NUM SUBMISSIONS

DUST IN THE MINES

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CONTENTS

REDUCING DUST LEVELS IN THE SOUTH AFRICAN MINING INDUSTRY

1. INTRODUCTION

1.1 HISTORICAL BACKGROUND: DUST - A PROBLEM

The earliest records of occupational lung disease amongst miners goes back to the works of Hippocrates and Celsus. This related to the difficult breathing of metal diggers and silicosis-type symptoms.

In her book "Response to Occupational Health Hazards" J. Corn quotes Celsus: "By far the most terrible form of emaciation is that which the Greeks call phthisis. It spreads to the lung. On top of this, ulceration occurs and a slow fever which at times disappears and other times reappears." She concludes that the association between mining, dust and disease was made at this stage.(1)

In the 16th and 17th centuries with the growth of the mining industry, there was a renewed interest in the diseases affecting miners. During this period a number of papers on disease in the mining industry began to appear. This continued into the early 1900's with a number of countries beginning to compensate workers with silicosis.

By the late 1930's silicosis had been identified as an industrial disease caused by the inhalation of silica dust. The development of silicosis depended on the amount of free silica in the dust, the concentration of the dust and duration of exposure.(1)

In 1902 the Government Mining Engineers Report (Transvaal Mines Department) showed that 225 workers had died out of 1377 machine men employed before 1899. Following this report a Commission was established in 1902. This Commission reported that of the miners examined 15.5% were affected by miners phthisis. The Commission laid the basis for a number of Commissions which were appointed between 1912 and 1955.

1.2 OVERVIEW OF COMMISSIONS

The 1902 Commission examined 1210 white miners out of 4403 who were employed on the Witwatersrand mines. The Commission found 187 miners (15.5%) to have contracted silicosis (known at the time as Phthisis) and 88 (7.3%) were suspected of having the disease. (2)

The Commission reported that the cause of miners' phthisis in their opinion "has been shown to be a chronic fibrosis of the lung (due to) the inhalation of fine dust suspended in the mine atmosphere".

In recommending preventative measures the Commission stressed the need to prevent the generation and dissemination of dust.

The medical committee reporting to the Commission recommended that "dry mining must become as far as practicable wet mining".

Commissions appointed between 1912 and 1955 on dust prevention, occupational diseases and compensation:

1.	1912 -	Prevalence of Miners' Phthisis and Pulmonary Tuberculosis on Mines (in) South Africa.
2.	1915 - 1919	Miners' Phthisis Prevention.
3.	1918 -	Inquiry into the Working of the Miners' Phthisis Acts.
4.	1921 -	Miners' Phthisis Commission of Enquiry.
5.	1929 -	Miners' Phthisis Commission of Enquiry.
6.	1935 -	Commission to Inquire into the Position of Miners' Phthisis Beneficiaries.
7.	1941 - 43	Miners Phthisis Acts Commission.
8.	1926 - 37	Miners' Phthisis Prevention Committee (The Prevention of Silicosis on the Witwatersrand.)
9.	1951 -	Commission of Enquiry Regarding the Occurrence of Certain Diseases other than Silicosis and

Tuberculosis, Attributed to the Nature of Employment in the mines.

10. 1952 - Commission of Enquiry into the Functioning of the Silicosis Medical Bureau and the Silicosis Board of Appeal.

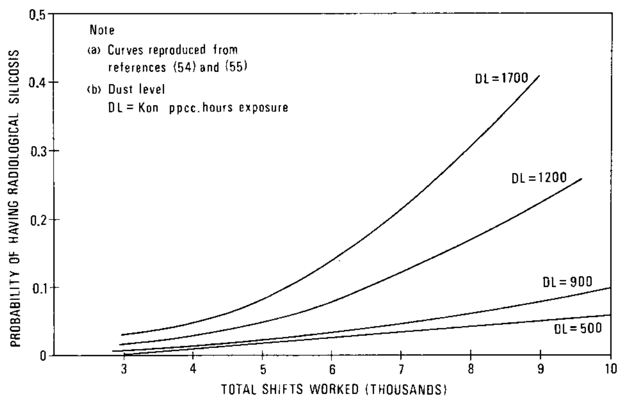
11. 1955 - Departmental Committee of Enquiry into the Relationship between Silicosis and Pulmonary Disability and the Relationship between Pneumoconiosis and Tuberculosis.

These Commissions investigated various aspects of occupational lung diseases and made recommendations, some of which have been incorporated into legislation governing the mines. (2)

Legislation was introduced to regulate dust control measures in the mines. Wet drilling was regulated in 1905. In 1908 regulations forbidding entry into working places until blasting fumes dissipated were introduced. And in 1917 blasting was only allowed once in 24 hours.

1.3 THE BEADLE STUDY AND OTHERS

In a study conducted by Beadle in the mid-1950's 650 miners employed in 11 occupational categories on 20 mines were sampled. The results were then correlated with the medical and work histories of a cohort of 1 187 white mineworkers. The group of workers had started work on the Witwatersrand mines in the years 1934-38, had worked 3000 shifts and had no other known occupational dust exposure.



PROBABILITY OF HAVING RADIOLOGICAL SILICOSIS AT THE STATED NUMBER OF SHIFTS FOR DUST LEVELS AS MEASURED BY THE KONIMETER

The first results of the study were published in 1965 and indicated a clear relationship between the probability of radiological silicosis[1] and total shifts worked. This is indicated in the preceding graph. (2)

In a study done by LEGER (3), which analysed published and unpublished data between 1915 and 1988, indications are that occupational lung diseases might be on the increase.

- Incidence among white and coloured workers (from 1962) are as follows;

1915 to 1925 :	20 - 40 per 1000.
1925 to 1930 :	7 per 1000.
1930 onwards :	the figure has dropped to 8-15 per 1000.

The same study published the following figures for black workers:

1,8 per 1000 in 1917 to 8 per thousand in 1953. From 1957 onwards the figure is 1 per thousand and the figure rose again from the early 1980's to about 5 per 1000 workers and this is attributed to the stabilisation of the black work force in the mines since 1975. (3)

Historically, black workers have not had access to well equipped medical facilities to monitor their exposure to silica dust. As a result, a large number of black mine workers remain under-diagnosed. (3)

Very few epidemiological studies have been carried out over the years to assess the actual extent of dust related diseases in the mining industry, especially amongst black mineworkers. The reason given for this is that black workers have worked intermittently on the mines, introducing a variable into these studies that is difficult to control.

[1] Radiological Silicosis is identified by the use of X-Rays. The ILO has a detailed international classification system for pneumoconiosis.

However, such an argument has become irrelevant because black workers spend more time in the mines than previous decades.

2. NATURE AND EXTENT OF THE HAZARD

2.1 NATURE OF THE HAZARD

The nature of the dust hazard depends primarily on the following factors. These include:

- nature of dust;
- duration of workers exposure to dust;
- concentration of dust particles in the environment.

2.1.1 Nature of Dust

Particles Size

Dust particles are formed in various sizes. The mechanisms of the human respiratory are able to effectively remove most of these particles. Only dust particles less than 7µm in size are able to penetrate into the alveoli of the lung where they can pose a health risk to exposed workers. This dust is usually referred to as respirable dust. Because of the very small size of the particles they are usually invisible to the naked eye under normal circumstances. Respirable dust is formed when a solid mineral structure is destroyed by crushing, cutting or grinding. (4)

The curve which most closely represented the deposition of respirable particles in the human lung was accepted at the Johannesburg Conference of 1959. In terms of this curve, instrumentation has been developed to collect particles within the range of 1µm to 7µm.

It is this system which South Africa began using towards the end of the 1980's and has become known as the "Johannesburg Curve".

Mineralogical Composition

The composition of the dust relates to the mineralogical composition. The extent to which lung diseases are caused depends on the composition of the dust. Mineral dust is a major component of mine aerosols[2], but the latter may also contain oil mists from drills, particulates from diesel exhausts[3], and radioactive particles derived from radon gas emanating from rock faces and broken rock. (5)

The mineral composition of particles vary from mine to mine. According to information available from the Department of Mineral and Energy Affairs there are approximately 60 different types of minerals which are mined in South Africa. These minerals are listed in Appendix 1.

The extent to which substances can cause disease is well documented in international literature. (6) (7) However, in most non-coal mining sectors, free crystalline silica is considered to be the most important constituent which causes silicosis in exposed workers. (5)

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[2]Mine Aerosols are particulates which are produced during mining operations and become airborne in the working environment.

[3]Diesel fumes are generated by the use of motorised vehicles and machinery in the workplace. If these fumes are not effectively filtered they are released into the working environment. Minetek is currently involved in research on Diesel Fumes.

2.1.2 Duration of workers exposure to dust

The duration workers spend in a dusty environment contributes directly to the extent to which their health is affected. The study by Beadle showed that radiological silicosis was directly related to the number of shifts worked.

2.1.3 Concentration of dust particles in the environment

The quantity of dust entering the workers' system is also directly related to the health effects. International standards have been developed for a limited number of airborne contaminants and are known as Threshold Limit Values (TLV) or Occupational Exposure Standards (OES).

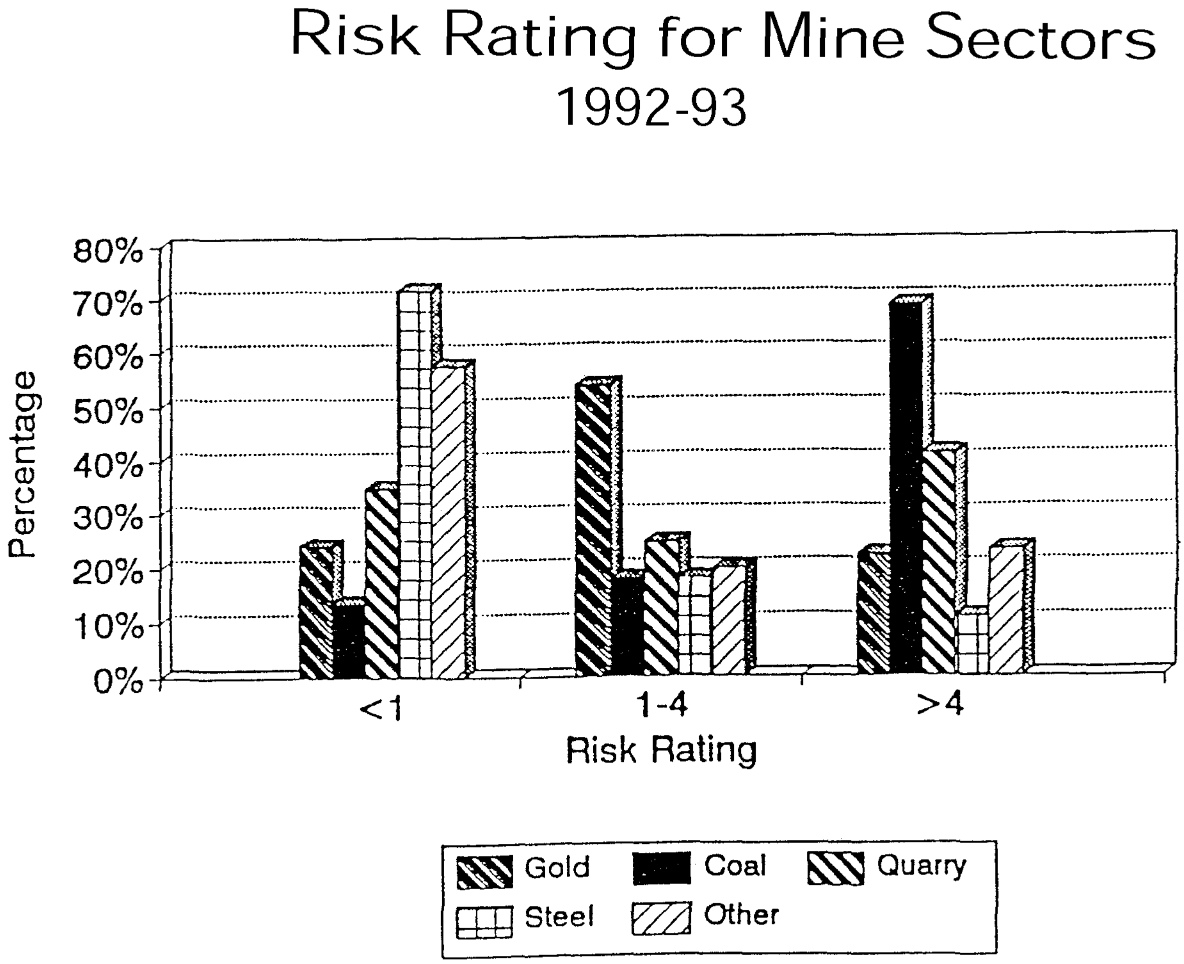
However, there are a number of limitations associated with the development and applications of these standards. In a study conducted by Seixas et al. in 1988 which looked at approximately 3000 mineworkers who were exposed to low levels of dust (mean 1.2 mg/m^3) since new standards were enforced in the USA in 1969, they concluded that the standards were not "completely effective in preventing measurable adverse respiratory effects" in the study sample. (8)

2.2 EXTENT OF THE HAZARD

Current data collection mechanisms have been developed to determine the risk rating of a mine in terms of the Occupational Diseases in Mines and Works Act. This rating is used solely for the purposes of determining the levy for each mine. The format in which the data is presented does not lend itself to be used as a means to determine to what extent workers health is affected. This issue will be discussed later.

Using recently obtained Risk Rating data from the Government Mining Engineer (GME) we can make some preliminary conclusions on the extent of the dust problem in the mining industry in South Africa.

The 1992-93 information indicates that over 36% of listed mines in South Africa have a risk rating of 4[4] or greater, and 27% have a rating between 1-4. The percentages of mines with ratings greater than 4 vary from sector to sector. In coal mines 68.7% of mines have a rating of greater than 4. At gold mines it is more than 22%, while at crushers and quarries there are over 40% of mines with this rating. Refer to the following figure.



[4]For the purposes of this document a risk of 4 is being considered as those mines which have a serious health problem. If AQI≥1 then the Risk % = 4 x $(AQI)^2$ = 4. However, it must be remembered that the risk rating is not for the purposes of identifying health problems, but for the purposes levy.

3. HOW IS DUST GENERATED AND HOW IS IT REMOVED

3.1 DUST GENERATION

Dust is generated when solid mineral structure is destroyed by crushing, cutting, grinding or drilling. This usually occurs when the mineral has to be broken into a convenient size so that it can be easily handled and transported to the area where it is processed. It is at these stages of production, transportation and processing that dust becomes a problem. Each process releases dust particles of varying sizes. The smaller the dust particles the greater the hazard.

Once the respirable particles become airborne they become a health risk to workers who are exposed to it. The areas of dust generation can be broadly classified into 3 areas. These are production, transportation and processing. Some of these areas are discussed below (9):

3.1.1 Drilling

A large quantity of rock is pulverised during the drilling process and produces dust, if this dust becomes airborne it constitutes a major underground dust hazard. (9)

3.1.2 Blasting

Blasting, particularly in hard rock, produces enormous quantities of dust in concentrations which have been shown to be higher than those produced by any other mining processes. (9)

3.1.3 Mechanical loading

After blasting, broken rock is mechanically loaded in development ends. This loading can generate high dust levels.

When the conventional exhaust overlap system[5] is used this dust is inhaled by all personnel working between the face and the exhaust inlet. When the extended exhaust system is used only personnel working ahead of the loader are exposed.(9)

3.1.4 Transportation of rock

Increased mechanisation in the handling of rock has become a major source of dust. In South African gold mines at present there are almost as many scrapers used as there are rock-drills and a large number of mechanical loaders are also in common use.(9)

3.1.5 Falling rock

When rock is handled underground, it often falls either over rock surfaces or through the air. The greater the impact (the speed and height of the fall), the greater the amount of dust that is produced.(9)

3.1.6 Transfer points

The number of transfer points varies considerably from mine to mine. Generally, the rock is tipped from the skips at the shaft into storage bins from which it is taken by conveyor belts to and from the different types of crushers, the screens and the mills. Storage bins are used at several points in the circuit, and these constitute still further transfer points. Large clouds of dust may be produced when rock travels long distances in the open.(9)

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[5] In the exhaust overlap system the exhaust column is carried to the face. A smaller diameter forcing column picks up air from the intake of the exhaust column and conveys it to the face

3.1.7 Screens

Stationary or vibrating screens are in common use for size classification of the broken ore. Large amounts of dust are released from the screen if the material is allowed to dry.(9)

3.1.8 Crushers

The crushing process is a source of large quantities of dust. The dusty air is in some cases, blown directly into the atmosphere.(9)

3.1.9 Miscellaneous operations

Other operations that generate dust are milling, rotary filters, grading rooms and assay crushers.(9)

3.2 DUST CONTROL: SUPPRESSION AND REMOVAL

The main objective of dust control in the mines should be to protect workers from being exposed to respirable dust and eliminate occupational lung diseases through preventing dust from being airborne, removing dust from the air and reducing or eliminating dust formation.

Dust control is established by reducing respirable dust levels in the air to acceptable standards. A number of countries have established "approved" standards in which it is acceptable for miners to work.

The International Labour Organisation has produced a Code of Practice on "Occupational Exposure to Airborne Substances Harmful to Health". Chapter 2 of the Code gives "Principles of the prevention of contamination of the Working Environment". See Appendix 2.

The control of dust usually involves one of the following methods of application (10):

i. The removal and dilution of dust by ventilation;

ii The control of the formation and dispersion of dust by attention to the method of mining and the way in which machines are operated;

iii. The application of water, either to limit the dispersion of dust into the air, or to suppress airborne particles;

iv. The use of exhaust ventilation to contain dust sources followed either by ducting the dusty air to unoccupied parts of the mine, or by filtration before returning it to the main ventilation current.

These methods are now discussed in detail.

3.2.1 Ventilation

Diluting the dust concentration

Mines which require good ventilation for the purposes of cooling or removing explosive gases, benefit from the reduced dust levels. The dust is not visible and does not affect productivity. (Refer to section 2.1.1) Hence, mines are not ventilated for dust removal purposes. (11)

The Minerals Act specifies that the working areas be ventilated to maintain safe and healthy environmental conditions and any dust in the air be rendered harmless (Reg 10.6.2). A minimum air velocity of 0.25m/s average over the working height of a stope is laid down. The minimum volume of air to be supplied to development ends and shaft sinkers is 150 cubic decimeters for each square meter of the average cross-sectional area of the excavation, or 0.15m/s velocity.

Rogan (7) shows how dust concentrations decrease substantially until approximately 1m/s, thereafter the velocity of the air tends to pick up the dust from the surroundings.

This may result in the reduction of the dilution effect at speeds of 2m/s.

3.2.2 Water in Dust Control

Water has been used to reduce dust levels for years and continues to play a major role in the control of dust. Various sections to the regulations refer to the use of water to control dust.

However, in a study conducted Germany in 1967 it was shown that while water spray jets removed about 90% of coarse dust from the environment it had little effect on the concentration of fine dust particles. (7)

In metalliferous and diamond mines water is the most widely used method of preventing dust from becoming airborne. Rather than attempting to capture airborne particles, water should be used to prevent dust from becoming airborne when used to suppress dust from machinery.

Section 10.20 of the Minerals Act stipulates that "every machine for ripping, picking, cutting, drilling or loading rock...be fitted with means or means shall be provided, either for applying water effectively to prevent dust being created by the operation of such a machine or for effectively trapping such dust by some suitable apparatus approved by the Inspector of Mines".

The regulation goes on to say that the GME can prohibit such a machine being used if it seriously and materially endangers the health of workmen. Effective atomisers or sprays in good working order are required at any main bin and orepass.

Water-fed rockdrills

The Minerals Act stipulates that water-fed rockdrills must be used in the mines, however this method has not been effective since there is often a compressed air leak into the front head of the machine, in this way water droplets are evaporated rapidly leaving behind in the air suspended dust particles.(8) An adequate maintenance programme must be implemented to ensure that dust control mechanisms continue to remain effective.

Scraping and Mechanical loading

No regulations are laid down for the design of other machinery which cause dust during scraping and mechanical loading.

Scraping: It has been established that running water along the footwall has failed to wet the top of the broken rock. The use of "drip feeds" - suitable pipes or hoses with holes or slots at regular intervals which drip water from above onto the broken rock - is a better system.(11)

Mechanical loading: Many of the loaders used in the mines are notdesigned to deal with the problem of dust. Loaders fitted with automatic water sprays would be more effective against dust.(11)

Wetting broken rock

The Minerals Act stipulates (regulation 10.10.1) that blasting shall only take place once in 24 hours. On re-entry (regulation 10.10) the face and broken rock must be wetted 15 minutes after blasting and 15 minutes prior to someone entering. The area must also be wetted if the conditions require it. These regulations are not always effective because at times when miners are under production pressure, or towards the end of the shift these regulations are disregarded. Off-shift wetting has proved to be more effective in this regard, using automatic water sprays. (11)

3.2.3 Removing dust from the air

Removing dust from the air occurs by use of exhaust ventilation. The extracted dust is removed from the site of generation by ventilation ducts and passed through a filter system. Dust is continuously removed from the face so that work is carried out in clean air.

For effective dust control the hood of the exhaust system must be kept as close to the working area as possible.

Filters

Bag filters are the most extensively used filters. The bags can be of varying efficiency in the respirable particle size range, but the efficiency decreases with decreasing particle size. These filters are employed primarily at tipping stations and loading points in the intake air haulage.

3.2.4 Respiratory Protective Equipment (RPE)

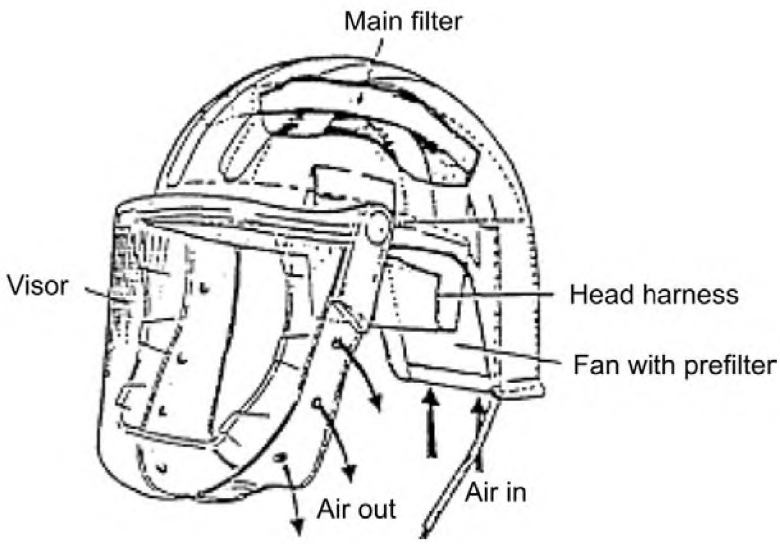
RPE is always the last resort in protecting the workers health. It is not a dust control measure, since it does not reduce or remove the concentration of dust in the working environment.

At present mines have disposable respirators for workers to use if so required. The use of RPE may not be suitable or comfortable in conditions where workers have to perform heavy work and the temperatures are very high. In these cases RPE may only be acceptable for a few hours. (11)

The choice of RPE should rest with the worker. RPE vary from disposable respirators to air supplied breathing apparatus. However, a major consideration should be the Protection Factor which the respirator offers in a particular risk area.

A recent development over the last few years has been the air-stream helmet for high concentrations of dust. This type of RPE has a filter unit at the back of the helmet and a rechargeable battery unit attached to the belt of the user. The fan blows filtered air across the users face. (12) (Refer to the following figure)

ILLUSTRATION OF A VENTILATED HELMET AND VISOR RESPIRATOR



4. DUST MEASUREMENT

4.1 WHY MEASURE DUST?

Dust should be measured for two basic reasons in the mines:

i) To determine the dust levels that result from mining procedures, work practises, and the conditions of ventilation at the workplace, the objective being to achieve engineering control over the generation and dispersal of dust.

ii) To obtain quantitative data on human exposure that will permit epidemiological study of the relation of human response to dose, with the goal of providing a quantitative basis for the setting of health preserving dust standards.

4.2 HISTORICAL OVERVIEW - CONSERVATISM OF INDUSTRY

Dust sampling on the mines occurs for two reasons. Firstly to meet the requirements of the Occupational Diseases in Mines and Works Act (ODMWA) for the determination of risk rating and secondly for the purposes of dust control as required in the Minerals Act.

Dust measurement began on the mines in 1914 when the Chamber of Mines established a Dust Sampling Unit. Initial sampling used the sugar-tube to conduct gravimetric sampling. However, this gave way to the Konimeter in around 1916. Routine Konimeter sampling began in 1919. (2)

The Konimeter is a snap sampler. The sample is collected on slide and dust particles are counted with the aid of a microscope. This method of sampling continued until the late 1980's when gravimetric sampling became the accepted method.

Internationally the move towards gravimetric sampling began after the Pneumoconiosis Conference held in Johannesburg in 1959. It was at this conference that the Johannesburg Curve was accepted and on which the collection of respirable dust is largely based today.

During the 1970's most countries had moved towards the method of gravimetric sampling. However, South Africa continued to use the Konimeter until the end of the 1980's. This has made it extremely difficult to compare South African conditions with those of other countries.

4.3 MEASURING INSTRUMENTS AND FORMULAE

Measuring Instruments

The use of the Konimeter to measure dust in the mines

The Chamber of Mines established its dust sampling limit in 1914 using sugar-tube sampling. The Konimeter sampling was introduced around 1919 (2). The Konimeter is a spot sampler in both place and time. If a Konimeter measurement is made at half-hour intervals during a working shift at a given workplace with operations starting and stopping, variations in the order of 5:1 in the readings are counted. The instrument and the standard procedures of sampling used with it are therefore unsuitable for determining the total exposure to dust to which a worker may be subjected over a working shift.(13)

Despite its limitations the Konimeter continued to be used in the mines until around 1988. Discussions and research began within the mining industry regarding the need for a more effective sampling method. By the end of the decade there was general acceptance that the use of the Konimeter was no longer effective for determining personal exposure and there was a need to move towards gravimetric sampling.

The introduction of gravimetric sampling in the mines.

Gravimetric sampling was introduced to comply with paragraph 3 of Section 20 of ODMWA No 78 of 1973. The document containing the guidelines is divided into a parent and supporting documents. (14)

A "Guideline for the Gravimetric Sampling of Airborne Particulates for Risk Assessment in Terms of the Occupational Diseases in Mines and Works Act" (here-in-after referred to as the "Guidelines") outlines a sampling strategy for the gravimetric sampling of dust in mines and works.

This document outlines sampling procedures, procedures for the submissions of results to the GME, and the measuring instruments to be used. It also includes a number of supporting documents.

Gravimetric sampling is done through the collection of dust particles on a filter medium. This sampling consists of collecting a representative portion of the dust from the air using a size selective sampler. The sample is then weighed to determine the actual portion of dust collected. Assessment of composition of the collected material is done by X-ray diffraction or chemical means (14).

The "Guidelines" provide a supporting document for the selection of sampling equipment and filter media. These guidelines meet the internationally accepted requirements for gravimetric sampling. Only sampling instruments approved by the GME can be used and these are listed in supporting document number 3.

Occupational Exposure Standards

The setting of Occupational Exposure Standards (OES) is geared towards establishing effective minimum levels for the protection of the health of workers.

Various countries have established occupational exposure standards. These standards and terminology may vary from country to country. In the US they are referred to as Threshold Limit Values; and Occupational Exposure Standards in the UK.

The setting of these standards are based on two broad aspects. Firstly, scientific evidence that exposure to a particular substance will affect the health of workers and secondly, the socio-economic conditions existing at the time these standards were established.

Scientific evidence uses three methods (individually or in combination) for the establishment of OES these include: industrial experience; animal experimentation and human experimentation where possible (15).

Once scientific evidence has identified a problem there is usually negotiations amongst the affected parties on the level at which the standard should be set. This means that standards are constantly being reduced as new information becomes available or socio-economic conditions changed.

International standards are based on the Threshold Limit Value - Time Weighted Average (TLV-TWA) concentration for a normal 8-hour workday and a 40-hour work week, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. (15)

The Guidelines in defining TLV-TWA excludes the 40 hour work week limitation which international standards use. If we consider that South African mineworkers work shifts of approximately 48 hours a week, the current TLV-TWA would not offer adequate protection.

In addition, caution must be used in the application of occupational exposure standards. Existing standards have largely been developed in Europe and North America. These conditions and standards may not adequately protect workers under South African conditions.

The standards are based on normal respiratory rates. If workers are involved in heavy work under difficult conditions their respiratory rate will increase. This will result in greater quantities of airborne substances entering the respiratory system. The standards would therefore not be effective.

In addition there have been a number of concerns about the manner in which standards have been established by the ACGIH. There has been a large corporate influence over the establishment of these standards. Castleman[6] has published a number of articles raising these issues.

Supporting Document 2 of the Guidelines list TLV's for approximately 52 substances. These are generally based on the American Conference of Governmental Industrial Hygienists (ACGIH) standards. However there are certain differences.

Some of the standards set for particular pollutants deviate from the international standards, especially for asbestos fibres and Quartz, which have been specified by the GME. The quartz standards set by the GME are aggregated when compared to international standards.

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[6] Castleman B I (1983) The Double Standards in Industrial Hazards, International Journal of Health Services, 13:1

TABLE: GME Standards vs International Standards

GME Standards		International Standards (* according to ICEF publication: TLVs Best Prevailing Standards)	
Asbestos		Asbestos	
Amosite	2,0	Amosite	0,5
Chrysotile	2.0	Chrysotile	2,0
Crocidolite	0,2	Crocidolite	0,2
Alpha Quartz $Si0_2$	< 5%	Silica - Crystalline standards are given for:	
- Coal Mines	2.0	amorphous	3.0
- Platinum mines	3.0	cristobalite	0.05
Alpha Quartz	> 5%	quartz	0.1
- all mines	0.1	Tridymite	0.05
		Tripoli	0.1
		Silica fused	0.1

This report will not look at the reasons for the differences in the standards. It is more important to establish an acceptable procedure for the establishment of these standards by all parties involved (16).

The current process for the establishment of these standards rests entirely with the GME. In terms of the Minerals Act Reg 10.1.2 the Director-General may specify standards from time to time.

The ILO Code of Practice on Airborne Substances (16) devotes an entire chapter to standards. This chapter deals with the following:

i. The establishment of Standards
ii. Application of standards
iii. Measurement of substances.

This chapter is included in Appendix 2.

Supporting document 11 gives specific guidelines on asbestos sampling.

Formulae

The Guidelines are directed towards the determination of risk at each mine. To this end there are a number of formulae which are used to determine the risk. Supporting Document 5 gives a detailed breakdown on how the risk rating for each mine is determined.

The primary data used in this calculation is the Time Weighted Average Concentration of each airborne substances in the working environment.

The risk rating for each mine is arrived at by the use of the average gravimetric sample collected at each area and a number of formulae. The basic calculation is based on the Air Quality Index (AQI). These results are used to calculate the Air Quality Index (AQI) for each Statistical Population (Stat Pop).

The AQI is the average TWA concentration/ TLV-TWA for that substance. The average AQI for a stat pop is the sum of all the AQI with a value in excess of 0.1 of the TLV-TWA for a particular stat pop.

(9)

$$\text{Risk \% (Stat pop)} = 4 \times (\text{AQI of stat pop})^2.$$

$$\text{Risk Rating\%} = \frac{(\text{N(Year 1)} \times \text{Risk\% (stat pop)}) + (\text{N(Year 2)} \times \text{Risk\% (stat pop)})}{\text{N1+N2}}$$

where N is the number of persons employed in each stat pop[7] area for the year.

The series of computations are then used to determine the average risk for the entire mine.

[7]Statistical Population has been defined by the Guidelines as consisting of a group of persons working in an environment of approximately the same pollutant content.

4.4 SAMPLING STRATEGY AS OUTLINED IN THE "GUIDELINES"

The main objectives of the guidelines are to achieve the following:

i) to assess the labour force exposure relative to a set of standards for risk determination purposes;

ii) to encourage the implementation of better control measures;

iii) for epidemiological purposes.

The document gives a detailed strategy for the determination of risk. This is done by collecting gravimetric samples and submission of results to the GME: Directorate of Mine Environmental Control (MEC).

The strategy includes the following:

i. Identify all persons who are exposed or potentially exposed to harmful pollutants.
ii. Establish sampling areas
iii. Special attention to certain categories of workers
    - highlight women at risk
    - include contractors
iv. Establish statistical populations from an analysis of the process/ occupations/ labour force
v. Determine number of samples
vi. Select samples for analysis
vii. List total number of persons in and percentages of samples taken at statistical populations.

Each mine should have its own expertise and sampling equipment. Where this is not possible the services of an Accredited Authority must be used. All equipment must be SABS approved. The guidelines provide a list of Accredited Authorities (supporting document number 10).

These results must be submitted every 6 months to the MEC on the prescribed form. Copies of these forms must also be sent to the Regional Mining Engineer.

Once the results are received by the MEC it is used to determine the risk rating for each mine.

5. LEGISLATION

5.1 THE ACT

Dust in the mining industry is regulated by the Minerals Act and the Occupational Diseases in Mines and Works Act (ODMWA).

The Minerals Act is responsible for the control of dust while the ODMWA is responsible for protecting the health of workers by determining the risk rating for each mine and collecting a levy based on the risk.

In the Minerals Act, Chapter 5: Safety and Health, states that the mine manager is responsible for taking "all reasonable measures to ensure the safety and health of employees..." [Section 31(1)a(ii)].

Section 34 of the Act allows the regional director to ask mine managers to develop Codes of Practice on any health and safety problem. There are no Codes of Practice for dust.

5.2 THE REGULATIONS

The control of dust in mines is administered by two regulations (17):

i.	Chapter 2:	Responsibility
ii.	Chapter 10:	Ventilation, Gases and Dust

Chapter 2: Responsibility

Chapter 2 deals with the responsibility for ensuring that the working environment is safe for workers.

This responsibility lies with the Environmental Control Officer who is appointed by the Mine manager (Section 2.16.1.1). This person is responsible for amongst others:
" ...examine or cause to be examined the environmental conditions at all places in or on the mine...".

The Environmental Control Officer shall also report to the mine manager on the following (amongst others):

i. "the quantity of respirable dust and noxious and flammable gases present in the air";
ii. "the quantity, quality and distribution of the mine's ventilating air".

Chapter 10: Ventilation, Gases and Dust

The main regulation dealing with the control of dust in mines and works is Chapter 10 of the regulations. This chapter also deals with ventilation and gases.

This chapter can be broadly divided into a number of sections. Those which relate to dust include the following:

i. Philosophy

    The heading of this section states "No work in harmful air". It then goes on to state that no person shall work in harmful air unless the person is using effective apparatus which has been approved by the Director-General (10.1.1).

ii. Dust Control

    This forms the core portion of the regulations. Section 10.2.1 states that "...the liberation of dust in the atmosphere shall be effectively controlled by the use of water or other dust allaying agent or by a dust extraction system." during all processes occurring in the mines.

Thereafter various subsections deal specifically with the control of dust. They cover the use of water, ventilation, dust allaying procedures, and the use of machinery supplied with water to reduce the levels of dust.

The control of diesel emissions is covered by section 10.25.

iii. Sampling

Section 10.5.1 covers the sampling of dust in the mines. It requires that sampling be carried out every 3 months in each area referred to in section 10.2.1. These results must be recorded.

Sections 10.9.1-4 deal with air measurements and sampling in various mining sectors. It indicates where and how often the sampling should occur.

vi. Removal of workers

Section 10.6.5 allows for the withdrawal of workers by the person in charge if the levels of "flammable or noxious gases" are dangerously high.

v. Standards

Section 10.1.2 states that no one may work, cause or permit another person to work in any place where the air concentration for dust exceeds standards which have been set by the Director-General unless that person is wearing approved effective apparatus.

Section 10.6.6 deals specifically with the standards of certain gases which are present in the atmosphere. These include carbon dioxide, carbon monoxide, oxides of nitrogen, hydrogen sulphide and flammable gases.

vii. Coal Dust explosions

Section 10.24 deals specifically with the prevention of explosions in coal mines.

6. ENFORCEMENT

The Chief Directorate for Mine Environment Control (MEC) is the Department responsible for environmental hazards. There is a Sub-Directorate for Mine Pollution Control. This department is responsible for receiving the dust sampling results from each mine in terms of the guidelines and determining the risk rating for the mines.

The mines also have to send a copy of the results to the Regional Offices. It is the responsibility of the regional office to ensure that environmental conditions at each mine is acceptable to the guidelines and the regulations of the Minerals Act.

6.1 MINE POLLUTION CONTROL (MPC)

This is one of three departments within Mine Environmental Control. MPC employs 10 staff. These include the Deputy Director, 3 Assistant Directors and 6 technical staff. They are responsible for collating the results from the various mines in terms of the Guidelines.

These results are then checked for accuracy and processed by computer to determine the risk factor for the mine. These risk factors are then presented to the Risk Committee which meets 4 times a year.

Broadly the MPC have two responsibilities:

i. To ensure that the mines are correctly carrying out the sampling procedures and systems as required in the Guidelines.
ii. To act as Consultants to the regions.

The entire focus of this department is on the determination of risk rating as required by the ODMWA, and auditing sampling procedures that are carried out at the mine. The MPC does not have any line authority to the regions. They see the enforcement of the Minerals Act as the responsibility of the regions.

6.2 REGIONAL OFFICES

The Regional offices are required to ensure that all health and safety conditions and requirements as stated in the Minerals Act are met by each mine. This includes the responsibility of ensuring the dust levels in the mines are within acceptable standards.

Each mine's dust levels which are sent to the MEC are also sent to the regional offices. The MEC has issued a directive (No. A25 dated 13 September 1993) which requires that Regional Mining Engineers (RME) respond to AQIs of greater than 2.

The RME must investigate the conditions and report what remedial action will be taken by the mine.

The RME's use a basic dust measuring device called the Hund Tyndallometer, to take small measurements of dust levels to ensure that the mine is within the standards. This is only done if there is a complaint or if the inspector thinks that the levels are high. If dust levels are too high the mine could be issued with a section 27(1)(a) order to immediately rectify the situation. If after the allotted time period there is no improvement in the dust levels the MEC is brought in to determine the source of the problem and to make recommendations.

The regional offices do not carry out any gravimetric sampling and do not have the equipment to carry out such sampling.

A common concern raised at regional offices was that of the capacity to fulfill all the requirements of the act. The reason put forward was the limited human resources and the skills of the inspectors at the regions.

6.3 CRITIQUE OF THE SYSTEM

For the purposes of this report we met with Chief Directorate of Mine Environmental Control (MEC) and the Deputy Director of Mine Pollution Control to determine how they functioned with respect to dust.

From discussions with these persons who are responsible for the enforcement of dust regulations, it is clear that the entire focus is on sampling and sampling procedures, and not on the control of dust or hazard abatement.

The MPC carries has the specific task of determining risk factors for mines. However, the limited focus of the department does not allow it to use the information at its disposal for the purposes of reducing dust levels on the mines.

The results that have been received from the department indicate that more than 30% of mines have a risk factor greater than 4. From our discussions at various levels it was obvious that there is no clear strategy to reduce dust levels. The responsibility for the reduction of dust levels lies very much with the mines.

The MPC indicated that if they were required to look at controlling dust on the mines, they would require additional staff.

I believe that while this department is strategically placed to reduce dust levels on the mines, it may be necessary to restructure and refocus the departments objectives towards doing so. The dust returns from the various mines are structured in such a way that it is possible (with a few changes) to develop computer software systems to analysis results and identify areas of priority. This would assist in developing a clear programme for the overall reduction of dust levels on the mines.

The high percentage of mines with a risk of greater than 4 indicates that the effectiveness of the enforcement system is limited and needs to be restructured.

7. THE MINES ROLE

The mining industry has played a very limited role in the reduction of dust in the industry. The major focus of research has been the analysis of data which the Chamber of Mines Research Organisation (COMRO) collected between 1963 - 1988 at various gold mines; and the methodology for the introduction of gravimetric sampling on the mines. Most of this work was carried out by COMRO. Mining Technology at the CSIR is now responsible for conducting research under the direction of the Safety In Mines Research Advisory Council (SIMRAC).

Current research is looking at diesel emissions and the effectiveness of gravimetric sampling.

7.1 THE RESPONSIBILITY OF THE MINE

The legislation places a responsibility on the mine to ensure that adequate environmental conditions are achieved.

Ultimate responsibility for healthy working conditions at the mine rests with the mine manager. The mine manager has to appoint, amongst others, an Environmental Control Officer (ECO) to ensure that air quality throughout the mine meets the standards as required by the legislation. The ECO is responsible for monitoring dust levels and inspecting ventilation systems in the mine.

The legislation also places the responsibility on a chain of other persons in the mine. Some of these have specific responsibility for health and safety, while others have general production responsibilities as well. All these persons have to record their findings, or observations. These records have to be checked by the mine manager and he is in the final instance responsible for conditions in the mine. Such persons include the Environmental Control Officer, Mine Overseer, Shift Boss, Chief Safety Officer, Safety Officer, and Safety Representative.

In terms of the Minerals Act the mine has to carry out sampling every three months. Every 6 months results must be submitted to the MEC for risk determination purposes. All results must be recorded.

7.2 OVERVIEW OF ROLE OF ANALYTICAL LABORATORIES

Analytical laboratories are responsible for analysing samples which are collected by the mines. They are usually independent organisations - which provide a service to industry. They have to achieve standards which have been set by the South African Bureau for Standards. There is a "round-robin" system which exists amongst the laboratories (for quality control purposes) hereby samples are swapped between the laboratories and analysed.

In addition mines can employ an Approved Accredited Authority (AAA) to carry out the sampling at the workplace. These AAA are approved by the GME to conduct the sampling procedures as required by the Guidelines.

7.3 CRITIQUE OF THE SYSTEM

The entire system is geared towards and focuses on the monitoring of dust levels because it is a requirement of the legislation. The system should concentrate on reducing dust levels and monitoring should be directed at ensuring that control measures are effective and are meeting standards.

Mines are responsible for the measurement of dust levels on an internal basis. In addition the analysis is commissioned by the mining houses to private laboratories or in-house laboratories. This allows room for abuse of the system in that the mine can protect itself and thereby reduce the rate of the levy which the mine would have to pay if its dust returns are high. In some instances laboratories have requested mines to resubmit samples if they thought the sample was too high. An effective system for auditing both the sampling strategy and the sampling itself needs to be developed.

The information provided by the MPC indicates that dust levels on the mines continue to be high. The role of the mines in reducing dust levels has been limited and is not having the desired effect.

8. OVERALL CRITIQUE

8.1 LEGISLATION

The Minerals Act details a number of methods for the control of dust in the works and on the surface of mines. However, the first two sections lay a very weak foundation for the sections that follow. These two sections emphasise the use of personal protective equipment in the event of hazardous situations occurring.

Section 10.1.1 which is titled " No work in harmful air" goes on to state: "... unless such (exposed) person is wearing effective apparatus,...to prevent the inhalation of smoke, gas, fumes or dust."

Section 10.1.2. which allows the Director-General to establish occupational exposure standards also continues with the trend of relying on the use of personal protective equipment if the standards are exceeded.

Under the Minerals Act, health and safety in the mines is the primary responsibility of the mine owners. The following regulations relate to the responsibilities of mine owners:

- Chapter iv. Section 34: The manager of any mine or works shall, if required by the regional director concerned, draft codes of practice in respect of ventilation system...regarding any safety and health in connection with any mine or works.

- Regulation 10.9.1.1 At every metalliferous or diamond mine, where the manager shall make an appointment under regulation 2.16.1.1 (a) determinations shall be made of the ventilation and environmental conditions and the amount of dust in the air in the main airways and at the faces of working stopes, development ends and shafts in the course of being sunk.

The legislation needs to clearly identify the order of priority in which the dust hazard must be reduced. The tendency to rely on PPE must be limited and reduced. The focus must be on the use of engineering controls and changing the production process to reduce dust levels.

8.2 RESEARCH AND DATA COLLECTING

The research reports that have been available from COMRO have been restricted to analysing dust submissions from the mines for risk assessment purposes. While these reports have identified areas of risk, they have not gone further in identifying control measures for the reduction of dust/s in mines.

The research conducted by COMRO has been limited to analysing dust returns from the various mines. Between 1964 and 1988 there were 10 reports that were complied in 3 year intervals. These returns have been based on the use of the Konimeter. One of the objectives of this study was to make suggestions "on which dust suppression measures could be most advantageously applied". However, the reports did not look at control measures.

The final report produced in 1989 showed that some mines had reduced their dust levels by more than 100%. However, no indication is given on how this was achieved or if other mines could possibly implement similar control measures.

The 1989 report showed that dust conditions on mines were the lowest since the surveys began in 1964. However, the limitations in terms of the Konimeter (as discussed in Section 4.3) must be considered when analysing these results.

In a paper written by H.H.E Schroder et al in 1982, which analysed the seventh dust survey in the mines, it was concluded that since 1964 dust conditions have improved in the mines. However, the paper goes on to show that in the last few years, dust conditions have deteriorated in the underground and open cast mines. Especially around the tips, loading boxes and in the stopes. (18)

None of the above reports or paper indicated how dust control was achieved or if it was sustainable. During the period when Schroeder indicated that conditions had deteriorated there was no indication of why this was so or how the conditions could be reversed.

The change to gravimetric sampling now makes it difficult to compare the results of the previous South African studies with the data now being collected by the GME.

8.3 TRADE UNIONS EXCLUDED FROM EFFECTIVE PARTICIPATION

According to regulation 2.18.1 employers have the powers to appoint safety representatives in the mines, this legislation is silent on the role of trade unions in regard to health and safety matters in the mines. Workers are not informed about the results of dust samples done in their own mines, let alone at industry level, what the accepted procedures of measurements are and what the purpose of taking samples aim to achieve.

In processes of establishing standards as well as determining research needs trade unions have not been allowed to play a role. If any dust reduction programme is to be effective, workers and their trade unions must play a role in the decision making processes.

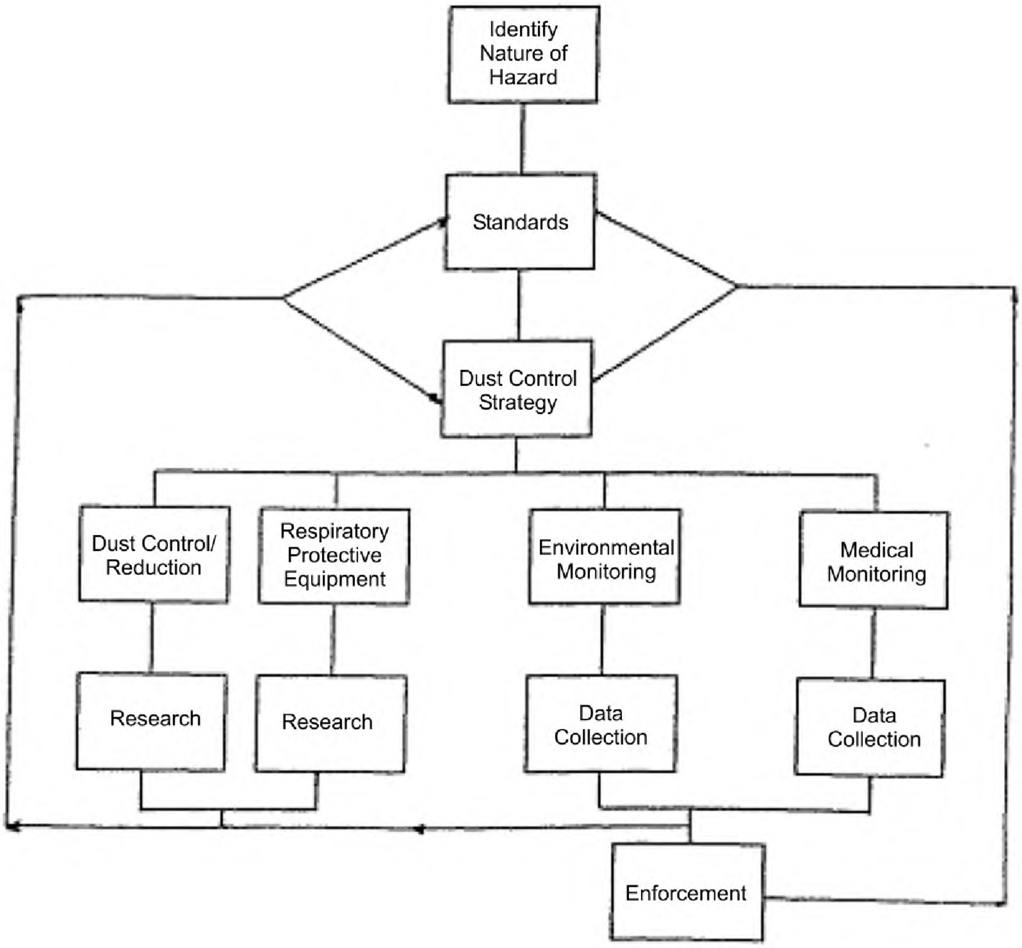
9. RECOMMENDATIONS

This preliminary investigation into the control of dust in the mining industry indicates that the problem of dust on the mines is extensive. However, there is no clear direction on how dust levels on the mines are going to be reduced in the short, medium and long term.

To begin the process of reduction of dust on the mines we should change the philosophy of the legislation from allowing mine management to rely on PPE and look towards engineering controls to reduce dust levels on mines.

Figure 1 puts forward a suggested framework for the reduction of dust levels on the mines and better protection for the health of workers.

FIGURE 1: Suggested Framework for a Dust Abatement Programme



The basis of this framework is that a structure involving all the affected parties' needs (labour, employer, and state):

1. to establish enforceable standards for the harmful airborne substances in the working environment;

2. develop a clear programme (Dust Abatement Programme) for the reduction of dust levels to set standards within a set period of time;

3. to enforce this programme by equipping the necessary state structures to ensure that individual mines and the industry as a whole is achieving the targets which have been set in the programme;

4. develop adequate data collecting mechanisms to be used for enforcement and research purposes;

5. identify research priorities and direct resources towards the reduction of dust levels

Developing Standards

The establishing of standards is a crucial area in a dust reduction programme. This sets the target which each mine must strive to achieve. The important step in accepting any standard is the participation of all parties involved.

The ILO Code of Conduct gives detailed guidelines for the establishment of standards. These guidelines should be used as a basis for setting standards in the future. In addition all existing standards must be reviewed and the necessary changes made to ensure that they adequately protect the health of the workers.

Dust Abatement Programme

The Dust Abatement Programme must have the following object (as stated in the ILO Code of Conduct):

> "The ultimate aim of programmes of prevention of contamination of the working environment is to eliminate contamination in order to protect the health of workers; and if that is not possible, the intermediate objective is to keep contamination at as low a level as possible by choosing the least harmful materials and products or by taking other technical measures to reduce the contamination of the working environment to the lowest possible level and at any rate to the exposure limit established by the competent authority or recommended by scientific bodies."

The strategy must include the following components:

i. A clear programme for the reduction of dust levels to the lowest possible levels;
ii. A programme for the selection, use and maintenance of Respiratory Protective Equipment (RPE);
iii. An environmental monitoring programme to determine the effectiveness of dust control;
iv. A medical monitoring programme for all exposed workers.

This Dust Abatement Programme could form the basis for a Code of Practice. This programme must be developed together with the unions, management and the state. This Abatement programme needs to be developed at the industry level and the mine level.

Dust Reduction

This is the most crucial component of the Programme. This programme must include a timeframe by which the industry and a mine will reduce the dust level to the acceptable standard.

Dust reduction should include the following approach in order of priority:

- Reducing dust levels at source of generation by the use of different technologies and methods in the production process
- Reducing contamination of the working environment during the handling and processing of dust creating materials
- The use of adequate ventilation systems
- Isolating the numbers of workers who are exposed to high dust levels
- Reducing the amount of time spent in contaminated / dusty areas

Respiratory Protective Equipment (RPE) Programme

The use of RPE must always be considered a "last resort" option. RPE should only be considered after all reasonably practicable measures have been taken to protect the health of workers; or as a short term measure during periods of high dust levels.

When a decision is taken that RPE is necessary a clear programme must be developed for the selection and use of the RPE. The programme should also include a training component for all workers who may be required to use the RPE. (9)

Selection of RPE

The following factors must be considered during the selection process for an adequate RPE for a particular task or workplace:

- Type and level of hazardous atmosphere
- Degree of exertion and thermal stress
- Use in low and high temperatures
- Communication
- Work Duration and Comfort
- Access and mobility for the wearer
- Fit and Seal
- The degree of protector the respirator will offer (i.e. the Protection Factor)

The acceptability of the wearer together with the consideration of the above factors is crucial for the programme to be effective.

Use of RPE

Once the RPE is selected, procedures must be established for the correct use, care, maintenance and storage of the RPE. Other facilities should include cleaning and disinfection as well as removal of and availability of disposable filters and respirators.

Training

For an RPE programme to work effectively there is a need for training to occur at various levels. These include:

- the person who will manage and monitor the programme;
- for all persons who will issue and maintain the RPE
- for all persons who will use the RPE

Environmental Monitoring

The Guidelines which have been developed form an acceptable basis for the monitoring of environmental conditions at each mine. The monitoring programme should be used as a mechanism for ensuring that mines are achieving the targets which they have set in reducing dust levels.

Each mine must submit their results on a 3 monthly basis to the GME and regional office concerned.

The information from the monitoring programme should be collected and used for the purposes of enforcement and research.

Medical Monitoring

Each mine needs to have an effective medical programme to monitor the health of workers who are exposed to unhealthy conditions at the workplace. This report will not go into the details of a medical monitoring programme as a separate report will be covering this section.

Data Collection

An effective data collecting system is crucial to evaluating current regulatory systems and the effectiveness of the Dust Abatement Programme.

The GME already has a basis for the collection of data relating to dust levels at mines. The systems and software need to be adapted and developed so that the data can be used to analyse dust levels in risk areas across the industry, and strategise for further reducing the levels in hazardous areas. In addition data needs to be collected on the health status of workers on an ongoing basis.

The data collected should be used for enforcement as well as determining if targets in the Dust Abatement Programme are being achieved. The information must also be used to identify areas for further research.

Systems need to be investigated which will prevent the duplication of submitted results to various structures. The regional offices of the GME should be linked to the central database.

All information which relates to the levels of dusts at mines and works, and statistics of the health of mineworkers must be published regularly (at least once a year).

The GME should publish annual summary reports of dust samples taken in the mines. These reports should be made available to unions and employers. The summary should cover the following:

- to what extent mines have complied with the "Guidelines".

- identifying specific categories of workers who are more exposed to dust.
- identifying work activities and machinery which generates the most dust.
- assessing and evaluating current dust standards.

Research

Research refers to the analysis of collected data and ongoing investigations to find solutions to reduce the levels of dust in the working environment and thereby protect the health of workers.

Due to a lack of reliable data on the incidence of occupational diseases among black miners, the following recommendations are made:

A full scale epidemiological investigation should be carried out immediately. The study should aim to establish the following:

- Incidence and prevalence of pneumoconiosis in relation to dust exposure;
- The study should take into account types of occupation, length of service, initial period of exposure, age, medical history, mineral dust levels, comparison between underground and surface workers and identify high risk employment groups;
- Evaluation of the present methods of dust control and identification of new methods to reduce the level of dust in the mines;
- Existing medical and employment records should be used as a basis for the investigation.
- All parties affected and concerned, i.e. employers, the government and the unions should be involved in the planning and monitoring of the investigation.

Enforcement

The enforcement of the standards and legislation needs to occur at four levels. These include:

- <u>GME: Directorate of Mine Environmental Control (MEC)</u>

  The Mine Pollution Control of the MEC should enforce the Dust Abatement Programme on a national basis to ensure that the targets which have been set for the various sectors in the mining industry are being achieved.

  This can be done by an analysis of data which is submitted by the mines. The MPC should also conduct regular independent audits of the dust levels in the mines to determine the accuracy of the submitted results.

  The MPC should also fulfill the role of the "component authority" as specified in the ILO Code of Conduct. The MPC must have the necessary skills and resources to fulfill its role. In addition the MPC should have line authority to the regions to ensure that the Dust Abatement Programme is being accomplished at a regional level.

- <u>The Regional Office</u>

  At the mine level the responsibility for ensuring that each mine is achieving the targets of the Programme must be the responsibility of the Regional Office. This can be done on the basis of dust results which are submitted every 3 months.

  The Regional Office must have the capacity to undertake instantaneous dust samples to determine accuracy of results. If there are differences in the results, the Regional Office should call in the MPC to carry out a verification of the dust levels.

If possible there should be regional dust specialists to monitor the progress in the Dust Abatement Programme.

- <u>Union Safety Representatives</u>

  Union safety representatives should be trained on how to audit the Dust Abatement Programme. This will ensure that there is regular enforcement of the programme at the workplace. For this purposes the safety representatives would need to receive adequate training and skills in order to perform this task effectively.

10. CONCLUSION

Dust levels on South African mines continue to pose a risk to workers. Existing regulations and systems have proved ineffective in adequately reducing the levels of dust.

If workers health on the mines are to be adequately protected there is a need for a comprehensive Dust Abatement Programme which will focus on the reduction of dust levels.

This programme must be developed jointly with labour, employers and the state. Resources must be directed towards finding effective systems for the reduction of dust levels. This must include directing resources towards research, training at various levels, and an effective auditing and enforcement system. Enforcement must occur on the basis of the accepted Programme.

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APPENDIX 1

Different Types of Minerals mined in South Africa

Andalusite
Andesite
Antimony
Asbestos
Attapulgite
Barytes
Betonite
Beryl
Calcite
Calcrete
Chrome
Clay
Coal
Copper
Diamonds
Dolerite
Dolomite
Dwyka
Feldspar
Felsite
Fireclay
Flintclay
Flourspar
Gold
Granite
Granite Dimension Stone
Gravel
Gypsum
Limenite
Iron-Ore
Kaolin
Lead
Limestone
Magnesite
Manganese
Marble
Mica
Mineral Pigments
Nepheline
Norite
Perlite
Phosphates
Platinum
Pyrophylite
Quartzite
Quartzite Dimension Stone
Salt
Sand
Shale
Silica
Silicon Metal
Slag
Slate Dimension Stone
Talc
Tigers Eye
Tin
Titanium
Vermiculite
Zinc
Vanadium