Safety in Mines Research Advisory Committee

Quantification of Dust Generating Sources in Gold and Platinum Mines

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Executive Summary

This report outlines the findings of a study performed to establish the respirable dust generation characteristics of a number of mining activities. A series of thirty-eight tests were performed on five mines in order to establish the respirable dust generation rates linked to activities presumed to be hazardous in this respect.

The aim of this study was to identify prominent dust sources that occur in hard rock mines and to characterise these by means of on-site measurement of dust generations. The activities identified for the studies were drilling, scraping, tipping, crushing and rock transfer. The study indicates that dust generation rates are activity dependent and that geological areas contribute to the silica content of the dust.

The results indicate that higher levels of mechanization lead to higher generation rates. In addition blasting has been confirmed to generate massive amounts of dust. These points need to be considered in view of developments in modern mining methods that consider the use of mechanised methods together with increased blasting intensity. The results are summarised in the table below.

In order to determine the inherent crystalline silica content of dust sources, stope rock samples from all the identified mines were analysed. The analysis of both type of samples indicated a variation of silica content. In the platinum mines visited inherent silica content was less than 1% while in the gold mines this varied between 9 and 39%. Similarly, a total of 38 airborne gravimetric respirable dust samples collected in various identified samples were analysed for silica content. The platinum mine dust samples contained silica content of less than 0,2% while in the gold mines this varied between 4,5 and 57% showing consistency between inherent silica content and airborne silica. Knowledge of this information together with the generation rates from different processes are important in assessing the risk of exposure to these and to decide on the most adequate means of controlling this hazard. The size characterization of respirable dust collected on the dust filter was not possible due to instrument limitations.

Ore transport, transfer and drilling are the greater contributors to respirable dust generations in more conventional operations. The correct use of water seems to control the dust generations effectively. However, alternatives are required in order to avoid the

increased use of water underground as this might lead to other hazards and increased operational costs. The suggested combinations of dust control components and research topics discussed in Section 6 would enable the mines for effective protection of workers from harmful respirable dust as well as projections for future work.

Summary of dust levels from test mines

Mine	**Mine Type**	**Dust Source**	**Dust Levels** [mg/m^3]			**Crystalline Silica** [%]
			Min	Max	Avg	
1	Gold [West Wtis]	Intake	0.09	1.57	0.46	9.92
		Tips	0.23	0.65	0.49	
		Transfer boxes	0.59	0.81	0.70	
		Return airway	0.49	1.77	0.88	
		Development	0.34	8.19	1.76	
		Stope tips	0.58	0.87	0.73	
		Stope face	0.57	1.40	0.89	
2	Gold [Vaal]	Intake	0.02	0.73	0.29	39.05
		Tips	0.06	5.65	1.41	
		Transfer boxes	0.74	3.99	2.19	
		Return airway	0.69	14.12	4.62	
		Stope tips	0.41	4.22	1.69	
3	Platinum [Western limb, BIC]	Intake	0.10	0.36	0.20	0.45
		Tips	0.02	0.59	0.30	
		Transfer boxes	0.22	1.49	0.53	
		Return airway	0.63	3.47	1.73	
		Development	0.76	1.88	1.23	
		Stope tips	0.59	2.63	1.31	
		Scraping	0.71	1.51	1.19	
4	Platinum [Western limb, BIC]	Intake	0.09	0.84	0.34	0.45
		Tips	0.07	0.34	0.21	
		Conveyor belt	0.01	0.90	0.39	
		Return airway	0.44	1.69	1.06	
		Shaft	0.01	0.27	0.15	
		Development	0.48	2.09	1.23	
		Stope face	0.28	1.01	0.71	
		Scraping	0.25	0.92	0.54	
5	Diamond [Gauteng]	Intake	0.03	1.54	0.57	0.45
		Drilling	0.44	0.44	0.44	
		Loading	3.28	16.14	8.45	
		Crusher	5.61	8.63	7.12	
		Return airway	1.44	2.07	1.75	

Note: Maximum measured dust levels in the heading, tips and transfer points was mainly due to blast induced dust

Glossary of abbreviations, symbols and terms

Abbreviations

ARD	Airborne Respirable Dust
ANOVA	Analysis of Variance
BMRC	British Medical Research Council
DME	Department of Minerals and Energy
MRE	Mine Research Establishment
SA	South Africa
SIMRAC	Safety in Mines Research Advisory Committee
TWA	Time-Weighted Average

Symbols

%	percentage
µm	micrometres/microns
L/min	litres per minute
m	metre
m/s	metres per second
m^2	square metre
m^3/s	cubic metres per second
mg/m^3	milligrams per cubic metre
mm	millimetre

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? Underground Project Team members:

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1 Introduction

Occupational Lung Diseases, such as silicosis, has been recognised by many as being the most serious occupational disease in South African hard rock mines. Gold Mines in particular are most adversely affected considering the higher average silica content of the ore body and country rock mined in these operations.

The philosophy and intent underlying the Mine Health and Safety Act are aimed primarily at the prevention of hazards. Applied to the risks posed by inhalable toxic particulates this would entail the prevention of dust generation into the atmosphere. Up to now no studies have been performed to characterise the nature of dust generation from different activities linked to mining operations. The work described in this report is aimed at ranking a number of these activities in terms of dust generation potential and at assigning numerical values to these. This will identify the more hazardous operations, from a dust generation perspective and will assist practitioners in improving hazard identification and amelioration. Another aim of this work is to provide data that will assist designers to provide adequately effective dust abatement or control measures for the equipment used in these activities.

Presently, in terms of the occupational exposure limits contained in the guidelines for the generation of Mandatory Codes of Practice in terms of Section 9(2) of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996), exposure to silica dust is limited as follows:

Crystalline Silica:	0,1 mg/m^3.
Amorphous Silica (Inhalable)	6,0 mg/m^3
Amorphous Silica (Respirable)	3,0 mg/m^3

Mineral dusts are generated primarily in the production of ore through the following operations:

- Blasting
- Blast hole drilling.
- Support and rigging hole drilling
- Blast hole cleaning.
- 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].
- 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.

Good practice in risk management procedures involves the elimination or at least the limitation of any hazard at the source. Dispersion models of respirable dust clouds indicate a pattern that is random, irregular and prone to agglomeration. This signifies that once emitted, the dust, and in particular the finer portion thereof cannot be controlled easily. Therefore the most effective strategy is to prevent the generation of dust into the atmosphere.

2 Scope of Work

Most of the research work performed up to now has been focussed on the exposure of workers to the hazard of respirable dust. In contrast to this, this project is aimed at characterising the dust produced during different activities in the course of various underground mining operations.

Characterisation of dust sources and generation in terms of dust quantities emitted and of particle size analysis has not been performed extensively in South African hard rock mines. It is reasoned that this information is the basis for the development of adequate systems that would prevent the generation of dust effectively. A better understanding of dust generation characteristics could form the basis for the design of a new generation of equipment or process-designed dust-allaying systems that will reduce dust generation more efficiently and are therefore more likely to lower workers' exposure to this hazard.

This project is aimed at identifying firstly the more prominent sources of dust generation identified from previous qualitative work. The work undertaken as part of this study consisted in taking a number of positional samples at selected positions in various mines in order to quantify the generation rates from a number of activities.

The first step consisted in reviewing any literature available in this area in order to identify a number of risk activities. This was followed by the selection of different mine sites that would be characteristic of a number of operations typical in South African hard rock mines. Sampling was performed over a number of shifts. This consisted in collecting respirable dust samples and establishing the generation rates as well as the crystalline silica content of these.

The aim was to cover as extensive an area as possible in terms of activities within types of mining and different types of geophysical environments.

3 Review of Previous Work

The relative severity of the dust-producing operations listed above has been rated by SIMRAC (Unsted, 2001) and is reproduced in Table1 below:

By definition, dusts tend to be heterogeneous systems characterised by poor stability. These contain particles that vary in size between 0.001mm and 100mm (Schroder, 1989). The shapes of dust particulate vary significantly depending on the way in which they are generated. These shapes also characterise the way in which the particulate behaves in a fluid flow, is suspended or is precipitated and the time over which these processes occur.

Dust has been described by a number of parameters that determine the assessment of the dust concentration and, relatively the magnitude of the risk posed by dust as a health hazard. These parameters are:

- The mass per unit volume.
- The number of particles per unit volume.
- The size distribution of the particles.
- The surface area of dust per unit volume.

The first parameter is presently being used n South African Mines to estimate worker exposure to dust. The second parameter was used until 1991 to determine risk of exposure. The last are used for research purposes and are not considered by many to be of significance in the aetiology of occupational lung disease.

More importantly, the first four parameters are dependent on the mode of formation of the dust as well as on the physical properties of the particles themselves – particularly when considering the stability of the dust clouds and persistence or sedimentation of dust.

The concentration and size distribution of dust in an air stream depends on factors such as mode of dust generation, Brownian motion, sedimentation, electrical charges, diffusion properties, thermal currents, coagulation, etc. Over-arching this effect to a significant extent are the physical properties of the dust itself.

For mining considerations, particle size distribution is possibly the most important parameter as it determines the length of time over which the dust is suspended in the air. The settling of dust in mine airways is dependent on the flow pattern of the air. In laminar flows, the tendency is for dust to settle in accordance with Stokes' Law. In turbulent flows, the motion of dust is largely unpredictable and dust maybe deposited more as the result of impingement rather than sedimentation.

Table 3: Relative severity of dust emitting operations.

Approximate Severity	**Operation**
1	Blasting
2	Drilling
3	Crushing
4	Grinding
5	Scraping
6	Barring
7	Lashing
8	Tipping
9	Loading

This hierarchy is confirmed to a certain extent by work done in 1968 by Kitson and Haven in relation to collieries. The results of comparative sampling done using MRE samplers are shown in Figure 3a.

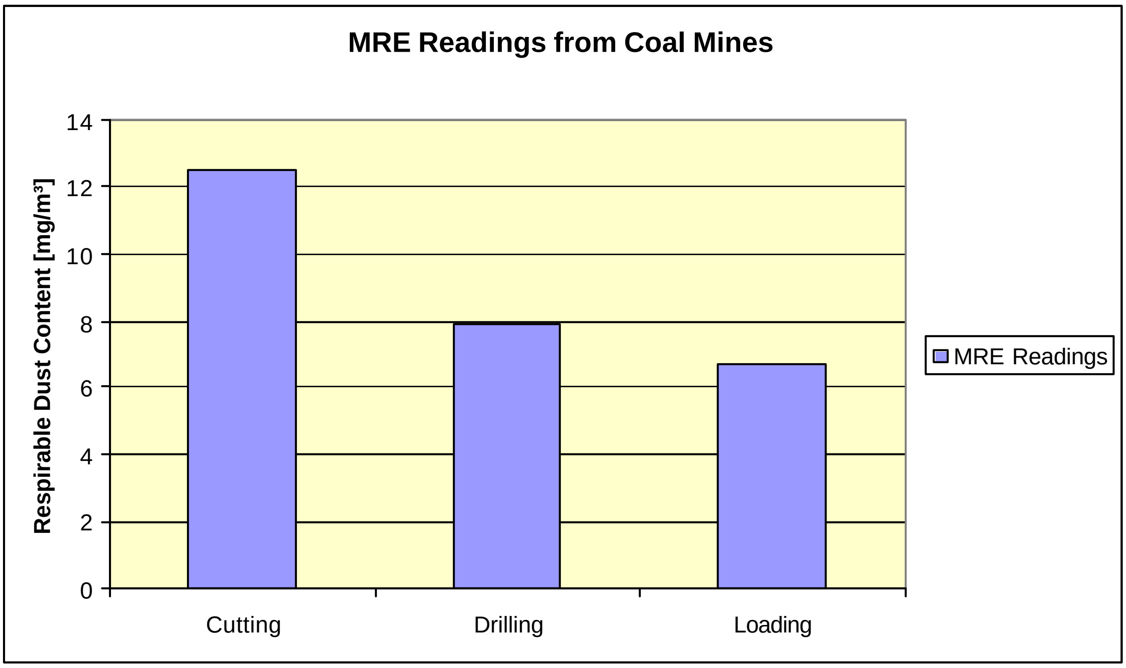

Figure 3a: Comparison of respirable dust emitted during selected colliery operations.

In an analysis of a much broader parent population using photoelectric readings [PERs] obtained from modified thermal precipitators over a period of 11 years similar trends are shown in Figure 3b.

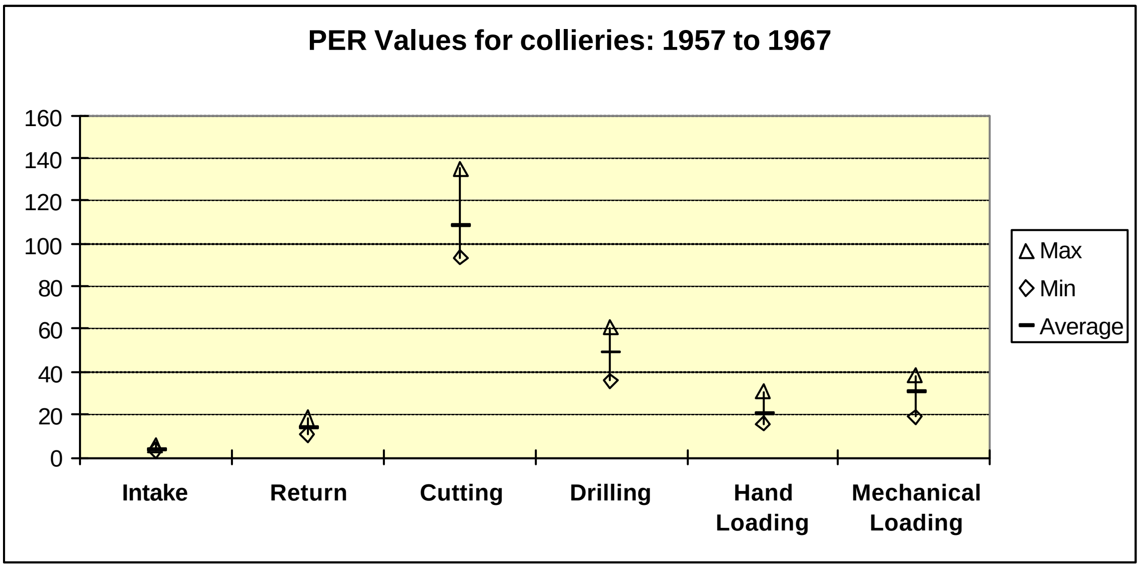

Figure 3b: Comparison of respirable dust emitted during selected colliery operations – Photoelectric readings.

The values displayed in Figure 3b are not comparable with those in Figure 3a but nevertheless indicate a similar trend in terms of the dust produced in different operations.

In addition to the above, some work performed by Alexander10 et al indicted that during the blasting of stopes, respirable dust in excess of 200,0 mg/m³ could be generated during stoping operations. Partyka (1990) and Partyka et al (1997) produced a mathematical model to predict the generation of dust during blasting. The model requires that variables obtained in solving the equations obtained be established through measurements. In further work carried out by these researchers, it was established that for Vertical Retreat Mining methods [VRM], the amount of respirable dust produced would be of the order of 1300,0 mg/m³ during the blast.

Other work performed by Bell and Lynch (1996) identified a number of job categories at higher risk in Australian gold mines by means of personal sampling. In their analysis the researchers concluded that for gold miners, exposures were ranked as follows [in order of descending exposure]:

Assayers/samplers [4,15 mg/m³]
Crusher operators [3,1 mg/m³]
Truck drivers [1,8 mg/m³]
Dozer drivers [1,45 mg/m³].

A similar exercise was undertaken in 2000 and 2001 by the author as part of a joint project lead by Anglo Health Services and Anglogold [SIMHEALTH 606:"Silicosis prevalence and risk factors in black gold miners]. The results of the worker monitoring are reproduced here with the permission of the project manager and shown in Figure 3c below.

From the figure the following worker categories seem to be mostly at risk [in descending order]:

Mining crews in stopes [in general, as a broad category]
Team leaders
Drill operators
Scraper winch operators
Locomotive drivers and crew.

The results of this survey were used as a starting point to decide on the activities to be monitored in this project.

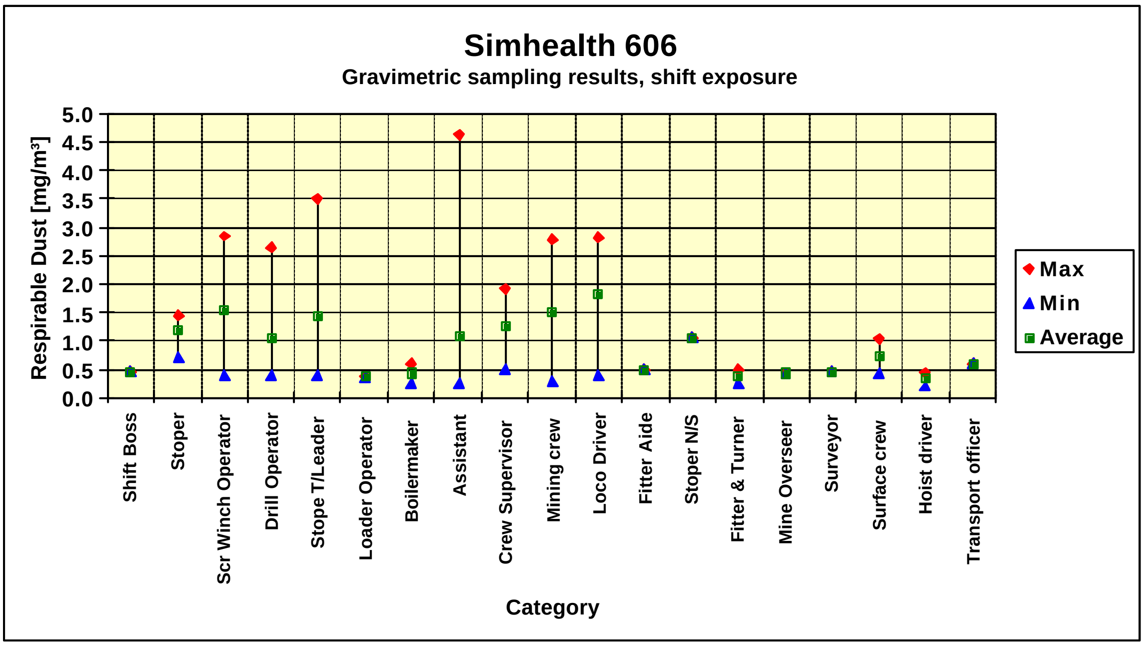

Figure 3c: Exposure of South African gold mine workers to dust.

4 Methodology

Having reviewed the results of studies performed so far in this area, the following activities were selected for monitoring as part of this project:

- Hole drilling [stoping and development]
- Crushing
- Scraping [stoping and development]
- Tipping [in stopes and at shaft stations]
- Loading [development ends and drawpoints]

The activities chosen for this project are also considered "high impact activities" in that they take place mostly in stopes and development ends, areas where the majority of the underground work force is active for a large portion of the shift. In addition, even if not directly exposed to some of these activities, the dust emitted during these activities is likely to affect an even greater section of workers considering the way in which air is circulated and distributed underground.

In addition to the above, the persons responsible for the measurements were instructed to record and measure the occurrence of incidental events during the monitoring shifts. This resulted in the recording of the effects of mud blasting. The contribution of blasting to the dust loading on a mine has been quantified by others [Alexander et al (1987) and Partyka et al (1997)] and is of little relevance as part of this study since re-entry periods are observed and should be monitored by all mines. However, this may have to be revisited in the future since in the future mines are proposing to increase blast frequency leading to more frequent stope blasting. It is suggested that in order to demonstrate that the risk arising from the increased blasting frequency is not excessive, mine managements would have to undertake studies of this nature. It is therefore significant that the theories proposed by Praktyka et al (1997) be reviewed and applied in order to assess the feasibility of increased stope blasting frequencies.

Sampling was performed using near real time and gravimetric-type dust-monitoring instruments as area samplers. For this study it was assumed that the cyclone samplers gave negligible errors and "true" measurement of area concentration.

4.1 Test mines

In order to provide a wide coverage encompassing different mining methods and geophysical areas, five mines were selected for this study:

- One gold mine in the Witwatersrand,
- One Gold mine in the Vaal Reefs area,
- One platinum mine in the northern section of the Bushveld Igneous complex,
- One platinum mine in the southern section of the Bushveld Igneous complex and
- One diamond mine in the Gauteng region.

A summary of the sampled mines and individual sampling locations is given in Table 4.1.

Table 4.1: Summary of underground mines and mining operations monitored

Mine type	Mine symbol	Operations monitored
Gold	**1**	Reef and waste tips; shaft station
		Internal tips
		Development end and stope combination
	2	Reef and waste tips; shaft station
		Internal tips
		Development end and stope combination
Platinum	**3**	Reef and waste tips; shaft station
		Internal tips
		Development end and stope combination
	4	Reef and waste tips; shaft station
		Internal tips
		Development end and stope combination
		Main level conveyor transfer points
Diamond	**5**	Ore passes
		Haulages
		Development heading
		Crusher and transfer points

The latter was chosen to provide indication of the effect, if any, of increased mechanization on dust generation. This is another avenue that hard rock mines may want to pursue in the exploitation of wider ore bodies – particularly occurring at great depths in the Witwatersrand.

A team of researchers collected the data over a number of weeks. Sets of data were collected in stopes [drilling, scraping, tipping and backfill], in development headings [drilling and loading], in tunnels and haulages [loading and belt operation], at an underground crusher site, at draw-points [mechanized loading] and at station tipping areas. In order to collect samples large enough, the sampling was performed over full shifts were recorded in each instance. Data was collected during day, afternoon and night shifts as well to obtain the widest coverage.

Although it was intended to perform a size analysis of the samples collected, this was not possible as the dust quantities collected were too small for this purpose. The problem posed by size distribution is probably best addressed as part of a more focused project dedicated to this aspect of the problem.

4.2 Dust Sampling and Instrumentation

4.2.1 Airborne respirable dust (ARD) sampling definitions

The sampling definitions currently used in the field of occupational hygiene and mine environmental control vary widely and therefore the following definitions have been adopted for this report:

Fixed or Area or Environmental Sampling: An area or environmental sample is taken at a fixed location in the workplace, in an environment or area of interest. The dust sample reflects the average concentration in the area of interest and does not reflect the exposure of any particular worker in that area. In this study, results are thus classified as area samples.

Engineering Sampling: An engineering sample is taken at a “predetermined” location representative of the position of workers in the immediate neighbourhood. It determines the dust concentration near machinery, tipping points, air filters, etc. and characterizes the generation source or the effectiveness of dust-suppression or control measures. The engineering sample enables the effectiveness of dust-control and ventilation systems to be measured and evaluates both management (administrative effectiveness) of the dust-control system and engineering effectiveness of the dust-control system.

Personal Sampling: A personal sample is the dust sample collected in the breathing zone of a worker performing occupational duties during a work shift. The worker wears the sampling train (cyclone, pump, tube and sample filter) for the entire shift (bank to bank). In this study, for practical reasons, none of the personal sample was collected.

4.2.2 Dust instrumentation

Sampling trains were prepared and positioned closest to the identified dust generating sources. To determine the respirable dust sample concentrations, the sampling set-up contained gravimetric sampler, i.e. a Higgins-Dewell-type cyclone (GME G05 cyclone) and a Hund tyndallometer at some locations. Each gravimetric sampler consisted of an air pump drawing 2,2 L/min of air through a cyclone, which separated the respirable dust fraction (< 10 µm) from the total sample and deposited it on a pre-weighed filter disc. The gravimetric samplers were operated at a flow rate of 2,2 L/min, according to the latest ISO/CEN/ACGIH respirable curve with a D50 of 4 mm. Trials were planned to collect dust over the entire shift where possible.

A Gravimetric sampler and real-time respirable dust monitor (Hund tyndallometer) were positioned together to collect near real-time dust levels and relate these to specific activities. Average gravimetric respirable dust concentrations were determined for the sampling period were used to convert the Hund data to airborne respirable dust (ARD) mass concentrations (mg/m^3). Real-time dust-sampling results allow the comparison of source-dust concentrations under different ventilation and mining conditions.

Filters were weighed on an analytical electronic balance readable to 0,0001 mg to determine the dust mass. The procedures used for determining the particulate mass were in accordance with the DME Guidelines (1994). Well-maintained pumps were used to avoid the effect of pump pulsations and fluctuations in the flow rate.

4.2.3 Experimental Methods

The following procedure were followed for each experiment:

- Before the start of the experiment, the pumps of all the identified monitoring instruments were calibrated using a Gilibrator primary standard flow meter. The required flow rate for each dust monitor was using an equivalent pressure restriction of the cyclone and filter assembly.

- All dust-monitoring instruments were positioned correctly near the dust generating sources, switched on and the operating time recorded.

- Throughout all tests, the condition of the air pumps, the sampling train and other parameters in the section (air velocity, humidity, presence of diesel-operated machinery and work activities) were monitored and recorded.

- At the conclusion of the test, a computer was used to download data from the real-time monitoring instruments. Data were converted into ASCII text files and read with a spreadsheet program to calculate the average dust concentrations during the test periods.

- After each sampling shift, sampling units (dust monitors) were cleaned, new pre-weighed filters installed and prepared for the next test.

4.2.4 Data Analysis Procedure

The dust concentrations presented throughout this report reflect respirable gravimetric dust measurements taken over different sampling periods. Using the mass of dust collected on the filters, the sample dust concentration is obtained as follows:

$$\text{Sample Dust Concentration (SC)} = \frac{(C_f - C_i)}{Fl \;?\; T} \qquad (1)$$

where: SC = sample dust concentration measured in mg/m^3

Ci = corrected initial filter mass in mg

Cf = corrected final filter mass containing dust in mg

Fl = sample flow rate in m^3/min

T = sampling time in min

The relationship between dust generating sources and respirable dust levels was examined by compiling scatter diagrams and near real-time plots.

5 Discussion of Results

The results shown in this section are the product of twelve weeks' work, thirty-eight tests and an analysis of over 250 gravimetric samples in five mines backed-up with real-time monitoring. Table 5 below is a summary of the results obtained while Figure 5a represents the combined results graphically. Details of the results obtained may be seen in Appendix "A".

In reviewing the results it must be remembered that the figures quoted relate to the mass emitted [mg] per unit volume passing over the source. The fact that the dust generation rates may seem low compared to allowable shift exposure limits should not be misleading. What is significant is the time over which this generation takes place and the portion of this generation that reaches the workers’ breathing zone. These results indicate a ranking in term of high and low generation rates only and the drawing of a relationship with worker exposure levels requires careful assessment of a number of factors.

In order to determine the inherent silica content of dust source, stope rock samples were collected. Individual rock samples were crushed in the CSIR-Miningtek laboratory to determine the inherent silica content. The analysis of samples indicated a variation of silica content. In the platinum mines visited this was less than 1% while in the gold mines this varied between 9 and 39%. Figure 5a shows the variation in analysed inherent dust source.

Similarly, airborne gravimetric respirable dust samples collected in various identified samples were analysed for silica content at CSIR-Miningtek laboratory. A total of 33 dust samples were analysed, viz., 11 samples from gold mine-1, 10 samples from gold mine-2, seven samples from platinum mine-3, three samples from platinum mine-4 and two samples from diamond mine. The platinum mine dust samples contained silica content of less than 0,2% while in the gold mines this varied between 4,5 and 57% showing consistency between inherent silica content and airborne silica. Figure 5b shows the variation in analysed inherent dust source for silica in gold, platinum and diamond mines.

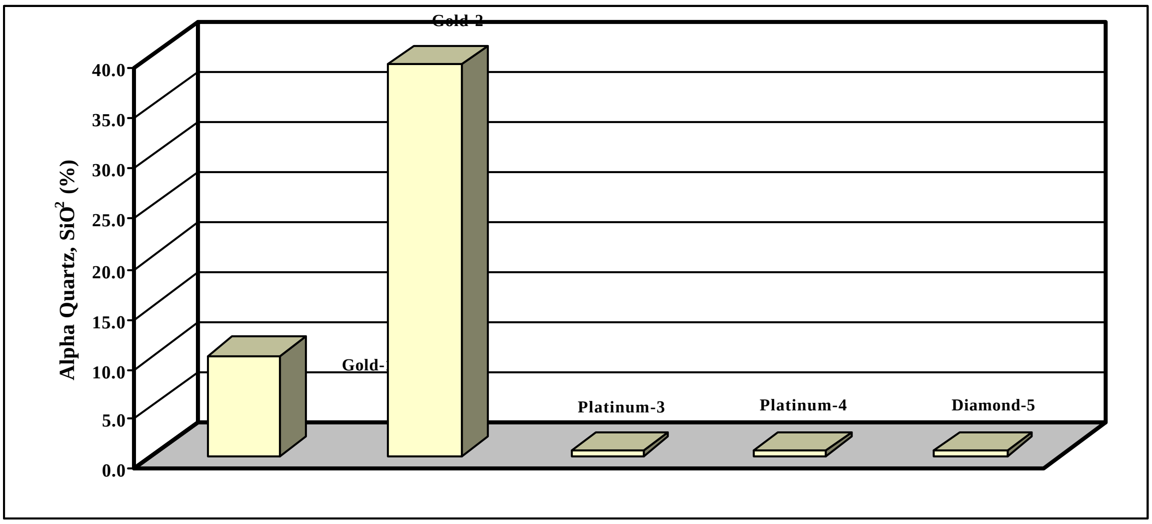

Figure 5a: Plot of silica content of inherent rock

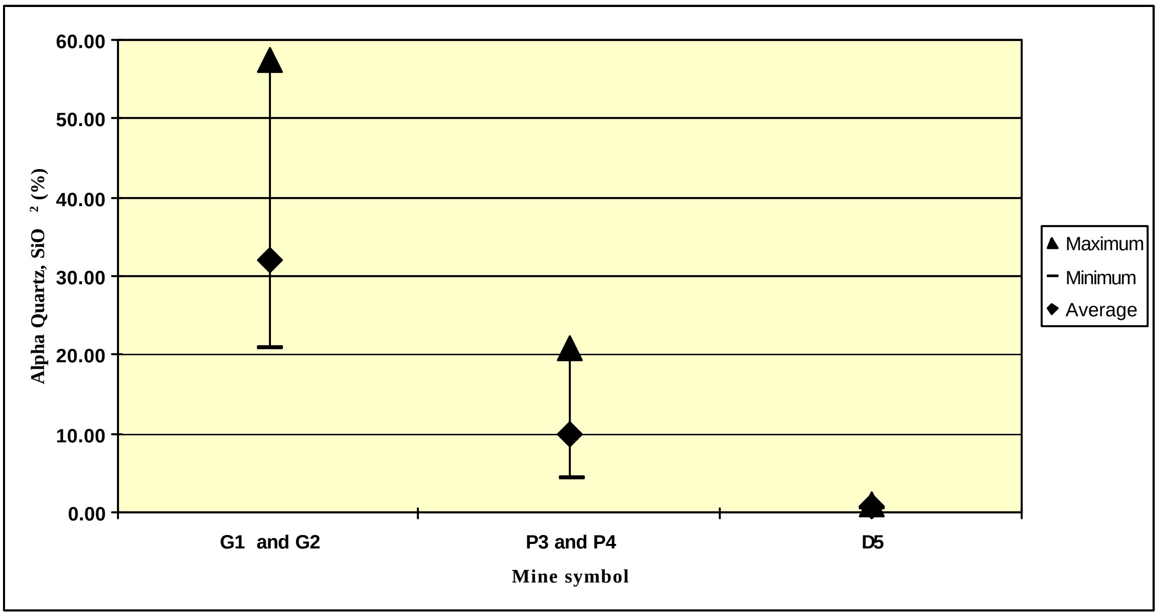

Figure 5b: Plot of silica content of airborne respirable dust

Results are in general in line with initial expectations and qualitative results obtained in previous analyses. Table 5 indicates the results for each mine together with the inherent silica content. The high dust readings displayed in some of the results are due mainly to mud-blasting as is also seen in Figure 5b. Another "peak" generation is as the result of mechanical loading in trackless operations.

Operations typical of narrow reef mining occupy a band lower down as shown in Figure 5c. As expected the variance of some of these figures is wide-spread. Another observation that is made is that dust emitted during drilling operations is lower than other activities. In some of the samples, the effect of drilling resulted in a negative dust load. This is ascribed possible to the effectiveness of water in reducing the generation and “scrubbing” the air effectively.

The following are noted from these results:

- The use of mechanized equipment leads to higher respirable dust levels. This may be argued in terms of the movement of the vehicles in relation to the dust load along road ways, the larger payload invariably lead to larger dust loading and there is a possibility that some readings may have been “masked” by the presence of diesel particulate matter from the engines’ exhaust fumes.

Table 5: Summary of dust levels from test mines

Mine #	Mine Type	Dust Source	Dust Levels, mg/m^3			Silica
			Min	Max	Avg	%
1	Gold	Intake	0,09	1,57	0,46	9,92
		Tips	0,23	0,65	0,49	
		Transfer boxes	0,59	0,81	0,70	
		Return air	0,49	1,77	0,88	
		Heading	0,34	8,19	1,76	
		Stope tips	0,58	0,87	0,73	
		Stope face	0,57	1,40	0,89	
2	Gold	Intake	0,02	0,73	0,29	39,05
		Tips	0,06	5,65	1,41	
		Transfer boxes	0,74	3,99	2,19	
		Return air	0,69	14,12	4,62	
		Stope tips	0,41	4,22	1,69	
3	Platinum	Intake	0,10	0,36	0,20	0,45
		Tips	0,02	0,59	0,30	
		Transfer boxes	0,22	1,49	0,53	
		Return air	0,63	3,47	1,73	
		Heading	0,76	1,88	1,23	
		Stope tips	0,59	2,63	1,31	
		Gully	0,71	1,51	1,19	
4	Platinum	Intake	0,09	0,84	0,34	0,45
		Tips	0,07	0,34	0,21	
		Conveyor belt	0,01	0,90	0,39	
		Return air	0,44	1,69	1,06	
		Shaft	0,01	0,27	0,15	
		Heading	0,48	2,09	1,23	
		Stope face	0,28	1,01	0,71	
		Gully	0,25	0,92	0,54	
5	Diamond	Intake	0,03	1,54	0,57	0,45
		Drilling	0,44	0,44	0,44	
		Loading	3,28	16,14	8,45	
		Crusher	5,61	8,63	7,12	
		Return air	1,44	2,07	1,75	

Note: Maximum measured dust levels in the heading, tips and transfer points was mainly due to blast induced dust

- Blasting operations lead to the release of very large quantities of dust. In the observations made during these tests, the release of respirable dust during the re-entry period of a development end [not the one shown in Figure 5c above] indicates that the release was as high as 14 300mg/ton blasted during the re-entry period. This emphasizes the need for effective watering-down on re-entry.

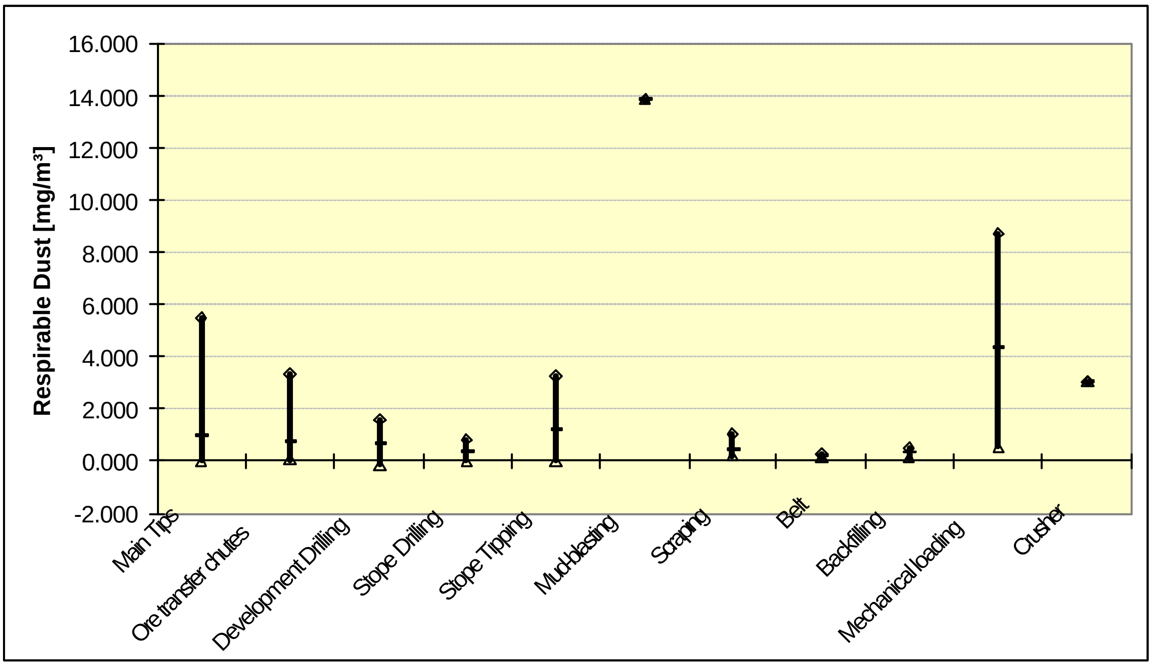

Figure 5c: Summary of Results

- The use of underground crushers could lead to high dust loading –despite the operation of a dust-extraction system.

- The relative risk for more conventional operations in gold and platinum mining seems to reflect the work done in SIMHELATH 606 with ore tipping, transfer and scraping being the highest contributors. This is shown in Figure 5d.

- Drilling operations present a lessened exposure than expected. This is probably due to the fact that the correct use of water can reduce the dust emitted in the air effectively. In some cases, the dust loading on the return side of the drilling operations was noted to be lower than at the inlet.

In general, however, the selected operations indicate high potential exposures. In most cases, the generation rates are in excess of 1,0mg/m^3. This implies that in some of the more continuous operations, as is the case for tip attendants, scraper winch operators rock transport crews and drill operators, the exposures may be considerable.

In some extreme cases, the presence of diesel exhaust particulate affected the measured dust levels. In these cases the dust filters were distinguished by a deep grey deposition.

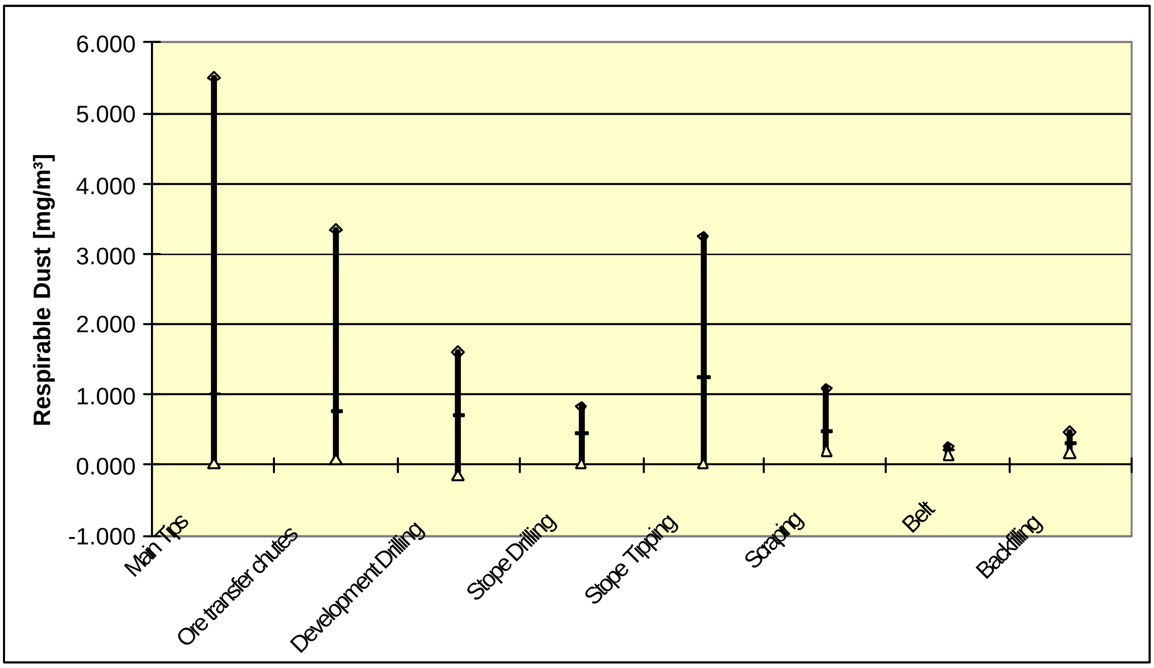

Figure 5d: Test results – details for gold and platinum routine operations

6 Conclusions and Recommendations

The tests indicate the presence of variances in the generation of respirable dust. These may lead to considerable exposures depending on the nature of the dust cloud, the length of the exposure and position of the worker in relation to the generation source.

It is concluded that dust generation and liberation into the atmosphere is dependent on the type of operation that is being undertaken. This points to the need for custom-designed engineering solutions based on the process being addressed. The risk is compounded further by the [crystalline] silica concentration in the rock being mined. This has been shown in many studies to be a function of the geological area being mined and is again reflected in this research.

Of particular concern is the effect that increased mechanization might have on generation rates. The generation rates recorded for this type of observations are considerably greater than traditional operations. This underscores the need for a closer analysis of the risks involved in increasing the level of mechanization in future mine strategies.

The use of explosives results in very high dust generation. This is not a new finding and the results of this study support previous findings. However this is the first time that the generation is characterised in terms of mud-blasts. Form this it can be inferred that the introduction of more intensive mining methods that use more frequent blasting [i.e. more than once daily, with reduced re-entry periods] require a careful assessment. It is suggested that proper measures must be available to restore adequate air conditions by the time workers re-enter the work-place at the start of next shift.

The movement and transfer of rock, in its many forms seem to be liberating large quantities of dust. The control measures at tipping and transfer points should be revised and modified to be brought in line with modern mining needs. Of particular value could be the development of alternative methods to allay dust in these processes so as to avoid the use of copious quantities of water that may result in mud-rushes and that has to be pumped out of the mine.

One of the aspects again proven in this study is the effectiveness of water in reducing respirable dust loads. If used correctly, this agent is very effective and is probably, the most effective means of controlling this hazard.

It is suggested that the following research topics be considered as possible projections for future work or for existing conditions as means to control or improve the control of dust generation sources:

- ✍ Improve the application of water to the dust sources though improved nozzle design and spray pattern.
- ✍ Use of fan-powered scrubbers at the return of development headings.
- ✍ Use of conveyor belt enclosures at transfer points. Full enclosure might allow higher belt operational speeds without additional risk.
- ✍ Use force-exhaust systems in development headings.
- ✍ Design and develop “mini” air-scrubbers for stopes that could also be used for localised cooling.
- ✍ Application of two-phase spray systems for mechanised loaders.
- ✍ Increase ventilation air quantity to the face to dilute the dust by eliminating excessive leakage.
- ✍ Effective use of personal protective equipment where no alternative way of abating the dust is possible.

- Employ fan powered dust collectors at the crushing plant.
- Provide enclosed cabins for crusher and locomotive operators.
- Improved work practices and awareness.

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