



**South African  
Mining Industry Best  
Practice  
on the  
Prevention of Silicosis**

**Prepared By**

**David W Stanton, Bharath K Belle, Kobus JJ Dekker and  
Jan JL Du Plessis**

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## Foreword by the Chief Inspector of Mines

### **Silica exposure is a still a significant risk in many mines in South Africa, most notably gold and coal**

Crystalline silica, microscopic in size, can scar the lining of the lung. As this lining thickens, the lungs are less able to extract oxygen from the air and supply it to the blood. Susceptibility to other infections such as TB increases. Mineworkers with silicosis cough painfully. They are short of breath and suffer from tightness of the chest. Physical exertion is difficult. In acute situations, after very high levels of exposure, the symptoms of silicosis develop rapidly and death follows quickly. In other circumstances, the silicosis presents after many years of exposure or becomes apparent only after miners have left the industry.

Silica dust has also been linked to cancer and has been classified as a carcinogen.

As with many occupational health and safety challenges in our mining sector, silicosis has a bitter legacy. Since gold mining began in the late 1800s, we do not know exactly how many mineworkers have died from the disease. As migrant workers, most went home between contracts and many never returned to the mines after falling ill at home. In 1904, many miners from Britain who had been "imported" to work on the gold mines could not return to South Africa after the Anglo-Boer war because they had succumbed to silicosis. In the miner's strike of 1907, silicosis featured as an important concern. At that time, rock drillers had a life expectancy of only five years once at work. As late as 1995 the Commission of Inquiry into Safety and Health in the Mining Industry concluded that dust levels had "...remained roughly the same over a period of about 50 years", that this amounted to "a priori evidence that the absence of a downward trend in the official figures for certification [of respiratory diseases] is correctly interpreted as a failure to control dust related disease." – Section 4.6.5 of the Commission report.

Preventing silicosis is an operational matter once provision has been made for the necessary resources to address the problem. Silica dust sources must be identified and better work practices must be implemented to reduce dust generation and capture dust at source. Wet drilling, effective design and maintenance of ventilation systems, watering down, dust suppression and capturing systems, adequate re-entry arrangements and, as a last resort, correct use of respirators, are examples of good practice.

In 2003, the mining sector committed itself to eliminating silicosis at the Mining Summit, which was convened in terms of the Mine Health and Safety Act of 1996. While there have been many individual initiatives to prevent silicosis, these must become widespread and on-going if the goal of elimination is to be achieved.

This guide on best practice is a significant step in the right direction, supporting miners' well-being and an important goal. It is also a step away from a legacy which this sector must and will overcome. The value of this guide will be judged by its effective implementation. Together with you, I look forward to seeing the results reflected in reduced exposure levels and declining incidence of silicosis.



**May Hermanus**  
**Chief Inspector of Mines**  
**December 2005**

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- Chapter 15: Sources and Methods of Dust Control, Environmental Engineering in South African Mines. The Mine Ventilation Society of South Africa, 1989.
- Control of respirable crystalline silica in quarries. HSE (UK) Publication HS(G)73, 1992.
- Dust Control: Best Practice Environmental Management in Mining Environment Australia, 1998.
- Dust handbook CSIR-Miningtek, South Africa 2001.
- Dust & You "The Menace Remains". RJB Mining, UK, 1998.
- Dust – What You Can't See CAN Hurt You! Mine Safety and Health Administration, USA, 1999.
- Guidelines for Environmental Protection at Continuous Miners Research Organisation, Chamber of Mines of South Africa, User Guide No. 2, 1987.
- Handbook for Dust Control in Mining. IC 9465 Information Circular/2003 DHHS (NIOSH) Publication No. 2003 –147, USA.
- QuarrySAfe: Hazardous Substances in Quarries. The Mining and Quarrying Occupational Health and Safety Committee (MQOHSC), Australia, 1998.
- Respirable crystalline silica – Phase I. Variability in fibrogenic potency and exposure-response relationships for silicosis. HSE (UK) Hazard assessment document EH75/4 2002
- Silicosis Prevention Folder. National Industrial Sand Association (NISA), USA, 1995.
- Standard Practice for Health Requirements Relating to Occupational Exposure to Respirable Crystalline Silica ASTM Publication E 1132-99a, USA, 1999.

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# Mining Industry Best Practice on the Prevention of Silicosis

## I. Background

Silicosis is a lung disease associated with exposure to airborne respirable crystalline silica dust. This debilitating and sometimes fatal lung disease persists worldwide despite long-standing knowledge of its cause and methods for controlling it.

In 1995 the International Labour Organization (ILO) and the World Health Organization (WHO) Joint Committee on Occupational Health launched a global programme for the elimination of silicosis from the world by 2030. Positive experience gained by many countries shows that it is possible to significantly reduce the incidence of silicosis by using appropriate technologies and methods of dust control. It is strongly believed that the goal of the global elimination of silicosis is realistic and can be achieved through: compliance with occupational exposure limits and technical standards, dedicated national action programmes, industry commitment, multi-disciplinary efforts of occupational health and safety practitioners, health education and training, raising public awareness and international collaboration.

The Chamber of Mines of South Africa has been active in the prevention of silicosis for many years. Recent initiatives have included regional and national workshops in 2002 – 2004 to determine what research is required on silicosis prevention. A major Safety in Mines Research Advisory Committee (SIMRAC) Silicosis Elimination Programme (SIM 03-06-03) was implemented in 2005. The three main tracts of this five-year programme cover Dust Measurement and Reporting, Environmental Engineering/Dust Control and Silicosis Prevention Awareness. As an interim measure this booklet on best practice for silicosis prevention in the mining industry has been published. The booklet is supported by a Silicosis Prevention Information Resources CD, training CDs on airborne dust and two DVDs with silicosis prevention videos.

## 2. Why do we need best practice?

At the Mine Health and Safety Summit on the 24 October 2003 the Minister of Minerals and Energy, Phumzile Mlambo-Ngcuka, stated that further improvements were needed in health and safety in the South African mining sector, with Silicosis a major concern. The Summit agreed that milestones for the eradication of silicosis needed to be set. The agreed milestones are:

*By the year 2008, 95% of all exposure measurements results will be below the occupational exposure limit (OEL) for respirable crystalline silica of 0.1 mg/m<sup>3</sup>. These results are individual readings and not averaged results.*

*From the year 2013, using current diagnostic techniques, no new cases of silicosis will occur among previously unexposed individuals.*

In response to the Global Programme, the Minister of Labour, Membathisi Mdladlana, officially launched the National Programme for the Elimination of Silicosis in South Africa (NPES) on the 28 June 2004. The Department of Labour has established a National Working Group to develop and manage the NPES. The National Working Group consists of the major role players namely government (including representation from the Department of Minerals and Energy), organised labour, organised business and interested and affected parties.

The Chief Inspector of Mines in a Keynote talk at the 2004 Annual Conference of the Southern African Institute for Occupational Hygiene (SAIOH) stated that:

- ☛ silicosis is incurable, irreversible and progresses after removal from the exposure
- ☛ rate of silicosis (17.2%) diagnosed at autopsy unchanged since 1975
- ☛ prevalence rate varies: gold miners at 22.1% in older miners, coal miners 7.3% and platinum at 4.4%
- ☛ exposure to silica increases TB risk fourfold
- ☛ compensation for respiratory diseases in 2002 included:
  - 596 cases for Silicosis I with compensation paid of R19 916 963 and
  - 262 cases for Silicosis II with compensation paid of R15 121 419
  - 1 215 cases for TB with compensation of R13 372 240

This best practice booklet on silicosis prevention has been developed to strengthen existing programmes on dust control in the mining industry and to give substance to the milestones developed by the Mine Health and Safety Council (MHSC) on the eradication of silicosis. Further resources on silicosis prevention will be developed through the extensive SIMRAC research programme SIM 03-06-03.

Since silicosis is an incurable disease, prevention is the only answer. The keys to prevent silicosis are straightforward: Identify employee exposures to respirable crystalline silica (commonly known as silica) dust and then eliminate or control employee exposures to silica dust. The term “respirable” is used as this relates to the very small particles of dust (less than 10 microns in diameter) which penetrate deep into the lungs.

Best practice<sup>1</sup> silicosis prevention can be achieved by:

1. employer commitment to a Silicosis Prevention Programme
2. identification of dust sources and assessment of employee dust exposures during the active phases of all mining operations
3. control of dust sources to eliminate or minimise dust exposures during the active phases of all mining operations
4. maintenance, examination and testing of dust control measures
5. employee involvement and commitment to the Silicosis Prevention Programme
6. employee education and training so that employees know about silicosis and how to control and minimise their dust exposure
7. administrative controls and work practices including the correct use of appropriate respiratory protection to minimise dust exposures
8. periodic medical surveillance of employees exposed to airborne silica dust
9. auditing of the Silicosis Prevention Programme
10. planning in the case of new or expanding mining operations to eliminate or minimise dust exposures

### **3. What is silicosis?**

Silicosis is a progressive lung disease caused by breathing dust containing particles of respirable crystalline silica – particles so small you can see them clearly only with a microscope. The respirable dust particles are tiny, less than 10 microns in diameter (for comparison a human hair is 40 – 50 microns in diameter). The silica particles when inhaled become trapped in the lungs and damage the tissue. As a result, the lung tissue scars and forms small, rounded masses called nodules. Most people diagnosed with silicosis are asymptomatic (without symptoms), but over time, as their disease progresses, breathing becomes increasingly difficult. In the more severe cases, symptoms may include cough and shortness of breath. A complete work history, a chest x-ray, and a lung-function test will determine whether or not a worker has the disease. The disease can be detected by chest x-ray in the early stages before symptoms develop, and if detected early, steps can be taken to prevent further exposure to silica dust. The diagnosis of silicosis and the resulting disability requires specialist training.

Exposure to various levels of respirable silica dust can result in different forms of silicosis e.g. chronic silicosis, accelerated silicosis and acute silicosis.

- **Chronic silicosis:** Most workers who develop silicosis don't show any symptoms for 10 or more years. That's because their exposures to silica dust are fairly low, but frequent.
- **Accelerated silicosis:** As exposure levels to silica dust increase, however, silicosis can appear much earlier. For example, those diagnosed with accelerated silicosis show features within five to 10 years.
- **Acute silicosis:** Workers exposed to extremely high levels of silica dust may develop acute silicosis, a condition that can show symptoms within only a few weeks after an initial exposure. Acute silicosis can occur in miners exposed to very high dust levels, particularly among workers who produce finely ground silica – sand blasters, tunnelers, and rock drillers – especially if the material drilled is sandstone or other material with a high silica content. Acute silicosis is most common among sand blasters because of the high levels of silica dust they may breathe.

Progressive massive fibrosis (PMF) may occur in chronic or accelerated silicosis, but is more common in the accelerated form. Progressive massive fibrosis results from severe scarring and leads to obliteration of normal lung structures.

The presence of silica in the lung also increases the risk of developing pulmonary tuberculosis. Silica particles can destroy or alter the metabolism of the pulmonary macrophages, thereby reducing their capacity for anti-bacterial defence. The risk of developing pulmonary tuberculosis while exposed, and also after exposure ends, depends on the amount of cumulative silica dust exposure.

Chronic Obstructive Pulmonary Disease (COPD) is a lung disease that develops primarily in people who smoke, but silica dust exposure potentiates the damage done by smoking. Nonsmokers rarely develop severe COPD from the effect of silica dust only.

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<sup>1</sup>. Best practice can simply be explained as “the best way of doing things” and can be defined as the most practical and effective methodology that is currently in use or otherwise available.

## 4. What is crystalline silica?

The compound silica ( $\text{SiO}_2$ ) is formed from silicon (Si) and oxygen (O) atoms. Because oxygen is the most abundant element in the Earth's crust and silicon is the second most abundant, the formation of silica is quite common in nature. "Crystalline" refers to the orientation of the Silicon Dioxide ( $\text{SiO}_2$ ) molecules in a fixed pattern as opposed to a nonperiodic, random molecular arrangement defined as amorphous.

The three most common crystalline forms of silica encountered in the workplace environment are quartz, tridymite, and cristobalite. Of these forms, quartz is the most common; in fact it's the second most common mineral on the planet. (Feldspar is most common.)

## 5. How much crystalline silica is hazardous?

How much crystalline silica is hazardous depends on how long and how often a worker is exposed as well as the level of exposure. Because respirable silica dust particles which are the cause of silicosis cannot be seen with the naked eye and because the dust which can be seen is coarse and comparatively harmless, the human eye is not a reliable guide to any dangerous dust in the air. It is therefore necessary to make use of dust sampling instruments which are capable of providing indications of the concentrations of respirable dust in air. Any respirable dust sampling instrument should be designed to capture only dust particles of a size considered to be dangerous to health – usually smaller than about 10 microns.

A specialist or trained, competent person in airborne dust measurements can determine whether or not a worker is over-exposed by sampling the air a worker breathes and comparing the exposure measured with the relevant Occupational Exposure Limit (OEL). The OEL is a limit value set for an occupational exposure in the workplace and represents conditions under which it is believed that nearly all workers may be repeatedly exposed day after day for a working life without adverse health effects. In the case of crystalline silica the OEL is the maximum amount of airborne respirable crystalline silica dust that one can be exposed to during a full work shift and is expressed in milligrams per cubic meter (abbreviated to  $\text{mg}/\text{m}^3$ ). Under the Mine Health and Safety Act (MHSA) exposure to respirable quartz should be as low as reasonably practicable below the OEL of  $0.1 \text{ mg}/\text{m}^3$ .

## 6. What diseases are associated with the inhalation of coal dust?

Workers exposed to airborne coal mine dust are at risk of developing simple coal workers' pneumoconiosis (CWP), silicosis, progressive massive fibrosis (PMF), and other diseases collectively known as Chronic Obstructive Pulmonary (or Airway) Disease (COPD or COAD). The latter includes emphysema and chronic bronchitis, and are thought to be more prevalent among people exposed to dust than in the general population. These diseases have other important causes, notably tobacco smoking. While the incidence of pneumoconiosis has been shown to be related to average cumulative exposure to respirable dust, the exposure relationships for other dust aggravated diseases (e.g. COPD) is not so well understood but may involve the large dust particle sizes.

In South Africa the OEL stipulated for respirable coal dust is  $2 \text{ mg}/\text{m}^3$  and is applied uniformly to every coal type. Where the crystalline silica content of respirable coal dust is greater than 5%, the OEL for respirable crystalline silica of  $0.1 \text{ mg}/\text{m}^3$  is applied.

## 7. What is coal workers' pneumoconiosis (CWP)?

CWP or 'black lung' is one of the most widespread diseases caused by mineral dust throughout the world. It is a chronic disease that develops over years of exposure and is caused by the breathing in and build-up of respirable coal mine dust in the lungs. It covers a wide range of illness including breathing and heart problems and is usually diagnosed based on x-ray findings and a history of work in coal mines.

Simple CWP shows up as small spots less than 10 millimetres (mm) on a chest x-ray. It is caused by the collection of coal dust around the respiratory bronchioles, which lead to the alveoli. With continuing exposure more dust is deposited and lesions called macules are formed. These are typical of CWP. Coal macules are actually macrophages loaded with dust, mostly found around the respiratory bronchioles. A miner with simple CWP may not seem sick, so x-rays and a detailed history of work in coal mines are important in making an early diagnosis. If the disease is detected early the worker may be appropriately advised and moved to a less dusty atmosphere. Studies, however, indicate that CWP can progress even after exposure has stopped. There is no cure for CWP. Prevention is the only answer!



Progressive Massive Fibrosis (PMF) occurs if a miner with simple CWP continues to be exposed to high levels of respirable coal mine dust, causing large areas of scar tissue to form in the lungs. On autopsy it appears as large black nodules and black lung tissue, while on an x-ray the disease appears as large spots. A miner with PMF will feel short of breath on exertion and have a persistent cough. The miner may also be awakened by night sweats. As the disease progresses, the shortness of breath gets much worse. Eventually the miner cannot work or perform simple everyday activities. Other symptoms include chest pain, coughing blood and weight loss. In CWP the heart become enlarged with heart failure a likely result. The miner might also die from pneumonia or other infections that attack the weakened lungs.

## 8. Examples of airborne dust sources in mining

### 8.1 Hard rock mines (gold, platinum, etc.)

The largest quantities of airborne dust are often produced in a mine by blasting operations and mechanical mining systems. Mechanical operations that produce airborne dust include drilling, scraping, barring, lashing, tipping and loading.

Some of the fine dust produced during blasting is carried away by the ventilating air stream. However a large amount of dust is trapped with the rock broken by blasting. Some of the coarse particles that have become airborne settle out on the foot-wall and some of the finer particles collide with each other and aggregate to form larger particles, which settle out. If precautions are not taken, these settled particles, if disturbed, can become airborne during the shift when persons are present in the workings and thus become available for inhalation.

Most of the dust produced by drilling is captured by water flowing down the drill steel and exits the hole being drilled as sludge. Unfortunately, all the dust is not controlled in this way because some compressed air usually leaks past the piston of the rockdrill and finds its way down the drill steel to the bottom of the hole where it collects some dust before escaping into the atmosphere.

Blowing out of a drill hole using compressed air is another major source of airborne dust.

When a piece of rock covered with fine dust is allowed to fall, as happens when it is transferred from one conveyor belt to another or when it is dropped into a tip or onto a stockpile, it is subject to gravitational acceleration and subsequently to a sudden stop or deceleration. These processes release dust into the air and if the tip is, for example, upcasting or downcasting this dust is then carried into the ventilating air.

Common sources of airborne dust in a hard rock mine include:

- ☛ Blasting
- ☛ Blast hole drilling and blast hole cleaning
- ☛ Support and rigging hole drilling
- ☛ Barring-down of loose rock
- ☛ Face cleaning
- ☛ Sweeping of fines
- ☛ Ore tipping
- ☛ Ore transport and handling (horizontally and vertically in hoppers, skips, trucks and on conveyors)
- ☛ Re-entrainment of dust in dry intake airways owing to increased intake airway velocities and vehicle movement
- ☛ Transfer and movement of ore in ore-passes and from chutes
- ☛ The movement of people and rolling stock along haulages, travelling ways and production areas liberating settled dust
- ☛ Rock crushing
- ☛ Screening, grinding, milling and pulverising of the ore during processing
- ☛ Backfill placement.

All workers on a mine are potentially at risk from exposure to airborne respirable dust. This includes both surface and underground workers. The following underground worker categories are potentially at higher risk of exposure:

- ☛ Mining crews in stopes and development
- ☛ Team leaders
- ☛ Drill operators
- ☛ Scraper winch operators
- ☛ Tip operators
- ☛ Locomotive drivers and crew.

## **8.2 Coal mines**

Dust in coal mining is released during blasting, drilling, cutting and transportation.

In conventional coal mining all the face production activities are dust sources. Coal cutting and drilling are the two highest dust-generating sources. Roof drilling for support can also be a major source of quartz dust without dust suppression (wet drilling or dust extraction system). Blasting the coalface results in a short period of high dust concentrations, during which personnel should be removed from the explosion site, only returning once the face area is cleaned from dust and harmful gases by the ventilating air.

The primary areas of dust generation outbye of the face area are conveyor belts, coal haulage transfer points and haulage roads. Dust adhering to the surface of the conveyor belt can be made airborne by the vibration of the belt as it passes over the belt rollers. Dust adhering to the bottom belt, when returning, can be crushed and pulverised creating an important source of respirable dust. Coal transfer points where dust can be generated include feeder breaker to belt, stage loader to belt, belt to belt, belt to transfer chutes, and belt to silos.

The dust generated in the transport roadways of a mine can be problematic as most of these roadways are situated in the fresh air intake. The finer airborne dust particles will most probably travel throughout the section and mine. The coarser particles may settle out (be deposited), but the crushing and pulverisation of these particles through vehicle tyres will be a significant dust source in the intake air unless the roadway is treated with some kind of binding agent.

The continuous miner, shuttle cars, and roof bolter are the major dust generation sources in a continuous mining operation. Feeder breakers, conveyors, and outbye equipment also produce dust. The coal cutting process is by far the most important contributor to the generation of airborne coal dust and very high dust exposures can be expected where ventilation, water supply, spray systems and onboard scrubber are neglected. During the process the cutting pick impacts the coal face, tears coal from the face and crushes it under high normal forces imposed by the cutting picks. The depth of cut is affected by the condition of the picks. Worn picks not only increase the amount of dust generated by limiting the depth of cut that can be achieved, but also cause picks to become very hot owing to frictional heating.

While high levels of airborne respirable dust can be generated by continuous miners, respirable particles also adhere to the cut coal. Some of the dust that adheres to the broken coal becomes dislodged and airborne during coal handling such as at the loading point on a continuous miner; the transfer point from the continuous miner to the shuttlecar; the belt loading point, and on all subsequent belt transfer points.

In longwall mining the major dust sources are the shearer/plow, stage loader/crusher and the movement of roof supports. The amount of airborne dust produced by the shearer depends on the seam conditions, the operational parameters and the types of internal and external water sprays in operation. The amount of airborne dust generated by the support advance depends on the immediate roof conditions, and it varies with the support advancing operation and the setting and yielding loads of the supports. As the setting and yielding loads increase, greater amounts of dust are generated.

Dust dispersed into the air from a roof fall in the goaf area is dependent on the size of the fall. If the goaf position is relatively close to the face, (small goaf) the amount of dust generated and entrained will be less than if a large goaf takes place resulting in a large volume displacement and energy release.

## **8.3 Surface mines**

At surface mines, drilling, blasting, and primary crushing at tips are the major sources of airborne dust. Operation of heavy equipment such as loaders, shovels, dozers, draglines and haul trucks also produces dust. Dust on roadways and around stockpiles and loading operations is often a problem and also where secondary crushing/screening takes place.

In quarrying, dust is generated at all stages of the production process. In the hard rock sector the main risk areas are in exploratory drilling, drilling at the face, on roads and on the crushing plant with the higher risk occupations being driller, plant operator and maintenance operator. In monumental stone and slate quarrying operations, dust is produced from hand operated drills, portable hand operated saws and during splitting and dressing.

## **8.4 Mineral processing**

In any minerals processing facility, dust is generated when ore is shattered or broken as in dumping, loading, transferring, or handling. Potential dust sources in minerals processing operations include:

- processing equipment such as crushers, screens, grinding mills and dryers
- bulk material handling equipment such as belt conveyors, screw conveyors, bucket elevators, feeders, and hoppers.

Processing equipment processes the ore into a final product. Bulk material handling equipment transfers ore between processing equipment and the mine to the processing facility.

## 9. Sources of crystalline silica in mining

As crystalline silica (quartz) is a component of nearly every mineral deposit and is at least a component of almost every rock type, exposures to silica dust are quite prevalent in mining operations. In some rocks or soils the percentage of silica is greater than 90% with some sandstones being almost pure quartz. Table 1 gives an indication of the levels of free crystalline silica in minerals sources, but it must be noted that these values vary. The material with the highest inherent free crystalline silica will produce, on average the greatest exposure levels. However, the correct assessment of exposure levels can only be determined by respirable dust and crystalline silica measurement.

Table 1 Typical levels of free silica in mineral sources (HS(G)73, HSE (UK) 1992)

Ball Clay	Up to 25%
Basalt	Up to 5%
Dolerite	Up to 15%
Flint	Greater than 90%
Granite	Up to 30%
Gritstone	Greater than 80%
Iron Ores	7 – 15%
Limestone	Usually less than 1%
Quartzite	Greater than 95%
Sand	Greater than 90%
Sandstone	Greater than 90%
Shale	40 – 60%
Slate	Up to 40%

In platinum mining operations, the quartz content of the ore is often low and exposure measurements in South Africa have indicated low exposures to respirable crystalline silica. SIMRAC Project GAP 802 (2003) reported that analysis of stope rock samples in some platinum mines indicated that the inherent silica content was less than 1% while in the gold mines this varied between 9% and 39%. Airborne respirable dust samples collected in the platinum mines contained a silica content of less than 0.2% while in the gold mines this varied between 5% and 57%. Respirable dust in gold mining often has a higher quartz content because of the gold bearing reef which has a hard conglomerate of quartz pebbles cemented together by an equally hard siliceous matrix.

Coal dust contains many different elements and their oxides, and its mineral content varies from seam to seam. Despite the variety, coal dust is composed essentially of the elements carbon, hydrogen and oxygen with smaller quantities of nitrogen and sulphur and, in all cases, mineral matter that remains as ash when the coal is burnt. Respirable coal mine dust normally contains a small proportion (usually < 5%) of quartz or silicates, mostly from dirtbands within the coal stratum. GAP 802 reported that the average measured silica content of South African coal seams was 3.5%. Elevated silica exposures may occur when miners remove the overburden or tunnel through rock to get to the coal to be mined. Sources of silica dust in coal mining include shafts and roadways driven through other strata with hard rock, rock above or below the coal seam, rock encountered in faults/dykes and sandstone bands within the coal seams. These may increase the quartz component of the respirable dust to about 10%, or to even greater levels if significant rock cutting is being undertaken. In a Scottish coal miners' study in the 1970s exceptionally high levels of respirable quartz (up to 60%) were generated by mechanical cutting into sandstone strata above and below a coal seam (HS(G)73).

In South African diamond mines airborne respirable dust generally has a low silica content. GAP 802 reported silica levels as less than 5% in drilling dust.

The Australian Mining and Quarrying Occupational Health and Safety Committee (MAQOHSC) reported that none of the commonly quarried rocks or minerals can be guaranteed silica free although many basalt deposits (but not all) test at less than 1% crystalline silica. Rocks classified as limestone have been shown to contain up to 40% crystalline silica and granites 55% crystalline silica. Quartzites and natural sands are normally in the range 80% – 100% crystalline silica. Recycled concrete has a high silica content (greater than 80%).

Crystalline silica will be encountered in a variety of mineral processing operations such as crushing, grinding, milling, furnace additions, slag removal, furnace rebuild, ladle relining and during abrasive blasting.

## 10. What increases the risk of developing dust diseases?

Miners who work in dusty conditions should consider themselves potentially exposed to respirable dust when the mine has:

- ☛ inadequate dust control measures
- ☛ inadequate respiratory protection.

Efforts to prevent silicosis (as well as other lung related dust diseases) may be inadequate if there is:

- ☛ no employer/employee commitment to silicosis prevention
- ☛ a lack of adequate risk assessment and air monitoring for respirable dust
- ☛ a lack of awareness about the sources of dust exposure, the nature of silicosis, and the causes of the disease
- ☛ poorly or wrongly designed engineering dust controls
- ☛ a lack of adequate maintenance of engineering dust controls
- ☛ a lack of adequate respiratory protection and respirator training
- ☛ a lack of adequate medical screening and monitoring programmes
- ☛ no silicosis prevention programme or inadequate programme
- ☛ no auditing of the silicosis prevention programme
- ☛ a lack of planning in the case of new or expanding operations to eliminate or minimise dust exposures.

## 11. How can dust exposures be prevented or reduced?

The severity of silicosis or CWP is directly related to the amount of dust deposited in the lungs. Therefore, prevention depends on limiting the amount of dust breathed by miners. An effective prevention programme requires:

- ☛ use of engineering controls and their proper maintenance to reduce worker exposures to airborne dust. Examples of controls include: ventilation and dust collection systems, water sprays, wet drilling, enclosed cabs and drill platform skirts. The practice of preventive maintenance will enhance the effectiveness of dust control systems (Silica dust is very abrasive and can damage the control systems).
- ☛ training of workers on the hazards of respirable dust, engineering controls and work practices that reduce dust exposure, the importance of maintenance, good housekeeping and which operations and materials present a respirable dust hazard.
- ☛ sampling of workplace air to determine dust exposure levels, to help determine where controls may be necessary and to monitor the effectiveness of engineering controls
- ☛ a written respiratory protection programme. Ensure employees have properly fitted, approved respirators when engineering controls alone are insufficient to keep exposures within safe levels. Be sure respirators are kept clean and properly maintained and that employees are trained in their use
- ☛ medical screening to identify miners who have early evidence of the development of respiratory diseases
- ☛ auditing of the silicosis prevention programme.

## 12. Best practice in silicosis prevention

### 12.1. Employer commitment to a Silicosis Prevention Programme

The following needs to be in place for an effective programme:

- 12.1.1 An executive designated with programme oversight
- 12.1.2 Designated person(s) to co-ordinate programme implementation

- 12.1.3 A silicosis prevention task team/committee (depending on size of the company and existing structures)
- 12.1.4 Appropriate resources made available to facilitate the implementation of company strategy to deal with silicosis
- 12.1.5 A reporting mechanism to indicate progress on silicosis prevention. To include key indicators from occupational hygiene and occupational medicine
- 12.1.6 Management performance assessment to include a health and safety component which includes silicosis/CWP prevention
- 12.1.7 Key employer/company documents, e.g. annual reports to safety bulletins to include information on silicosis prevention
- 12.1.8 An employer programme to include progress monitoring of the SIMRAC Silicosis Prevention Programme (SIM 03-06-03). Any dust control initiatives identified by this project to be evaluated for relevance and implemented if appropriate.

## **12.2 Identification of dust sources and assessment of employee dust exposures during the active phases of all mining operations**

Silicosis prevention is linked to the control of dust generation and liberation into the working environment. Levels of airborne respirable dust in the workplace are therefore an indicator of risk and the possibility of the development of silicosis.

- 12.2.1 The risk assessment process should identify the sources of airborne dust and employees at risk from silicosis/ CWP.
- 12.2.2 Prepare a mandatory code of practice (COP) and ensure compliance with the requirements of the DME Guidelines for compilation of a mandatory code of practice for an occupational health programme on personal exposure to airborne pollutants. This COP should include:
  - ☛ utilisation of appropriate and correct airborne dust sampling equipment and procedures
  - ☛ prompt utilisation of the respirable dust measurements (without waiting for quartz analysis) as an indicator for the need for dust control
  - ☛ use of approved /reputable laboratories for quartz analysis
  - ☛ measures to ensure correct statistical analysis and interpretation of homogeneous exposure group data

## **12.3 Control of dust sources to eliminate or minimise dust exposures during the active phases of all mining operations**

### 12.3.1 Ventilation systems

Main and auxiliary ventilation air reduces dust by dilution and by displacement.

The basic principle behind dilution ventilation is to provide more air and thus dilute the dust concentration. Most of the time, the dust concentration is reduced roughly in proportion to increased airflow.

The basic principle behind displacement ventilation is to use the airflow in a way that confines the dust source and keeps it downwind from employees.

During the design and operation of any ventilation system the following issues must be addressed (as a minimum):

- ☛ Ensure adequate main ventilation system performance, e.g. appropriate dilution ventilation for airborne dust and correct haulage transport velocities to prevent re-entrainment of dust
- ☛ Ensure adequate auxiliary ventilation where required to control dust
- ☛ Ensure proper maintenance of ventilation systems

### 12.3.2 Dust control

The major control methods for dust in mining operations continue to be dust suppression with water; airborne dust dilution and capture at source with dust extraction systems.

The basic rules to be followed if the control of dust exposure is to be effective include:

- keeping the dust generation to a minimum
- preventing it from contaminating the atmosphere by controlling it at source.
- reducing the amount of dust present in the air.
- removing the worker from the dust laden air.
- placing a barrier between the worker and the dust laden air.
- ensuring that the installed systems for dust control are working at maximum efficiency for the maximum period of time.

For dust control to be effective, regular maintenance of the service equipment is required.

For further information on dust control see:

**Appendix A – Dust control in gold mines**

**Appendix B – Dust control in coal mines**

**Appendix C – Dust control in surface mines and quarries**

#### ***12.4 Maintenance, examination and testing of dust control measures***

Irrespective of the type of dust control systems used, maintenance of the equipment in good working order is necessary to achieve low dust levels. Maintenance of dust equipment should not be the responsibility of management alone, but of everyone involved in the mine (including suppliers).

12.4.1 Any dust control measures provided should be maintained in an efficient state, efficient working order and in good repair.

12.4.2 There must be a thorough examination and testing of all engineering controls and suitable records must be kept.

#### ***12.5 Employee involvement and commitment to the Silicosis Prevention Programme***

The involvement and commitment of employees in the silicosis prevention programme is critical.

12.5.1 Employees should be encouraged to participate actively and in a positive manner in all pollutant control activities.

12.5.2 The results of any dust survey should be made available to all employees.

12.5.3 The results and recommendations from such surveys should be discussed at the relevant health and safety meetings.

#### ***12.6 Employee education and training***

It is a legal requirement for an employer to provide health and safety training under the Mine Health and Safety Act (No. 29 of 1996). No worker can be expected to assist in making a control programme effective if he/she does not know the reasons for it in the first instance. It is important that employees know about silicosis, silica-dust hazards, and how to control their exposure. Their training and education should cover the following:

12.6.1 The health effects of exposure to crystalline silica and or coal dust.

12.6.2 The importance of effective controls, safe work practices, and personal hygiene.

12.6.3 The importance of airborne dust monitoring and how to interpret the results obtained.

12.6.4 The importance of medical surveillance.

12.6.5 How to use and care for personal respiratory protective equipment.

12.6.6 Information on the health effects of smoking in exacerbating lung damage

12.6.7 The early symptoms and signs of active tuberculosis (TB), which is a potential complication of silica exposure.

12.6.8 Refresher training and additional training as appropriate for health and safety personnel involved with silicosis prevention.

## 12.7 Administrative controls and work practices including the correct use of appropriate respiratory protection to minimise dust exposures

Work practices are procedures prepared by employers and must be followed by employers and employees to control hazards in the workplace.

### 12.7.1 Written procedures for dust control.

These need to be sufficiently detailed to provide the information required by those people and their supervisors who install, operate, monitor and maintain the dust control measures including suppliers. They need to allow the design intention, as identified in the risk assessment, to be applied in a practical way.

The written procedures for dust control must specify the control measures. They will need to include the following:

- an outline description of the plant or processes identified in the risk assessment as sources of airborne dust
- details of the equipment provided in connection with each of these sources to prevent or minimise dust being produced or becoming airborne
- details of any equipment provided to remove dust from the air before it reaches a workplace
- the design and minimum operating criteria for such equipment, including as appropriate, quality of water, water flow rates and pressures, pick sharpness, etc.
- the design and minimum required ventilation flow rates
- the systems of work to be adopted to eliminate or reduce the need for workers to go into hazardous areas close to downstream of dust sources
- arrangements for supervision and maintenance of control measures
- the respiratory protective equipment (RPE) to be provided (such as disposable dust masks) and rules about when it needs to be used to best effect, while taking account of risks to health and safety from other hazards which may be made worse by the use of RPE
- arrangements for ensuring the correct use/wearing of RPE

### 12.7.2 Removal of personnel

This is an important method of reducing employee exposure to airborne dust. Where blasting is conducted, re-entry periods are specified to prevent employees from being exposed to dust generated by blasting operations both during and after the blasting has taken place.

- Procedures must be put in place to ensure that no employee will be directly exposed to blasting fumes and associated dust.

### 12.7.3 Respiratory protection

The protection of individual workers by respiratory protection should be the last resort, but such measures may be implemented as a temporary measure. It is important that employees are involved in the selection of the type of respirator to be utilised. It is no good having state-of-the-art respirators available if employees do not utilise them correctly.

Where RPE is utilised as a means of exposure control, cognisance must be taken of the following (as a minimum):

- RPE must comply with national standards (SANS 0338).
- RPE must be appropriate for the task being performed and the environment where the task will be performed.
- RPE must be comfortable to wear and accepted by the employees required to utilise it.
- Appropriate training, awareness, maintenance and issuing facilities and procedures must be implemented.
- Special preventive measures such as the provision of airline supplied respirators may be required for high-risk areas, e.g. abrasive blasting.

### 12.7.4 Hygiene facilities

To ensure that the duration of dust exposure does not extend beyond the workshift and to provide added protection to employees and their families, special attention should be given to workers personal hygiene. An employer must provide and ensure that workers use the washing facilities.

Work clothes should not be cleaned by blowing with compressed air or shaking as this creates additional dust exposure.

An employer should ensure that there are:

- adequate handwashing facilities
- showers for each sex supplied with hot and cold water. Clean individual towels, body soap, and other appropriate cleaning agents
- clean change areas with separate storage facilities for protective work clothing and equipment and for street/personal clothes that prevent cross-contamination
- procedures for handling dusty work clothes.

### ***12.8 Periodic medical surveillance of employees exposed to airborne crystalline silica dust***

A medical surveillance programme includes medical and work history tracking, regular physical examinations, chest x-rays and lung function tests. Participating in a medical surveillance programme can help in the early detection of silicosis and associated diseases.

12.8.1 The medical surveillance required is stipulated in the regulations for silica dust exposure and for coal dust exposure under the Mine Health and Safety Act (Act No. 29 of 1996).

12.8.2 An employer must establish and maintain a system of medical surveillance for all employees in any working environment where exposure to crystalline silica occurs in excess of 10% of the OEL for crystalline silica, or where exposure to coal dust occurs in excess of 50% of the OEL for coal dust with less than 5% crystalline silica content.

### ***12.9 Auditing of the Silicosis Prevention Programme***

The purpose of an audit is to examine occupational health programmes to verify their effectiveness for preventing occupational disease and to ensure compliance with company and government standards and regulations. In addition, an audit must verify that the programme documentation will withstand third-party scrutiny.

12.9.1 Conduct an initial audit to define the current status of the silicosis prevention programme, to outline problem areas, to check documentation and to provide a baseline to document progress.

12.9.2 Rectify problem areas that may arise.

12.9.3 Ensure the provision of proper documentation.

12.9.4 Conduct periodic audits of the silicosis prevention programme.

### ***12.10 Planning in the case of new or expanding mining operations to eliminate or minimise dust exposures***

Lessons learnt from existing mines on silicosis and CWP prevention should be incorporated into the planning of new or expanding mining operations. Companies should:

12.10.1 consider each possible dust generating source and proactively plan control measures to prevent or reduce dust generation from these sources

12.10.2 select equipment with design features aimed at minimising dust generation/providing effective control of airborne dust

12.10.3 adopt methods of work and layouts that minimise the need for workers to be downwind of major dust sources.



## **APPENDIX A – Dust control in gold mines**

### **A.1 Prevention of dust formation at source**

All efforts should be concentrated on the prevention of the generation and liberation of dust at source. If this is not possible efforts should be directed towards reducing the possible exposure of employees to the airborne dust through appropriate control measures.

### **A.2 Footwall, sidewall and hanging wall cleaning**

Cleaning mechanisms and associated procedures must be put in place, as practical as possible, to ensure that all intake airways are kept clean of respirable dust or potential respirable dust generating sources. This should include the removal of both mud and dust from the footwall, sidewall and hanging wall as dust previously deposited onto these surfaces may be re-introduced into the atmosphere, if disturbed. The success of the cleaning mechanism will depend on the concentration of the chemical dust suppression agent, the amount and nature of traffic in the airway, the frequency of application of a dust suppression agent or the frequency of cleaning the airway and relative humidity and air speed in the airway.

### **A.3 Drilling operations**

Drill dust is suppressed by water injected through the drill steel which has been a common practice for many years. This does not, however, prevent dust from entering the air during the initial collaring period as the drill hole is started. Various means have been tried to prevent the escape of dust during collaring. These range from simple hand held sprays to elaborate types of suction traps around the end of the drill steel.

Factors that can lead to poor dust control on drills are often related to poor maintenance. These are failure to use water; inadequate quantities of water; plugged water holes in the drill bits, dull or damaged drill bits and dry collaring. Good drill dust control requires good maintenance. Use of compressed air to clean the drill holes is the main cause of dust exposure at the working face.

### **A.4 Blasting operations**

Procedures must be put in place to ensure that no employee will be directly exposed to blasting fumes, or required to travel in areas where blasting fumes may still be present in the atmosphere.

To minimise exposure to dust and blasting fumes a re-entry period is specified and applied. Persons are removed from the mine during blasting operations and may not re-enter the mine for a recommended period after blasting.

### **A.5 Scraping and slushing activities**

Scraping or slushing is a major source of dust generation in the underground environment. Dust concentrations produced from these activities could be reduced by:

- using high-capacity scrapers of as light a construction as possible, consistent with operating requirements
- reducing scraper speeds to approximately 0.6 m/s or less
- using scraper shovels in tandem as required for the desired tonnage
- keeping broken ore wet.

### **A.6 Tipping and transfer points**

When ore is handled underground, it often falls either over rock surfaces or through the air. The greater the impact, the greater the amount of dust produced, and in certain situations such as at large tips and belt transfer points high dust concentrations may be generated in spite of the measures taken to keep the material wet.

The most common method of dust control at transfer points is to enclose the transfer point tightly, exhaust the dust-laden air from the enclosure through a duct, and either remove the dust from the air with a dust collector or discharge it to the return airway.

## **A.7 Ore pass design and shute (finger<sup>2</sup>) controls**

Traditionally ore pass systems have been designed with finger controls. These finger controls (in conjunction with the dust filter plants) were utilised to ensure that a negative ventilating pressure was maintained in the ore pass system, thus ensuring that no dust flows from the ore pass to the intake airways. Mechanisms must be utilised to ensure that no dust will escape the ore pass system and be allowed to enter the intake airways, especially where finger controls are no longer appropriately utilised.

## **A.8 Existing dust filtration installations**

Appropriate inspection and maintenance programmes must be introduced to ensure that all existing dust filtration installations are operating effectively and in accordance with design specifications.

## **A.9 New dust filtration installations**

It is paramount to ensure that appropriate dust control methods are selected for dust control (dry scrubber, wet scrubber, filter bags, etc.).

In designing new dust filtration installations particular cognisance must be taken of the following design factors:

- Quantity of air that must be filtered to ensure that a constant negative pressure is maintained on the entire ore pass system
- Expected dust load in the air to be filtered by the installation to ensure that appropriate and effective maintenance and inspection frequencies and procedures are implemented
- Dust filtration efficiency rating of the filtration media must be appropriate for the expected dust composition and dust load to be filtered
- Possible leakages that may result from structural failures or as a result of increased static pressure must be identified and eliminated.

## **A.10 Maintenance (cleaning) of dust filtration installations**

Maintenance programmes must be designed to ensure that:

- the employees performing the maintenance are not exposed to high dust concentrations
- the maintenance activity itself will not result in employees downstream from the activity being exposed to elevated dust concentrations.

## **A.11 Efficiency testing procedure for dust filtration products**

As a minimum, all dust filtration product must comply with the testing standards as specified in SABS 1424, or BS EN 779, or DIN EN 1822 (depending on country of manufacture), or any other internationally recognised test standard. Care should be taken to ensure that the efficiencies for both large particles (also called arrestance or overall efficiency) and small particles (also called dust spot efficiency) are appropriate for the intended dust filter installation.

## **A.12 Efficacy testing of dust filtration installations**

In determining the efficacy of a dust filtration installation cognisance must be given to the efficiency of the entire dust filtration installation and not only the theoretical filtration efficiency of the filtration media.

## **A.13 Backfill spillages and exposed backfill in working areas**

Appropriate procedures and engineering control mechanisms must be put in place to ensure that any backfill spillages or exposed backfills in working areas are removed/corrected as soon as reasonably practicable.

## **A.14 Sludge pipe spillages**

Appropriate procedures and engineering control mechanisms must be put in place to ensure that any sludge pipe spillages are removed/corrected as soon as reasonably practicable.

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<sup>2</sup>. Mechanism installed in vertical ore pass system to control the flow of ore.

## **A.15 Transportation spillages (e.g. skips, empty material cars, hoppers)**

The ore and material transportation mechanisms must be designed to prevent any mud or dust from escaping these devices. Where mud or dust does escape, a remedial action procedure must be put in place to ensure that these spillages are cleaned as soon as reasonably possible.

## **A.16 Dust control from other sources (e.g. shot creting, scrapping operations, installation of support, water jetting operations, blast hole cleaning, working face cleaning, sweepings, rock crushing, rock screening, rock grinding, rock milling and drain cleaning)**

In implementing controls or work procedures to ensure reduced dust exposure from dust sources it must be ensured that:

- employees involved in these activities are not exposed to high dust concentrations
- employees downstream from these activities are not exposed to elevated dust concentrations resulting from these activities
- working areas are not contaminated with dust resulting from these activities
- any dust or mud generated or removed during these activities is appropriately contained so as to not contaminate any other part of the working environment during transportation or disposal
- the dust control initiatives implemented at these activities are appropriately implemented, maintained and frequently inspected for efficacy.

## **A.17 Screens**

Stationary or vibrating screens are utilised for size classification of the ore mined. Large amounts of dust are released if the material is allowed to dry, but if it is wet, screening does not usually present a hazard. If dust levels are high at screens the screens should, in most cases, be enclosed and exhaust ventilation should be used with wet scrubbers to capture the dust.

## **A.18 Crushers**

Large quantities of dust are produced at crushers. Most crushers are supplied with exhaust ventilation, the method applied depending on the type of crusher, size and location. To prevent contaminating the atmosphere a wet scrubber dust filter is generally utilised. Enclosures are also effective and sometimes essential.

## **APPENDIX B – Dust control in coal mines**

### **B.1 Background**

The production of the South African coal mining industry currently has a ratio between opencast and underground mining of around 48% to 52%. Conventional mechanised mining started in the 1940s with the introduction of coal cutters creating a secondary free face reducing the risk of explosions and assisting in coal fragmentation after drilling and blasting. Mechanical loaders collected the coal and conveyed it into waiting shuttle-cars. The first continuous miners were introduced into South African underground coal mines in the early 1970s.

The rate of advance per shift in headings in the South African mines is comparatively greater than those in European or US mines (SIMRAC COL 603). Thus dust and methane control (to prevent explosions) requires special provisions to ensure effective dust control and face ventilation systems.

### **B.2 Continuous miners**

A combination of dust control systems is required on continuous miners (CM) to contain the dust cloud at the CM face and to prevent rollback of the dust contaminating the incoming air breathed by coalface workers. The most commonly used ventilation and dust control systems for CMs are on-board scrubbers, water sprays, water powered air movers and auxiliary ventilation systems such as brattices, jet fans, force ventilation and force and exhaust ventilation systems. In addition, remote control has enabled an operator to be in the fresh air intake and reduce his or her dust exposure levels.

Machine mounted scrubbers collect dust laden air through one or more inlets near the front of the CM and discharge cleaned air at the back of the CM. The most commonly used scrubbers in South African coal mines are of the wet fan design. Inside the scrubber, the dust laden air passes over a fan and water spray arrangement that remove dust via the centrifugal force created by the fan's motion, it then passes through a knit wire mesh panel that is wetted with water sprays, which cause the dust particles to be captured by the water. After passing through the filter panel, the air stream then enters a demister, which removes the dust laden water droplets from the air stream. The cleaned air is discharged at the back of the scrubber unit.

The role of water sprays are (a) to wet coal surfaces to immobilise newly formed dust and prevent it from becoming airborne, (b) to collide with and engulf airborne dust particles, enabling them to settle from the air stream (airborne capture), (c) as an anti-rollback system and (d) to sweep the coal face of methane by using a directional spray pattern together with the water powered air movers. Of these, wetting the broken surfaces is the most effective dust suppression mechanism. Adequate wetting is extremely important for dust control. The vast majority of dust particles created during breakage are not released into the air, but stay attached to the surface of the broken material. Wetting the broken material ensures the dust particles stay attached. As a result, adding more water can usually, but not always, be counted on to reduce dust. Unfortunately, excessive moisture levels can also result in a host of materials handling problems, operational headaches, and product quality issues so an upper limit on water use is sometimes reached quite quickly. As a result, an alternative to adding more water is to ensure that the broken material is wetted uniformly.

Ventilation air reduces dust through both dilution and displacement. The dilution mechanism operates when miners are surrounded by a dust cloud and additional air serves to reduce the dust concentration by diluting the cloud. The displacement mechanism operates when workers are upwind of dust sources and the air velocity is high enough to keep the dust downwind reliably. CM faces use displacement ventilation. The difficulty is that when workers are near a dust source, keeping them upwind requires a considerable air velocity. Two techniques are used to compensate for the lack of air. The first is to reduce the cross-sectional area of the air course between the worker and the dust source. This confines the dust source by raising the air velocity. Secondly, the turbulence of the dust source is reduced. A turbulent dust source creates dusty eddy currents of air that back up against the airflow and push upwind towards the worker. When the dust source is less turbulent, less air is required to confine the dust cloud.

The South African Department of Minerals and Energy (DME) issued a directive in 1997 to reduce the dust concentration level (engineering sample) to below 5 mg/m<sup>3</sup> at the operator's position. This was achieved through multi-party involvement in various SIMRAC sponsored projects (e.g. COL 518). These projects involved tests on a model CM in a ventilation simulation tunnel at the CSIR's Kloppersbos Research Facility. The systems tested needed to comply with two main criteria: adequate methane dilution at the face and keeping the respirable dust concentrations below 5 mg/m<sup>3</sup>.

Control systems developed from this research and successfully applied underground are the half-curtain system, the retro-fitted hood system, the double scrubber system and the integrated hood system. Of all the systems tested, the half-curtain dust control system proved to be the most successful for CMs. Details of the systems are discussed in the SIMRAC research reports COL518 and COL619. Elements of a typical half-curtain dust control system are:

- a hollow-cone spray nozzle (1.6 mm inlet/2.0 mm outlet diameter) with a Kloppersbos directional spray system
- air movers fitted over the flight conveyor
- an extended scrubber intake with an inlet cone fitted
- a physical half curtain.

### B.3 Road headers

The first boom type road heading machines were reportedly developed in the 1940s, but it was not until the late 1960s that use of the machines became widespread in the European coal industry, largely replacing drill-and-blast techniques for roadway development. In Europe, traditionally, underground coal production is predominantly carried out using longwall techniques requiring a large amount of preparatory roadway development in the form of single, straight line drivages.

In South Africa, road heading machines were introduced in the mid 1980s and found application as an extraction system by many of the coal operators. Although the machines used in the local coal industry are a similar type to the European heavy duty ripping head machines, their use in South Africa for room and pillar production presents quite different operational conditions with regard to environmental control. In European coal mines, primary control systems in the form of auxiliary ventilation, can be quite complex and highly engineered to ensure consistent ventilation conditions from day to day, since a single drivage may take several months to complete. In South African bord and pillar mining, however, the workplace is forever changing and production requirements demand that auxiliary ventilation be simple and easy to move. Furthermore, the much greater advance rates (and the associated increased dust and methane production) in South Africa means that better standards of environmental control are often required to achieve working conditions similar to those in Europe.

The dual requirements to control dust while ensuring adequate ventilation for the removal of methane in coal mining means that control of the environment comprises a number of different elements, incorporating:

1. primary ventilation of the workplace (including auxiliary ventilation) generally to provide fresh air; remove gas and dust and maintain an acceptable working climate
2. secondary, machine mounted ventilation systems (including scrubbers, fans, spray systems and air curtains) to ensure adequate ventilation flows at the face and around the machine to prevent any dangerous accumulation of methane and control of dust from cutting
3. water spray systems for dust suppression and ignition prevention.

In high seam coal mining headings, the control of dust is difficult as the water sprays or air movers alone will not be able to contain the rollback of dust towards the operator. During 1999 and 2000, CSIR Miningtek successfully developed a dust control system, which was able to contain the engineering dust concentration levels at the operator's cabin position to less than five mg/m<sup>3</sup> in a mining seam height of 5.2 m. A unique feature of the new dust control system was a 'concave spade plate' that prevented the rollback of dust from the falling coal, and assisted in containing it in the face area, while at the same time guiding in a smooth airflow to and across the face area. The concave shape of the plate prevents or slows down the momentum of falling dust cloud or rollback dust, and prevents further travelling towards the operator's cabin, acting as a physical shield. As the falling dust rolls towards the spade area, its concave shape forces the dust to travel back towards the face. On the other hand, when auxiliary ventilation such as a jet fan and column are used, the concave shape of the spade plate does not act as a shield and rather guides the fresh air to reach the face area.

The critical elements of the road header dust control system (COL 603) are as follows:

- Hollow cone single inlet-nozzles – 1.6 mm (inlet)/2.0 mm (outlet) with a new spray configuration
- Physical half-curtain covering an area from the scrubber on the left hand side (LHS) of the machine to the middle of the machine over the flight conveyor. This curtain consists of a conveyor belt positioned approximately one metre from the scrubber inlet.
- Concave spade plate
- Air movers on the flight conveyor and on the LHS of the operator
- Jib sprays on the LHS and concave spade plates
- Flight conveyor discharge cover
- 45° scrubber deflector plate
- Operating water spray pressure ranging from 15 to 20 bar at a flow rate of 3.0 to 3.5 L/min/nozzle.

## B.4 Longwall operations

Longwall coal mining operations have several major benefits for underground mining operations. The most important of these are increased extraction of the coal deposit compared to extraction of the order of 60% with conventional and CM bord and pillar operations and an improvement in ground water control.

Currently, only a handful of longwall faces are operational in South Africa. A local study of personnel exposure data from underground coal mines indicates that the highest dust concentrations in coal mines were experienced in 'longwall mining sections'.

Similar to dust control in other mining methods, ventilation is still the primary dust control means in a longwall operation. Homotropical ventilation, ventilation in the same direction as the coal is transported, is the most effective technique. Apart from the ventilation, water is the principal means used for dust suppression in coal mining. As such, a shearer-spray-system design with adequate water pressure, water quality, and water delivery system is paramount in effective control of dust.

### B.4.1 Kloppersbos Shearer Spray Curtain (KSSC) Dust Control System (COL 807)

In the longwall face dust is effectively controlled using different approaches:

- Suppressing the dust using sprays
- Containing the dust at the face using curtains
- Directional external sprays
- Preventing the dust from the upwind drum into the walkway by effective ventilation system.

For the most effective dust control, the external spray system must be orientated in the direction of the primary airflow. The principle of the KSSC design is that the sprays would direct the dust downwind towards the return air and confine the dust to the face area through sprays and physical air curtains, thereby creating a clean air split over the walkway. The design is most effective when using the correct type of nozzle, optimum water pressure and flow rate on both external and drum sprays and maintaining a minimum air velocity of 2.0 m/s.

### B.4.2 External spray and drum spray nozzles – spray configuration

Selection of the correct nozzle types, number of nozzles, position of nozzles and the direction of these is critical for effective dust control. By selecting the optimum water pressures, flow rate and proper orifice size of nozzle, effective dust control results can be obtained even where limited water supply exists.

Sprays are commonly installed on the cutting drum referred to as spray drums of longwall mining machines. Sprays mounted on the drum are effective in suppressing the respirable dust at the bit-coal interface and preventing it from becoming airborne. Sprays on the body of the machine, referred to as external sprays, are used to redirect dust that has already become airborne away from the machine operator as well as capturing airborne dust.

The KSSC dust control design is expected to improve dust control because:

- the design uses the principle that splits the dusty and clean air at the front end of the shearer by using the external spray bar, where the operator will be in the clean air
- the nozzle position on the external spray arms is configured to direct the dusty air against the face and towards the return, without spilling out onto the walkway
- the upwind splitter arm length extends beyond 0.35 m from the cutting edge of the upwind drum
- the downwind splitter arm is at least 1.25 m from the end of the tail-end drum, which together with a designed spray configuration guides and contains the dust
- hollow cone nozzles are used as external spray nozzles
- the nozzles on the body of the shearer are positioned at an angle ranging from 15° to 45° in the direction of the return air
- conveyor belting is used in the front end and tail end of the shearer, which will contain the dust inside the walkway
- the external nozzle design positions ensure that debris will not block it and will require minimum maintenance.

### B.4.3 Water pressure and flowrate

Proper selection of nozzles with optimum water pressure and water flowrate is critical for controlling dust. Solid stream nozzles are recommended for drum sprays. The optimum drum spray pressure ranges from 5 to 7 bar with water flow rate of

3.5 L/min. The recommended nozzle orifice for the drum sprays is 1.8 mm. The recommended pressures are operating pressures at the nozzle, and can be measured with a T-connector inserted into the spray block with the spray at one end of the tee and the pressure gauge at the other end. The increased water supply and pressure to the drum sprays reduces the shearer dust generation, increases dust knockdown and reduces airborne dust. The total water flow to the drum sprays is in the order of 200 to 250 L/min. Higher water flow to the shearer drum further wets the coal and reduces the entrainment of dust during the transport of coal along the belt lines. Hollow cone nozzles are to be used for external sprays. The recommended hollow cone nozzles have an orifice size of 2.0 mm. The external spray pressure should range between 15 and 20 bar at the nozzle.

## **B.5 Conveying**

Conveying by rail car usually generates little dust. Rubber tired vehicles will kick up dust if the mine floor is dry. The dust from the floor can be reduced by wetting down, by using calcium chloride as a binding agent, or by using any of the chemical additives to control dust at surface mines.

A conveyor belt can generate large amounts of airborne dust from several sources. Dust can originate at transfer points and can be shaken from the belt as the belt passes over the idlers. Spillage of material from the belt can also be a big contributor. Further, high velocity of ventilation air (>4m/s) will assist the release of dust by drying the material and entraining settled dust.

If dust concentrations are high in belt roads, the relevant questions to address are:

1. Are transfer points enclosed? A simple enclosure with an internal spray or two may be adequate. If not then the air inside must be exhausted to a dust collector, with all of the leakage points on the enclosure properly sealed.
2. Is the material being conveyed adequately wet, but not so much that it leaves a sticky mud residue on the belt? When this residue dries, dust is released, thus an end result of excessive wetting can be increased belt dust.
3. Are the undersides of both the top and the bottom belts wetted so that dust sticking to the belt is not shaken loose by the idlers? Does the belt stay wet or is it drying out and releasing dust?
4. Are the belt scrapers working properly? Is a second set of scrapers being used? Has a belt washing system been tried?
5. Is the belt running and not spilling its contents?

## **Appendix C – Dust control in surface mines**

### **C.1 Background**

There are several types of surface mining, but the three most common are open pit mining, strip mining, and quarrying. Open pit mining often results in a large hole, or pit, being formed in the process of extracting a mineral. It can also result in a portion of a hilltop being removed. In strip mining, a long, narrow strip of mineral is uncovered by a dragline, large shovel, or similar type of excavator. After the mineral has been removed, another strip next to the original one is excavated and the waste material deposited in the first strip. Strip mining is usually used in cases of long, flat deposits of coal. Traditionally, quarrying involved the excavation of large blocks of stone and raw minerals for ornamental use. Today, the term quarrying has been applied to the mining of sand, gravel, and crushed stone for the production of roads, cement, concrete, etc. The processes used in this type of quarrying are similar to those used in open pit mining.

All 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. The 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 wide range of surface mining activities can generate dust. Dust sources may be localised, from drilling, blasting, truck loading, and ore crushing and conveyor transfer within the process plant. Other sources of dust around the mine site are more diffuse, typically arising from relatively large areas such as haul roads, waste rock dumps, pits, tailings impoundments and miscellaneous areas of disturbed and bare ground in and around the site. These are categorised as 'fugitive' dust emissions sources, in contrast to point source emissions.

Overburden drilling is a major source of the respirable dust that affects workers at surface mines. Control measures vary from using water during the drilling operation to the provision of local exhaust ventilation to remove the dust from the head of the hole to a dust collection unit, to the provision of a ventilated cabin for the operator. The most effective of these precautions is the provision of a control cabin on the drilling rig provided with a suitable extraction system fitted with a dust filter to remove harmful dust and maintain the dust level within the cabin to below acceptable control levels. Any extraction equipment should periodically be examined to ensure it is maintained to its design standard.

Overburden removal by mobile excavation equipment such as bulldozers, front-end loaders, and haulage trucks can be dusty, particularly under dry and windy conditions. Tightly enclosed cabs with dust filtration systems can substantially lower the dust exposure of both drill and mobile equipment operators. Haul road dust control can be achieved by water application or chemical application.

### **C.2 Enclosed cabs on drills and mobile equipment**

Enclosed cabs can work well to reduce dust exposure, but require a lot of maintenance. Older cabs can be improved by being retrofitted with systems that heat, cool and filter the air and by being tightly sealed. Since positive pressurisation cannot be achieved unless cabs are leak tight, they should be checked regularly for leaks. Cab interiors should also be regularly vacuumed and cleaned to remove the dust that drifts in through open windows or is carried in on an operator's clothing. The practice of operating with doors or windows open on enclosed cabs should be avoided.

### **C.3 Haul road dust control**

Many methods are available for haul road dust control. Water application to the road surface is the most obvious, but there are other binding agents such as salts, surfactants, soil cements, bitumens and films. The best control method depends on the type of road and type and quantity of spillage that will be encountered. Various parts of a test section of the road can be controlled with different products, if there is uncertainty about the type of control to be used. If the process fails at the test section, only a small investment and time have been lost.



## **C.4 General precautions for avoiding dust (adapted from Mining and Quarrying Occupational Health and Safety Committee, Australia recommendations)**

- C.4.1 Measures should be aimed at containment and/or removal of the generated dust at source and reliance on personal protective equipment should be regarded as a last resort.
- C.4.2 Drills should have dust extraction systems with collectors fitted. Do not merely allow drilling dust to vent to atmosphere.
- C.4.3 Controls remote from drill mast are advisable. Use cabin if fitted to rig.
- C.4.4 If drilling (or rock cutting) method does not permit effective dry dust extraction at the collar then water application should be used to minimise risk and use of a suitable dust mask is advised.
- C.4.5 Loaders and trucks should have well maintained air conditioning/filtration systems fitted and the practice of operating with doors or windows open should be avoided.
- C.4.6 Keep door and window seals in good order.
- C.4.7 Cabins of loaders and trucks should be cleaned regularly by vacuum to avoid constant disturbance of any accumulated dust.
- C.4.8 Roadways should be watered constantly during dry periods. Suppressants can be useful in some cases. In ground sprays can be used in some cases.
- C.4.9 Ensure that vehicle exhausts do not point down at road surface.
- C.4.10 Crushing plant should be operated from enclosed cabins that have adequate air-conditioning/filtration system fitted (preferably pressurised).
- C.4.11 Remove dust build up (which arises from shoes, etc.) from cabin regularly and preferably daily by means of a vacuum fitted with a fine particulate filter.
- C.4.12 All transfer points should be fitted with dust boxes and ideally filter type extraction systems.
- C.4.13 Screens should be enclosed in either a clad structure or by rubber dust covers. Enclosures should have extraction systems.

Note: Dust can build up to extremely large volumes in screenhouses, particularly on wall girts and “dead” areas even where extraction is used. This creates a risk for people entering the enclosure for maintenance or other reasons.

Never enter a screenhouse whether the screen is operating or not without wearing an appropriate dust mask.

- C.4.14 Crushers should be enclosed where possible in enclosures with extraction systems. Alternatively, an extraction system should be fitted at the discharge box/chute. Impact and autogenous crushers are prone to generating large volumes of dust compared to other types, owing to their speed and method of operation, .
- C.4.15 Use windsocks or other appropriate dust control methods at bin discharges. Devise a system to avoid persons leaving trucks or standing at the bin lever to load trucks.
- C.4.16 Use sprinkler system on open stockpiles where necessary.
- C.4.17 Use tarps or covers on road trucks.
- C.4.18 Do not use oxy-set or compressed air to clear dust. Maintenance operators who disturb dust accumulations are at risk. Controls should be put in place to minimise this risk, e.g. removal of dust by vacuum prior to commencement of work. Use appropriate particulate dust masks where there is a risk of disturbing dust accumulations.

- C.4.19 In areas where dust cannot be engineered out, prevent entry to area unless a respirator programme has been implemented.
- C.4.20 Avoid all eye contact.
- C.4.21 Introduce a regular, planned programme of dust monitoring, both personal and by location to ensure that the dust control methods remain effective.
- C.4.22 Change and wash facilities should be provided and used.
- C.4.23 Wash dusty clothes regularly and separately from other clothes. Research suggests contamination of other clothes by dust during the washing process may put others at risk.
- C.4.24 Clean all personal protective equipment prior to storing or re-use.

## Appendix D – Legislation (South Africa)

### Department of Minerals and Energy (DME)

Mine Health and Safety Act (MHSA) (No. 29 of 1996)

- ☛ Regulations under the MHSA (Occupational Hygiene), 2002
- ☛ Guideline for the compilation of a mandatory code of practice for an occupational health programme on personal exposure to airborne pollutants, 2002 (under revision)
- ☛ South African Mines Occupational Hygiene Programme Code Book, 2002 (under revision)
- ☛ Guidance note for the prevention of flammable gas and coal dust explosions in collieries, 2002
- ☛ Gravimetric dust sampling at mechanical miner sections in collieries (Instruction), 2004
- ☛ Regulations for Medical Surveillance for Silica Dust Exposure and for Coal Dust Exposure, 2004.

### Department of Labour (DoL)

Occupational Health and Safety Act (No. 85 of 1993)

- ☛ Hazardous Chemical Substances Regulations, 1995

Table DI Listing of OELs for respirable crystalline silica and coal dust

Substance	CAS Number	DME OEL 2002 mg/m <sup>3</sup>	DoL OEL 1995** mg/m <sup>3</sup>
<b>Silica, crystalline*</b>	–	–	0.4
Cristobalite	14464-46-1	0.1	0.4
Quartz	14808-60-7	0.1	0.4
Tridymite	15468-32-3	0.1	0.4
Tripoli	1317-95-9	0.1	0.4
<b>Coal dust</b>	–	–	2
<5% crystalline quartz/silica	–	2	–
>5% crystalline quartz/silica	–	see silica – crystalline (quartz)	–

\* Must be kept as far below the OEL as is reasonably practicable.

\*\* Based on the HSE (UK) OELs at that time. In 2005 the DoL planned to reduce its crystalline silica OEL-Control Limit to 0.1 mg/m<sup>3</sup> in 2006.

## Appendix E – Variability in fibrogenic potency of respirable crystalline silica

The HSE (UK) introduced a Maximum Exposure Limit (MEL) for respirable crystalline silica (RCS) of 0.4 mg/m<sup>3</sup> (8-hour time weighted average [TWA]) in 1992. In 1997, the MEL was reduced to 0.3 mg/m<sup>3</sup> following the adoption of the ISO/CEN sampling convention for respirable dusts. In 2003, the HSE issued a chemical hazard alert notice (CHAN 35) on RCS that stated that current evidence indicates that if workers are exposed regularly to 0.3 mg/m<sup>3</sup> there is a much higher risk of lung damage than had been previously thought. HSE believes it should now be reasonably practicable for all industry sectors to control RCS to 0.1 mg/m<sup>3</sup> (8-hour TWA). The purpose of CHAN 35 was to raise awareness among employers and workers about the new evidence on RCS and to advise that employers should aim to control exposures to 0.1 mg/m<sup>3</sup> (8-hour TWA) or below.

A review of the variability in fibrogenic potency and exposure response relationships for silicosis was published by the HSE in 2002 (EH75/4). The following text is from the report summary.

All forms of crystalline silica have the potential to cause silicosis. This is an irreversible and progressive condition in which healthy lung tissue becomes replaced with areas of fibrosis. However, human experience and experimental evidence both indicate that at specified levels of exposure, the potential to cause silicosis may be influenced by the type of industrial processing and by the presence of surrounding minerals associated with the crystalline silica. Such factors are capable of modifying the surface chemistry and thus the biological effects of crystalline silica, as well as changing the particle size characteristics. Thus in different occupational settings, exposure to the same airborne mass concentrations of RCS might pose greater or lesser risks to health depending on the influence of such factors, referred to as ‘Potency Factors’.

### Variability according to polymorphic type of crystalline silica

Experimental evidence indicates that the toxicity of crystalline silica varies according to polymorphic form; cristobalite, tridymite and quartz appear more reactive and more cytotoxic than coesite and stishovite. Quartz is by far the most commonly encountered polymorph of crystalline silica, although in some circumstances there can also be occupational exposure to cristobalite, e.g. from the conversion of quartz in the high temperature conditions of industrial furnaces and kilns. Overall, it is concluded that there are no theoretical grounds or any convincing scientific evidence to indicate any differences in the toxic properties of cristobalite and quartz.

### Variability owing to the presence of other minerals

Occupational exposure to quartz may occur as a result of its close geological association with aluminium-containing clay minerals, such as muds, marls or shale-based clays. Such materials are used in the heavy clay industry to make bricks, tiles and pipes. In some coal mines, some of the quartz present may be coated with aluminium containing clay minerals such as kaolinite and illite, found in dirt bands associated with coal deposits. There is experimental, animal and human evidence all consistently pointing in the same direction to indicate that the toxic effects of quartz are reduced in the presence of such aluminium containing clay minerals. It has been suggested that this is because of the binding of aluminium ions (Al<sup>3+</sup>) to the surface silanol groups of quartz. Over the millions of years of geological formation of coal, the surface of quartz grains in dirt bands associated with coal strata can become coated or intergrown with clay minerals. Note that these quartz grains are merely liberated and not fractured during coal getting activities, and retain their mineral coating. It may well be that it is the amount of ‘free’ quartz surface, rather than the total amount of quartz present in respirable coal mine dust that is relevant to the risk of coal workers’ pneumoconiosis.

However, there is evidence from a number of animal studies indicating that the protective effect of aluminium containing minerals is not permanent. This is presumably because of the differential clearance of Al<sup>3+</sup> and quartz from the lungs. The retained ‘cleaned’ quartz eventually begins to express its pathogenic properties. This may partly explain the progression of pneumoconiosis in retired coal miners, but there is a lack of clear evidence on this point.

### Variability owing to particle number, size and surface area

Current knowledge suggests that regardless of the type of dust, the total surface area of dust retained in the lungs is an important determinant of toxicity. Surface area is related to particle size – small particles possess a larger surface area per unit mass compared to larger sized particles. Hence, smaller particle size fractions (very fine dust) of RCS would be expected to produce more lung damage than equal masses of larger respirable size fractions.

## Variability between freshly fractured and “aged” surfaces

Cleavage of crystalline silica particles into smaller fragments results in the formation of reactive radical species at the newly generated particle surfaces. This leads to an increase in cytotoxicity in the short-term in-vitro tests independent of particle size reductions. However, the activity of the free radicals decays with time, a process known as “aging”. This occurs slowly in air, but rapidly (within minutes) in water. This phenomenon has not been well studied in animals, but available evidence demonstrates enhanced lung damage with freshly fractured quartz. Inferences drawn from human studies are consistent with the contention that exposure to aged surfaces may be less hazardous than exposure to freshly cut surfaces of quartz. From what is understood about particle aging, the use of “wet-processes” will help to reduce the reactivity of any freshly cut quartz surfaces, by quenching the formation of free radicals at the cut surfaces. However, this will depend on the effectiveness of the wetting process and the time interval between dust generation and inhalation. In the seconds (or less) between generating the dust and the deposition of the dust into the lungs, it is unlikely that wet processes could completely alleviate the enhanced toxicity of freshly cut surfaces. Freshly cut surfaces may be generated in abrasive processes such as grinding, drilling and crushing.

## Exposure response relationship(s) for silicosis

Widely different estimates have been reported for the risk of developing silicosis in different epidemiological studies covering a range of industries in which exposure to crystalline silica occurs. Much of this variation is considered to be caused by inaccuracies in the assessment of past exposure, uncertainties in the diagnosis of silicosis and differences in study design. However, in some studies, it is possible that the low observed prevalences of silicosis relative to other studies may be caused by co-exposure to aluminium containing minerals as well as the absence of significant exposures to freshly fractured surfaces.

The numerical risk estimates derived from the Scottish coal miners’ study are shown below in Table E1. Note that they apply to the risks of developing silicosis 15 years post-exposure, which reflects the long period of radiological follow-up in this workforce.

In this study the workers encountered major seams of sandstone (almost pure quartz), which generated relatively high exposures to freshly cut surfaces of respirable quartz, uncontaminated with other minerals. It is emphasised that exposures to quartz in this study are not typical of most coal mining situations where quartz is more closely admixed with coal minerals.

It should be noted that these risk predictions only apply when individual exposures do not exceed absolute concentrations of 2 mg/m<sup>3</sup>. If average exposures exceed this value, even for periods of just a couple of months, then the risks of developing silicosis are likely to rise to exceptionally high levels. This is presumably because of an overwhelming of the lung defence mechanisms at high rates of dose delivery.

**Table E1 Predicted risks of developing silicosis based on a study on Scottish coal miners**

15 years exposure to crystalline silica (8-hour TWA) mg/m <sup>3</sup>	Equivalent cumulative exposure mg/m <sup>3</sup> years	Risk of developing silicosis 15 years post-exposure as indicated by ILO score 2/1
0.02	0.3	0.25%
0.04	0.6	0.5%
0.1	1.5	2.5%
0.3	4.5	20%

In most studies that have investigated exposure response relationships for silicosis, lower radiological scores, either Category 1/0 or Category 1/1, have been used as indicators of silicosis development. However, Category 1/0 represents only minor radiographic abnormality, and is not necessarily indicative of the development of silicosis, nor would it be expected to be associated with any functional impairment. A key difficulty associated with the ILO score Category 1/1 relates to the subjective nature of the scoring process. There is a particularly high degree of inter-reader variability associated with Category 1/1 that makes it difficult to reach agreement on the number of x-ray films that should be assigned this score.

In contrast the scoring of Category 2/1 is less subject to problems of reader variability. Furthermore, compared to Categories 1/0 and 1/1, the ILO score Category 2/1 is a more specific, though less sensitive indicator of the presence of silicosis in workers with a history of occupational exposure to crystalline silica.

Because of the exposure durations that applied in the Scottish coal miners' study, there are uncertainties in extrapolating the risks to a 40-year working lifetime. However, observations in retired workers from the Vermont granite industry (USA) have shown that a very low risk (<1%) of developing silicosis (Category 2/1) results from a 20 – 40 year exposure to RCS when exposures are controlled to 0.06 mg/m<sup>3</sup> (8-hour TWA).

The following "Potency Matrix" (Table E2) proposes how various factors might influence the fibrogenic potency of RCS, i.e. its ability to cause silicosis in different circumstances of occupational exposure.

Table E2 Respirable crystalline silica (RCS) potency matrix

Potency Factors	Comment	Relevant Exposure Situations
Dust of extremely small particle size	Enhanced potency compared with exposures to the same mass of larger size respirable particles	High energy grinding and abrasive processes. Exposure to silica flours
Production of dry freshly cut surfaces of RCS	This form of RCS is presented as the "reference point" against which the potency of forms is compared	Drilling, blasting, grinding and all other abrasive processes
Wetting of freshly cut surfaces	Reduced potency compared to dry freshly cut surfaces.	Wet extraction or handling processes
<i>Effect depends on efficiency of wetting and how long the surfaces have been wetted prior to inhalation. Note that the main risk management benefit of wetting is <u>dust suppression</u> rather than potency reduction.</i>		
Exposure to "aged" dusts Dusts that have not been freshly cut or ground	Reduced potency compared to freshly cut or ground dusts	Handling or non-abrasive processing of dusts after storage
Presence of aluminium-containing clay minerals which coat the surfaces of the silica particles	Reduced potency compared to freshly fractured uncoated surfaces. <i>The clay coating may wear off during residence in the lungs allowing the toxicity of the quartz particles to be expressed</i>	Work in the heavy clay industry or in mines extracting low rank coals
Cristobalite	Equivalent potency to quartz for equivalent conditions of exposure	Heating of quartz-containing materials in furnaces and kilns

## Appendix F – Respirable dust measurement

Respirable dust measurements may be taken for a variety of reasons including to determine employee exposures to airborne dust to assess compliance with occupational exposure limits, to determine where controls may be necessary, or to monitor the effectiveness of engineering controls. The concentration of respirable dust shall be determined from the fraction passing a size selector with an efficiency in accordance with the ISO/CEN size selective criteria that will allow:

97% of particles of 1  $\mu\text{m}$  aerodynamic diameter

50% of particles of 4  $\mu\text{m}$  aerodynamic diameter

30% of particles of 5  $\mu\text{m}$  aerodynamic diameter

1% of particles of 10  $\mu\text{m}$  aerodynamic diameter

Exposure to respirable crystalline silica must be kept as far below the OEL as is reasonably practicable.

Guidance on respirable dust sampling is given in the Silicosis Prevention Information Resources CD.

## Appendix G – Medical surveillance

Medical surveillance is required for workers exposed to crystalline silica dust where significant risk occurs. Regulations were issued in South Africa in 2004 under the Mine Health and Safety Act (No. 29 of 1996) for workers exposed to coal dust and crystalline silica dust.

### Regulations for medical surveillance for coal dust exposure

#### 11.6 Coal dust

##### System of Medical Surveillance

11.6(1)(a) The employer must establish and maintain a system of medical surveillance as contemplated in section 13, for all employees who perform work in any working place where exposure to coal dust occurs in excess of 50% of the OEL for coal dust with less than 5% crystalline silica content as set out in Schedule 22.9(2)(a) and (b).

(b) If the crystalline silica content of the coal dust is 5% or more, the employer must establish and maintain a system of medical surveillance as contemplated in regulations 11.7(1) to 11.7(7):

##### Types of Examinations to be Performed

11.6(2) The system of medical surveillance contemplated in regulation 11.6(1)(a) must consist of an initial examination, periodic examinations and an exit examination.

##### Initial Examination

11.6(3) The employer must ensure that an initial examination is performed before an employee commences employment, or within 30 days of commencement of employment, in any working place contemplated in regulation 11.6(1)(a). The initial examination must consist of:

(a) the completion of an appropriate respiratory questionnaire aimed at establishing the employee's medical profile, including current and past cardio-respiratory problems and an occupational history detailing possible exposure to coal dust.

(b) a cardio-respiratory examination, including:

(i) a full size chest x-ray; and

(ii) a lung function test.

##### Periodic Examinations

11.6(4) The employer must ensure that the following periodic examinations are conducted on all employees required to undergo medical surveillance in terms of regulation 11.6(1)(a):

(a) a cardio-respiratory examination, including a lung function test, but excluding a chest x-ray, one year after the initial examination contemplated in regulation 11.6(3); and thereafter

(b) a cardio-respiratory examination, at three yearly intervals, which includes:

(i) a full size chest x-ray; and

(ii) a lung function test.

##### Exit Examination

11.6(5) In addition to the exit medical examination for the purposes of section 17, the employer must arrange a cardio-respiratory examination for every employee subject to medical surveillance in terms of regulation 11.6(1)(a) and who is permanently transferred to a working place in respect of which medical surveillance is not required under regulation 11.6(1)(a).



11.6(6) A full size chest x-ray conducted within the preceding twelve months may be used as the exit chest x-ray for the purposes of section 17 and regulation 11.6(5).

11.6(7) A lung function test conducted within the preceding twelve months may be used as the lung function test for the purposes of section 17 and regulation 11.6(5).

## **Regulations for medical surveillance for silica dust exposure**

### **11.7 Crystalline silica dust**

#### **System of Medical Surveillance**

11.7(1) The employer must establish and maintain a system of medical surveillance as contemplated in section 13, for all employees who perform work in any working place where exposure to crystalline silica dust occurs in excess of 10% of the OEL for crystalline silica dust as set out in Schedule 22.9(2)(a) and (b).

#### **Types of Examinations to be Performed**

11.7(2) The system of medical surveillance contemplated in regulation 11.7(1) must consist of an initial examination, periodic examinations and an exit examination.

#### **Initial Examination**

11.7(3) The employer must ensure that an initial examination is performed before an employee commences employment, or within 30 days of commencement of employment, in any working place contemplated in regulation 11.7(1) The initial examination must consist of:

(a) the completion of an appropriate respiratory questionnaire aimed at establishing the employee's medical profile, including current and past cardio-respiratory problems and an occupational history detailing possible exposure to silica dust.

(b) a cardio-respiratory examination, including:

(i) a full size chest x-ray; and

(ii) a lung function test.

#### **Periodic Examinations**

11.7(4) The employer must ensure that the following periodic examinations are conducted on all employees required to undergo medical surveillance in terms of regulation 11.7(1):

(a) a cardio-respiratory examination, including a lung function test, but excluding a chest x-ray, one year after the initial examination contemplated in regulation 11.7(3); and thereafter

(b) a cardio-respiratory examination, at three yearly intervals, which includes:

(i) a full size chest x-ray; and

(ii) a lung function test.

#### **Exit Examination**

11.7(5) In addition to the exit medical examination for the purposes of section 17, the employer must arrange a cardio-respiratory examination for every employee subject to medical surveillance in terms of regulation 11.7(1) and who is permanently transferred to a working place in respect of which medical surveillance is not required under regulation 11.7(1).

11.7(6) A full size chest x-ray conducted within the preceding twelve months may be used as the exit chest x-ray for the purposes of section 17 and regulation 11.7(5).

11.7(7) A lung function test conducted within the preceding twelve months may be used as the lung function test for the purposes of section 17 and regulation 11.7(5).

## **Definitions**

**Full size chest x-ray** – a chest x-ray using a photographic plate measuring 35 cm x 35 cm or 35 cm x 42 cm or the digital equivalent

**Lung function test** – the measurement of the inspired and expired volume of air by means of spirometry

**Cardio-respiratory examination** – a clinical examination of the cardio-respiratory system including a full size chest x-ray and a lung function test.

## **Appendix H – Case studies: Australia, South Africa, Sweden and the USA**

This appendix covers the:

1. Standing Committee on Dust Research and Control, New South Wales, Australia.
2. Work of AngloGold to Manage Dust in Underground Gold Mines in South Africa.
3. The Elimination of Silicosis in Sweden.
4. Advisory Committee on the Elimination of Pneumoconiosis Among Coal Mine Workers (Advisory Committee), USA.
5. National Campaigns to Eliminate both Black Lung and Silicosis, Mine Safety and Health Administration (MSHA), USA.
6. Silicosis Prevention Program, National Industrial Sand Association (NISA), USA.
7. ASTM E 1132-99a “Standard Practice for Health Requirements Relating to Occupational Exposure to Respirable Crystalline Silica”, USA.

## **Standing Committee on Dust Research and Control, New South Wales, Australia**

In the decade leading up to the creation of the Joint Coal Board (JCB), the problem of dust-related lung disease amongst coal mine workers attracted widespread public attention, resulting in the 1939 Royal Commission into Health and Safety recommending a minimum dust concentration standard.

The creation of the Joint Coal Board in 1947 provided greater institutional and government commitment to enforcing compliance with this dust standard and the Board began to manage dust suppression techniques and practices that had been mandated by amendments to the Coal Mines Regulation Act. At that time, pneumoconiosis prevalence was 16% (all categories) and 4.5% (category 2 or worse).

In 1954 the Board formalised its management of dust control by establishing a unique tripartite committee, the Standing Committee on Dust Research and Control, dedicated to the vigilant and strategic monitoring of dust levels and to supporting research on methods of dust suppression. Representatives were drawn from colliery proprietors, mining unions, government departments and JCB medical and engineering personnel. The main role of the Committee was to:

- monitor the results of respirable dust sampling
- evaluate dust hazards
- research improved dust control methods
- disseminate information
- educate mine personnel in matters related to dust control.

Over the years the Standing Dust Committee has initiated a number of innovative and important changes in dust control techniques within the industry and produced publications that have been widely circulated. These include, but are not limited to: Technical bulletins and reports, Respirable Dust in Coal Mines booklet, Dust the Invisible Killer booklet and video, Disposable dust masks for underground use, Respirable Quartz booklet and Diesel Particulate booklet and video.

Pneumoconiosis prevalence today is so low that no new cases have been recorded in New South Wales in the past 10 years and it has been acknowledged that the Standing Dust Committee has been instrumental in effecting this improvement.

The Committee has examined the "Review of the Australian Occupational Exposure Standard for Crystalline Silica" and has recommended that a separate review be undertaken to determine an occupational exposure standard for respirable crystalline silica in coal dust.

The Standing Dust Committee meets bimonthly, usually at mine sites.

## Work of AngloGold in South Africa to Address Airborne Dust

Paper presented at the MVS Annual Congress 2002 (excluding figures)

### “MANAGING THE BASICS”

#### A HOLISTIC APPROACH TO MANAGING DUST IN UNDERGROUND GOLD MINES

By Kobus Dekker

#### Synopsis

*“While our historic preoccupation with the recognition of occupational diseases and the compensation of workers have value in their own right, we must focus on prevention.”*

May Hermanus, Chief Inspector of Mines – October 2001<sup>1</sup>

The aim of this paper is:

- ☛ To describe the management process that was adopted to facilitate the implementation of a process used to control, minimise and ultimately to eliminate the associated health risk to which our employees may be exposed, and
- ☛ To highlight some of the findings that resulted from the implementation of this process.

### Introduction

In his award-winning paper “from dust to dust”<sup>2</sup> Des Wrigley explained the process being followed by AngloGold in addressing the Occupational Dust Health Risk. He discussed in detail the implementation of an appropriate dust concentration evaluation and recording system which is used to control, minimise and ultimately to eliminate the associated health risk to which our employees may be exposed.

Silicosis and tuberculosis are only two of the lung diseases listed in the Occupational Diseases in Mines and Works Act (Act 208 of 1993). Silicosis occurs as a result of exposure to silica dust particles<sup>3</sup> that are small enough to reach the alveoli of the lung. Exposure to silica dust can also increase a person’s susceptibility to tuberculosis.<sup>4</sup>

The main sources of dust and dust generation in underground mines have been well defined and documented by both Mine Ventilation Engineers<sup>5</sup> and research organisations, such as SIMRAC. These sources include dust generation from blasting operations, rock cutting and loading, raise and blind hole boring equipment, drilling operations, transportation of rock and ore tipping at transfer points.

For numerous years the mining industry has been developing methods to control dust concentrations liberated by these sources. Traditionally, controls were implemented, but sadly not always maintained. In some instances so called best practice controls were implemented and the same controls later proved to be totally ineffective.

Without the resources to inspect each dust control mechanism on a daily basis it become apparent that a holistic approach was required to monitor and control dust concentrations in the underground environment.

### Resources

During February 2002 AngloGold reviewed its safety and health thrusts. During this meeting Dust was identified as one of the strategic thrust areas. The Dust Steering Committee was tasked to lead AngloGold in the management of dust exposures.

The Dust Steering Committee was established during 1998 and pioneered the implementation of HEGs (based on ventilation districts) to determine dust exposure profiles, instead of the previously used Statpops (based on mining sections).

This team’s vision is to achieve a quantum reduction in dust exposure in AngloGold, thereby achieving a significant improvement in the long-term health outcomes of employees.

The Dust Steering Committee consists of the Head of Occupational Environment Safety and Health (O-ESH), the Manager Occupational Environment, the Occupational Hygiene (Dust) Specialist, the Consultant Occupational Health, a Senior O-

ESH Representative from the deep mining environment and a Senior O-ESH Representative from the metallurgical plants. The main function of this committee is to determine strategic direction and ensure the implementation of the dust management programme.

A Dust Technology and Innovation Supporting Team was also established, headed by the Dust Specialist. The team consists of representatives (Mine Occupational Hygienists) from each of the South Africa Region Business Units. This team meets on a monthly basis and information and practices from all levels within the organisation and industry is shared, evaluated and (if required) adopted for implementation throughout AngloGold S A Region.

The establishment of these two committees not only ensures proper implementation of appropriate technologies but also ensures clear communication between the executive level and mine operational level (Management, Employees, Unions and Associations).

## **Management systems**

### ***Introduction of a new dust monitoring method***

The new personal dust monitoring method (as described by Des Wrigley in his paper)<sup>2</sup> has been implemented at all AngloGold South Africa Region Business Units as from October 2001. This method mainly incorporates the establishment of ventilation districts (sampling areas) and activity areas (Homogeneous Exposure Groups) within these ventilation districts.

### ***Integrated risk management system (IRMS)***

A computerised system was developed to assist AngloGold in managing its health and safety risks. The dust-monitoring module of this programme was also revised to include all airborne pollutants, including toxic gases and vapours. It also addresses all the requirements of the Department of Minerals and Energy's "Guideline for the compilation of a mandatory Code of Practice for Airborne Pollutants".<sup>6</sup>

Personal monitoring sample results are entered into this programme on a daily basis. The programme is then utilised to update employees' personal occupational hygiene exposure records (on a monthly basis) and to generate engineering control reports (discussed in detail later in this paper).

### ***Key result indicators***

Four main key result indicators were identified, namely:

- % of employees exposed to respirable dust concentrations above 1 mg/m<sup>3</sup>
- % of employees exposed to respirable dust concentrations > 0,5 to 1 mg/m<sup>3</sup>
- % of employees exposed to respirable dust concentrations below 0,5 mg/m<sup>3</sup>
- Average respirable dust concentration.

It must be noted that these indicators are for respirable dust concentrations and not just for a specific pollutant such as alpha quartz. The use of respirable dust as an indicator facilitates proactive management of dust concentrations, as no delay for pollutant analysis results are required.

These indicators are monitored on a monthly and quarterly basis for each Business Unit, each ventilation district (sampling area) within the Business Unit, and each HEG within each ventilation district.

This information is then utilised to monitor the results of any implemented controls and track dust exposure trends at operational level, to identify any problem areas.

By viewing the same information for each ventilation district the problem ventilation district can be identified. Similarly, by viewing the same HEG information for the problem ventilation district, the problem HEG can be identified and corrective action plans can be formulated (after proper area investigation).

### ***Auditing/evaluation***

Gravimetric dust sampling results are mainly used to measure our dust performances and also to direct remedial and technology initiatives. A comprehensive dust auditing protocol has been formulated and implemented. The purpose of this annual audit is to maintain good quality management and thus also accurate statistics.

The following issues are evaluated:

- Measuring equipment (Maintenance, calibration, etc.)
- Statistical analysis of Homogeneous Exposure Groups (2 Standard Deviations at 95% confidence level)
- Sampling methodology (Correct classification of ventilation districts and HEGs)
- Integrated Risk Management System (IRMS) Dust and Hygiene modules
- Reporting (Appropriate level, follow-up, etc.)
- Remedial action (Reduction of "high" exposures)
- Technology and Innovation (Implementation of new initiatives).

### ***Employee hygiene register***

This requirement is addressed by the implementation of the IRMS Airborne Pollutants and Hygiene Register modules.

## **Interesting discoveries/findings during implementation of controls**

### ***Footwall treatment***

Scientific tests were conducted on the flammability and evolution of gases during combustion, toxicity and corrosivity (on various footwall treatment products) and these proved to be within acceptable limits. The tests were conducted to ensure that the utilisation of these products would not result in the introduction of other health and safety risks.

Most footwall treatment products consist of molasses or sugar compounds, which also contains Lignosulphonate. Lignosulphonate is an additional binding agent added to the molasses. Once applied the binding effect of the product is visible on the footwall.

A project was conducted to establish the dust allaying effect of these products. The underground working levels selected were those with the highest air velocities and highest tramming traffic. Gravimetric sample positions were selected and samples were taken at the selected points before the application and again after treatment with the dust allaying products.

This project proved the effectiveness of the product to control footwall dust.

### ***Dust filtration***

Each type of fabric bag dust filter (currently utilised) was tested to determine its fractional dust filtering efficiency and dust holding capacity<sup>7,8</sup>. It was decided to determine the fractional dust filtering efficiency as small dust particles ( $> 1 \mu\text{m}$ ) are capable of entering the deeper regions of the respiratory tract. Even if a high overall dust filtering efficiency (all particle sizes) is maintained it is still possible for large quantities of respirable particles to pass through the filter. The fractional dust filtering efficiency was determined by utilising instruments that could count the number of dust particles within a specified dust size category.

This initial investigation would suggest that fabric dust filters (currently in use) have no meaningful effect on the elimination of harmful airborne pollutants. In perusing the test data, it becomes apparent that the combination of pre-filtration with high efficiency secondary filtration offers the best prospects for success in the underground environment.

### ***Administrative controls***

Numerous administrative controls are already implemented (blasting schedules, re-entry periods, etc.) to prevent employees from being exposed to the harmful contaminants generated by blasting operations.

It is of utmost importance that the effectiveness of these controls be audited on an ongoing basis.

### ***Respiratory protective equipment (RPE)***

Because of a variety of ergonomic constraints, the 'Personal Protective Equipment route' should always be regarded as the last resort in any strategy designed to protect employees from workplace hazards.<sup>9</sup>

To gain the maximum benefit of any intended PPE; the most fundamental issue is employee acceptance. This is a complex requirement and also the single most important motivation for conducting a RPE field trial. The primary purpose of the trial

was to assess ergonomic acceptance of RPE for different realistic scenarios. It is of no use to issue employees with the best and most costly RPE, if they do not want to wear it. Eight different types of respirators (1 360 units) were evaluated.

The results of the trial indicated that employees prefer to use valve fitted disposable RPE. The majority of employees working in critical occupations or employed in areas with "high" dust concentrations preferred half-mask, non-disposable RPE.

### **Real-time dust monitor**

The objective of the Real-time Dust Monitor Project is to design an automated monitoring system for measurement of airborne silica dust. This instrument must also have an alarm capability that can be used to warn employees when "high" dust concentrations are experienced. Employees can then withdraw from the affected area until normal conditions have been restored. Meetings held with leaders in the instrument-manufacturing field revealed that the technology does not yet exist for this objective to materialise. It has therefore been decided that this project will be put on hold.

### **Effect of (hydropower) water jetting on dust concentrations**

The project was conducted during day shift. Two water jets were in operation at the time of the investigation. Gravimetric dust samples (used to monitor the panel dust conditions) were taken at 15-minute intervals. The forces created by the two water jets were adequate to hamper the designed ventilation flow as it reversed the ventilating airflow direction.

The two operating water jets resulted in an 86.7% (0,341 to 0,636 mg/m<sup>3</sup>) increase in stope dust concentrations and a 433% (0.341 to 1.818 mg.m<sup>3</sup>) increase in panel dust concentrations.

This increase in dust concentrations was mainly due to:

- The reversal of the ventilating airflow direction. Thus not sufficient dilution ventilation is available (in the panel) to reduce the dust concentration.
- The lack of proper watering down practice. The hanging wall is washed by using the water jet guns. This practice is deemed by the stope team as adequate watering down, as the water used to clean the hanging wall also falls onto the footwall.
- The dust kicked up by the "pressure wave" of the water jet.

## **Other medium and long term dust issues**

Some medium and long-term dust issues have also been identified by the "Dust Technology and Innovation Supporting Team" for investigation and possible projects for 2003 onwards. These include:

- Ore transfer areas: Dust load determination methodology, filter efficiency determination methodology, dust characteristic determination methodology, captured displacement and excavation (capacity) determination methodology and maintenance program content.
- Intake airways: Drain cleaning methodology, shotcrete dust control, backfill pipes maintenance and possible enhancement/substitution, washing of side walls and hanging walls and influence of foot wall treatment products on water quality.
- Shaft areas: Backfill pipes maintenance and possible enhancement/substitution, management of sludge pipes and spillage's with regards to skips and management of empty material cars and hoppers.
- Working Places: Drilling operations, scraping operations, transport of employees and material, exposed backfill, installation of support, ore handling/loading, water jetting operations and employee exposure to blasting fumes.

### **Conclusion**

It should be apparent that the management of dust (airborne pollutants) in the underground environment is no small order. Implementation of the management programme (as described in this paper) will certainly assist mine management to better manage the dust health risk.

Some immediate issues (actions that can be/were immediately implemented/reinforced) are:

- Regular watering down of intake airways
- Watering down on re-entry (from intake side where possible)
- Dust filter plants to be regularly cleaned and maintained
- Respiratory protection to be worn by persons at or involved in tipping operations, sweeping, water jetting, filter plant cleaning/ maintenance, etc.



- Ore pass controls (finger controls, chutes, tip covers, etc.) to be in working order at all times.
- Settler efficiency to be rigorously maintained
- Ventilation controls to be rigorously maintained.

Only dedication, commitment and enthusiasm by all stakeholders (management, employees, unions and associations) will result in reduced dust concentrations thus reduced medical outcomes.

### **Acknowledgement**

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### **References**

- 1 GUILD, R., EHRLICH, R.I., JOHNSTON, J.R., ROSS, M.H. 2001. SIMRAC Handbook of Occupational Health Practice in the South African Mining Industry. Johannesburg. Creda Communications. Foreword.
- 2 WRIGLEY, DE. 2001. Mining methods and occupational hygiene for the new millennium: from dust to dust. Journal of the Mine Ventilation Society of South Africa, 54(3):73-77, July/September.
- 3 GUILD, R., EHRLICH, R.I., JOHNSTON, J.R., ROSS, M.H. 2001. SIMRAC Handbook of Occupational Health Practice in the South African Mining Industry. Johannesburg. Creda Communications. 160 p.
- 4 GUILD, R., EHRLICH, R.I., JOHNSTON, J.R., ROSS, M.H. 2001. SIMRAC Handbook of Occupational Health Practice in the South African Mining Industry. Johannesburg. Creda Communications. 160 p.
- 5 BURROWS, J., HEMP, R., HOLDING, W., STROH, R.M. 1989. Environmental Engineering in South African Mines. Cape Town. CTP Book Printers. 379 p.
- 6 SOUTH AFRICA. Department of Minerals and Energy. Mine Health and Safety Inspectorate. Guideline for the compilation of a mandatory code of practice for an occupational health programme on personal exposure to Airborne Pollutants. 2002.
- 7 South African Bureau of Standards. SABS 1424:1987. Standard Specification for Filters for use in air-conditioning and general ventilation. 1987.
- 8 British Standards Institution. BS EN 779:1993. Particulate air filters for general ventilation - Requirements, testing, marking. 1993.
- 9 KIELBLOCK, J. 2001. Personal protection as an interim strategy to reduce occupational dust exposure: PPE selection and allocation. (RPE Field Trail developed for AngloGold SA Region). (Unpublished.)

## The Elimination of Silicosis in Sweden

Summary of publication "Silicosis. On Research and Regulations in Sweden" by Arne Westlin, National Board of Occupational Safety and Health. Published by ASF (The Swedish Work Environment Fund), Stockholm, Sweden 1977.

### Summary

The Division of Occupational Medicine of the Swedish Public Health Service, in cooperation with the National Board of Occupational Safety and Health, made a major effort to get a handle on the silicosis problem in Sweden in a special Silicosis Investigation 1963 – 1969. Its findings are reported in the document *Silikos i Sverige* ("Silicosis in Sweden").

The Silicosis Investigation presented information on exposure to silica dust at 170 workplaces in the most important branches where such exposure occurred – foundries, steel mills, mines, quarries and the ceramic industry. The construction industry and stone crushing facilities were also investigated to some extent.

Regulations were then developed for foundries, steel mills, quarrying, mines, rock drilling and explosives work, stone crushing work and the ceramic industry. An important part of the regulations was the requirement for industrial hygiene monitoring.

The Swedish Confederation of Labour demanded that the Investigation be extended to all workers exposed to silica. The so-called "Silicosis Project" 1968 – 1974 was headed by Prof. G Gerhardsson, and the findings were published in three reports (Sampling Methods and Sampling Strategy; Goals, Scope and Findings; and Preventive Measures). The project showed that in Sweden there were approximately 3 000 workplaces with silica dust, and about 30 000 workers exposed.

A "Silicosis Follow-up Project" was started in 1974 to work to ensure the implementation of the necessary dust control measures at the firm level. A large number of citations were issued. All 118 iron foundries were inspected, and 98 citations issued. Follow-up inspections were later undertaken to check whether the required changes had been made.

In 1976 the use of silica in jet blast cleaning was banned.

### Ordinance on Silica

The basic protective measures for all work where silica dust is present were summarized in a general silica directive which entered into force on the 1 January 1982 (Ordinance on Silica AFS<sup>1</sup> 1981:16). Sections covered: definitions; general requirements (replacement by less harmful substances, limitation of exposure); marking of packages containing powdered silica; prohibition of the use of silica-containing agents for non-mechanised abrasive blasting; restrictions on the use of silica-containing materials (measures to prevent dust spread); dust control by enclosure and local exhaust ventilation; elimination of dust deposited at the workplace; wearing of dustmasks; monitoring of workplace air to assess silica dust exposure. Detailed comments.

The ordinance was revised by AFS 1983:14 and AFS 1992:16 which both included medical supervision of exposed workers (chest X-ray).

### Further Information

Further work on silicosis elimination in Sweden has been reported in the journal *OSH & Development* (<http://www.ufa.se>) published by the Swedish Association for Occupational and Environmental Health & Development (SFA).

The End of Silicosis in Sweden – a Triumph for Occupational Hygiene Engineering  
Gideon Gerhardsson, *OSH & Development*, No. 4 May 2002

Driving Forces Behind the Elimination of Silicosis in Sweden  
Per Malmberg, *OSH & Development*, No. 6 March 2005

See also the Historical section of the Silicosis Prevention Information Resources CD.

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1. AFS (Arbetsmiljöverkets författningssamling) – Statute Book of the Swedish Work Environment Authority

## **Advisory Committee on the Elimination of Pneumoconiosis Among Coal Mine Workers (Advisory Committee), USA**

### **Background**

The Advisory Committee was established by the Secretary of Labour (Secretary) on 31 January, 1995, in accordance with the provisions of the Federal Advisory Committee Act (1988), and the Federal Mine Safety and Health Act of 1977 (Mine Act). The Secretary charged the Advisory Committee to make recommendations for improved standards, or other appropriate actions, on permissible exposure limits to eliminate coal workers pneumoconiosis and silicosis (commonly referred to as 'Black Lung'); the means to control respirable coal mine dust levels; improved monitoring of respirable coal mine dust levels and the role of the miner in that monitoring; and the adequacy of the current sampling programme to determine the actual levels of dust concentrations to which miners are exposed.

On 14 November, 1996, the Advisory Committee submitted its report to the Secretary. The report contained numerous recommendations directed toward elimination of coal workers' pneumoconiosis and silicosis. The report concluded that:

... although progress towards making mines safer from the health hazards of respirable coal mine dust is substantial, it is not sufficient to achieve the intent of the Coal Act [the predecessor to the Mine Act]. The committee believes that the elimination of coal workers' pneumoconiosis and silicosis requires a systematic approach incorporating simultaneously:

(1) greater reduction of dust generation and entrainment, (2) greater reduction of ambient concentrations through better dust control plans, (3) improved continuous monitoring and dust sampling programmes, (4) greater reduction of personal exposures, (5) enhanced training of miners and mine officials on relevant aspects of coal mine dust control, (6) upgraded medical surveillance programmes, (7) more rapid intervention programmes, (8) enhanced research on continuing vexing scientific, engineering, and medical issues, and (9) continuous critical evaluation of the coal mine respirable dust standard of 2.0 mg/m<sup>3</sup> and the silica standard of 0.1 mg/m<sup>3</sup>.

Recommendations of the Advisory Committee address each of these areas in detail. There are 20 principal recommendations set out in the Advisory Committee report, which are further subdivided into a total of approximately 100 distinct action items.

## Mine Safety and Health Administration (MSHA), USA

Adapted from an article by Brandy E Fisher titled "Between a Rock and a Healthy Place". Published in Environmental Health Perspectives (EHP) Vol. 106 Number 11 November 1998

<http://ehp.niehs.nih.gov/docs/1998/106-11/spheres.html>

EHP is a publication of the Public Health Service, US Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences (NIEHS).

### Lung disease

MSHA has initiated national campaigns to eliminate both black lung and silicosis through strengthened regulations, stricter enforcement, updated technology and public education.

**Black lung.** The key to eliminating black lung is to continue reducing the amount of respirable dust in coal mines, thereby decreasing miners' exposure. MSHA requires that coal miners' exposure to respirable dust be maintained at or below 2 mg/m<sup>3</sup>. Because miners are still contracting black lung, either the current exposure standard is too high to prevent the disease or some mine operators are not consistently ensuring that dust controls are in place to keep dust exposures below the permissible limit.

MSHA officials believe one problem is that the current system for enforcing mine dust controls is fundamentally flawed. The system requires mine operators submit bimonthly air samples from their mines that reflect environmental dust levels to MSHA, which will then issue citations and collect penalties if the samples show that the dust levels exceed the permissible level. Says McAteer (assistant secretary for Mine Safety and Health), "This same system, if applied to the nation's highways, would require each of us to pull over if we exceeded the speed limit and send a notice to the state police, who would send us a speeding ticket. The system is illogical and needs to be changed."

Evidence shows that there have been extensive problems in the past of mine operators tampering with measurement devices and samples. From 1991 to 1997, more than 160 companies or individuals were convicted of or pled guilty to criminal acts of fraudulent dust sampling. "People are going to great lengths to falsify samples," says Joe Main, of the United Mine Workers in Washington, DC. "Companies engage in these illegal activities to gain a competitive edge in the market by producing more coal, cheaper. This puts safer mines out of business. We think the government needs to move forward very aggressively and harshly in this area. If [mine companies] destroy the health of miners, they should be treated [as criminals]." To address these issues, the pneumoconiosis advisory committee recommended that in addition to the samples that are required to be submitted by mining companies, MSHA inspectors conduct inspections of all underground mines four times a year and collect dust samples twice a year over the course of several days.

### National campaigns to eliminate both black lung and silicosis

In December 1997, MSHA launched the 'Eliminate Black Lung Now' programme, a public education campaign. MSHA is also hosting seminars for miners to raise awareness that black lung is not a disease of the past. "Part of the problem with health matters is the latency periods [of mine-related diseases]. The danger is not always apparent to the person who is facing it today, which is why we have to educate," says McAteer.

**Silicosis.** MSHA is co-ordinating a similar national campaign to eliminate silicosis. Historically, efforts to prevent lung diseases have focused on underground miners. Results from x-ray screening, however, show that surface workers at mines develop silicosis at an equal or higher rate than do underground miners. In July 1994, MSHA and NIOSH implemented a programme in Pennsylvania offering free, confidential chest x-ray screening to surface coal miners in response to concerns by a workers' compensation insurer over the number of miners, some young, found to qualify for silicosis compensation. Since then, screenings have been conducted in West Virginia, Oklahoma, Wyoming, and Kentucky. The programme not only provides an opportunity for miners to determine if they have contracted silicosis, but also allows MSHA to determine what specific mining occupations are associated with the development of silicosis, what age groups of miners are affected, and what areas of the country have the highest rates of the disease. NIOSH is interpreting and compiling the cumulative x-ray results.

The main focus of MSHA's campaign to eliminate silicosis is education. It has produced and distributed educational materials to raise awareness of silicosis, including a video, hard hat stickers, fact sheets, brochures, posters, and pocket cards for miners detailing dust monitoring information. In March 1997, MSHA co-sponsored a conference with NIOSH, the Occupational

Safety and Health Administration, and the American Lung Association to share ideas and discuss practices on how to best eliminate silicosis.

MSHA also publishes spreadsheets showing silica sampling results on the Internet. This not only gives miners access to the levels of respirable silica to which they are being exposed, but also offers an opportunity for mine health officials and mine operators to track their progress and compare mines.

Mines that have resolved respirable silica problems serve as models for those with continuing problems. Mining industry organisations are utilising the data in their efforts to assist companies in achieving acceptable dust levels.

## **Silicosis Prevention Program, National Industrial Sand Association (NISA), USA**

NISA, a national trade association representing companies involved in the mining and processing of industrial sand, developed an occupational health programme for exposure to crystalline silica for its members in 1977 to protect employees from developing silicosis. NISA created a silicosis prevention programme to focus more broadly on silicosis prevention in 1993. The ultimate goal of the programme is to prevent the development of new cases of silicosis in member company employees. The goal is supported by a series of objectives and tasks in the various programme elements. It stresses the significance of a safe and healthy workplace in today's changing work environment. It is also designed to recognise the efforts of member companies towards achieving this goal.

The NISA Silicosis Prevention Program defines six programme elements to which companies voluntarily commit to achieve the goal of preventing the development of new cases of silicosis.

- NISA Occupational Health Program for Exposure to Crystalline Silica
- Medical surveillance of pneumoconioses
- Surveillance of crystalline silica exposure
- Control of crystalline silica exposure
- Employee involvement in the Silicosis Prevention Program
- Smoking cessation programme (to reduce the added impact of smoking on top of the health effects of silica exposure).

All companies that commit to this programme complete a self-administered checklist to measure implementation of each programme element. A volunteer assistance programme is available to assist member companies in implementing and improving the programme. Companies are formally recognised by NISA for each completed element.

### ***Publications for order via the NISA bookstore include:***

<http://www.sand.org/bookstore/bookstore.asp>

- Controlled Maintenance Program: Dust Collection Equipment & Facilities
- Implementation of Dust Control: New or Existing Facility
- Respirator Guidelines for Dust Exposures in the Industrial Sand Industry
- Silicosis Prevention Folder (guiding principles, overview, application, checklist, participating companies, and a suggested press release)
- Occupational Health Program for Exposure to Crystalline Silica in the Industrial Sand Industry
- Respiratory Health Effects of Crystalline Silica Folder
- Dust Control – It's Everyone's Business (Videotape)
- Silicosis – A Preventable Disease (Videotape).

## **ASTM E 1132-99a “Standard Practice for Health Requirements Relating to Occupational Exposure to Respirable Crystalline Silica”**

American Society for Testing Materials (ASTM) 1999

Available for purchase as a downloadable pdf file via the ASTM website: <http://www.astm.org>

This practice is designed to help protect the health of workers where there may be occupational exposure to quartz dust.

General requirements cover:

- occupational exposure limits
- exposure assessment and monitoring
- methods of compliance
- engineering controls
- work practices and administrative controls
- respiratory protection
- hygiene facilities (applies to work places with combined exposures to crystalline silica and heavy metals (for example, lead, zinc, cadmium) above permissible exposure limits)
- change rooms
- showers
- lunch rooms
- lavatories
- respiratory medical surveillance
- medical protection
- worker training and education
- warning signs and labels
- record keeping
- observation of exposure monitoring.

## Appendix I – Checklist

### 10 Point checklist for silicosis prevention

1. Company commitment to a Silicosis Prevention Programme
  - Signed letter of commitment to silicosis prevention by senior executive
  - Appointed persons(s) to co-ordinate silicosis prevention programme
2. Identification of dust sources and employee dust exposures
  - Baseline and periodic airborne dust surveys conducted to determine employees exposed to airborne crystalline silica
  - Dust sources identified for corrective action
3. Control of dust sources to eliminate or minimise dust exposures
  - Implemented engineering and administrative controls to reduce dust exposures
4. Maintenance, examination and testing of the dust control measures
  - Dust control measures provided are maintained in an efficient state, efficient working order and in good repair
  - Thorough examination and testing of all engineering controls and suitable records kept
5. Employee involvement and commitment to the Silicosis/CWP Prevention Programme
  - Encouraged employee involvement in the prevention of silicosis
6. Employee education and training
  - Implemented employee training on silicosis prevention, including the need for engineering controls and work practices
  - Implemented employee training on respiratory protection
7. Administrative controls and work practices including the correct use of appropriate respiratory protection to minimise dust exposures
  - Implemented a written silicosis prevention programme
  - Implemented a written respiratory protection programme
8. Periodic medical surveillance of employees exposed to airborne crystalline silica dust
  - Medical surveillance in place for employees at significant risk to health from exposure to airborne dust
9. Auditing of the Silicosis Prevention Programme
  - Periodic audits of the silicosis prevention programme conducted
  - Remedial action based on audit implemented
10. Planning in the case of new or expanding mining operations
  - Control measures planned to prevent or reduce dust generation and dust exposure in new or expanding mining operations.



## Appendix J – Key terms

**Abrasive blasting:** A process for cleaning metal and other surfaces using material in a high-pressure stream. The material is blasted against a surface to remove paint or contaminants. If silica sand is used as the material, this process is called sand-blasting.

**Accelerated silicosis:** A form of silicosis that shows symptoms within five to 10 years.

**Acute silicosis:** A form of silicosis that develops in workers exposed to very high levels of crystalline silica. Symptoms may appear within only a few weeks of an initial exposure.

**ACGIH:** American Conference of Governmental Industrial Hygienists.

**Acute effect:** An effect that occurs immediately or shortly after a single, high-level exposure.

**Airborne contaminant:** An airborne contaminant is a potentially harmful substance that is either normally absent from air, or present in an unnaturally high concentration, and to which workers may be exposed in their working environment.

**Air monitoring:** The use of specialised equipment to measure types of pollutants and their concentrations in the atmosphere.

**Alpha quartz:** Polymorphic form of crystalline silica (for other forms see crystalline silica). In nature, the alpha (or low) form of quartz is the most common. This form is so abundant that the term quartz is often used in place of the general term crystalline silica.

**Alveoli:** Thin-walled air sacs at the distal end of the conducting airways of the lungs, where gas exchange occurs between air and blood.

**Asthma:** Variable airflow obstruction/airflow limitation.

**Audit:** Examination and verification.

**Auditor:** One who examines and verifies.

**Best practice:** Can simply be explained as “the best way of doing things” and can be defined as the most practical and effective methodology that is currently in use or otherwise available.

**Bord and pillar:** “Bord” is an old English word meaning “house” and a Yorkshire miner, digging himself a “bord” in a coal seam, also spoke of the “roof”, the “floor” and the “walls” of the cell he excavated. When a “bord” was hollowed out to about three square metres, the olden-day miner moved on and began another. The coal left standing between the “bords” was named a “pillar”.

**Brattice or brattice cloth:** Fire-resistant fabric or plastic partition used in a mine passage to confine the air and force it into the working place. Also termed “line brattice,” “line canvas,” or “line curtain.”

**Breathing zone:** A person’s breathing zone has been (arbitrarily) defined by a hemisphere of 300 mm radius extending in front of the face and measured from the midpoint of an imaginary line joining the ears.

**Bronchitis:** Cough and/or sputum production.

**Cancer:** A malignant tumour of an organ or tissue arising from the uncontrolled division of cells that can spread to other organs of the body either by direct growth or through transport channels (blood, lymph, etc.). This is distinct from a benign tumour, which cannot usually spread.

**CCOD:** Compensation Commissioner for Occupational Diseases (administers ODMWA).

**Certification:** Official documentation of fitness to work, or in the case of compensation, of presence of occupational disease.

**Chronic bronchitis:** Inflammation of the bronchi, the main air passages in the lungs, which persists for a long period or repeatedly recurs.

**Chronic obstructive pulmonary (or airway) disease (COPD or COAD):** Group of lung diseases involving limited airflow and varying degrees of air sac enlargement, airway inflammation, and lung tissue destruction. Emphysema and chronic bronchitis are the most common forms of COPD.

**Chronic silicosis:** The most common form of silicosis. Workers usually don’t show symptoms for 10 years or more after an initial exposure.

**CM:** Chamber of Mines of South Africa.

**COAD/COPD:** Chronic obstructive airways or pulmonary disease (i.e. chronic persistent airflow obstruction or limitation).

**Coal dust:** Coal dust typically contains variable but substantial amounts of mineral matter, of which quartz is an important component. The major exposures to coal dust occur during mining and processing of coal. In these operations, the

exposure includes dusts generated not only from the coal but also from adjacent rock strata and other sources. These may increase the quartz component of the airborne dust to about 10% of the total mixed dust, or to even greater levels if significant rock cutting is being undertaken.

**Coal workers pneumoconiosis (CWP):** Occupational lung disease caused by continued exposure to excessive amounts of respirable coal mine dust.

**Cohort:** A designated group of persons that is followed or traced over a period of time.

**Cohort Study:** Follow up or longitudinal study of a defined cohort.

**COIDA:** Compensation for Occupational Injuries and Diseases Act (Act 130 of 1993). It governs the reporting and compensation of all injuries and occupational disease in South Africa (excluding miners with occupational lung disease).

**Colliery:** A workplace consisting of a coal mine plus all the buildings and equipment connected with it.

**Compensation:** Statutory provision for medical aid, for direct payment to an individual or for death benefits as a result of an occupational injury or disease.

**Continuous miner (CM):** A machine that continuously extracts coal while it loads it. This is to be distinguished from a conventional, or cyclic, unit that must stop the extraction process for loading to commence.

**Cristobalite:** A form of crystalline silica that is stable at the highest temperature. It occurs naturally in volcanic rock.

**Cross-sectional study:** A study of the prevalence of a disease and other variables as they exist in a defined population at a specific time.

**Crystalline:** Having a very structured molecular arrangement.

**Crystalline silica:** Crystalline silica may be found in more than one form (polymorphism). The polymorphic forms of crystalline silica are alpha quartz, beta quartz, tridymite, cristobalite, keatite, coesite, stishovite, and moganite. Each polymorph is unique in its spacing, lattice structure, and angular relationship of the atoms. In nature, the alpha (or low) form of quartz is the most common. This form is so abundant that the term quartz is often used in place of the general term crystalline silica.

When low temperature alpha quartz is heated at atmospheric pressure it changes to beta quartz at 573°C. At 870°C tridymite is formed and cristobalite is formed at 1470°C. The melting point of silica is 1610°C, which is higher than iron, copper and aluminium, and is one reason why it is used to produce moulds and cores for the production of metal castings.

**Cytotoxicity:** The degree to which something is toxic to living cells.

**Disability:** Alteration of an individual's capacity to meet personal, social or occupational demands or statutory or regulatory requirements because of impairment.

**DME:** Department of Minerals and Energy, South Africa.

**Dusts:** Solid particles generated and dispersed into the air by handling, crushing and grinding of organic or inorganic materials such as rock, ore, metal, coal, wood or grain.

**Emphysema:** Lung disease that involves damage to the air sacs (alveoli). The air sacs are unable to completely deflate (hyperinflation) and are therefore unable to fill with fresh air to ensure adequate oxygen supply to the body.

**Engineering controls:** Methods of controlling worker exposures to hazardous agents by adjusting the source or reducing the amount released in the workplace. Examples include a change in process, substitution of less harmful job activities or materials, isolation, and ventilation. Engineering controls are the preferred method for targeting work site hazards.

**Epidemiology:** A study of the relationships of various factors determining the distribution of disease in a human community.

**Exposure control:** A means of eliminating or reducing workplace hazards. Examples include engineering, work-practice, and administrative controls.

**Fan, auxiliary:** A small, portable fan used to supplement the ventilation of an individual working place.

**FEV1:** Forced expiratory volume in one second.

**FVC:** Forced vital capacity.

**FEV/FVC:** A commonly used index of airflow obstruction.

**Fibrosis:** Scarring of the lungs because of breathing harmful dusts or chemicals such as crystalline silica. As the disease develops, the lungs begin to stiffen and become less flexible, making breathing more difficult.

**Fibrogenic dust:** A dust (e.g. crystalline silica or asbestos) that causes the formation of fibrotic (scar) tissue after its deposition in the gas-exchange region of the lung.

**Fitness to work:** Ability to meet specific requirements of a task or job.

**Fit testing:** A procedure for checking to see that a respirator fits properly and does not allow pollutants to be inhaled.

**Free crystalline silica:** Pure crystalline silica that is chemically uncombined.

**Gate, loader gate, tail gate:** A mine roadway associated with a coal face. The loader (or main) gate is normally used for intake ventilation and coal clearance, and the tail (or supply) gate for transport of materials and return ventilation.

**Goaf:** Empty space (from the Welsh 'ogof' meaning hollow). The worked volume, including the immediately collapsed ground, behind a coal face, also known as the waste.

**Hazard:** The intrinsic ability of an agent or process to produce adverse effects on health.

**HEG:** Homogeneous exposure group or similarly exposed group (SEG). Means a group of employees who experience pollutant exposures similar enough that monitoring exposures of any representative sub-group of employees in the group provides data useful for predicting exposures of the remaining employees.

**HSE:** Health and Safety Executive (UK).

**IARC:** International Agency for Research on Cancer, a subsidiary of the World Health Organisation.

**ILO:** International Labour Organization, a specialised agency of the United Nations to deal with labour issues.

**ILO classification of the radiographs of the pneumoconioses (ILO classification):** Method for classifying chest x-rays of pneumoconioses by comparison with standard x-ray films. Can be used to grade silicosis from normal to severe using a numeric scale.

**Inby:** In the direction of the working face.

**Intake:** The fresh air circuit of a mine ventilation system.

**IRS:** Infra-red spectroscopy.

**Inhalable fraction:** The amount of dust capable of entering and depositing in the upper respiratory tract (<100 µm in diameter).

**In vitro:** In an artificial environment outside the living organism, e.g. within a test tube.

**In vivo:** Within a living organism (a cell).

**ISO/CEN:** International Organisation for Standardisation (ISO)/European Committee for Standardisation (CEN).

**Limit of detection (LOD):** The lowest concentration of substance, e.g. crystalline silica, that can be determined to be statistically different from a sample that contains none of that substance.

**Local exhaust ventilation:** An air movement system for capturing pollutants in the air directly where they are produced and carrying them away before they can spread throughout the work area.

**Longwall:** A coal face with a length usually measured in high 10s or low 100s of metres.

**Medical benefit examination:** Statutory examination to determine whether or not a miner or ex-miner has a compensable lung disease in terms of ODMWA.

**Methane:** A gaseous hydrocarbon (CH<sub>4</sub>) that occurs naturally. It is liberated from coal seams during the mining process. The methane content of a coal seam is measured typically in cubic metres per ton.

**Micron, micrometre (µm):** One thousandth of a millimetre.

**Mineral:** Naturally occurring crystalline solids, usually made from oxygen, silicon, sulfur, and any of six common metals or metal compounds.

**Morbidity:** Measured health outcomes (e.g. hospital admissions) for a particular cause or disease (excluding death).

**Mortality:** Deaths from a certified cause or all causes.

**MQOHSC:** Mining and Quarrying Occupational Health and Safety Committee, Australia.

**NIOH:** National Institute for Occupational Health (South Africa).

**NIOSH:** National Institute for Occupational Safety and Health (United States).

**NOHSC:** National Occupational Health and Safety Commission (Australia).

**NPES:** National Programme for the Elimination of Silicosis.

**Occupational hygienist:** A professional trained to recognise, evaluate and develop controls for occupational health hazards.

**Occupational exposure limit (OEL) for an airborne pollutant:** The maximum amount of an airborne pollutant (e.g. airborne crystalline silica dust) that one can be exposed to during a full work shift.

**ODMWA:** Occupational Diseases in Mines and Works Act (Act 78 of 1973) (as amended from time to time). It deals with certification and compensation for occupational lung diseases in the mining industry in South Africa.

Radiological methods and the grading of radiological changes in pneumoconiosis shall be in accordance with the ILO Classification of Radiographs of the primary category only. The following shall be used by the certification committee in the certification of inorganic occupational lung diseases:

With accompanying lung function test:

If lung function test show:

moderate restrictive or obstructive abnormality, in the presence of radiological pneumoconiosis, impairment shall be assessed at between 10 – 40%, which is first degree.

severe restrictive or obstructive abnormality, in the presence of radiological pneumoconiosis, impairment shall be assessed to be more than 40%, which is second degree.

Without accompanying lung function test:

ILO profusion of = 2/0 or PMF (progressive massive fibrosis), shall be assessed at at between 10 – 40%, which is first degree.

**OSHA:** Occupational Safety and Health Administration (United States).

**Outby (or outbye):** Nearer to the shaft, and hence farther from the working face. Toward the mine entrance. The opposite of inby.

**Personal sample:** An atmospheric sample collected from within the breathing zone of an individual.

**Personal sampling:** A method whereby air is sampled from within employees' breathing zones to evaluate personal exposure to airborne contaminants.

**PMF:** Pulmonary massive fibrosis.

**Pneumoconiosis:** A lung disease caused by inhaling hazardous dusts. Inflammation commonly leading to fibrosis of the lungs caused by the inhalation of dust incident to various occupations; characterised by pain in the chest, cough with little or no expectoration, dyspnea, reduced thoracic excursion, sometimes cyanosis, and fatigue after slight exertion; degree of disability depends on the types of particles inhaled as well as the level of exposure to them.

**Polymorphic:** Relating to the crystallisation of a compound in two or more different forms. See also crystalline silica.

**Powered supports:** Longwall face supports that are advanced and set utilising hydraulic power.

**Prevalence:** The ratio (for a given time period) of the number of occurrences of a disease or event to the number of units at risk in the population, e.g. the proportion of people with silicosis at the time of the survey. Prevalence is entirely dependent on the group studied and is meaningless if this context is not given. For example, a sample of in-service miners, which includes a large number of short service workers, will have a low prevalence of silicosis even if the lifetime prevalence is high.

**Progressive massive fibrosis:** Results from severe scarring and leads to obliteration of normal lung structures. May occur in simple or accelerated silicosis, but is more common in the accelerated form.

**Quartz:** The most common type of crystalline silica. Quartz occurs as two polymorphs, alpha quartz (or low quartz) and beta quartz (or high quartz). Beta quartz is stable only at temperatures above 573°C and converts to alpha quartz on cooling. The quartz form is so abundant that the term quartz is often used in place of the general term crystalline silica.

**Quarry:** A large artificial hole in the ground where stone, sand, etc. is dug out of the ground for use as building material.

**Quarrying:** Traditionally quarrying involved the excavation of large blocks of stone and raw minerals for ornamental use. Today, the term quarrying applies to the mining of sand, gravel and crushed stone for the production of roads, cement, concrete, etc. The processes used in this type of quarrying are very similar to those used in open pit mining.

**RCS:** Respirable crystalline silica.

**Rehabilitation:** Process of returning a physically or psychologically impaired employee to optimal functioning.

**Respirable dust:** Dust that contains particles small enough to enter the gas exchange region of the human lung (less than 10 microns in accordance with the ISO/CEN curve).

**Respirator:** A device worn over the mouth and nose or entire head to protect a user from inhaling harmful agents.

**Return:** The used air circuit in a mine ventilation system.

**Risk:** The likelihood that a hazard will give rise to an adverse effect on health.

**Road header:** A track mounted cutter/loading machine with an articulated boom with rotary cutting head, used for the mechanised drivage of mine roadways.

**Roof bolt:** A long steel bolt driven into the roof of underground excavations to support the roof, preventing and limiting the extent of roof falls.

**Sandblasting:** A process for cleaning metal and other surfaces using sand in a high-pressure air stream. The sand is blasted against a surface to remove paint or contaminants. This process is also called abrasive blasting.

**Shear:** A full cut of coal from one end of the face to the other.

**Shearer:** A machine for cutting coal on a longwall face.

**Silica sand:** The fine particles from ground rock containing a high content of crystalline silica.

**Silicates:** Mineral compounds containing silica, e.g., asbestos, talc, mica, feldspar, slate, sillimanite and various clays.

**Silicosis:** A disease that results from exposure to high levels of respirable silica dust and is characterised by scarred lung tissue. This reduces a lungs' ability to exchange oxygen with waste gases produced by the body. There is no cure for silicosis – prevention is the only answer.

For the definition of first and second degree silicosis for compensation purposes in South Africa see ODMWA.

**Silicotic:** A certified case of silicosis.

**Source controls:** Any engineering change made to eliminate or reduce exposures at the point where the hazard is generated (for example, enclosing equipment, putting up a barrier to the equipment, and using wet methods, dust collection systems, and substitution).

**Static sample:** An air sample taken at a fixed location, commonly between one and two metres above floor level.

**Substitution:** The removal of a harmful agent from a process and its replacement with an agent that is less harmful to health.

**Supplied-air respirator:** A protective device that delivers fresh (uncontaminated) air to a user through a supply hose connected to the face mask or enclosure.

**Tridymite:** A form of crystalline silica found in volcanic rocks and in fired silica bricks.

**TLV:** Threshold Limit Value.

**Tuberculosis:** Mycobacterium tuberculosis.

**TWA:** Time weighted average.

**Wet methods:** The use of water or another suitable liquid with industrial processes (cutting, sanding, grinding) to reduce dust concentrations in the air.

**WHO:** World Health Organization.

**Work practices:** The procedures followed by employers and workers to control hazards in the workplace (for example, use of wet methods to control dust).

**XRD:** X-ray diffraction.

# Can silicosis be eliminated?

‘Despite many obstacles, the idea of global elimination of silicosis is technically feasible. Positive experience gained by a number of countries shows that it is possible to reduce significantly the incidence rate of silicosis by using appropriate technologies and methods of dust control. The use of these technologies and methods has proved to be effective and economically affordable.’

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ILO/WHO Global Programme for the Elimination of Silicosis (GPES)  
International Labour Office

