted extraction system for enclosures	Implemented / Highly successful*
	Isolation of monazite separators to a dedicated plant room	Implemented / Highly successful*
	Enclosing conveyor and gravity transfer chute discharges and sealing elevator housings	Implemented / successful
	Installation of wall and floor partitioning to prevent airborne circulation	Implemented / successful
	Reduction of mineral abrasion (and dust production) during materials handling by replacement of multi-level gravitational transfer methods with a single-level, low profile circuit.	Plant design recommendation
	Remote process control	Implemented / successful
Work practices	Uniform workplace training	Implemented / successful
	Automated on-stream product analysis	Implemented / successful
Metallurgical - process modification	Wet magnetic separation, allowing early removal of monazite from the circuit	Not yet viable on industrial scale
	Mineral froth flotation replacing entire dry separation process	Not yet viable on industrial scale

*Highly successful—indicates an order of magnitude reduction in ambient radioactivity levels.

Implementing engineering measures of dust control was the most important factor in reducing dust and, consequently, radiation concentration levels in various processing plants of the dry mill and for all categories of mill workers. Modifying work practices has also been very successful in minimising dust exposure. An example is replacing manual handling of mineral by vacuuming (see photo page 3).

The dust monitoring program has played an important role in gauging the success of dust control measures. It has also improved understanding of dust particle size distribution, a central influence on the magnitude of radiation doses that mill personnel may receive. Results show large reductions in ambient dust levels, and therefore in the doses for the dry mill employees. Currently, all employee doses are below 2.5 mSv/y (limit is 100 mSv over consecutive five years or, on average, 20 mSv/y). Engineering modifications to the process plant enabled Westralian Sands Limited to significantly reduce dust hazards and operate well within the regulatory occupational health and safety requirements for dust levels.

Engineering improvements for mineral sands dust supression.



CASE STUDY 4

ESPERANCE PORT LOAD OUT, WESTERN AUSTRALIA - DUST CONTROL: RESULTS IN INNOVATIVE DESIGN

Iron ore from the Koolyanobbing mine near Southern Cross has been exported from a dedicated facility at Esperance, in Western Australia, since August 1994. The facility operated by the Esperance Port Authority was built after a formal public environmental impact assessment process, which placed stringent demands on its environmental performance. The Esperance Port Authority is responsible for all environmental matters at the Port. The reason for this approach was that the Esperance Port Authority consists of management and employees resident in the town who were acutely conscious of the communities concerns, and the need to ensure that the project met the environmental requirements. The facility is widely recognised for its success in a sensitive environmental setting.

After deciding that Esperance was the logical export point for its ore, the owners of the Koolyanobbing Project, Portman Mining, submitted a plan for an export facility with open ore stockpiles on the wharf. This proposal met staunch public opposition in Esperance, where tourism and the natural assets of pristine, white sand beaches and a clean town environment could be affected by red iron dust and stains. Consequently, a new scheme was proposed in which a purpose built shed with sophisticated dust extraction and covered conveyors for in and out loading stored the iron ore. This latter plan eventually gained statutory approval. Many design features incorporated in the new structure were ground-breaking and involved unproven methodologies. A certain amount of trial work and experimentation was required.

Photo: Esperance Port Authority

Esperance Port showing close proximity to the town and beaches.

The West Australian Minister for the Environment, as part of the project approval, set a condition on the Esperance Port Authority that no dust resulting from iron ore export operations could leave the facility. This condition made proponents and the Port Authority pay utmost attention to dust issues and control measures.

Initially, the project was built with baghouses on the storage shed, covers on top of the conveyor belts and belt scrapers at all transfer points. A dedicated shiploader with a telescopic delivery chute was used to feed iron ore deep into the ships' holds. Water sprays were fitted to the delivery chute.

During the first outloading it became apparent that, rather than controlling dust, the telescopic delivery chute created dust by a venturi effect created by the ore entering the chute and drawing large volumes of air into the bottom of the hold, and at the same time pushing dust-laden air out of the ship. The solution was to shorten the chute and install ring sprays around the base. This provided a blanket of water that effectively controlled dust carried upward by the air displaced from the hold (see photo page 24).

Photo: Esperance Port Authority

Covered load-out conveyors and a purpose-built shed for the storage of iron ore in the background.

The use of water and the total enclosure of stockpiles and materials handling equipment became the major dust control measures used. Attempts to maintain a negative pressure throughout the large storage shed proved unsuccessful. Buoyant warm air from the front end loader exhausts during outloading allowed small quantities of dust to escape through the eaves and ridge of the shed roof. Sealing of the offending areas removed this problem, however.

Similarly, the covering on the tops of conveyors was inadequate for the stringent environmental conditions imposed on the project. Dust could escape from the covers and belt undersides in high winds, particularly at belt tensioner sites and transfer points. Accordingly, full belt enclosures were progressively introduced in priority of how likely they were to create problematic dust.

Controlling ore moisture content during handling was critical. A series of water sprays was used at several points along outloading system. This allowed some flexibility in applying water. This flexibility is an important aspect given the significant variations in ore type, initial moisture content, and possibly changing conditions as outloading progresses.

The exacting standards of dust control that were applied to this facility resulted in innovative initial design features. The mine and port operators say these, along with subsequent modifications, have resulted in exceptional control of dust emissions and engendered confidence in the ability of the port to manage mineral export activities without compromising the high values of the coastal and foreshore environment. Those involved say an essential component of the success of this facility was having a positive employee attitude toward meeting environmental objectives.

CASE STUDY 5

BAYSWATER COLLIERY COMPANY, HUNTER VALLEY, NEW SOUTH WALES - THREE STEPS TO DUST MANAGEMENT

Bayswater Colliery Company Pty Limited operates the Bayswater No. 2 and Bayswater No. 3 open cut mining operations approximately 8 km south of Muswellbrook in the Hunter Valley, NSW. Bayswater Colliery maintains an environmental management system which includes the control and management of dust created from the mining operations.

Dust sources include:

- mine haul roads;
- areas stripped of topsoil ahead of mining;
- overburden dumps; and
- blasting.

Dust from traffic on mine haul roads is controlled at Bayswater using watercarts (see photo below), which apply water at $1L/m^2/hr$. Minimising open areas and a good understanding of the local weather conditions control dust from stripping, dumping, and blasting. Effective mine planning ensures that dust generated from topsoil stripping areas is minimised by reducing the area stripped ahead of mining at any one time. Overburden dumps are designed to minimise the dumping height, and dumping on high areas is discouraged during weather conditions when dust creation is more likely. Rapid rehabilitation of mining areas also reduces the area available for dust generation. The effects of dust generated from blasting on nearby residents is minimised by controlling the conditions under which blasting proceeds.

Photo: Bayswater Colliery Company Pty Ltd
Watercart operating at Bayswater Colliery.

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

The real-time monitor operates in conjunction with a weather station. Dust and weather data is continually relayed via a radio link to the mine site. A general dust 'risk factor' is calculated by assessing weather conditions such as wind speed and direction, temperature, solar radiation and rainfall and existing dust levels. When the dust risk factor is high, alarms alert the Environmental Officer and the Mine Supervisor, allowing mine operations to be adjusted to reduce dust. The same monitoring system is used to provide environmental clearance prior to blasting.

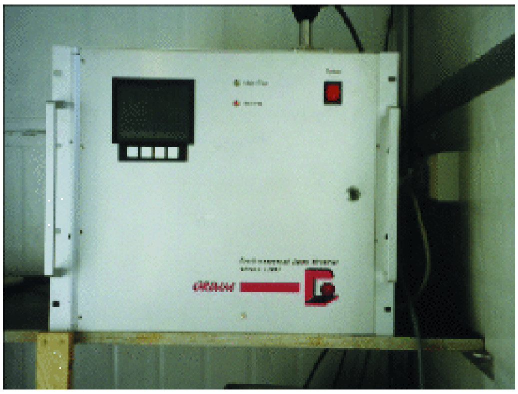


Photo: Bayswater Colliery Company Pty Ltd
'Real-time' laser dust monitor

Bayswater Colliery also operates a 24-hour environmental complaints 'hotline'. The hotline provides a quick response mechanism for the community to report dust incidents or other environmental aspects of the operation which they believe are creating a problem.

In summary, Bayswater Colliery approaches the issue of dust management at three levels:

- dust prevention by strategic mine planning and environmental controls;
- 24-hour real-time monitoring;
- the use of a dust 'risk factor' that alerts the mine operators to unfavourable weather conditions; and
- a prompt response to incidents of dust generation.