REPORTED DUST CONCENTRATIONS IN UNDERGROUND GOLD MINES OVER THE YEARS 1999 TO 2002

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In partial fulfilment of the requirements for

the degree of

Master of Public Health: Occupational Hygiene

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DECLARATION

I, Jacobus Andries Labuschagne, declare that this research report is my own work.

This research report is being submitted for the degree of Master of Public Health: Occupational Hygiene in the University of the Witwatersrand, Johannesburg.

It has not been submitted before for any degree or examination at this or any other University.

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___ day of _________________, 2006

ABSTRACT

Dust has been recognized as the most serious occupational health hazard across the South African Mining Industry. During 1998 more than 5600 mineworkers were certified with silicosis, a silica related lung disease. The objective of this research project is to describe the trend in respirable dust concentrations in four underground gold mines for the period 1999 to 2002.

The mines under discussion are situated in the Klerksdorp area and they were selected because they are a typical representation of deep underground gold mines. Typical gold mines use the same method of ventilation distribution and have similar dust sources e.g. breaking, transporting and tipping of rock. They are all situated in the same geographical area and all make use of conventional mining methods. A total of 4645 previously collected personal respirable dust samples were analysed for this research report making use of a central laboratory situated in the Klerksdorp area. The respirable dust samples were collected by the Occupational Hygienists appointed on the mines for control purposes over the years 1999 to 2002.

The arithmetic mean respirable dust concentrations for the four mines in discussion was 0,39mg/m^3 in 1999, 0,33mg/m^3 in 2000, 0,30mg/m^3 in 2001 and 0,31mg/m^3 in 2002 against the mine's internal target of 0,4mg/m^3.

The report shows a statistically significant downward trend in the proportion of measurements below 0,4mg/m^3 for mines 1, 2 and 3. The percentage of respirable

dust samples above the internal target of 0,4mg/m^3 was 6,78% in 1999, 6,15% in 2000, 4,71% in 2001 and 4,38% in 2002.

Although there is a general downwards trend in the percentage of samples above the target, there is an increase in the number of samples above the target. In 1999, 202 samples were above, 310 in 2000, 402 in 2001 and 361 in 2002.

The key limitation to the project is the integrity of the data. The major limitations identified include non compliance with the sampling strategy. There is no guarantee that the instrumentations were worn on the body for the whole shift or whether any tampering of the gravimetric pumps took place. The sampling strategy measures all occupations, but all occupations do not receive the same type and amount of exposure, making it impossible to allocate exposure to a certain workplace. Samples could get affected during storage and transport.

The most recent audits on the mine's central laboratory show 100% compliance with the required standards. The mines under study are well in line with the DME requirements on the guidelines for a measurement strategy of airborne pollutants. The gravimetric sampling strategy includes the scheduling of samples managed by the electronic database system.

Although the report indicates that the results are pointing in the right direction, the integrity of the data should be tested continuously. Supervision of the pump wearers is of great concern and training of these wearers is essential for explaining the purpose of the personal monitoring strategy.

There is a scarcity of published information on respirable dust concentrations in underground gold mines and further research is required.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

ACGIH

American Conference of Governmental Occupational Hygienists

HEG

Homogenous Exposure Group

IRMS

Integrated Risk Management System

MOH

Mine Occupational Hygienist

OEL

Occupational Exposure Limit

SIMRAC

Safety in Mines Research Advisory Council

Statpop

Statistical Population

TLV

Threshold Limit Value

TWA

Time Weighted Average

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

"It is obvious that before one starts dust sampling one should be quite clear as to the purpose of the sample"

Beadle, D.G., 1960

This chapter describes an overview of underground dust, it's liberation and how it interacts with the human body. It describes the changes in the dust measuring methodology as early as 1920 to the latest technology. The chapter deals with the different occupational exposure limits set by the Department of Labour and Department of Minerals and Energy and the role of the mine occupational hygienist.

1.1 Dust and the human body

Dust has been recognized as the most serious occupational health hazard across the South African Mining Industry [(1)]. During 1998 more than 5600 mineworkers were certified with silicoses, a silica related lung disease [(2)].

Underground gold mining operations are dusty due to the breaking of rock. Blasting operations produces enormous quantities of dust in concentrations which have been shown to be higher than those produced by any other mining process [(3)]. Loading, crushing and tipping of rock are other major sources of dust liberation. Big hole boring machinery such as raise bore and blind bore hole boring equipment have been in use since 1969 and because of the high rate at which rock is broken, high dust concentrations can be encountered. Rotary-percussive type drilling machines are in use in the underground gold mines and constitute a major dust hazard. Another major contributor is the transport of rock.

In the 2003 SIMRAC report “Quantification of Dust Generating Sources in Gold and Platinum Mines - M Biffi and B K Belle” the authors outline the findings of a study performed to establish the respirable dust generation characteristics of a number of mining activities [(4)]. The sample flow rate used for the study was set to 2,2l/m as per the ISO/CEN/ACGIH curve. The aim of this study was to identify prominent dust sources that occur in hard rock mines and to characterize these by means of on-site measurement of dust generations. 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 activities identified for the study 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 respirable dust generation rates. In addition blasting has been confirmed to generate massive amounts of dust. In order to determine the inherent crystalline silica content of dust sources, stope rock samples from all the study mines were analysed (see Table 1.1). The analysis of all 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 quartz 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.

Table 1.1: Summary of respirable dust levels in mg/m^3 in test mines as reported by Biffi and Belle, 2003

Mine	Mine Type	Dust Source	Dust levels (mg/m^3)			Average Crystalline Silica (%)
			Min	Max	Mean	
1	Gold (West Wits)	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	

Dust can be defined as a collection of solid particles, which are dispersed in a gaseous medium [5]. Particle size can vary from between 0,001µm to 1000 µm. Dust particles that are small enough to enter the alveoli are termed respirable dust. The nasal passages are the first line of defence and will trap most particles > 7 microns (see Figure 1.1). The lung's defences can still remove particles reaching the airway walls in the tracheobronchial tree, however, approximately 30% of inspired particles in the range 1-3 microns will be deposited in the lung tissue [6]

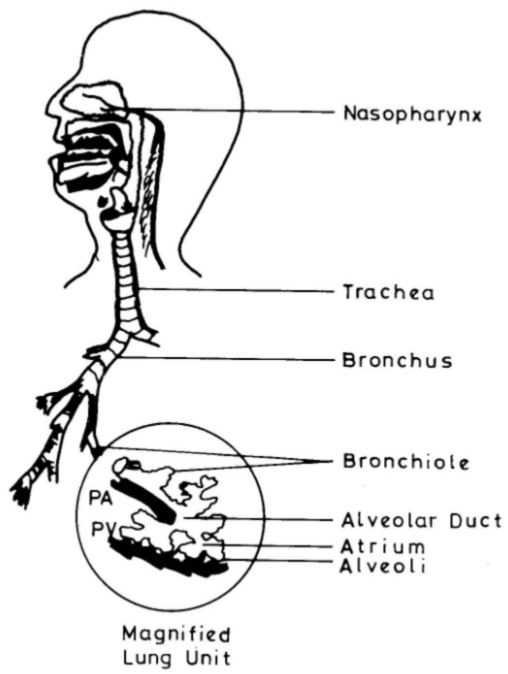


Figure 1.1: Diagrammatic representation of the respiratory tract [6]

Any extensive accumulation of mineral dust in the lungs together with the tissue reaction to its presence is usually referred to as pneumoconiosis, derived from the Greek words "pneumono" and "konios" meaning "breath" and "dust" [7]. The Occupational Diseases in Mines and Works Act (No. 78 of 1973) defines pneumoconiosis as “a permanent lesion of the cardio-respiratory organs caused by the inhalation of dust in the course of the performance of risk work”.

The most important lung disease in gold mining is silicosis. The risk of silicosis occurs in all types of activities where free crystalline silica particles are liberated and inhaled by an employee. The form of free crystalline silica found in gold mines is quartz.

During the early parts of 1990, a cross sectional study was performed by Cowie and Mabena [(8)]. The study included 1,197 black, male underground gold miners aged 28–76 with a mean of 25.1 years since first exposure. The study concluded that 857 miners had chronic silicosis. No silica exposure levels were mentioned in the report.

1.2 Literature review

Report of the Commission of Inquiry into Safety and Health in the Mining Industry (Leon 1995):

“It is not the role of the Commission to re-examine all the available evidence, but to form an opinion on the basis of the evidence submitted to it. No evidence was submitted to show that dust levels had decreased. It is a matter for concern that there is undue reliance on data which is now nearly 40 years old, and that the results of the many thousands of dust measurements which have been made in recent years have not been analysed and published in a form which makes it possible for experts in the field to describe the trends accurately, nor is it possible without access to the raw data to determine whether current sampling strategies and methods used to measure dust levels succeed in identifying the highest exposures accurately."[9]

Underground respirable dust measurements started in the early 1900's. Dust was measured using instruments such as the sugar tube, konimeter and the Greenburg-Smith impinger.

In 1937, a report was published by the Miner's Phthisis Prevention Committee showing results of dust measurements from the years 1915 to 1935 using the sugar tube method as set out in table 1.2 [10]. It must be noted however that the methodology and instrumentation was different and not necessarily respirable dust measured.

Table 1.2: Amount of dust in mine air, expressed in mg/m^3, as determined from samples taken through the medium of sugar tubes by the dust Inspectors of the Transvaal Chamber of Mines in various places in every mine

Survey period	Main travelling ways	Development ends	Shaft sinking	Stopes	Ore passes and bins	Sundry	General Average
1915	2.8	6.9	3.6	3.4	4.4	3.7	**4.9**
1916	1.7	5.8	4.7	2.7	4.0	5.0	**3.9**
1917	1.6	5.4	3.7	2.9	4.2	4.0	**3.8**
1918	1.6	4.4	2.9	2.2	3.7	3.0	**2.9**
1919	1.2	3.5	4.8	1.9	2.9	2.5	**2.4**
1920	1.4	2.9	4.9	1.7	2.7	2.0	**2.0**
1921	0.8	2.3	2.5	1.3	2.1	1.4	**1.6**
1922	0.9	2.4	2.8	1.2	2.2	1.3	**1.6**
1923	0.7	1.9	2.1	0.9	1.8	1.2	**1.3**
1924	1.3	1.2	0.4	0.7	2.0	1.4	**1.1**
1925	0.7	1.0	0.8	0.7	1.6	0.8	**0.9**
1926	0.6	1.1	1.3	1.0	1.8	1.0	**1.2**
1927	1.1	1.2	1.2	0.9	1.9	1.0	**1.2**
1928	0.9	0.8	0.9	0.6	1.5	0.6	**0.8**
1929	0.5	0.8	0.7	0.7	2.0	0.6	**1.0**
1930	1.1	1.0	0.9	0.7	1.2	0.6	**0.8**
1931	0.8	0.7	0.8	0.7	1.1	0.8	**0.8**
1932	1.1	0.9	0.7	0.8	1.4	0.8	**0.9**
1933	0.5	0.9	0.7	0.7	1.1	0.8	**0.8**
1934	0.5	0.9	0.7	0.7	1.1	0.8	**0.8**
1935	0.5	0.9	0.6	0.7	1.0	0.6	**0.8**

The sugar tube method proved to have errors due to the impurities of the sugar and the uncertainty of the exact weight of the ash content. The Greenburg-Smith impinger also showed inconsistency in the results because a proportion of the fine particles that are not caught in the water as particles may break up upon impact with the impinger plates. It seemed at the time that the konimeter was the most reliable instrument for the measurement of underground dust and in 1987 the Chamber of Mines released a report on measured respirable dust concentrations over a period from 1964 to 1985 [11].

The report shows a decline in overexposures (>200p/ml) to respirable dust from 1964 to 1978 with a slight upwards trend from 1979 to 1985 as shown in Tables 1.3 and 1.4 below.

Table 1.3: Percentage frequency distribution of dust concentrations for dust surveys of gold mines since 1964

Survey Period	Percent in concentration interval (p/ml)						
	0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	500 - 599	600 and over
1964/65	19,3	35,0	20,1	10,7	9,3	0	5,6
1968/69	21,0	37,9	20,5	10,2	7,0	0	3,4
1971/73	25,5	38,9	18,6	8,4	3,7	1,8	3,1
1974/74	29,9	37,3	17,3	7,6	3,5	1,6	2,8
1976/77	34,6	37,9	15,0	6,4	2,6	1,4	2,1
1977/78	41,6	35,6	12,7	4,8	2,2	1,2	1,9
1979/80	43,2	32,8	12,1	5,0	2,6	1,5	2,8
1980/83	46,9	30,1	12,3	5,0	2,2	1,2	2,3
1983/85	40,7	34,9	12,6	5,0	2,4	1,4	3,0

Table 1.4: Percentage samples above and below 200 p/ml for the period 1964 to 1985

Survey Period	Percentage samples >200 p/ml
1964/65	45,7
1968/69	41,1
1971/73	35,6
1974/74	32,8
1976/77	27,5
1977/78	22,8
1979/80	24,0
1980/83	23,0
1983/85	24,4

p/ml = parts per millilitre

1.3 Respirable dust legal limits

The Department of Labour's Occupational Exposure Limits (OELs) are largely based on the OELs published by the Health and Safety Executive in the U.K. The *Regulations for Hazardous Chemical Substances* under the Occupational Health and Safety Act, 1993, have assigned an 8-hour time weighted average (TWA) Occupational Exposure Limit - Control Limit (OEL-CL) for respirable crystalline silica of 0.4 mg/m^3.

The Threshold Limit Values (TLVs) of the American Conference of Governmental Industrial Hygienists (ACGIH) are utilized as guidelines in the mining industry in South Africa. The Department of Minerals and Energy has set an OEL of 0,1 mg/m^3 as listed in Schedule 22 of the Mines Health and Safety Act of 1996 and guidelines for the compilation of a mandatory code of practice – no. 1 personal exposure to airborne pollutants (12).

The company specific internal time weighted average target for respirable dust concentrations for the mines is set at 0,4 mg/m^3. This is derived from historical data where the quartz content was measured at an accredited laboratory and the highest result used for determining the target. The highest quartz content was measured at 25% and to obtain the TWA versus the legal limit of 0,1mg/m^3 for silica quartz is 0,1 ÷ 25% = 0,4mg/m^3 TWA.

The reason for making use of the internal respirable dust target is to take action on high readings as soon as the weigh is known rather than wait for the analysis results.

1.4 The role of the mine Occupational Hygienist

Section 12.1 of the Mine Health and Safety Act (Act 29 of 1996) specifies the appointment of a competent person that states "*The employer must engage the part-time or full-time services of a person qualified in occupational hygiene techniques to measure levels of exposure to hazards of the mine*". The Act further states the qualifications of the competent person in terms of section 12 that for underground mines the person shall be in possession of a certificate in mine environmental control.

Each mine was required to draw up a code of practice on airborne pollution in terms of section 9.1 and 9.2 of the MHSA referring to schedule 22 listing the OEL and TWA of all pollutants.

Respirable silica dust is a well recognised health hazard in gold mining, but recent published data on respirable dust levels in underground gold mines are scarce partly because of changes in the methodology and regulations. Hence this research project to describe the trends in respirable dust concentrations measured in four underground gold mines.

1.5 Research objectives

The aim of this research project is to describe the trend in reported respirable dust concentrations over the period 1999 to 2002 in four underground gold mines in the Klerksdorp area of South Africa.

The main objectives are to:

Summarise previous collected respirable dust concentrations for the period 1999 to 2002 in four underground gold mines in the Klerksdorp area; and

determine whether the proportion of respirable dust measurements exceeding the internal target of 0,4mg/m^3 decreased over the period 1999 to 2002.

CHAPTER TWO: MATERIALS AND METHODS

This chapter describes the reason for the selection of the four underground gold mines and the area classification. It deals with the sampling frequencies and type of instruments used for the measurement of underground respirable dust. The quality control and data reliability is described together with the data analysis and management. The ethical considerations are also covered under this chapter (see Section 2.6).

2.1 Mine selection criteria

The selection of the mines is based on their similarities and because they are typical of deep underground gold mines. Typical gold mines use the same method of ventilation distribution and have similar dust sources e.g. breaking, transporting and tipping of rock. The selected mines are all situated in the same geographical area and all make use of conventional mining methods. All the selected mines are on the same gravimetric sampling strategy and make use of a central laboratory promoting consistency in data.

2.2 Dust measuring methodology

2.2.1 Sampling strategy

2.2.1.1 Area classification, ventilation districts and HEGs

Prior to 1999, work areas were classified as per management responsibilities. During that time, a dust modus operandi was developed for the mines under discussion and after thorough investigation it was found that the dust results were not a true reflection of the areas identified. Persons working in an area of the previous classification were not exposed to similar occupational hazards and could not be classified as a Homogeneous Exposure Group (HEG). Reclassification was done classifying areas using the same ventilation flow through the underground workings and named ventilation districts. The ventilation districts were then broken down into HEGs based on certain activities such as stopes, development ends, haulages and stations.

The four mines under study in this report have been classified as per Table 2.1 below:

Table 2.1: Summary of the classification structure of the four underground gold mines

Mine 1		Mine 2		Mine 3		Mine 4	
Ventilation District Number	HEG Number	Ventilation District Number	HEG Number	Ventilation District Number	HEG Number	Ventilation District Number	HEG Number
1	1	1	1	2	1	1	3
	2		2		2		4
2	2		3		3	2	2
3	1	2	1	3	1		3
	2		2		2		4
4	1		3		3	3	2
	2	4	1	4	4		3
5	3		2				4
6	5		3			4	2
8	4	6	1				3
			3				4
		8	1			5	5
			2				
			3				
		9	2				
			3				

In certain cases a ventilation district will only operate for a short period of time and for the purpose of this report, only ventilation districts that were in full operation for the period 1999 to 2002 were considered. The ventilation district is an area with a common ventilation intake and return. The mine is divided into ventilation districts and each numbered e.g. VD1, VD2, etc. Each ventilation district is then sub-divided into homogeneous exposure groups and numbered.

2.2.2.2 Sampling frequencies

The sampling frequency is set out in the Guideline for a Mandatory Code of Practice for Airborne Pollutants as issued by the Department of Minerals of Energy in 2002 (see Table 2.2) and limits set in Schedule 22 of the Mine Health and Safety Act (act 29 of 1996).

Table 2.2: Summary of the sampling frequency as indicated in the DME Guidelines for the compilation of a mandatory code of practice – no. 1 personal exposure to airborne pollutants

CATEGORY	MINIMUM FREQUENCY
A	Sample 5% of employees within a HEG on a 3monthly basis with a minimum of 5 samples per HEG, whichever is the greater.
B	Sample 5 % of employees within a HEG on a 6 Monthly basis with a minimum of 5 samples per HEG, whichever is the greater
C	Sample 5 % of employees within a HEG on an annual basis with a minimum of 5 samples per HEG, whichever is the greater

The above sampling frequency is dependant on the classification of exposure as set out in the DME's Guideline for a Mandatory Code of Practice for Airborne Pollutants (See Table 2.3).

Table 2.3: Summary of the classification bands as indicated in the DME Guidelines for the compilation of a mandatory code of practice – no. 1 personal exposure to airborne pollutants

	CLASSIFICATION BANDS
CATEGORY	**PERSONAL EXPOSURE LEVEL**
A	Exposures ? the OEL or mixtures of exposures ?1
B	Exposures ? 50% of the OEL and < OEL or mixtures of exposures ? 0,5 and <1
C	Exposures ? 10% of the OEL and ? 50% of the OEL or mixtures of exposures ? 0,1 and ? 0,5

2.2.2.3 Type of samples

Respirable dust samples are collected as per the sampling frequency against the DME measurement guidelines. The samples taken in each HEG are forwarded to an accredited laboratory for silica analysis.

2.3 Measuring instruments

2.3.1 Types of measuring instruments

The *Gillian* gravimetric sampling pump (Figure 2.1) is in use on all the mines discussed in this report. They get calibrated against the standard flow rate of 1,9l/m by means of a Gilibrator (Figure 2.2) centrally in the laboratory and distributed to the mines as per a schedule drawn up by each mine.

Figure 2.1: Typical example of a Gillian gravimetric pump

Air is drawn by the pump through a MCES 25mm filter placed in a Higgins-Dewell-type cyclone at a flow rate of 1,9l/m capturing dust particles smaller than 7 microns (respirable dust).

Figure 2.2: Typical example of a Gillibrator calibration instrument

2.3.2 Flow rates

The flow rates of the gravimetric sampling pumps were set at 1,9 litre per minute for the years 1999 to 2002 as per the BMRC respirable curve. From the year 2003, the flow rate was increased to 2,2l/m as per the ISO/CEN/ACGIH curve.

2.3.3 Laboratory

The gravimetric dust sampling laboratory is situated on the premises of the four mines serving all of the mines in discussion. The Group Occupational Hygienist conducts quarterly audits and annual audits are done by the DME. Dust filters are sent to an independent accredited laboratory for quartz analysis.

2.4 Quality control and data reliability

The gravimetric dust sampling laboratory is equipped with two appointed air quality analysts who are responsible for the preparation and weighing of filters and the capturing of the results. The mines submit a sampling schedule as per the HEG classification and frequency to the laboratory on an annual basis with quarterly reviews which is being managed through the electronic database.

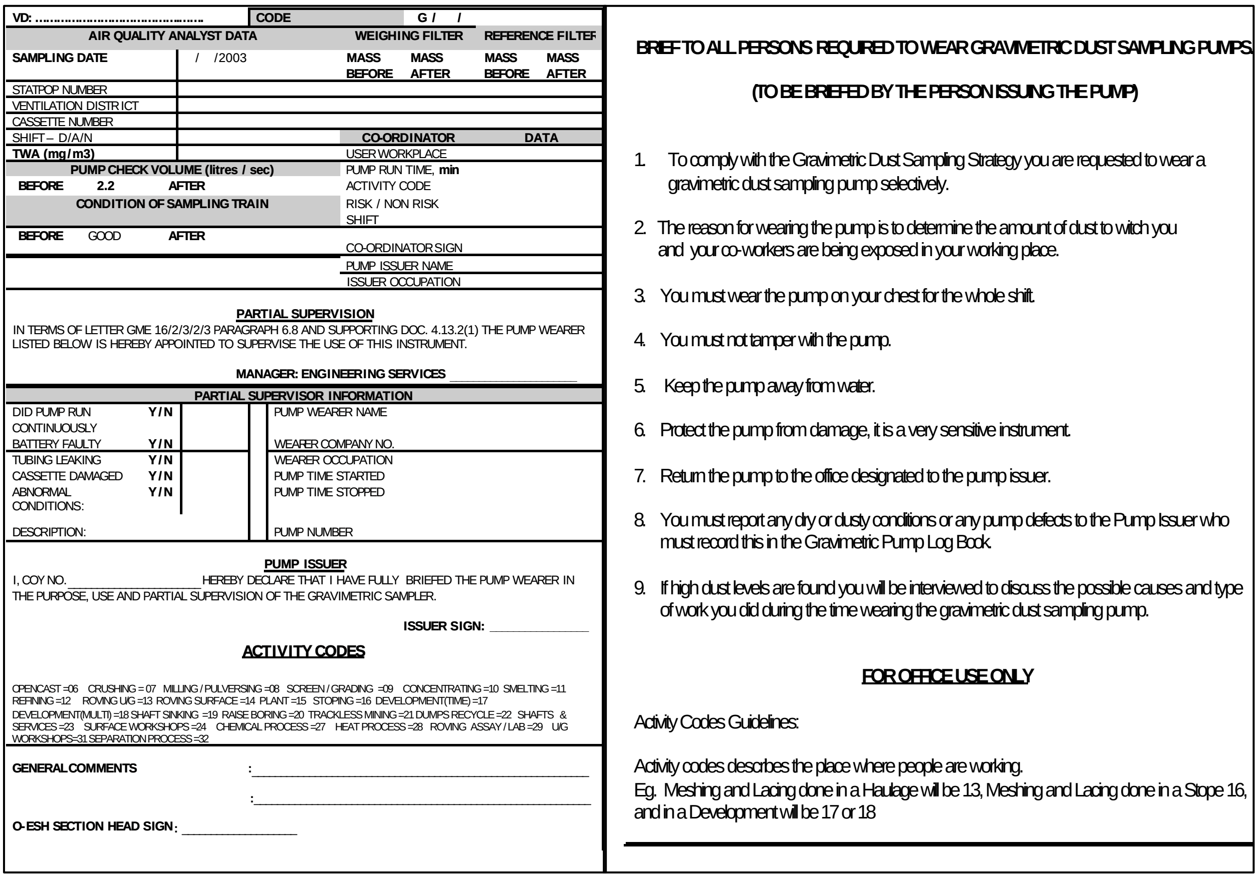
2.4.1 Data reliability

Certain measures are put in place to strive for reliability of data such as the appointments of Occupational Hygienists, training of wearers and audits that are being conducted.

Each mine has a Mine Occupational Hygienist (MOH) appointed in terms of Section 12 of the Mine Health and Safety Act (Act 29 of 1996). Part of this appointment is the management of the dust programme. The appointee is responsible for drawing up an annual schedule with dates and different occupations, which is forwarded to the laboratory. The laboratory personnel distribute the pumps to the MOH, according to the schedule, for placement underground. The wearer gets fitted with the pump before shift and the pump switched on. At the end of the shift, the MOH switches the pump off and prepares it for transport to the laboratory.

A partial supervision appointment is given to the wearer and training and induction provided.

With each pump issued a gravimetric dust sampling control card is completed requiring the wearer to report any anomalies observed during the shift such as pump defections, suspected high dust levels or any other reason that might have an effect on the dust results (see Figure 2.3). The mine occupational hygienist is responsible for signing off of the control card.



VD: ……………………………………… CODE G / /

AIR QUALITY ANALYST DATA		WEIGHING FILTER		REFERENCE FILTER	
SAMPLING DATE	/ /2003	MASS BEFORE	MASS AFTER	MASS BEFORE	MASS AFTER
STATPOP NUMBER					
VENTILATION DISTRICT					
CASSETTE NUMBER					
SHIFT – D/A/N		CO-ORDINATOR DATA			
TWA (mg/m3)		USER WORKPLACE			

PUMP CHECK VOLUME (litres / sec)
BEFORE 2.2 AFTER

CONDITION OF SAMPLING TRAIN
BEFORE GOOD AFTER

PUMP RUN TIME, min
ACTIVITY CODE
RISK / NON RISK SHIFT
CO-ORDINATOR SIGN
PUMP ISSUER NAME
ISSUER OCCUPATION

PARTIAL SUPERVISION

IN TERMS OF LETTER GME 16/2/3/2/3 PARAGRAPH 6.8 AND SUPPORTING DOC. 4.13.2(1) THE PUMP WEARER LISTED BELOW IS HEREBY APPOINTED TO SUPERVISE THE USE OF THIS INSTRUMENT.

MANAGER: ENGINEERING SERVICES ____________________

PARTIAL SUPERVISOR INFORMATION

DID PUMP RUN CONTINUOUSLY	Y/N	PUMP WEARER NAME
BATTERY FAULTY	Y/N	WEARER COMPANY NO.
TUBING LEAKING	Y/N	WEARER OCCUPATION
CASSETTE DAMAGED	Y/N	PUMP TIME STARTED
ABNORMAL CONDITIONS:	Y/N	PUMP TIME STOPPED
DESCRIPTION:		PUMP NUMBER

PUMP ISSUER

I, COY NO.____________________ HEREBY DECLARE THAT I HAVE FULLY BRIEFED THE PUMP WEARER IN THE PURPOSE, USE AND PARTIAL SUPERVISION OF THE GRAVIMETRIC SAMPLER.

ISSUER SIGN: _______________

ACTIVITY CODES

OPENCAST =06 CRUSHING = 07 MILLING / PULVERSING =08 SCREEN / GRADING =09 CONCENTRATING =10 SMELTING =11 REFINING =12 ROVING U/G =13 ROVING SURFACE =14 PLANT =15 STOPING =16 DEVELOPMENT(TIME) =17 DEVELOPMENT(MULTI) =18 SHAFT SINKING =19 RAISE BORING =20 TRACKLESS MINING =21 DUMPS RECYCLE =22 SHAFTS & SERVICES =23 SURFACE WORKSHOPS =24 CHEMICAL PROCESS =27 HEAT PROCESS =28 ROVING ASSAY / LAB =29 U/G WORKSHOPS=31 SEPARATION PROCESS =32

GENERAL COMMENTS :____

:____

O-ESH SECTION HEAD SIGN: ________________

BRIEF TO ALL PERSONS REQUIRED TO WEAR GRAVIMETRIC DUST SAMPLING PUMPS.

(TO BE BRIEFED BY THE PERSON ISSUING THE PUMP)

1. To comply with the Gravimetric Dust Sampling Strategy you are requested to wear a gravimetric dust sampling pump selectively.
2. The reason for wearing the pump is to determine the amount of dust to witch you and your co-workers are being exposed in your working place.
3. You must wear the pump on your chest for the whole shift.
4. You must not tamper with the pump.
5. Keep the pump away from water.
6. Protect the pump from damage, it is a very sensitive instrument.
7. Return the pump to the office designated to the pump issuer.
8. You must report any dry or dusty conditions or any pump defects to the Pump Issuer who must record this in the Gravimetric Pump Log Book.
9. If high dust levels are found you will be interviewed to discuss the possible causes and type of work you did during the time wearing the gravimetric dust sampling pump.

FOR OFFICE USE ONLY

Activity Codes Guidelines:

Activity codes describes the place where people are working.
Eg. Meshing and Lacing done in a Haulage will be 13, Meshing and Lacing done in a Stope 16, and in a Development will be 17 or 18

Figure 2.3: Example of a gravimetric dust sampling control card

Unfortunately, due to the vast number of pumps going underground, there certainly is a lack of supervision over the wearer, which could lead to tampering or abuse of the pumps. During underground visits the MOH will do an inspection on the wearers.

The Group Occupational Hygienist conducts quarterly audits on the mines as well as a quarterly audit on the laboratory (Appendix B). The audit includes the following areas:

- ✍ Gravimetric Dust Sampling Weighing Room
- ✍ Transparent Weighing / Stabilisation Cabinet
- ✍ Weighing Room Equipment
- ✍ Assembly of Sampling Train
- ✍ Filter Weighing Procedure
- ✍ Dust in Water
- ✍ Qualifications of personnel

The Department of Minerals and Energy conducts an annual audit on the Laboratory (Appendix C).

2.5 Data analysis and management

2.5.1 Period of data collection

The period of data collection for this report was selected for the years 1999 to 2002 for the following reasons: (1) The sampling strategy for the mines changed in 1999 when the new definition for classification of HEGs was determined; and (2) During 2002, the flow rate on gravimetric dust sampling pumps was reviewed to be in line with international standards and in July 2002, a Government Gazette Notice

23583, 2 July 2002 was released requiring that the gravimetric dust sampling flow rate be increased from 1,9 l/m to 2,2 l/m which would result in capturing dust particles up to 10 micron instead of 7 micron. The new flow rate was implemented at underground gold mines in 2003.

2.5.2 Data capturing system

During the early 1990's, a company specific database computer programme was developed called IRMS (Integrated Risk Management System). It was based on safety and health risk management and the occupational hygiene risk management part was developed several years later. The dust module was completed by 1999 and the central gravimetric dust sampling laboratory is responsible for the capturing of all dust results (see Figure 2.4). This happens on a daily basis as the filters are weighed and the results known.

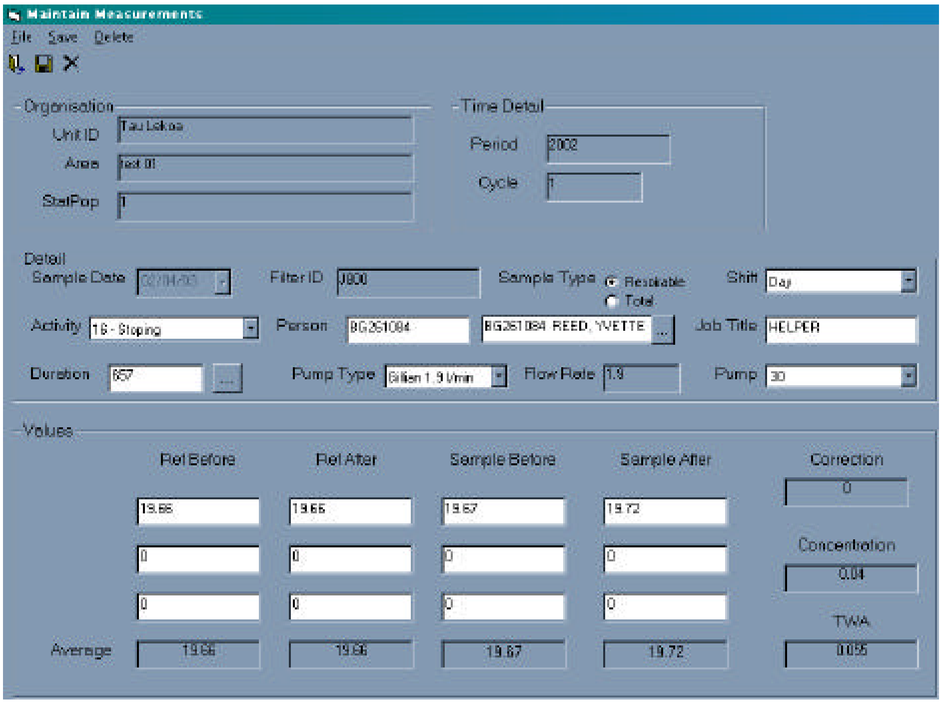


Figure 2.4: Example of the IRMS gravimetric sampling input sheet

The mines are responsible for populating the programme with all the relevant information including area codes, activities, HEGs etc. The database is linked to the Human Resources database and all employee information is pulled into the IRMS database.

2.5.3 Data analysis

Each mine can view their specific data through the IRMS system. For the purpose of this report, all the data had been exported from the IRMS system into a Microsoft Excel workbook.

Routine statistics are used to summarises the dust measurements and chi square trends were applied to evaluate the proportion of samples that exceeded the target over the years of study.

2.6 Ethical considerations

The research project was exempted from ethical approval (see Appendix A) by the Committee for Research on Human Subjects (Medical), University of the Witwatersrand. The exemption was granted, as no human or animal subjects were involved in the study.

CHAPTER 3: RESULTS

In this chapter, the respiravle dust measurements are presented for each mine and the trends in dustiness of the four mines under discussion are evaluated. The number of samples, the arithmetic mean, median and range, and standard deviations of respirable dust concentrations, the percentage samples above the legal limit and the percentage samples above the internal targets are discussed. A chi-square test was performed to evaluate trends in the proportion of dust samples exceeding standards.

In this chapter the “Target” is 0,4mg/m^3 because although the legal limit for quartz as set by the DME is 0,1mg/m^3, the company specific internal time weighted average target for respirable dust concentrations for the mines is set at 0,4 mg/m^3. This is derived from historical data whereby the quartz content was measured at an accredited laboratory and the highest result from these mines used for determining the target. The highest quartz content from the mines was measured at 25% and to obtain the TWA versus the legal limit of 0,1mg/m^3 for silica quartz is 0,1 ÷ 25% = 0,4mg/m^3 TWA.

A total of 4645 samples was taken on the four mines over the period 1999 to 2002 as set out in table 3.1. For the year 1999, 546 samples were taken, year 2000, 1089 samples, year 2001, 1550 samples and 1460 samples during the year 2002.

The respirable dust concentrations in mg/m^3 for each mine by ventilation district and HEG for 1999 to 2002 are shown in Table 3.2.

Table 3.1: Summary of the number of respirable dust samples taken per mine by ventilation district and by year

		Number of samples taken per year				
Mine	Vent district	1999	2000	2001	2002	Grand Total
Mine1	VD1	34	89	123	102	348
	VD2	3	10	13	12	38
	VD3	53	98	89	82	322
	VD4	27	86	115	93	321
	VD5	6	44	123	142	315
	VD6	5	26	90	106	227
	VD8	37	61	97	97	292
Mine1 Total		165	414	650	634	1863
Mine2	VD1	42	54	58	52	206
	VD2	22	26	39	38	125
	VD4	59	69	160	209	497
	VD6	16	47	48	39	150
	VD8	19	76	84	60	239
	VD9	14	29	41	25	109
Mine2 Total		172	301	430	423	1326
Mine3	VD2	67	109	108	62	346
	VD3	61	63	109	115	348
	VD4	23	23	26	20	92
Mine3 Total		151	195	243	197	786
Mine4	VD1	10	49	67	50	176
	VD2	20	35	34	32	121
	VD3	21	50	60	34	165
	VD4	6	41	54	50	151
	VD5	1	4	12	40	57
Mine4 Total		58	179	227	206	670
Grand Total		546	1089	1550	1460	4645

Table 3.2: Respirable dust concentrations in mg/m^3 for each mine by ventilation district and by HEG

	Vent District	HEG	n (Number of samples)	Mean	SD	Median	Range	%>0,4
Mine 1	1	1	282	0.35	0.4	0.20	0.019 - 1.787	31
		2	66	0.36	0.4	0.20	0.047 - 1.567	32
	2	2	38	0.30	0.3	0.21	0.028 - 1.810	18
	3	1	234	0.35	0.4	0.20	0.029 - 1.732	30
		2	88	0.36	0.4	0.20	0.054 - 1.612	30
	4	1	246	0.32	0.3	0.20	0.009 - 1.930	29
		2	75	0.34	0.4	0.20	0.032 - 1.897	25
	5	3	315	0.26	0.3	0.20	0.028 - 1.809	19
	6	5	227	0.25	0.3	0.20	0.047 - 1.678	17
	8	4	292	0.26	0.3	0.20	0.009 - 1.963	20
Mine 2	1	1	116	0.31	0.3	0.20	0.044 - 1.370	25
		2	43	0.39	0.2	0.16	0.038 - 0.634	30
		3	47	0.18	0.1	0.21	0.055 - 1.206	34
	2	1	75	0.31	0.4	0.20	0.028 - 1.962	23
		2	20	0.27	0.3	0.20	0.022 - 1.382	20
		3	30	0.21	0.3	0.20	0.054 - 1.162	10
	4	1	291	0.36	0.3	0.20	0.028 - 1.924	34
		2	110	0.31	0.3	0.20	0.038 - 1.338	26
		3	96	0.34	0.3	0.20	0.038 - 1.710	31
	6	1	110	0.38	0.3	0.20	0.019 - 1.547	35
		3	40	0.39	0.4	0.21	0.054 - 1.974	35
	8	1	94	0.39	0.3	0.20	0.052 - 1.641	46
		2	89	0.39	0.4	0.21	0.052 - 1.963	31
		3	56	0.29	0.2	0.19	0.054 - 0.944	21
	9	2	61	0.29	0.2	0.19	0.028 - 1.173	20
		3	48	0.37	0.3	0.20	0.054 - 1.074	38
Mine 3	2	1	215	0.31	0.3	0.20	0.021 - 1.656	27
		2	75	0.39	0.3	0.20	0.011 - 1.930	43
		3	56	0.18	0.2	0.20	0.054 - 1.370	4
	3	1	192	0.34	0.3	0.20	0.043 - 1.338	39
		2	85	0.36	0.4	0.20	0.011 - 1.941	31
		3	71	0.34	0.4	0.21	0.054 - 1.930	24
	4	4	92	0.26	0.4	0.20	0.011 - 1.820	20
Mine 4	1	3	66	0.25	0.3	0.20	0.009 - 1.798	14
		4	110	0.26	0.4	0.20	0.010 - 1.985	17
	2	2	54	0.37	0.4	0.20	0.019 - 1.524	33
		3	34	0.36	0.4	0.20	0.019 - 1.535	24
		4	33	0.39	0.5	0.22	0.055 - 1.448	24
	3	2	78	0.37	0.4	0.21	0.054 - 1.974	33
		3	35	0.38	0.3	0.22	0.055 - 1.327	29
		4	52	0.29	0.4	0.20	0.022 - 1.766	23
	4	2	53	0.45	0.4	0.20	0.010 - 1.700	45
		3	46	0.41	0.5	0.21	0.054 - 1.688	33
		4	52	0.40	0.3	0.20	0.043 - 1.984	48
	5	5	57	0.22	0.3	0.20	0.010 - 1.685	14

3.1 Mine 1

3.1.1 Number of samples collected

During 1999, a total of 165 samples was taken with a steady increase in the following years. There is a slight decrease noted in 2002 of 2,5% as per Figures 3.1 and 3.2.

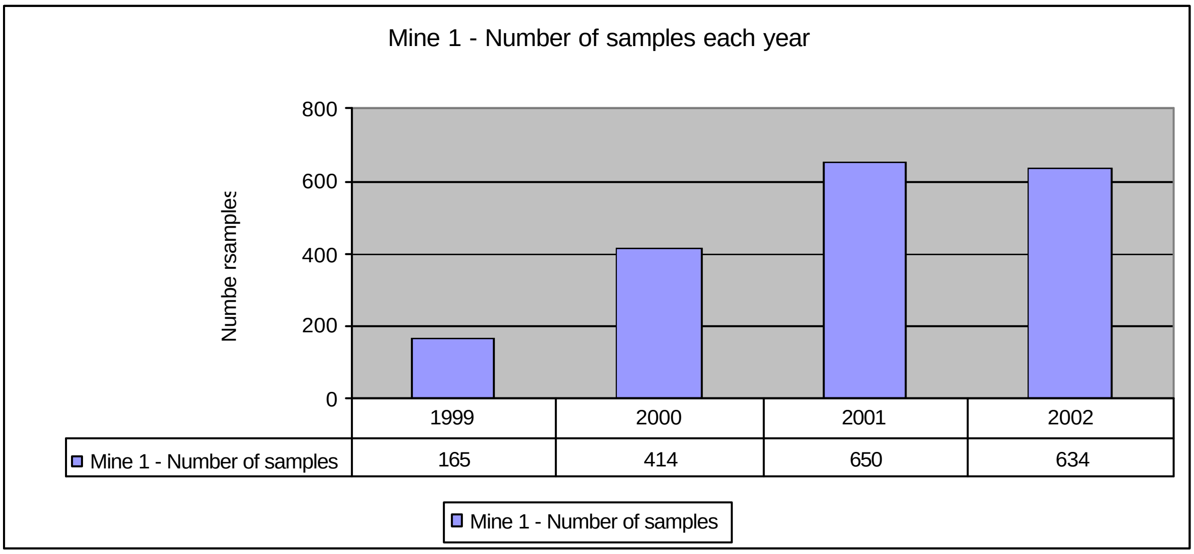


Figure 3.1: The number of dust samples collected for Mine1 over a year for the years 1999 – 2002

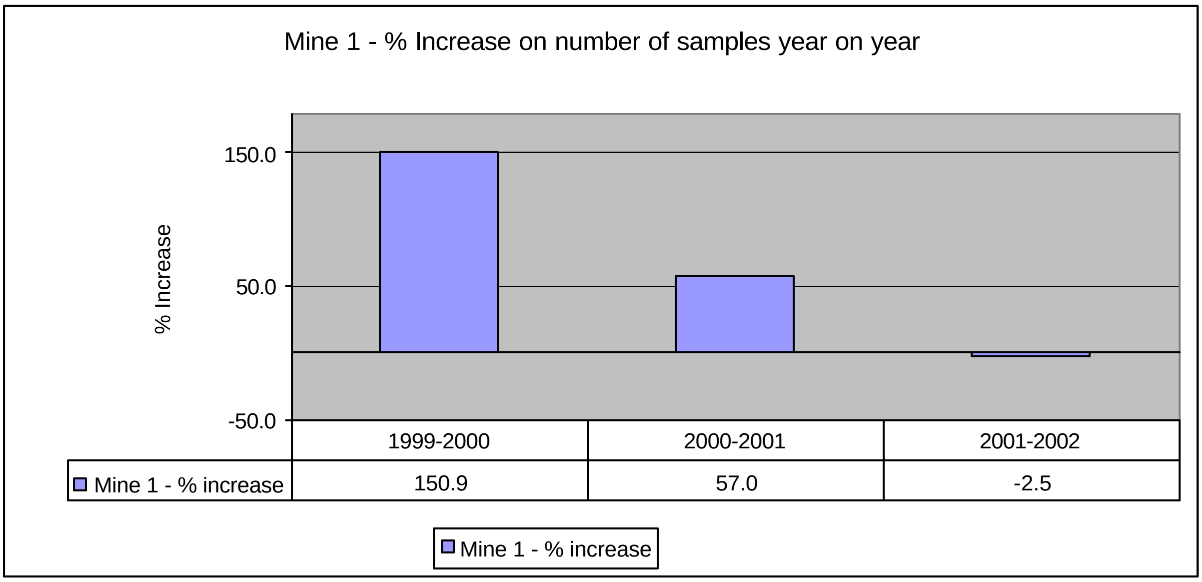
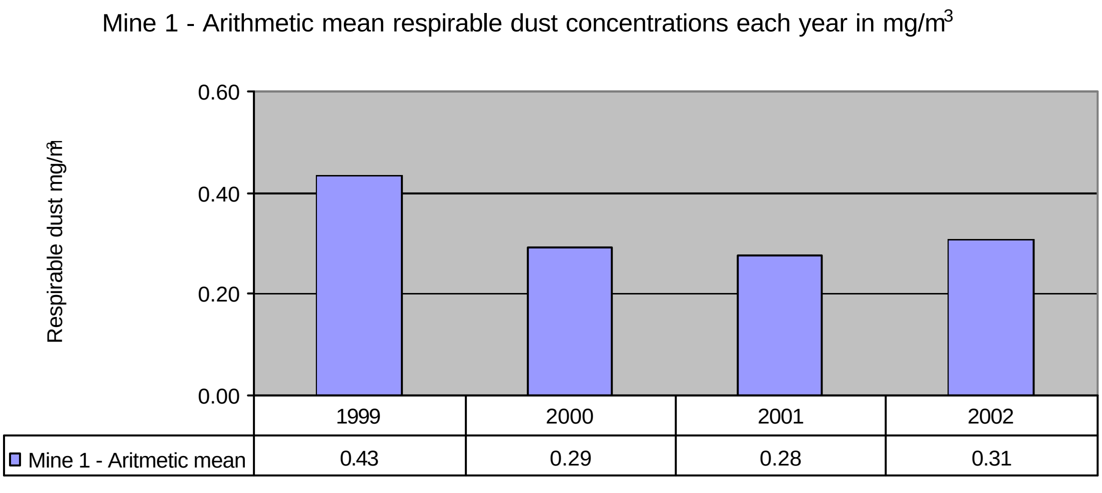


Figure 3.2: The % increase in number of dust samples taken for Mine1 over a year for the years 1999 – 2002

3.1.2 Respirable dust concentrations

Mine 1 is divided into 7 ventilation districts with 10 separate HEGs. For the year 1999, 5 HEGs had a arithmetic mean above the internal mine target of 0,4 mg/m^3, and 1 HEG in 2002 (see Appendix D) for detail.

A downward trend in the respirable dust concentrations is possible for the mine during the period 1999 to 2002, but the figure suggests a drop from year 1999 to 2000 and then a steady state till 2002. The last three years have an arithmetic mean below the internal respirable dust concentration target (see Figure 3.3). The improvement in the arithmetic mean year on year is shown in Figure 3.4. There is an increase noted after 2001 due to the increase in percentage samples above the target (see Figure 3.5).



	1999	2000	2001	2002
Mine 1 - Aritmetic mean	0.43	0.29	0.28	0.31

Figure 3.3: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine1 collected over a year for the years 1999 – 2002

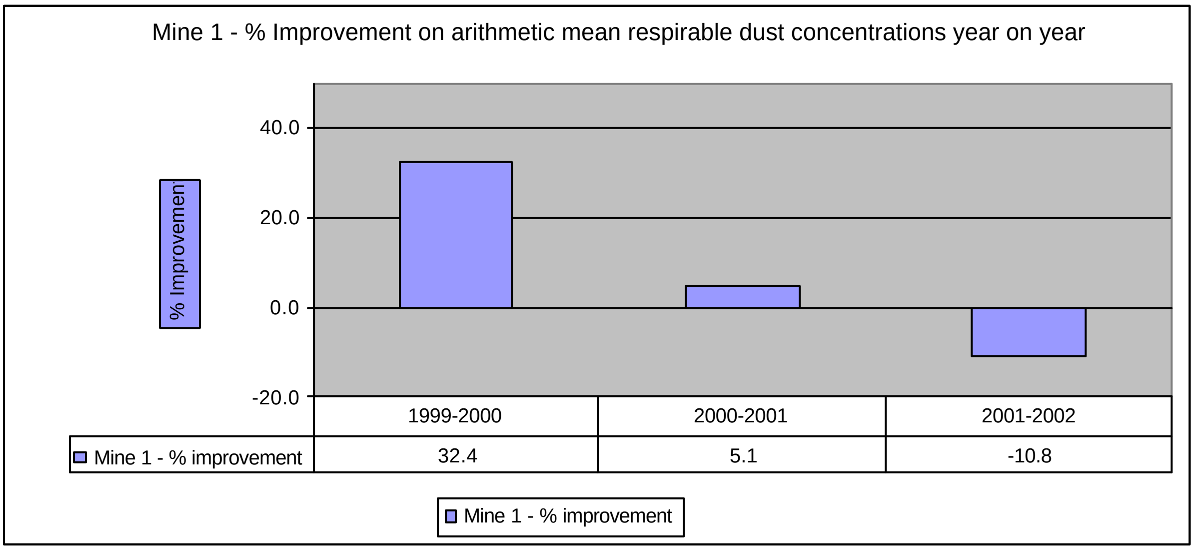


Figure 3.4: The % improvement of arithmetic mean respirable dust concentrations for Mine1 collected over a year for the years 1999 – 2002

3.1.3 Samples above the target and 1mg/m^3

During the first year, more than 40% of the samples were measured to be above the internal TWA target of 0,4mg/m^3. In the year 2002, the percentage of total samples above the target recorded were just over 24% as depicted in Figure 3.5 below.

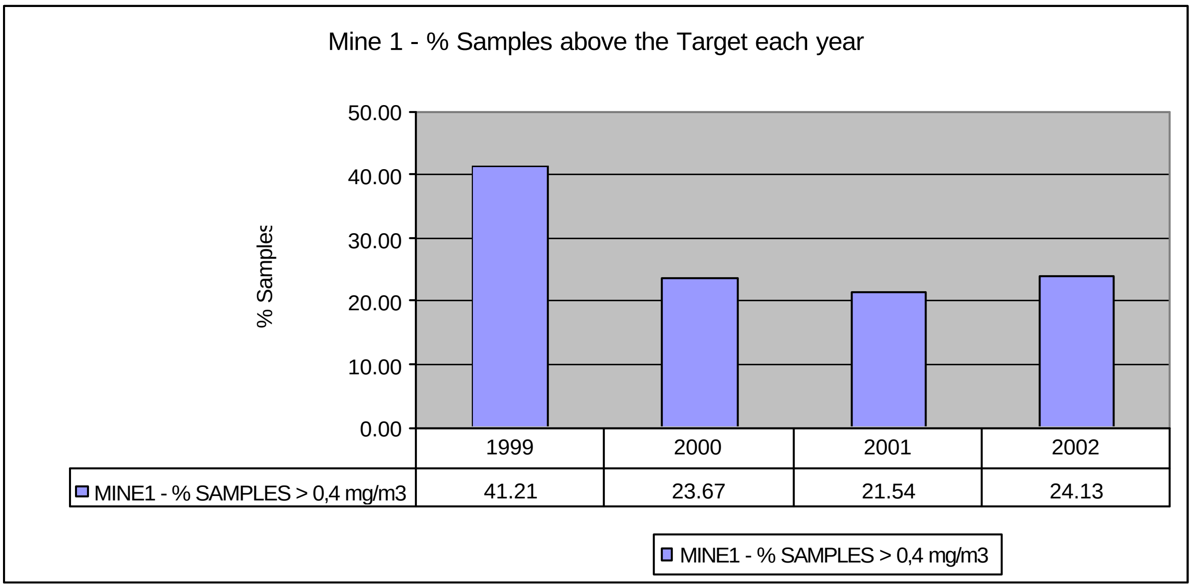


Figure 3.5: The % of dust samples above the TWA target of 0,4mg/m^3 for Mine1 over a year for the years 1999 – 2002

The samples above 1,0 mg/m^3 varies between 7 and 5% as shown in Figure 3.6 with a steady decline over the years.

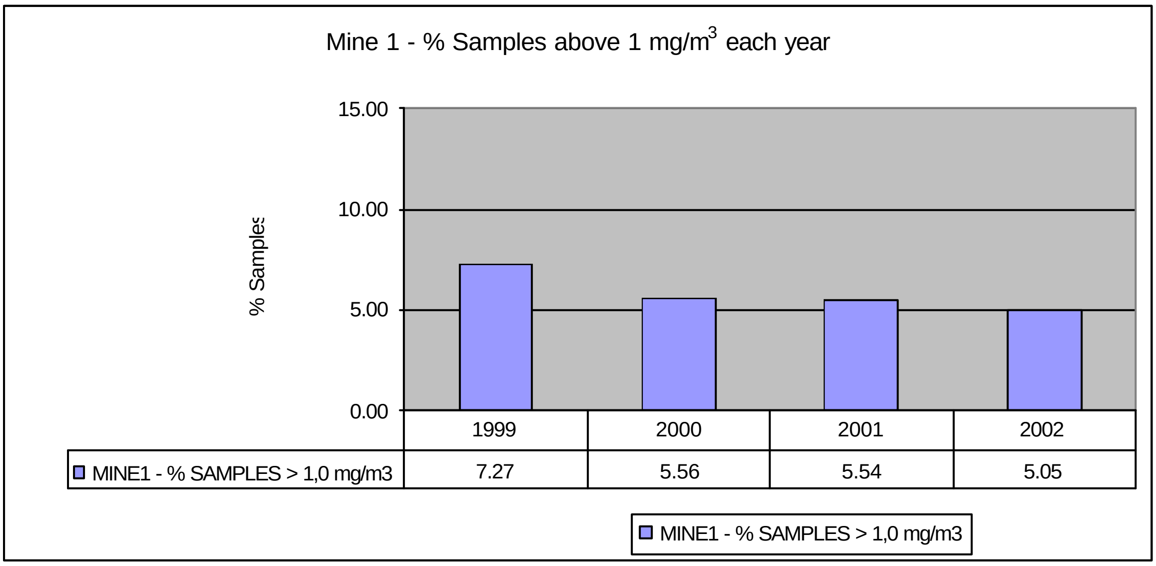


Figure 3.6: The % of dust samples above 1,0mg/m^3 for Mine1 over a year for the years 1999 – 2002

3.1.4 Chi-square test

A chi-square test for trend was performed on the proportion of respirable dust concentrations exceeding or equal to 0,4mg/m^3 for each HEG year on year over the four years as shown in Table 3.3.

A significant downward trend was evident for ventilation district 8.

Table 3.3: Trend in respirable dust concentrations in mg/m^3 exceeding or equal to the target of $0,4mg/m^3$ for the years 1999 to 2002 by ventilation district for Mine 1

Mine 1								
	Vent District	**VD1**	**VD2**	**VD3**	**VD4**	**VD5**	**VD6**	**VD8**
1999	No samples	34	3	53	27	6	5	37
	No >=0,4	17	1	21	11	3	0	15
	No <0,4	17	2	32	16	3	5	22
	%>=0,4	**50**	**33**	**40**	**41**	**50**	**0**	**41**
2000	No samples	89	10	98	86	44	26	61
	No >=0,4	26	2	26	20	4	4	16
	No <0,4	63	8	72	66	40	22	45
	%>=0,4	**29**	**20**	**27**	**23**	**9**	**15**	**26**
2001	No samples	123	13	89	115	123	90	97
	No >=0,4	31	1	26	33	23	13	13
	No <0,4	92	12	63	82	100	77	84
	%>=0,4	**25**	**8**	**29**	**29**	**19**	**14**	**13**
2002	No samples	102	12	82	93	142	106	97
	No >=0,4	35	3	24	26	31	21	13
	No <0,4	67	9	58	67	111	85	84
	%>=0,4	**34**	**25**	**29**	**28**	**22**	**20**	**13**

Chi square of linearity		0.88	0.01	0.72	0.14	0.65	1.53	13.84
p value		0.347546	0.906742	0.395535	0.70734	0.420646	0.215385	0.000199

3.2 Mine 2

3.2.1 Number of samples collected

The number of samples increased from 172 to 423 from the year 1999 to 2002 as shown in figure 3.7.

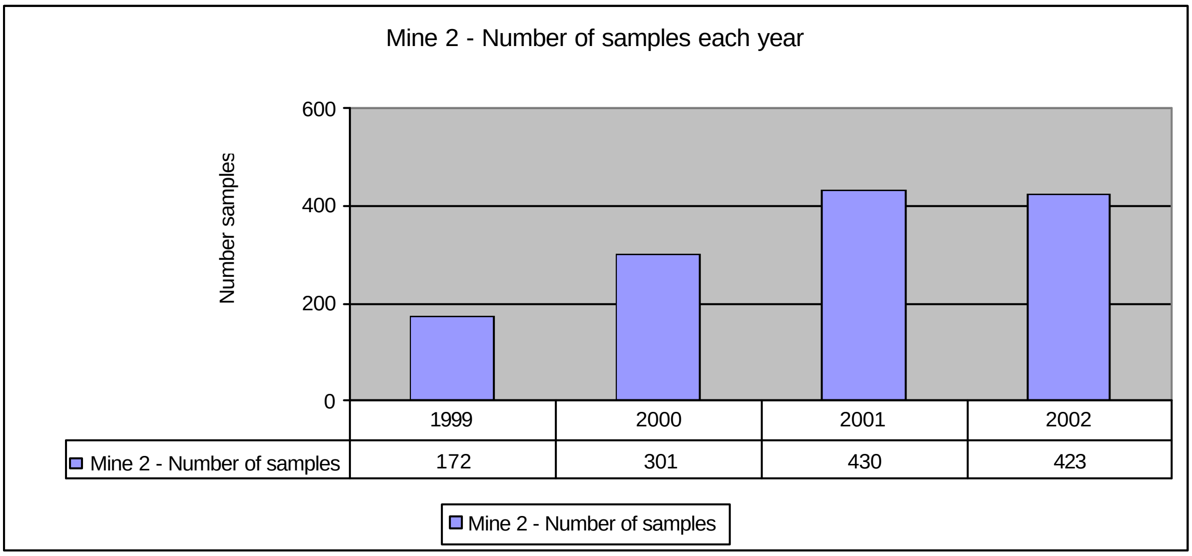


Figure 3.7: The number of dust samples collected for Mine2 over a year for the years 1999 – 2002

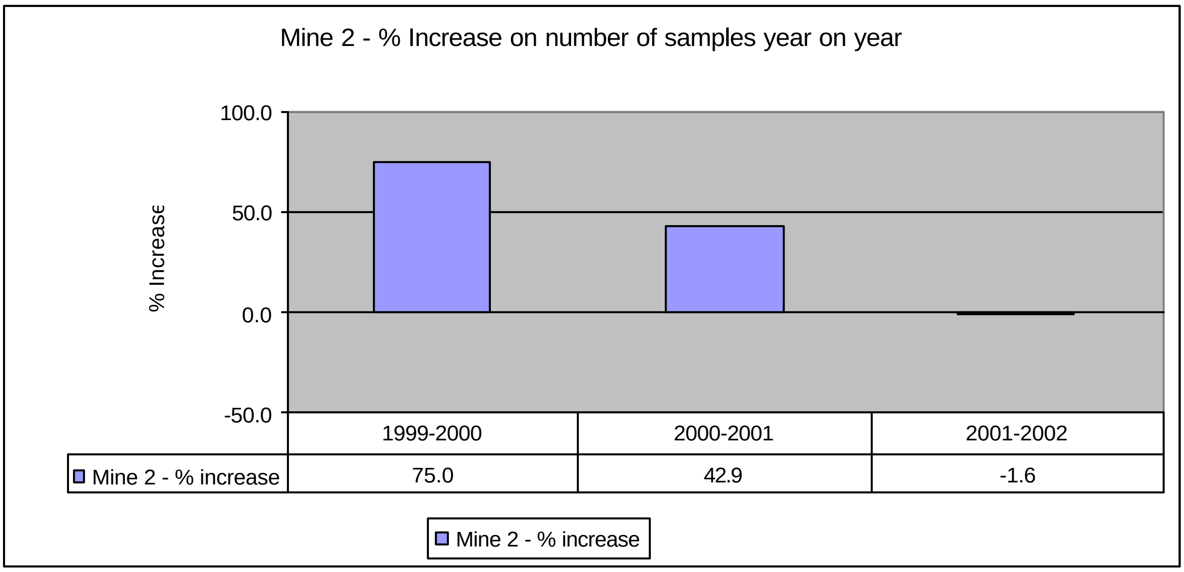


Figure 3.8: The % increase on number of dust samples taken for Mine2 over a year for the years 1999 – 2002

3.2.2 Respirable dust concentrations

Mine 2 has 5 ventilation districts with 16 HEGs. 4 HEGs were above the internal mine target TWA of 0,4 mg/m^3 on arithmetic mean in 1999, 6 in 2000, 3 in 2001 and 3 in 2002 (see Appendix D) for detail.

A general downward trend in the respirable dust concentrations is noted for the mine. All four years show an arithmetic mean below the internal respirable dust concentration target (see Figure 3.9). The improvement in the arithmetic mean year on year is shown in Figure 3.10 with a decrease of 6,1% in the year 2000 as shown in Figure 3.10.

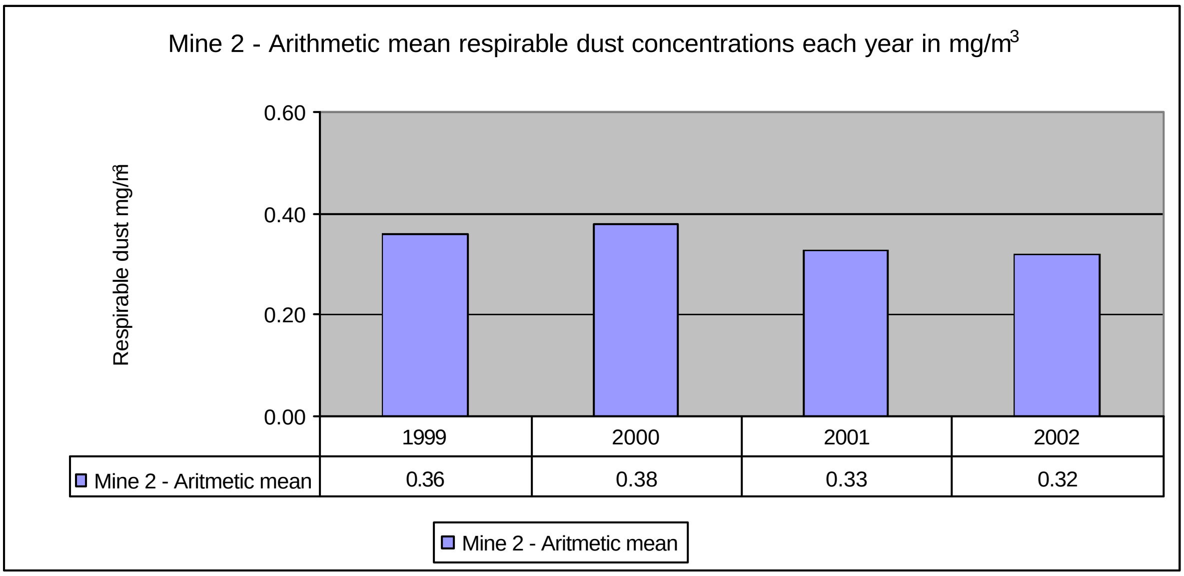


Figure 3.9: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine2 collected over a year for the years 1999 – 2002

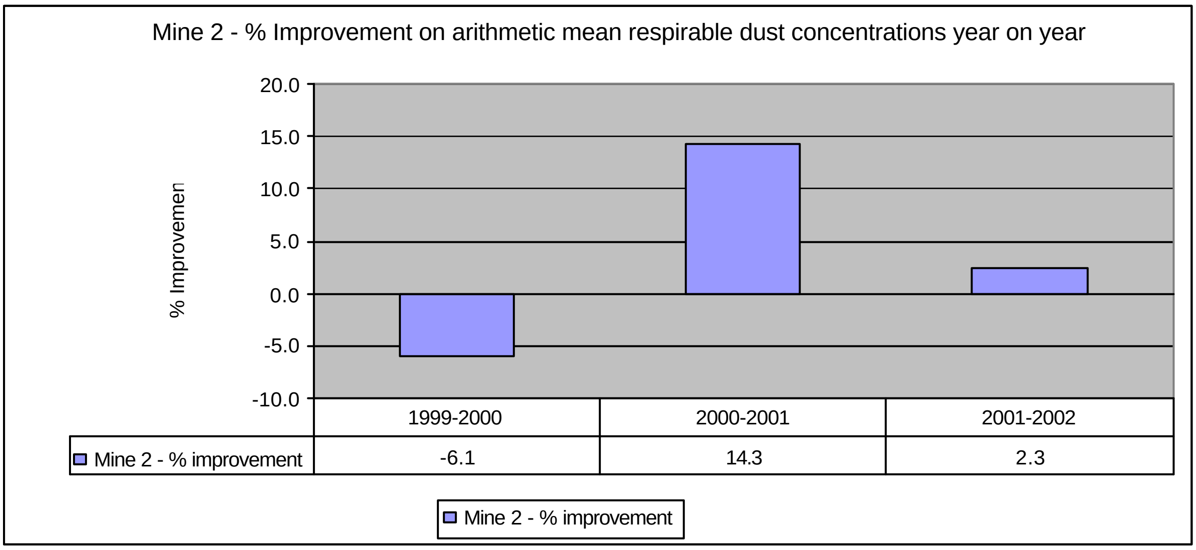


Figure 3.10: The % improvement of arithmetic mean respirable dust concentrations for Mine2 collected over a year for the years 1999 – 2002

3.2.3 Samples above the target and 1mg/m^3

Although a high percentage of the samples were above the internal TWA target of 0,4mg/m^3 of the mine, there is a decrease noted in the last three years as per Figure 3.11.

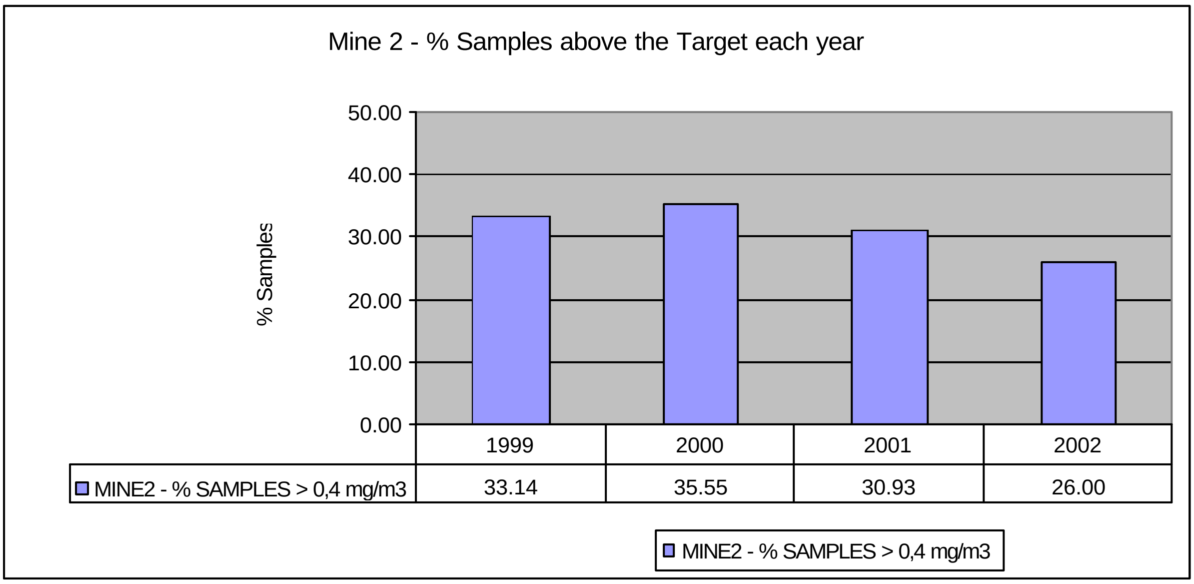


Figure 3.11: The % of dust samples above the TWA target of 0,4mg/m^3 for Mine2 over a year for the years 1999 – 2002

A good compliance against the 0,1mg/m^3 is noted during the last two years measured as can be seen in Figure 3.12.

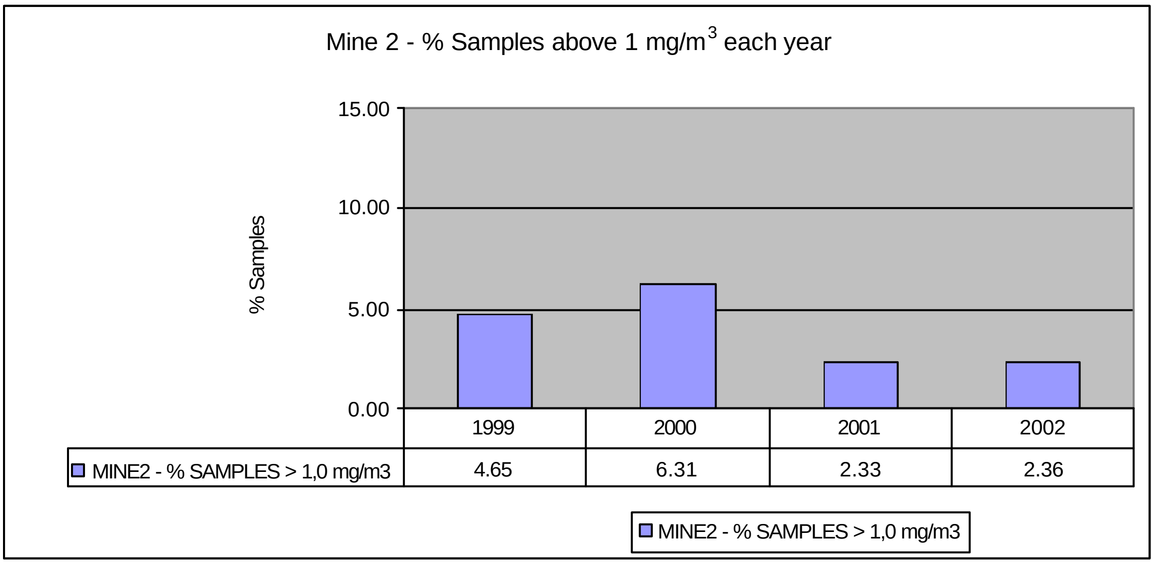


Figure 3.12: The % of dust samples above 1,0mg/m^3 for Mine2 over a year for the years 1999 – 2002

3.2.4 Chi-square test

A chi-square test for trend was performed on the proportion of respirable dust concentrations exceeding or equal to 0,4mg/m^3 for each HEG year on year over the four years as shown in Table 3.4.

Ventilation district 6 showed a statistically significant linear trend in the proportion of measurements below 0,4mg/m^3.

Table 3.4: Trend on respirable dust concentrations in mg/m^3 exceeding or equal to the target of 0,4mg/m^3 for the years 1999 to 2002 by ventilation district

Mine 2							
	Vent District	**VD1**	**VD2**	**VD4**	**VD6**	**VD8**	**VD9**
1999	No samples	42	22	59	16	19	14
	No >=0,4	10	4	21	10	8	4
	No <0,4	32	18	38	6	11	10
	%>=0,4	**24**	**18**	**36**	**63**	**42**	**29**
2000	No samples	54	26	69	47	76	29
	No >=0,4	19	8	23	17	31	9
	No <0,4	35	18	46	30	45	20
	%>=0,4	**35**	**31**	**33**	**36**	**41**	**31**
2001	No samples	58	39	160	48	84	41
	No >=0,4	16	6	55	16	25	15
	No <0,4	42	33	105	32	59	26
	%>=0,4	**28**	**15**	**34**	**33**	**30**	**37**
2002	No samples	52	38	209	39	60	25
	No >=0,4	13	6	60	10	19	2
	No <0,4	39	32	149	29	41	23
	%>=0,4	**25**	**16**	**29**	**26**	**32**	**8**

Chi square of linearity		0.07	0.67	1.3	5.2	1.89	1.91
p value		0.796862	0.414286	0.254519	0.022585	0.169434	0.166864

3.3 Mine 3

3.3.1 Number of samples collected

There is an increase in the number of samples from the years 1999 to 2001 with a decrease in 2002 as per Figure 3.13

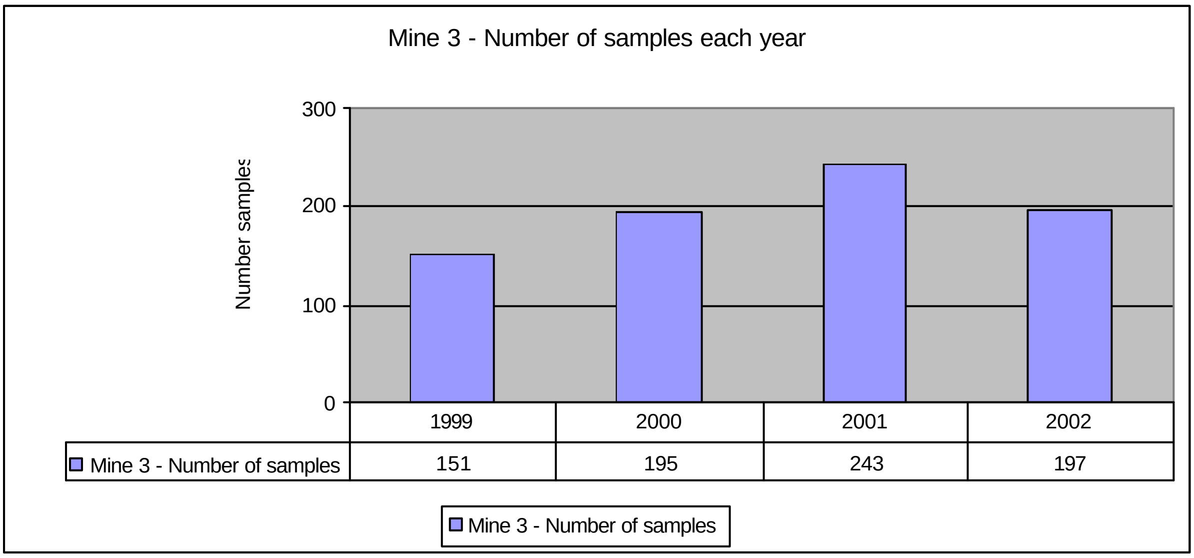


Figure 3.13: The number of dust samples collected for Mine3 over a year for the years 1999 – 2002

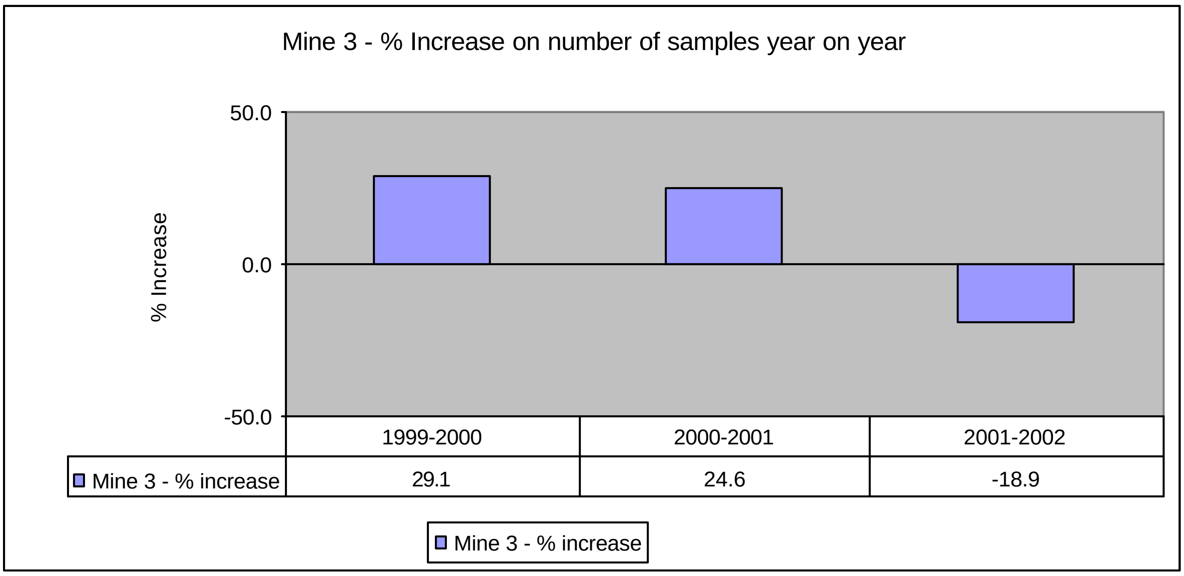


Figure 3.14: The % increase on number of dust samples taken for Mine3 over a year for the years 1999 – 2002

3.3.2 Respirable dust concentrations

Mine 3 has 3 ventilation districts with 7 HEGs. In 1999, 3 HEGs were above the internal mine target TWA of 0,4 mg/m^3 on arithmetic mean, 2 HEGs in 2000, none in 2001 and 1 in 2002 (see Appendix D) for detail.

As with mine 1, a slight increase is noted during the year 2002 due to the increase of percentage samples above the target and OEL. A general downward trend is observed. The improvement in the arithmetic mean year on year is shown in Figure 3.16 with a decrease of 3,3% in the year 2002. All four years show an arithmetic mean below the internal respirable dust concentration target (see Figure 3.15).

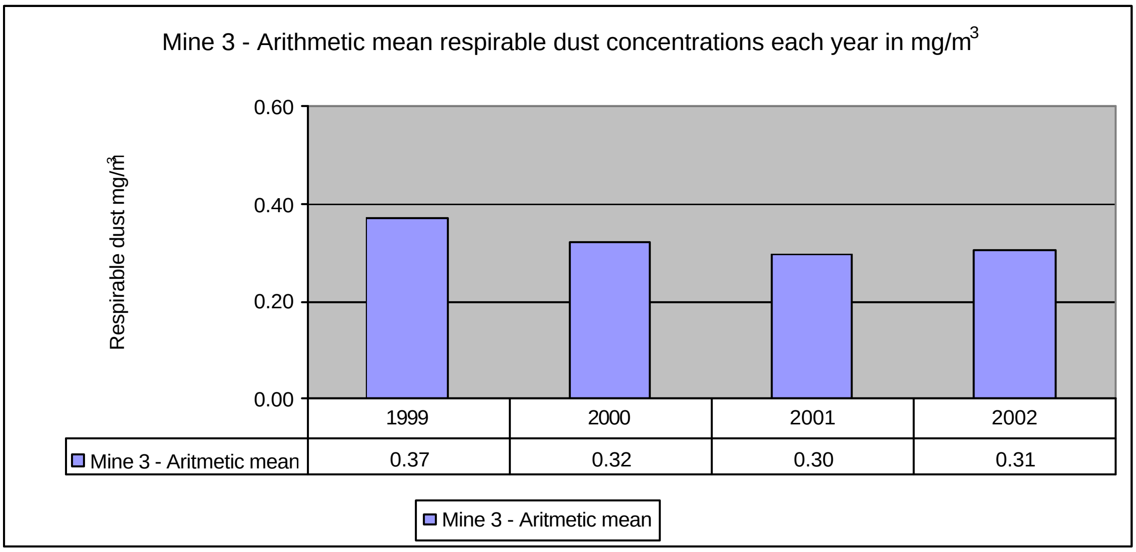
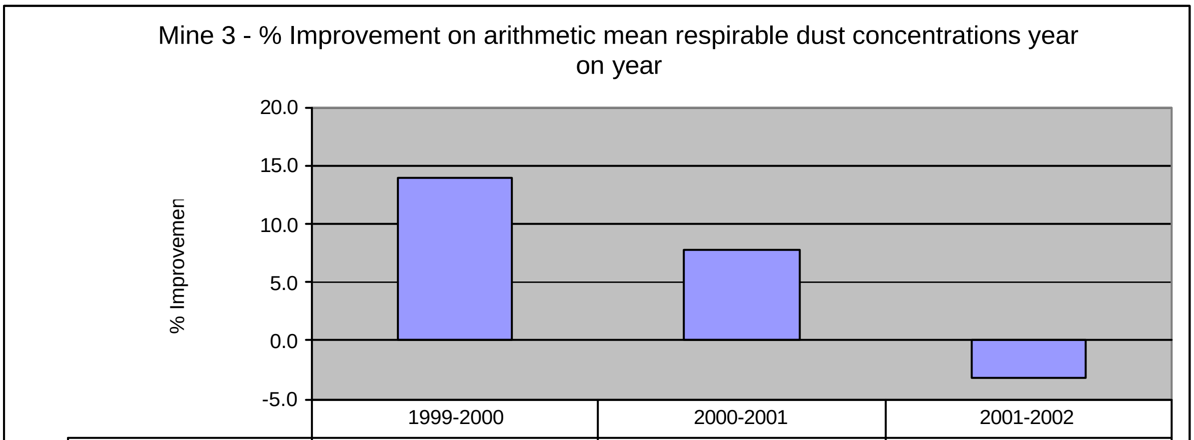


Figure 3.15: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine3 collected over a year for the years 1999 – 2002

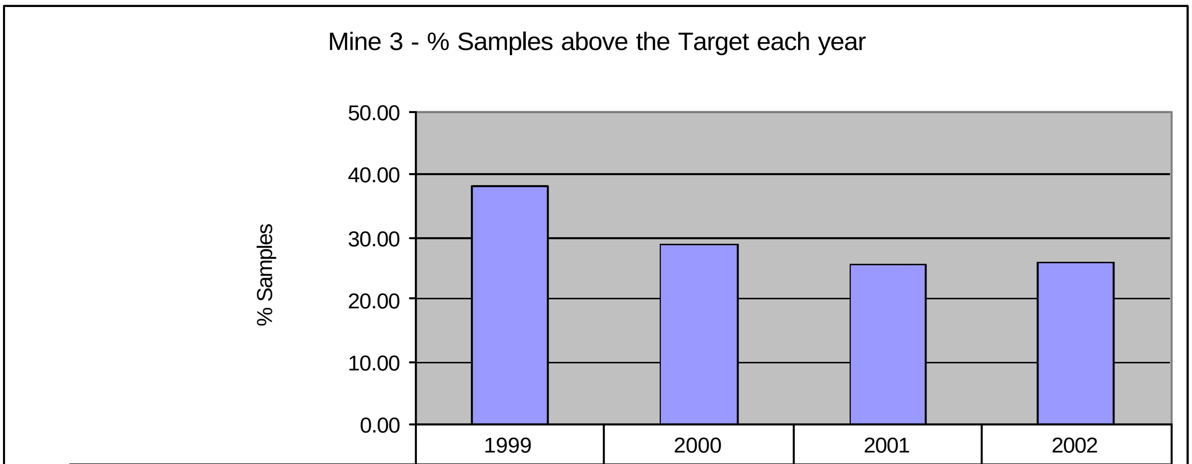


	1999-2000	2000-2001	2001-2002
Mine 3 - % improvement	14.0	7.9	-3.3

Figure 3.16: The % improvement of arithmetic mean respirable dust concentrations for Mine3 collected over a year for the years 1999 – 2002

3.3.3 Samples above the target and 1mg/m^3

The first 3 years show a decrease in the number of samples above the target of 0,4mg/m^3 with a slight increase in the final year (see Figure 3.17).



	1999	2000	2001	2002
MINE3 - % SAMPLES > 0,4 mg/m3	38.41	28.72	25.51	25.89

Figure 3.17: The % of dust samples above the TWA target of 0,4mg/m^3 for Mine3 over a year for the years 1999 – 2002

As with the increase in Figure 3.17, an increase is shown in the year 2002 for the percentage of samples above 1mg/m^3.

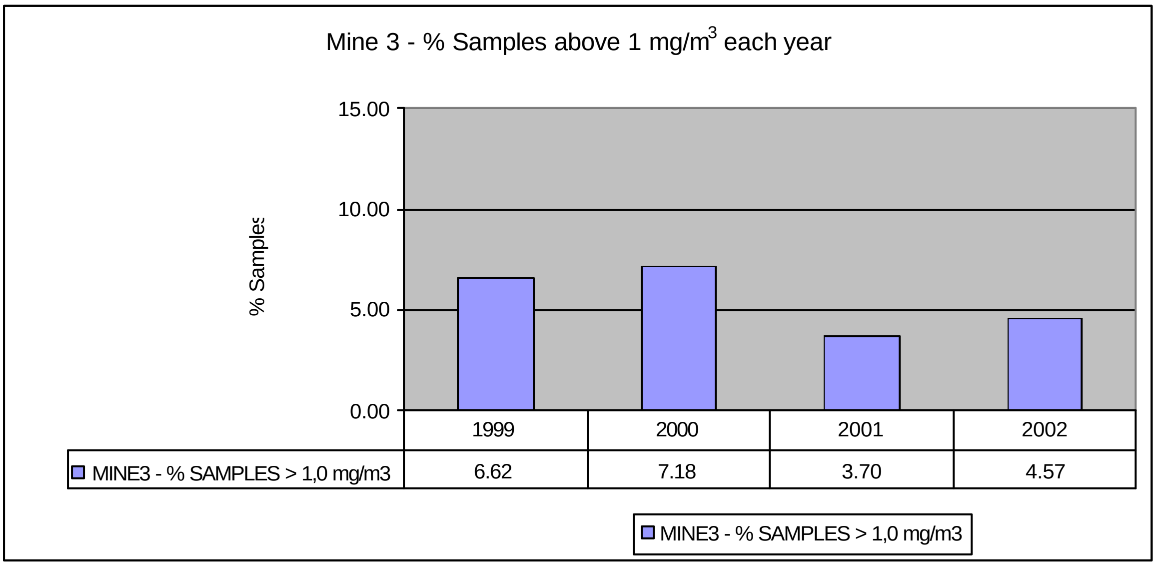


Figure 3.18: The % of dust samples above 1,0mg/m^3 for Mine3 over a year for the years 1999 – 2002

3.1.4 Chi-square test

A chi-square test for trend was performed on the proportion of respirable dust concentrations exceeding or equal to 0,4mg/m^3 for each HEG year on year over the four years as shown in Table 3.5.

Ventilation district 2 showed a statistically significant downward linear trend in the proportion of measurements below 0,4mg/m^3.

Table 3.5: Trend on respirable dust concentrations in mg/m³ exceeding or equal to the target of 0,4mg/m³ for the years 1999 to 2002 by ventilation district

Mine 3				
	Vent District	**VD2**	**VD3**	**VD4**
1999	No samples	67	61	23
	No >=0,4	27	26	5
	No <0,4	40	35	18
	%>=0,4	**40**	**43**	**22**
2000	No samples	109	63	23
	No >=0,4	29	22	5
	No <0,4	80	41	18
	%>=0,4	**27**	**35**	**22**
2001	No samples	108	109	26
	No >=0,4	23	34	5
	No <0,4	85	75	21
	%>=0,4	**21**	**31**	**19**
2002	No samples	62	115	20
	No >=0,4	13	35	3
	No <0,4	49	80	17
	%>=0,4	**21**	**30**	**15**

Chi square of linearity		7.12	2.63	0.34
p value		0.007629	0.105038	0.559971

3.4 Mine 4

3.4.1 Number of samples collected

There was a noticeable increase in the number of samples taken during the first 3 years with more than 200% in the first two years. A slight decrease of 9% is recorded for the year 2002 as per Figures 3.19 and 3.20.

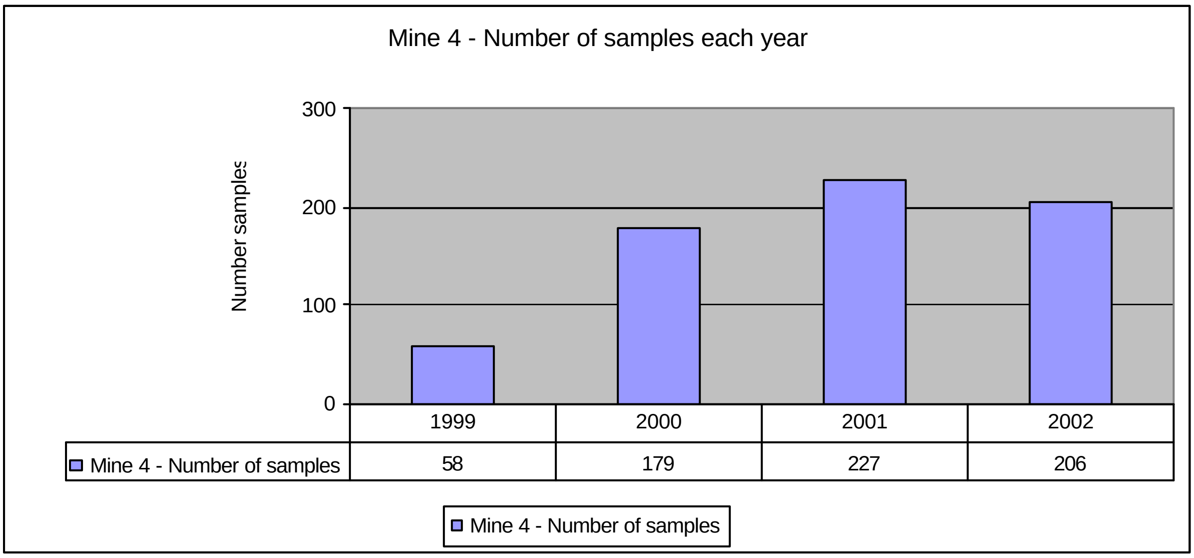


Figure 3.19: The number of dust samples collected for Mine4 over a year for the years 1999 – 2002

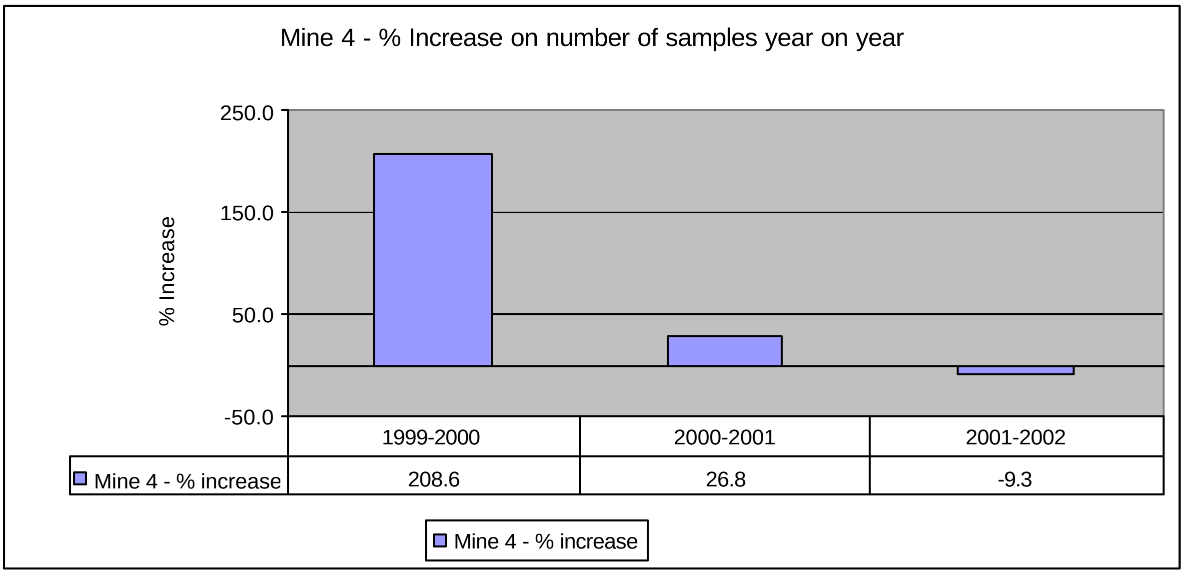


Figure 3.20: The % increase on number of dust samples taken for Mine4 over a year for the years 1999 – 2002

3.4.2 Respirable dust concentrations

Mine 4 is made up of 5 ventilation districts with 12 HEGs. 5 HEGs were above the internal mine target TWA of 0,4 mg/m^3 on arithmetic mean in 1999 and 2001, and 2 HEGs were above in the years 2000 and 2002 (see Appendix D) for detail.

There is a downward trend in the respirable dust concentrations for the mine. The last three years show an arithmetic mean below the internal respirable dust concentration target (see Figure 3.21). The improvement in the arithmetic mean year on year is shown in Figure 3.22.

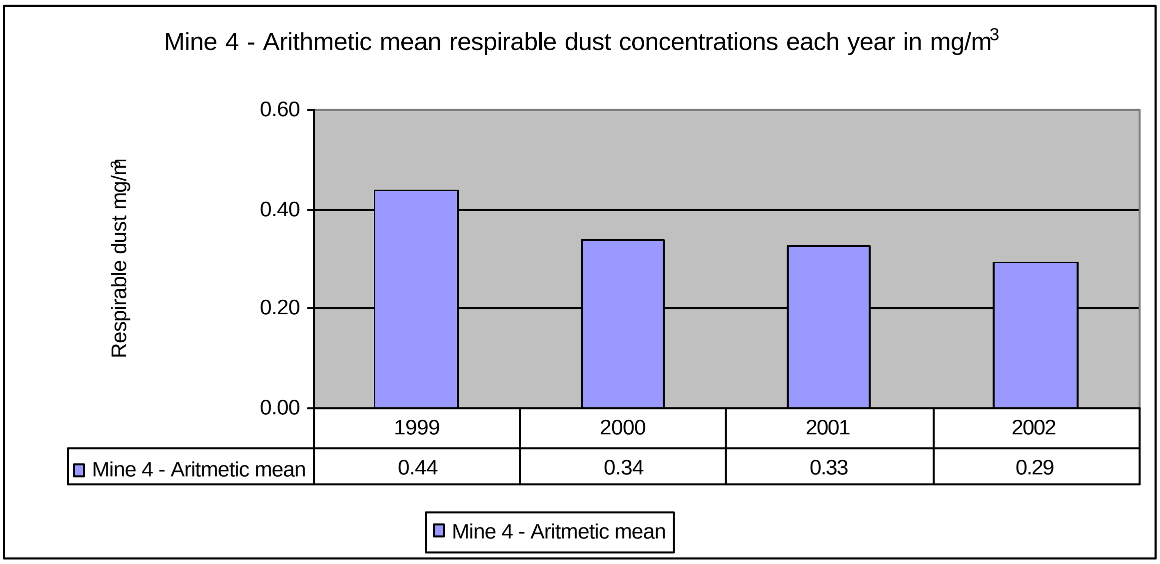


Figure 3.21: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine4 collected over a year for the years 1999 – 2002

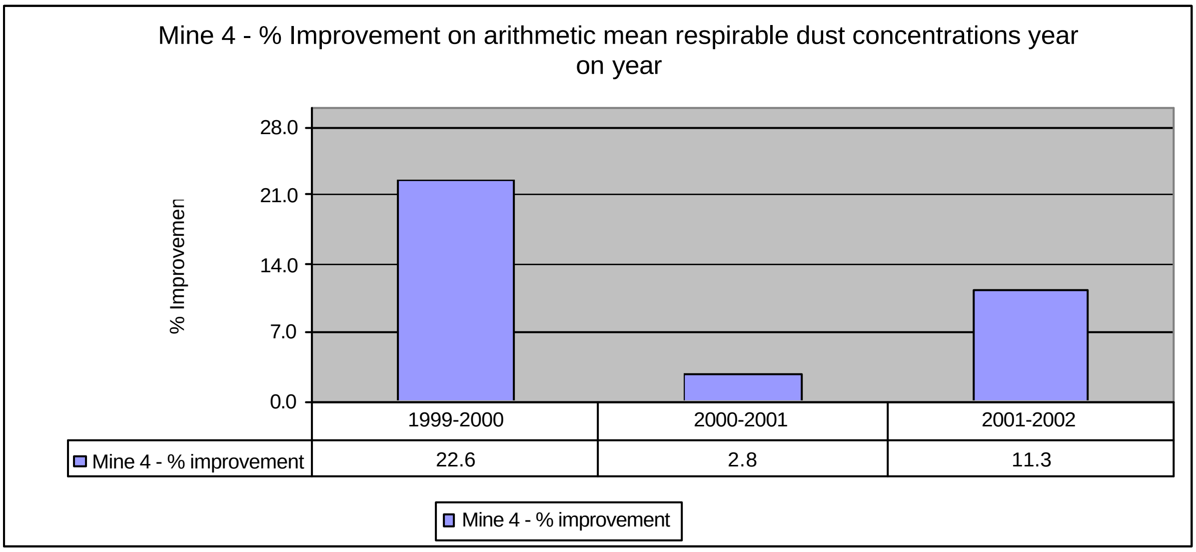


Figure 3.22: The % improvement of arithmetic mean respirable dust concentrations for Mine4 collected over a year for the years 1999 – 2002

3.4.3 Samples above the target and 1mg/m^3

A good decrease in compliance of samples above the internal TWA target of 0,4mg/m^3 and ,0mg/m^3 TWA for the years 2000 and 2002 was recorded (Figures 3.23 and 3.24).

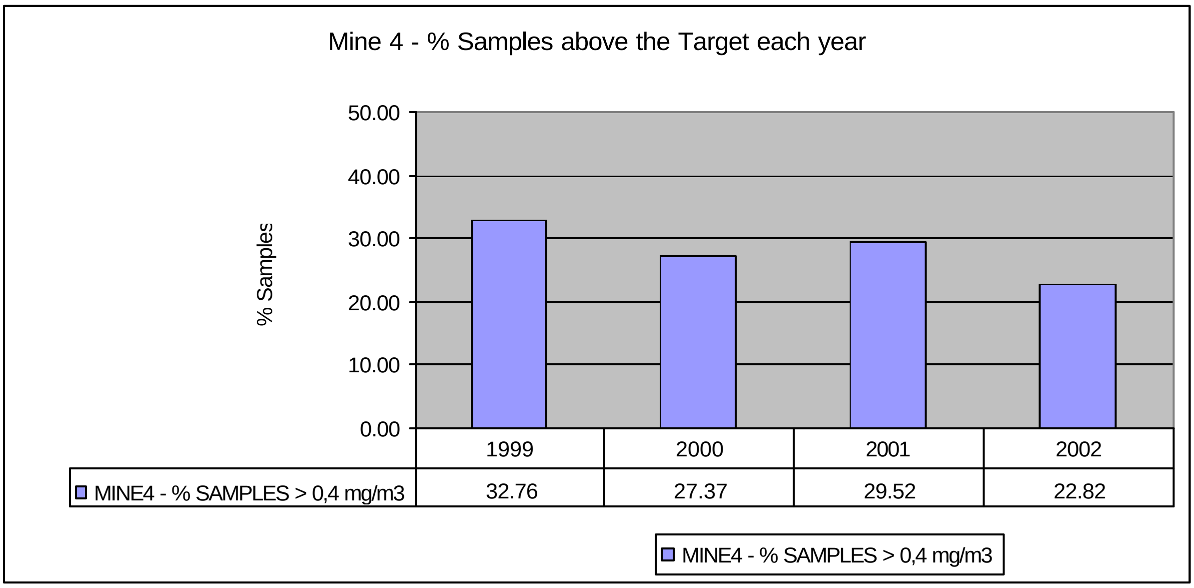


Figure 3.23: The % of dust samples above the TWA target of 0,4mg/m^3 for Mine4 over a year for the years 1999 – 2002

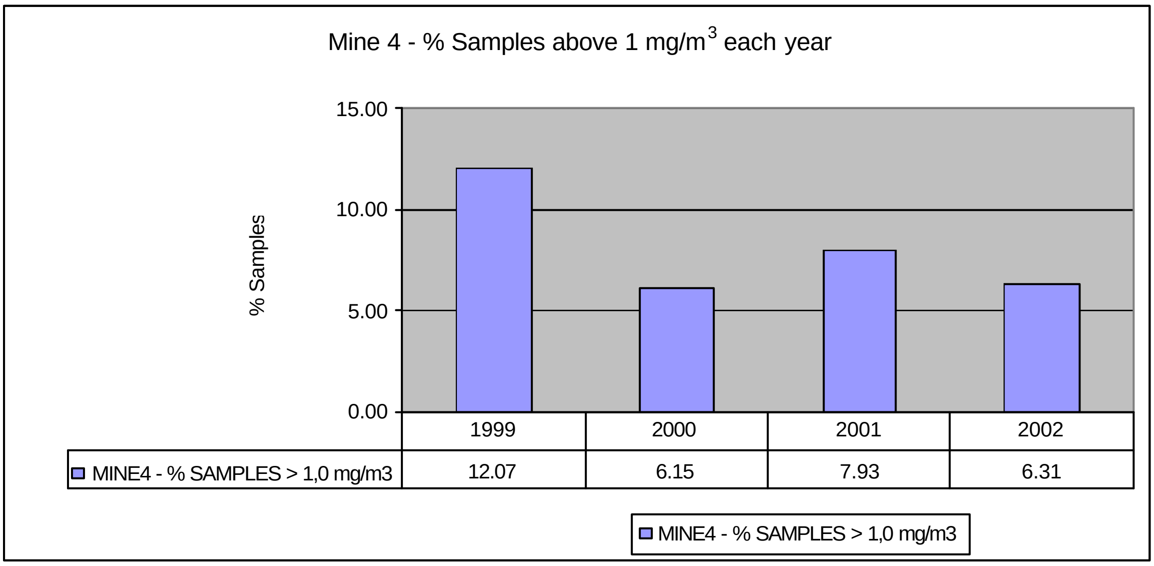


Figure 3.24: The % of dust samples above 1,0mg/m^3 for Mine4 over a year for the years 1999 – 2002

3.4.4 Chi-square test

A chi-square test for trend was performed on the proportion of respirable dust concentrations exceeding or equal to 0,4mg/m^3 for each HEG year on year over the four years as shown in Table 3.6.

A statistically significant decreasing linear trend for ventilation district 2.

Table 3.6: Trend on respirable dust concentrations in mg/m^3 exceeding or equal to the target of 0,4mg/m^3 for the years 1999 to 2002 by ventilation district

Mine 4						
	Vent District	**VD1**	**VD2**	**VD3**	**VD4**	**VD5**
1999	No samples	10	20	21	6	1
	No >=0,4	2	11	1	4	1
	No <0,4	8	9	20	2	0
	%>=0,4	**20**	**55**	**5**	**67**	**100**
2000	No samples	49	35	50	41	4
	No >=0,4	5	10	18	16	0
	No <0,4	44	25	32	25	4
	%>=0,4	**10**	**29**	**36**	**39**	**0**
2001	No samples	67	34	60	54	12
	No >=0,4	10	8	21	28	0
	No <0,4	57	26	39	26	12
	%>=0,4	**15**	**24**	**35**	**52**	**0**
2002	No samples	50	32	34	50	40
	No >=0,4	11	5	8	16	7
	No <0,4	39	27	26	34	33
	%>=0,4	**22**	**16**	**24**	**32**	**18**

Chi square of linearity		1.38	8.36	0.78	1.61	0.02
p value		0.240617	0.003832	0.377213	0.20408	0.900751

3.5 All 4 mines

3.5.1 Number of samples collected

The number of samples had almost doubled from 1999 to 2000 with another 42% increase in the year 2001. A 5% decrease is noted in 2002 (see Figures 3.25 and 3.26).

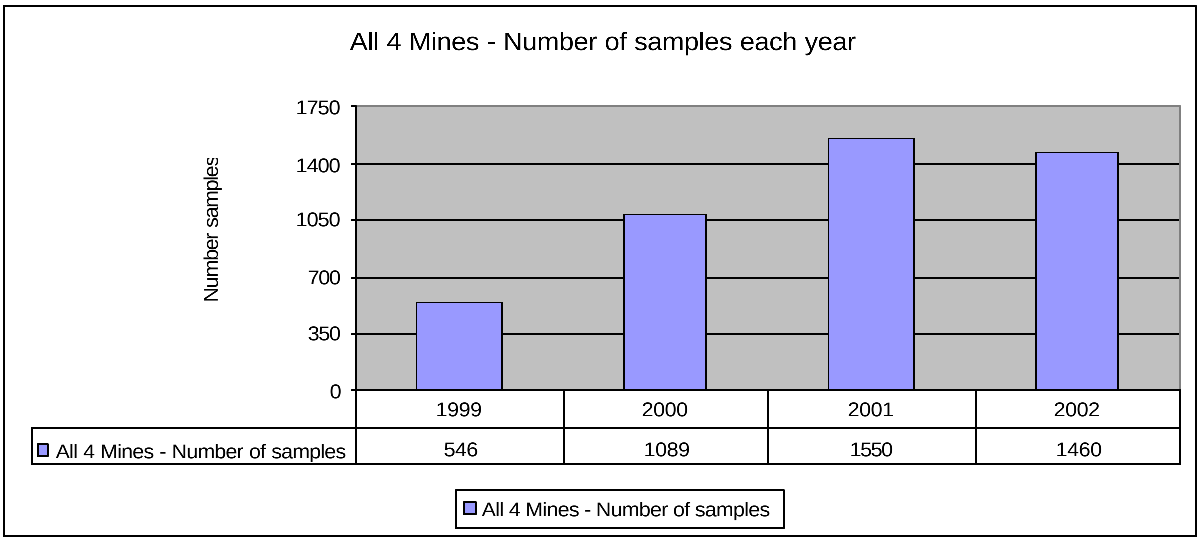


Figure 3.25: The number of dust samples collected for all 4 Mines over a year for the years 1999 – 2002

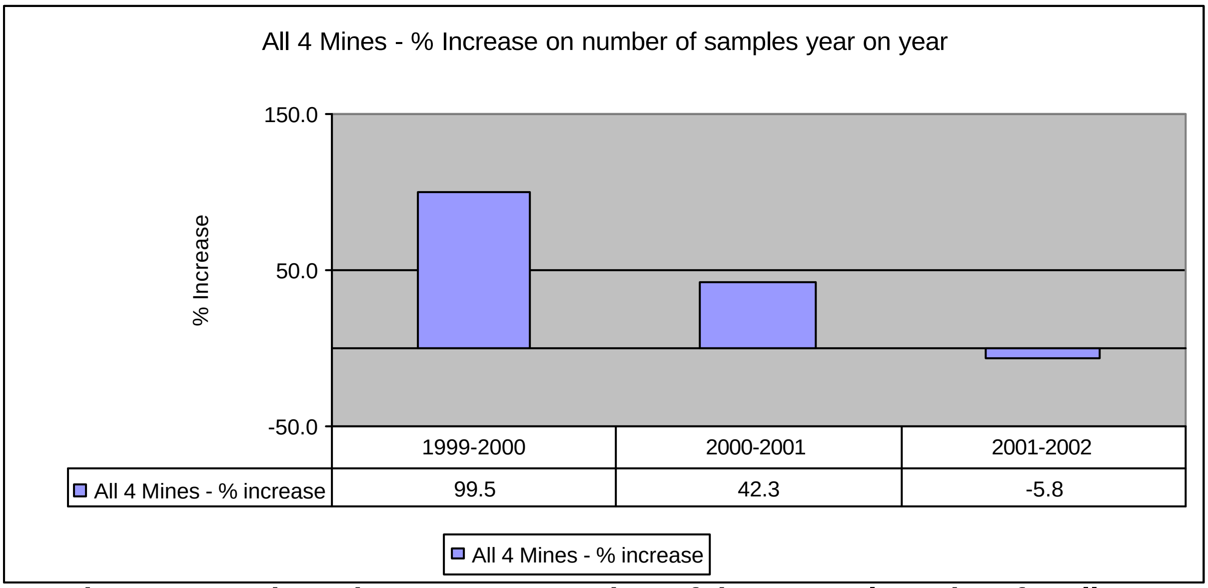
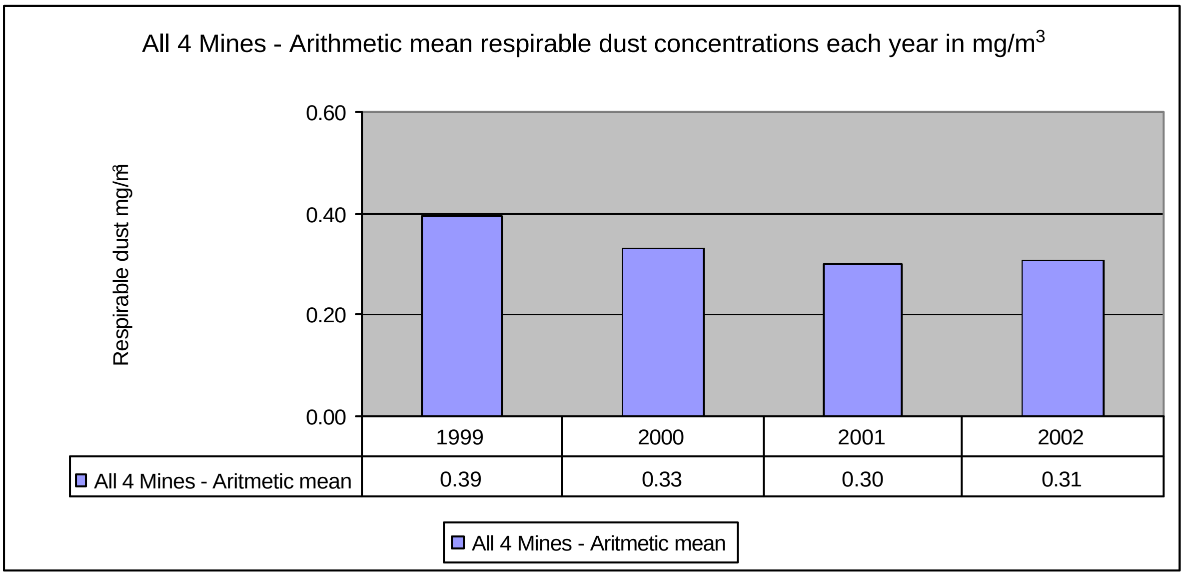


Figure 3.26: The % increase on number of dust samples taken for all 4 Mines over a year for the years 1999 – 2002

3.5.2 Respirable dust concentrations

The four mines under discussion have 21 ventilation districts with 45 HEGs. In 1999, 17 HEGs showed an arithmetic mean above the internal mines target TWA of 0,4 mg/m^3 , 10 Hegs above the target in 2000, 8 HEGs in 2001 and 7 in 2002 (see Appendix D) for detail.

There is a possible downward trend in the respirable dust concentrations for the mines over the years of 1999 to 2001 but the likely pattern is a drop from 1999 to 2000 and then a steady state as per Figure 3.30. All the years show an arithmetic mean below the internal respirable dust concentration target (see Figure 3.27). The improvement in the arithmetic mean year on year is shown in Figure 3.28.



	1999	2000	2001	2002
All 4 Mines - Aritmetic mean	0.39	0.33	0.30	0.31

Figure 3.27: The arithmetic mean respirable dust concentrations in mg/m^3 for all 4 Mines collected over a year for the years 1999 – 2002

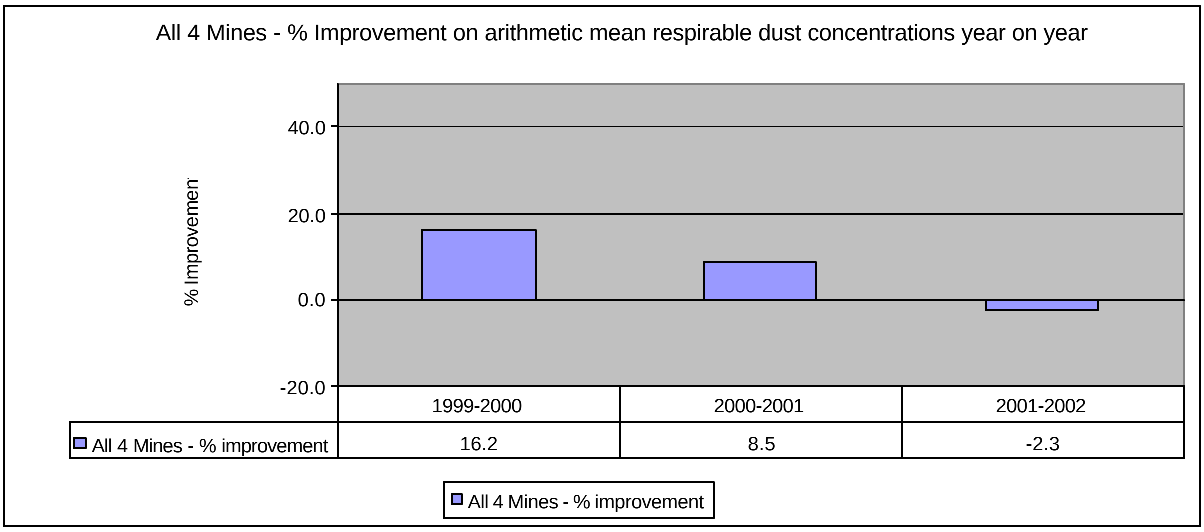


Figure 3.28: The % improvement of arithmetic mean respirable dust concentrations for all 4 Mines collected over a year for the years 1999 – 2002

3.5.3 Samples above the target and $1mg/m^3$

A good decrease in compliance of samples above the internal TWA target of $0,4mg/m^3$ and $1,0mg/m^3$ TWA for the years 2000 and 2002 was recorded (Figures 3.29 and 3.30).

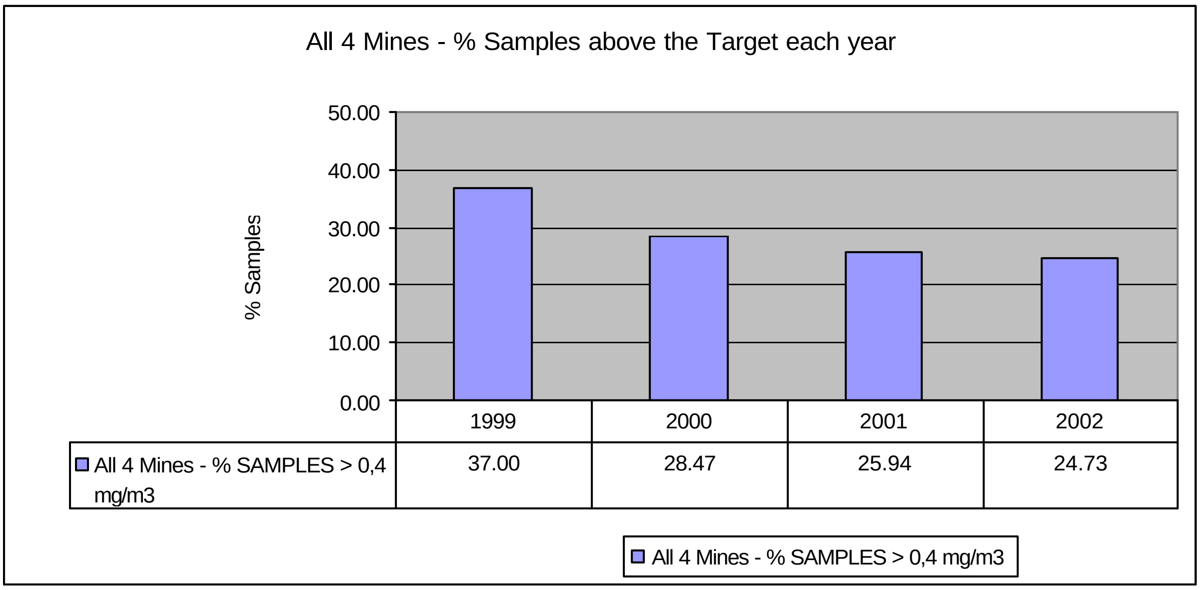


Figure 3.29: The % of dust samples above the TWA target of $0,4mg/m^3$ for all 4 Mines over a year for the years 1999 – 2002

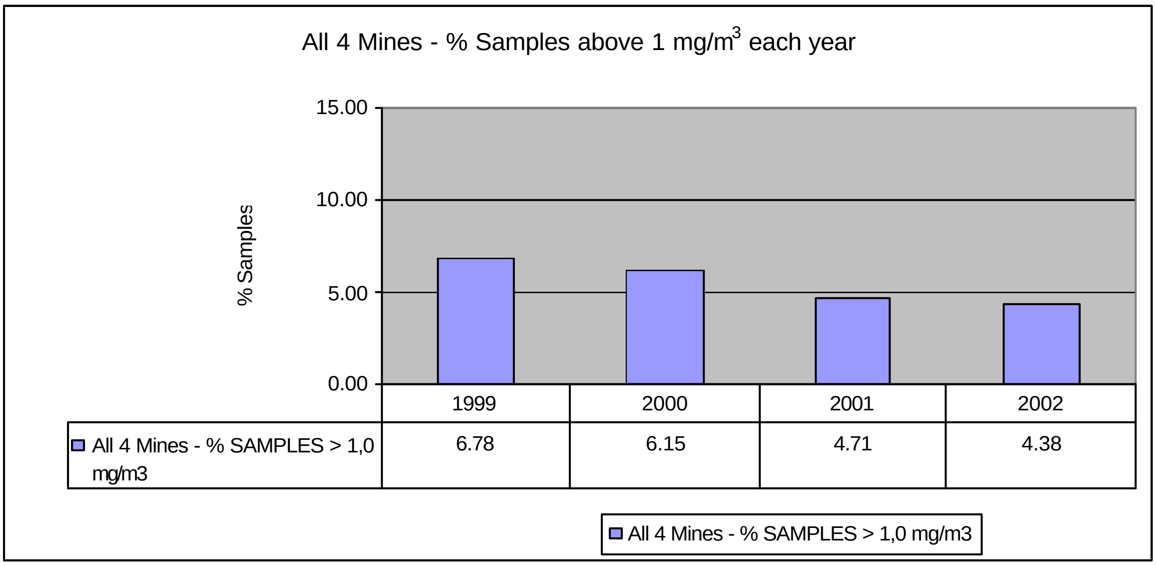


Figure 3.30: The % of dust samples above 1,0mg/m^3 for all 4 Mines over a year for the years 1999 – 2002

3.5.4 Chi-square test

A chi-square test for trend was performed on the proportion of respirable dust concentrations exceeding or equal to 0,4mg/m^3 for each HEG year on year over the four years as shown in Table 3.7.

A statistically significant downward trend for Mines 1, 2 and 3 for proportion of dust samples above 0,4mg/m^3 and only Mine 2 shows a statistically significant decreasing trend for proportion of dust samples above 1,0mg/m^3.

Table 3.7: Trend on respirable dust concentrations in mg/m^3 exceeding or equal to the target of 0,4mg/m^3 for the years 1999 to 2002 by Mines

All 4 Mines						
	Mines	**Mine 1**	**Mine 2**	**Mine 3**	**Mine 4**	**Total**
1999	No samples	165	172	151	58	546
	No >=0,4	68	57	58	19	202
	No <0,4	97	115	93	39	344
	%>=0,4	**41**	**33**	**38**	**33**	**36**
2000	No samples	414	301	195	179	1089
	No >=0,4	98	107	56	49	310
	No <0,4	316	194	139	130	779
	%>=0,4	**24**	**36**	**29**	**27**	**29**
2001	No samples	650	430	243	227	1550
	No >=0,4	140	133	62	67	402
	No <0,4	510	297	181	160	1148
	%>=0,4	**22**	**31**	**26**	**30**	**27**
2002	No samples	634	423	197	206	1460
	No >=0,4	153	110	51	47	361
	No <0,4	481	313	146	159	1099
	%>=0,4	**24**	**26**	**26**	**23**	**25**
Chi square of linearity		9.2	6.28	6.52	2.09	26.14
p value		0.002426	0.012204	0.010665	0.148147	0.000000

Table 3.8: Trend on respirable dust concentrations in mg/m^3 exceeding or equal to 1,0mg/m^3 for the years 1999 to 2002 by Mines

All 4 Mines						
	Mines	**Mine 1**	**Mine 2**	**Mine 3**	**Mine 4**	**Total**
1999	No samples	165	172	151	58	546
	No >=1,0	12	8	10	7	37
	No <1,0	153	164	141	51	509
	%>=1,0	**7**	**5**	**7**	**12**	**8**
2000	No samples	414	301	195	179	1089
	No >=1,0	23	19	14	11	67
	No <1,0	391	282	181	168	1022
	%>=1,0	**6**	**6**	**7**	**6**	**6**
2001	No samples	650	430	243	227	1550
	No >=1,0	36	10	9	18	73
	No <1,0	614	420	234	209	1477
	%>=1,0	**6**	**2**	**4**	**8**	**5**
2002	No samples	634	423	197	206	1460
	No >=1,0	32	10	9	13	64
	No <1,0	602	413	188	193	1396
	%>=1,0	**5**	**2**	**5**	**6**	**5**
Chi square of linearity		**0.89**	**6.24**	**1.8**	**0.74**	**6.9**
p value		**0.344129**	**0.012463**	**0.17918**	**0.391266**	**0.008641**

CHAPTER FOUR: DISCUSSION

In the discussion section, the major findings are summarised and possible limitations discussed.

The aim of this review of dust levels collected from four gold mines over the period 1999 to 2002 was to describe the trend in respirable dust concentrations. It is acknowledged that it would be better practice to report on the respirable crystalline silica dust but at the time, the mine’s practice to report on respirable dust was valued.

The arithmetic mean respirable dust concentration for the four mines in the report were 0,39mg/m^3 in 1999, 0,33mg/m^3 in 2000, 0,30mg/m^3 in 2001 and 0,31mg/m^3 in 2002.

All mines considered show a decrease in the proportion of respirable dust measurement > 0,4mg/m^3 from 1999 to 2002 with results of 36% in 1999, 29% in 2000, 27% in 2001 and 25% in 2002.

Although there is a general downward trend in the percentage of samples above the target, there is a definite increase in the number of samples above the internal target of 0,4mg/m^3. In 1999, 202 samples were above, 310 in 2000, 402 in 2001 and 361 in 2002. This may be because more samples were taken in dustier areas over the four years.

The major finding was that there was a general decrease in dustiness in the majority of the mines from 1999 to 2000 and then a steady state. Two mines showed a slight increase in the average levels from 2001 to 2002. The two mines mentioned also showed an increase in the proportion of samples above 0,11mg/m^3 for the same periods.

The study done for the Chamber of Mines during 1985, showed that in 1964/65 as many as 45% of the samples measured by means of a konimeter exceeded the limit. During the mid eighties, 24% of the samples were above the limit of 200pml. The mines under study in this report show between 4,38 and 6,78% samples above 0,11mg/m^3. The decrease was statistically significant for mines 1, 2 and 3.

During the year 2000, a study headed by GJ Churchyard was done on silicoses prevention and exposure-response relations in South Africa gold miners. The results show that the time weighted average was 0,35mg/m^3. During the same year, the results for the mines under study show a time weighted average of 0,33mg/m^3.

An extensive electronic search was conducted to find related publications on reported dust concentrations in underground gold mines to compare the results of this report to. As stated by Judge Leon in the Report of the Commission of Inquiry into Safety and Health in the Mining Industry in 1995, not much information is available.

In considering the findings, there are certain limitations that could influence the data. The most probable source of error would be non-compliance to the sampling procedure. It could be uncomfortable working in a confined space underground with extreme environmental conditions and still wear a gravimetric sampling pump on the body. The temptation might exist to remove the pump and leave it at a waiting place in clean air before entering the working face and fitting the instrument again once leaving the workplace. This is difficult to quantify due to the lack of resources for constant supervision.

Since the different occupations working underground are exposed to different conditions e.g. a machine driller would spent 100% of his shift at the working face whereby a machine driller assistant might only spend 60% of his shift at the same location, the results could not be assigned correctly to a specific workplace. All occupations in the HEG must be covered to get a true representation of the different occupations.

Abuse of the gravimetric pumps is another problem identified whereby sand was detected on the filters on occasions. In some cases water enters the cyclones damaging the filters. The Air Quality Analyst from the laboratory readily identifies these samples and a resample together with an investigation is requested. No statistics were available on these damages or tampered filters.

The pumps need to be started and stopped manually and the time recorded. At times it might happen that the pump was switched on long before issue or received back but not switched off immediately. This would result in readings not reflecting a full working shift.

The sample filters are being stored in special containers for transport as to prevent the loss of material on the filters. The samples are being transported from the mines to the laboratory by means of a vehicle and incorrect storage of the samples and very uneven surfaces could influence the results.

A huge amount of filters are being weighed in the gravimetric sampling central laboratory. All the results get entered into a computer database and some finger problems might creep in.

The management system in place to prevent such errors, include internal audits, external audits, investigations, inspections on the wearer and management of the output data.

Due to the constant changes in the mine planning, working places can cease operation for a month or two and start up again. During those non-production periods, no people are present in the workplace to do the gravimetric sampling as illustrated in Appendix D tables.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

This chapter concludes with a brief overview of the major findings. Recommendations are made for possible further research.

The mines under study are well in line with the DME requirements on the guidelines for a measurement strategy of airborne pollutants. The gravimetric sampling strategy includes the scheduling of samples managed by the electronic database system. The number of samples taken is based on the outcome of previous readings as directed by the DME guidelines.

The gravimetric dust sampling laboratory is being audited on a regular basis internally as well as by the DME. Both most recent audits showed a 100% compliance (Appendices A and B). Unfortunately, during the period 1999 to 2002 no independent verification was conducted but no change in the sampling procedure validates the 2003 audit.

The majority of the mines show a possible decrease in the respirable dust concentration time weighted average over time as much as 32% for mine1 (see Figure 3.2). It is interesting to note that the mines with major improvement also had the highest increase in the number of samples taken (see Figure 3.4). Mine1 for instance had a 150% increase in the number of samples and it can be deduced that more samples would give a better representation of the actual conditions in the workplace. The mines that did show an increase in the dust levels also showed an increase in the number of samples above the occupational exposure limits and it is possible that the samples were taken in a dustier area. It also is evident that the decrease show from the year 1999 to 2000 and then a steady state.

The data capturing system is adequate and stable. Back-up facilities are available on the company's main server in case of failure of the local system. The output information is user friendly enough for any competent person to manage the risks shown out.

The total dust management system for the mines seems to be in order, but there is a certain amount of risk involved. Supervision of the pump wearers is of great concern and training of these wearers is essential for explaining the purpose of the monitoring strategy. It is suggested that the MOH conducts random spot checks on the dust measurement system. They should randomly select a sample control card of a pump currently underground and visit the workplace where the pump had been allocated. The MOH should check whether the pump is on the designated wearer, correctly worn and question the wearer on the understanding of the objective of wearing the pump. He should acquire whether the wearer knows the importance of protecting the pump and any relevant information that should be reported to the supervisor. Internal audits on the mines should be conducted at least quarterly.

The appointed mine occupational hygienists should conduct a study on the effect of the dust suppressions systems in place as well as all new initiatives. Data from the dust sampling strategy must be managed on a weekly basis to detect any deterioration in the conditions underground (see Figure 5.1).

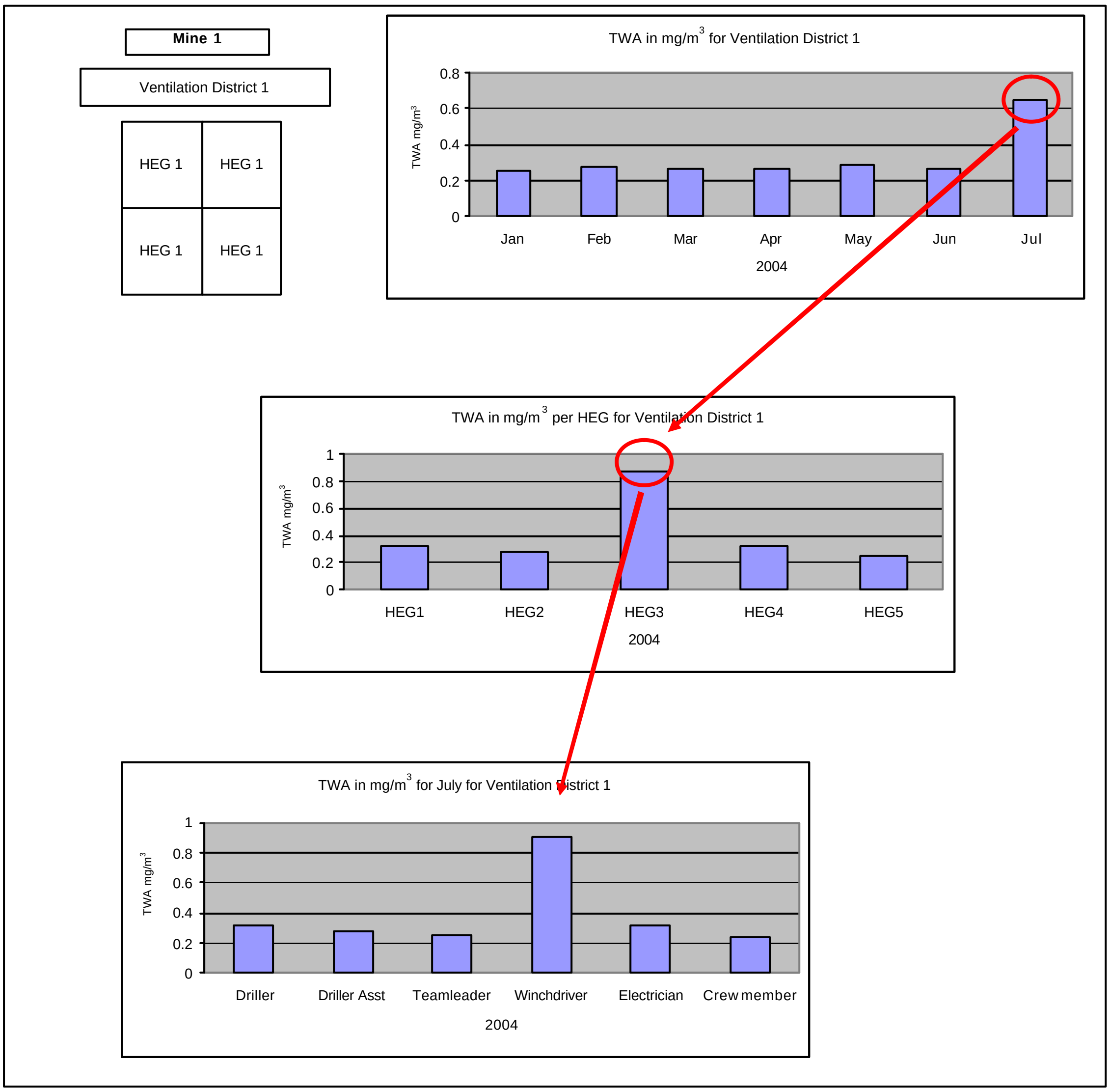


Figure 5.1: Schematic example of risk identification within a HEG

In the case where the MOH evaluates the data in a ventilation district and identifies high readings in the month, they should be able to drill into the system to identify the HEG responsible and even further down to identify the occupation.

They will then be able to do a thorough investigation into what resulted in the "high" exposures.

There should be a warning system in place as soon as a high reading is obtained so that an investigation can be conducted. The HEGs should be updated on a quarterly basis due the changes in the planning cycle.

Further research on the trends of respirable dust in underground gold mines should be conducted due to the limited availability of published data.

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APPENDIX A
Exemption from ethical clearance

University
of the Witwatersrand,
Johannesburg

Human Research Ethics Committee (Medical)
(formerly Committee for Research on Human Subjects (Medical)

Secretariat: Research Office, Room SH10005, 10th floor, Senate House • Telephone: +27 11 717-1234 • Fax: +27 11 339-5708
Private Bag 3, Wits 2050, South Africa

PC-J/247dsk9/es

Alison McLean
Postgraduate Office
Faculty of Health Sciences

9 September 2003

Dear Alison

re: Jacobus Andries Labuschagne

MPH: Occupational Hygiene
Reported dust concentrations in underground gold mines over the years [illegible]

This certifies that this project does not require clearance from the Committee for Research on Human Subjects (Medical). There is no participation from human subjects and no patient's records are involved.

Yours sincerely

Professor Peter Cleaton-Jones
Chair: Committee for Research on Human Subjects (Medical)

APPENDIX B

Internal gravimetric dust sampling programme audit (Laboratory)

Evaluation of the Dust Analysis Process at the Central Laboratory

H HIGH - Immediate Management Attention
M MEDIUM - Attention Required with Time
L LOW - Deviation Noted - No Action Required

		Actual Score (A)	Potential Score (P)	Compliance	Severity of Non Compliance or Deviations	
		A	P	%	H M L	Remarks
1. MEASURING EQUIPMENT		243	243	100		
1) Gravimetric Dust Sampling Weighing Room						
1	Dust and vibration free environment	3	3	100		
2	Windows kept close at all times	3	3	100		Windows sealed with Silicon
3	Airlock or self-closing door fitted	3	3	100		Self closing door
4	Atmosphere regularly checked for stability	3	3	100		Barometic pressure and Humidity are constantly checked
5	Air-conditioner able to maintain constant humidity and temperature	3	3	100		Air cond. installed
6	Room dedicated to filter weighing	3	3	100		New room prepared and in use
7	Signs displaced at entrance to weighing room	3	3	100		
		21	21	100		
2) Transparent Weighing / Stabilisation Cabinet						
1	Dimensions to be minimum of 0,8m length - 0,5m width - 0,5m height	3	3	100		
2	Body constructed of angle strip metal frame	3	3	100		
3	≥ 3mm thick transparent perspex (or glass) panels bolted or screwed to the metal frame	3	3	100		
4	Body consisting of 4 side panels and 1 top panel	3	3	100		
5	Sleeves or arm aperture seals made of non-static generating materials e.g. cotton	3	3	100		
6	Cabinet placed on anti-static mat slightly larger than cabinet	3	3	100		
7	No sealing material between cabinet and anti-static mat	3	3	100		
8	Metal frame independently earthed from anti-static mat.	3	3	100		
9	Cabinet not exposed to wide variations in temperature and humidity e.g. direct sunlight, heaters and air-conditioners must be kept continuously operational, no kettles may be boiled	3	3	100		
10	Pollution of surroundings must be avoided e.g. Dust, cigarette smoke	3	3	100		
11	Balance table, anti-static mat and cabinet dedicated solely to the purpose it was provided for.	3	3	100		
12	Sleeves covering the arms and cotton gloves used when weighing	3	3	100		
		36	36	100		
3) Weighing Room Equipment						
1	Balance capable of weighing to 5th decimal point of a gram - Filter weighing	3	3	100		
2	Balance capable of weighing to 4th decimal point of a gram - Filter Sponge Weighing	0	0		CL	Not Applicable
3	Balance located on a rigid specially designed balance table	3	3	100		
4	Balance correctly levelled	3	3	100		
5	Balance placed on properly earthen anti-static mat	3	3	100		
6	Balance left uncovered and side doors left slightly open	3	3	100		
7	Standard Weight used to check accuracy	3	3	100		
8	Annual calibration done (Scale)	3	3	100		Next calibration due in June 2003
9	Record of maintenance and calibration kept	3	3	100		
10	Anti-static mat for disassembly of cassette available	3	3	100		
11	Sufficient storage space available	3	3	100		
12	Filter stabilisation chamber available - Free air circulation must be possible	3	3	100		
13	Silica gel cooling box available - For sponge filters only	0	0		CL	Not Applicable
14	Spring-loaded tweezers for handling of filter paper available	3	3	100		
15	Petri slides/dishes for storing filters available	3	3	100		
16	Marking pens available - Ball point for filter paper & Fibre tip for rotating cup	3	3	100		
17	Suitable means for recording weighings available	3	3	100		
18	Non static cloth for cleaning purposes available	3	3	100		
19	Cotton gloves available - For handling of filter sponge cups	0	0		CL	Not Applicable
20	Gilibrator Calibrated	3	3	100		Next calibration due before the end of May 2003
21	Records of maintenance and calibration kept (Gilibrator)	3	3	100		
22	Sampling pumps calibrated daily - before and after sampling (max. variance = 5%)	3	3	100		
23	Records of maintenance and calibration kept	3	3	100		
		60	60	100		

4) *Assembly of Sampling Train*

	External Leakage's					
1	Gritpots tight-fitting with no cracks or cuts	3	3	100		
2	Rubber "O" rings in good order	3	3	100		
3	Plastic cassette segments firmly pressed together and checked for cracks	3	3	100		
4	Joints wrapped with insulation tape or shrink seal	3	3	100		
5	Transparent tubing free of cracks or weak areas	3	3	100		Lab personnel to request a census from the mines
	Internal Leakage's					
6	Filter paper fitted precisely on top of new support pad	3	3	100		
7	Filter paper faces intake air side of assembly	3	3	100		
	General					
8	All instruments cleaned after use	3	3	100		
9	Cyclones and plastic cassettes cleaned with ultra-sonic	3	3	100		
10	Ultra-sonic bath used as per manufacturers specifications	3	3	100		
		30	***30***	***100***		

5) *Filter Weighing Procedure*

1	Reference filters remaining in weighing room	3	3	100		
2	Reference filters weighed before and after mass determination of field filters	3	3	100		
3	Maximum allowable variation of same filter paper recorded (in 3 consecutive weighings of the same filter paper) - 0,05 mg for filter paper and 0,2 mg for filter sponges	3	3	100		Complies
4	Filters marked for identification purposes - As close to the edge of the filter as possible	3	3	100		Marking the backing pads only
5	Reference filters selected from each new batch/pack - Maximum 100 filters per batch/pack	3	3	100		
6	Filters stored in sealed containers until needed	3	3	100		
7	Reference filters and field filters allowed to acclimatise for at least 12 hours before being	3	3	100		
8	Balance allowed to warm-up for at least 30 minutes before being used. Not required for balances in "standby" mode	3	3	100		Balances stays "on"
9	Small "o" ring placed in centre of weighing pan - Not required for balances in "standby" mode	3	3	100		R2 and 20c coins used.
10	Reference filter to be weighed 3 consecutive times - Can be weighed simultaneously or individually	3	3	100		
11	Balance zero checked done after every weighing	3	3	100		
12	Maximum of 10 field filters weighed (3 times each) per weighing series - Can continue with next	3	3	100		
13	Samples transported in suitable containers - Minimise any particulate loss that can result from bumping, vibration or transportation in inverted position	3	3	100		
14	Selected field filters preserved for analysis purposes	3	3	100		
15	Measures in place to ensure that samples are discarded when tampered with or physically	3	3	100		
16	Reference filters left exposed in same cabinet for same period of time	3	3	100		
		48	***48***	***100***		

6) *Dust in Water*

	Sampling					
1	Water samples taken at required frequency					Done on mine
2	Water allowed to run before taking the sample					Done on mine
3	Bottle rinsed with water to be sampled					Done on mine
	Analysis					
4	5% hydrochloric acid added to the water	3	3	100		
5	Prepared sample allowed to stand for atleast 30 min.	3	3	100		Reason for requirement explained to Laboratory Staff.
6	Ammeter zero/calibration	3	3	100		Using distilled water
7	Nephelometer switched on 5 min before taking readings	3	3	100		
8	Insert solid standard and replace cover	3	3	100		
9	Adjust sensitivity control to give a reading of **78,3**	3	3	100		
10	Shake water sample and pour into clean nephelometer (2/3 full)	3	3	100		Glas stirrer to be purchased and utilised.
11	Dry outside of test-tube thoroughly	3	3	100		
12	Insert the test -tube in the nephelometer and replace the cover	3	3	100		
13	Allow micro-ammeter to reach a steady reading and record the nearest whole number	3	3	100		
14	Insert test-tube again (**78,3** +- 2 variance allowed)	3	3	100		
15	Action if variance to big. [Dust count = (10 x (10ml of prepared sample + 90 ml of clean water)) - (9 x (dust count of clean water))]	0	0		***CL***	Not Applicable
16	Nepholometer covered when not in use	3	3	100		
17	Records of maintenance and calibration kept	3	3	100		Due in November 2003
	On-site monthly calibration					
18	Graph indicating "Nepholometer VS deep-cell" count available	0	0		***CL***	Not Applicable
19	Date plotted against each plotted point	0	0		***CL***	Not Applicable
20	Results reported as "equivalent m.p.ml"	0	0		***CL***	Not Applicable
21	At least 2 new comparison point added per month	0	0		***CL***	Not Applicable
22	New graph generated after maintenance, new standard rod.	0	0		***CL***	Not Applicable
		39	***39***	***100***		

7) *Qualifications of personnel*

1	Supervisor - COM Certificate in Mine Environmental Control	3	3	100		J. Soden (OESH Manager Business Services) legally appointed
2	Laboratory Assistant - COM Certificate in Air Quality Analysis	3	3	100		Temp. staff member E. Erasmus services terminated on 9 May 2003. Yolande Klopper to start on 12 May 2003, qualified as AQA.H Coulsen = qualified AQA, started in lab on 8 May 2003.
3	SABS approved analytical methods used by analytical laboratory	3	3	100		
		9	***9***	***100***		

APPENDIX C

DME – Gravimetric dust sampling programme audit

DEPARTMENT OF MINERALS AND ENERGY

Minerals and Energy for Development and Prosperity

MINERALS AND ENERGY

Enquiries: S.Lesekele Tel No: (018) 4641631

Date: 2003-10-21 Ref No: RDNW (KL) 11/4/5-7

The Manager Occupational Environment
Anglogold
P O Box 62117
MARSHALLTOWN
2107

Sir

GRAVIMETRIC SAMPLING PROGRAMME AUDIT

Attached please find the report of the gravimetric sampling programme audit conducted at the Anglo Business Unit – Vaal River Operations on 2003-10-14.

The laboratory was found to be in good order.

Please acknowledge receipt of this letter.

Yours faithfully

K.L. MOAGI
PRINCIPAL INSPECTOR OF MINES
NORTH WEST REGION

DEPARTMENT OF MINERALS AND ENERGY

NORTH WEST REGION
TEL: 018 – 4641631
FAX: 018 -4629039

GRAVIMETRIC DUST SAMPLING PROGRAMME AUDIT

MINE'S NAME:	Anglogold (South African Region Business Services)
MANAGER'S NAME:	Mr D.E. Wrigley
DATE OF AUDIT:	2003-10-14

1	APPOINTMENTS	PARTICULARS		
		Name	Qualification	Date
1.1	PROGRAMME CO-ORDINATOR	M.M. Vermeijs	Intermediate Certificate	1982
1.2	HEALTH AND SAFETY REP	N/a		

2	GENERAL	YES	NO
2.1	Is there a gravimetric sampling strategy?	Yes	
2.2	Has the report, which contains quarterly information on airborne pollutants, been submitted to the Principal Inspector of Mines?	Yes	
2.3	Does the strategy list pollutants to be analysed?	Yes	
2.4	Are the pollutants analysed by methods approved by the SABS?	Yes	
2.5	Does an outside contractor do the sampling?	N/a	
2.6	Is the outside contractor an approved accredited authority?	N/a	
2.7	Is there a service agreement between the mine and the accredited authority?	N/a	
2.8	Does the accredited authority keep a logbook at the mine?	N/a	
2.9	Does the manager sign the logbook within one week of each inspection?	N/a	
2.10	Is the control sheet available?	Yes	
2.11	Does the programme co-ordinator have the required expertise and technical qualifications?	Yes	
2.12	Are results on pollutants analysed available?	Yes	
2.13	Are all employees trained on the reasons for gravimetric sampling?	Yes	
	Remarks: None		

3	SAMPLING		
3.1	Does the control sheet include the following?		
3.2	Date?	Yes	
3.3	Sampling area?	Yes	
3.4	Statistical population? (HEGS)	Yes	
3.5	Shift?	Yes	
3.6	Name of wearer?	Yes	
3.7	Occupation of wearer?	Yes	
3.8	Filter number?	Yes	
3.9	Pump number?	Yes	
3.10	Point of issue?	Yes	
3.11	Occupation of issuer?	Yes	
3.12	Volume flow? (Before and after)	Yes	
3.13	Pump start and stop time?	Yes	
3.14	Duration of sample in minutes?	Yes	
3.15	Does the issuer know how to check the flow rate after use? (Maximum 5% variation)	Yes	
3.16	Does the issuer know the calibration technique with the sampling train in line?	Yes	

	INSTRUMENTATION		
4.1	Are there enough pumps for all statistical populations?	Yes	
4.2	Are there enough cyclones for all statistical populations?	Yes	
4.3	Are there enough filter cassettes for all statistical population?	Yes	

4.4	Is the calibrator in good order?	Yes	
4.5	Are battery-charging units in good order?	Yes	
4.6	Does the sampling instruments and methodology comply with internationally compatible best practice?	Yes	
4.6	Is there a calibration procedure available?	Yes	
4.7	Does the carrying case of samples:		
4.8	Have markings to indicate 'right side-up'?	Yes	
	Lined with low-density sponge with suitable recesses to protect against shock and vibration?	Yes	
	So constructed to prevent inadvertent opening during handling or transport?	Yes	
4.9	Are pumps and cyclones maintenance carried out regularly?	Yes	

5	WEIGHING BY MINE OR ACCREDITED AUTHORITY		
5.1	Is there a room dedicated to weighing and preparation of filter cassettes only?	Yes	
5.2	Is the weighing room:		
	Located in an uncontaminated, dust free environment and no activity can cause vibration?	Yes	
	Windows kept closed (sealed) to avoid draughts?	Yes	
	Air conditioners designed to maintain a constant humidity and temperature?	Yes	
	Weighing room sign displayed?	Yes	
	No smoking sign displayed?	Yes	
	Acclimatization in progress sign displayed	N/a	
	Weighing in progress sign displayed?	N/a	
5.3	Is there a transparent cabinet dedicated to weighing only?	Yes	
5.4	Are apertures in the cabinet designed to keep the cabinet reasonably airtight during use?	Yes	
5.5	Is the cabinet placed on an anti-static mat?	Yes	
5.6	Is the mat of slightly larger dimensions than the cabinet?	Yes	
5.7	Is the metal frame of the cabinet properly earthed independently of the anti-static mat?	Yes	
5.8	Is the cabinet exposed to wide variations in temperature and humidity?		No
5.9	Is the cabinet exposed to direct sunlight?		No
5.10	Is the balance capable of weighing to the fifth decimal point of a gram?	Yes	
5.11	Is the balance correctly levelled on a rigid specially designed table?	Yes	
5.12	Is the balance regularly maintained and calibrated?	Yes	
5.13	Is there a standard weight to check the accuracy of the scale in the interim periods?	Yes	
5.14	Is there an additional anti-static mat for disassembly of cassettes and handling filters?	Yes	
5.15	Is there sufficient storage space for filters and associated equipment?	Yes	
5.16	Is the filter stabilization chamber so designed as to allow free air circulation?	Yes	
5.17	Are there carpets in the weighing room? (Problem of static build up)		No
5.18	Is there a silica gel cooling box? (For use with sponges only)	N/a	
5.19	Are there suitable spring-loaded tweezers or tongs for handling filter paper?	Yes	
5.20	Is there a non-static cloth for cleaning purposes?	Yes	
5.21	Are there cotton gloves or tongs for the handling of filter sponge cups?	Yes	

REMARKS
The laboratory was found to be in good order. The record keeping was also found to be in order.

INSPECTOR	SENIOR INSPECTOR	PRINCIPAL INSPECTOR
[signature]	[signature]	[signature]
DATE 2003-10-21	DATE 23/10/2003	DATE 27/10/03

APPENDIX D

Tabled detail of arithmetic mean TWA and number of samples for each HEG per ventilation district

Table D1: The arithmetic mean respirable dust concentrations in mg/m³ for Mine1 - Ventilation District 1 per year over the years 1999 – 2002

Mine	Mine1

Average of SampleTWA		Vent district HEG		
		VD1		VD1 Total
YEAR	MONTH	HEG1	HEG2	
1999	02	0.62	0.07	0.44
	06	0.25		0.25
	07	0.38		0.38
	08	0.97		0.97
	10	0.73	0.75	0.74
	11	0.47	0.22	0.44
	12	0.06	0.12	0.08
1999 Total		**0.46**	**0.33**	**0.44**
2000	01	0.43	0.06	0.33
	02	0.24	0.18	0.23
	05	0.28	0.15	0.27
	06	0.38	0.29	0.35
	07	0.21	0.45	0.26
	08	0.19	0.98	0.28
	09	0.25		0.25
	10	0.44	0.22	0.41
	11	0.29	0.61	0.34
	12	0.72	0.06	0.61
2000 Total		**0.32**	**0.35**	**0.33**
2001	01	0.31	0.08	0.27
	02	0.18	0.18	0.18
	03	0.56		0.56
	04	0.25	0.30	0.25
	05	0.36	0.60	0.43
	06	0.40	0.10	0.32
	07	0.35	0.68	0.45
	08	0.45	0.30	0.42
	09	0.07		0.07
	10	0.26	0.56	0.29
	11	0.22	0.11	0.20
	12	0.25	0.10	0.23
2001 Total		**0.31**	**0.34**	**0.32**
2002	01	0.35	0.28	0.34
	02	0.39	0.22	0.34
	03	0.19	0.06	0.12
	04	0.66	1.13	0.71
	05	0.09	0.15	0.10
	06	0.44	0.53	0.46
	07	0.56	0.41	0.51
	08	0.30	0.09	0.25
	09	0.06		0.06
	10	0.45		0.45
	11	0.39	0.72	0.48
	12	0.36	0.10	0.32
2002 Total		**0.39**	**0.39**	**0.39**
Grand Total		**0.35**	**0.36**	**0.35**

Table D2: The number of samples collected for Mine1 – Ventilation District 1 per year over the years 1999 – 2002

Mine	Mine1

Count of SampleTWA		Vent district HEG		
		VD1		VD1 Total
YEAR	MONTH	HEG1	HEG2	
1999	02	4	2	6
	06	6		6
	07	4		4
	08	2		2
	10	3	2	5
	11	7	1	8
	12	2	1	3
1999 Total		**28**	**6**	**34**
2000	01	3	1	4
	02	4	1	5
	05	13	2	15
	06	9	3	12
	07	10	3	13
	08	7	1	8
	09	4		4
	10	8	1	9
	11	11	2	13
	12	5	1	6
2000 Total		**74**	**15**	**89**
2001	01	13	3	16
	02	10	2	12
	03	6		6
	04	7	1	8
	05	9	4	13
	06	9	3	12
	07	10	4	14
	08	9	2	11
	09	2		2
	10	8	1	9
	11	10	2	12
	12	7	1	8
2001 Total		**100**	**23**	**123**
2002	01	11	2	13
	02	8	3	11
	03	1	1	2
	04	8	1	9
	05	9	2	11
	06	8	2	10
	07	7	4	11
	08	6	2	8
	09	1		1
	10	6		6
	11	10	4	14
	12	5	1	6
2002 Total		**80**	**22**	**102**
Grand Total		**282**	**66**	**348**

Table D3: The arithmetic mean respirable dust concentrations in mg/m³ for Mine1 - Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine1

Average of SampleTWA		Vent district	HEG
		VD2	VD2 Total
YEAR	MONTH	HEG2	
1999	02	0.18	0.18
	10	0.48	0.48
1999 Total		**0.28**	**0.28**
2000	02	0.20	0.20
	03	0.07	0.07
	05	0.38	0.38
	07	0.18	0.18
	08	1.81	1.81
	09	0.14	0.14
2000 Total		**0.36**	**0.36**
2001	01	0.19	0.19
	02	0.59	0.59
	03	0.06	0.06
	04	0.20	0.20
	05	0.20	0.20
	07	0.06	0.06
	08	0.14	0.14
	11	0.14	0.14
	12	0.38	0.38
2001 Total		**0.24**	**0.24**
2002	01	0.67	0.67
	02	0.11	0.11
	03	0.31	0.31
	04	0.68	0.68
	05	0.12	0.12
	07	0.10	0.10
	08	0.33	0.33
	10	0.03	0.03
	11	0.33	0.33
	12	0.44	0.44
2002 Total		**0.33**	**0.33**
Grand Total		**0.30**	**0.30**

Table D4: The number of samples collected for Mine1 – Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine1

Count of SampleTWA		Vent district	HEG
		VD2	VD2 Total
YEAR	MONTH	HEG2	
1999	02	2	2
	10	1	1
1999 Total		**3**	**3**
2000	02	2	2
	03	2	2
	05	2	2
	07	2	2
	08	1	1
	09	1	1
2000 Total		**10**	**10**
2001	01	2	2
	02	2	2
	03	1	1
	04	2	2
	05	1	1
	07	1	1
	08	2	2
	11	1	1
	12	1	1
2001 Total		**13**	**13**
2002	01	1	1
	02	1	1
	03	1	1
	04	1	1
	05	1	1
	07	1	1
	08	1	1
	10	1	1
	11	1	1
	12	3	3
2002 Total		**12**	**12**
Grand Total		**38**	**38**

Table D5: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine1 - Ventilation District 3 per year over the years 1999 – 2002

Mine	Mine1

Average of SampleTWA		Vent district HEG		
		VD3		VD3 Total
YEAR	MONTH	HEG1	HEG2	
1999	02	0.47	0.73	0.53
	03	0.14		0.14
	10	0.39	0.37	0.38
	11	0.54	0.14	0.43
	12	0.29	0.12	0.26
1999 Total		**0.42**	**0.39**	**0.41**
2000	01	0.25	0.14	0.23
	02	0.61	0.12	0.49
	03	0.06		0.06
	05	0.20	0.54	0.28
	06	0.29	0.56	0.35
	07	0.19	0.73	0.30
	08	0.46	0.12	0.37
	09	0.33	0.27	0.30
	10	0.28	0.56	0.36
	11	0.54	0.23	0.44
	12	0.23	0.12	0.21
2000 Total		**0.31**	**0.34**	**0.32**
2001	01	0.37	0.27	0.32
	02	0.40	0.14	0.27
	03	0.18	0.08	0.17
	04	0.31	0.07	0.27
	05	0.52	0.10	0.41
	06	0.52	0.40	0.49
	07	0.21	0.36	0.26
	08	0.45	0.30	0.39
	09	0.30	0.08	0.25
	10	0.44	0.17	0.35
	11	0.38	0.58	0.43
	12	0.18	0.38	0.25
2001 Total		**0.38**	**0.26**	**0.34**
2002	01	0.22	0.12	0.20
	02	0.35	0.54	0.43
	03	0.35		0.35
	04	0.11	0.39	0.18
	05	0.12	0.10	0.12
	06	0.51	0.46	0.50
	07	0.52	0.72	0.58
	08	0.27	0.62	0.38
	10	0.37	0.86	0.57
	11	0.46	0.50	0.47
	12	0.42	0.20	0.33
2002 Total		**0.34**	**0.49**	**0.38**
Grand Total		**0.35**	**0.36**	**0.36**

Table D6: The number of samples collected for Mine1 – Ventilation District 3 per year over the years 1999 – 2002

Mine	Mine1

Count of SampleTWA		Vent district HEG		
		VD3		VD3 Total
YEAR	MONTH	HEG1	HEG2	
1999	02	16	4	20
	03	2		2
	10	7	3	10
	11	8	3	11
	12	8	2	10
1999 Total		**41**	**12**	**53**
2000	01	12	2	14
	02	6	2	8
	03	3		3
	05	10	3	13
	06	7	2	9
	07	8	2	10
	08	8	3	11
	09	5	4	9
	10	5	2	7
	11	6	3	9
	12	4	1	5
2000 Total		**74**	**24**	**98**
2001	01	3	3	6
	02	5	5	10
	03	5	1	6
	04	6	1	7
	05	6	2	8
	06	9	3	12
	07	4	2	6
	08	6	4	10
	09	3	1	4
	10	4	2	6
	11	6	2	8
	12	4	2	6
2001 Total		**61**	**28**	**89**
2002	01	5	1	6
	02	5	3	8
	03	1		1
	04	6	2	8
	05	7	2	9
	06	8	3	11
	07	7	3	10
	08	7	3	10
	10	3	2	5
	11	6	3	9
	12	3	2	5
2002 Total		**58**	**24**	**82**
Grand Total		**234**	**88**	**322**

Table D7: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine1 - Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine1

Average of SampleTWA		Vent district HEG		
		VD4		VD4 Total
YEAR	MONTH	HEG1	HEG2	
1999	02	0.45	0.30	0.42
	10	0.48	0.10	0.41
	11	0.62	0.57	0.61
	12	0.47	0.07	0.39
1999 Total		**0.50**	**0.27**	**0.46**
2000	01	0.16		0.16
	02	0.38	0.28	0.35
	05	0.23	0.12	0.22
	06	0.49	0.08	0.42
	07	0.35	0.26	0.32
	08	0.45	0.16	0.39
	09	0.22	0.55	0.29
	10	0.18	0.79	0.28
	11	0.16	0.44	0.23
	12	0.19	0.06	0.15
2000 Total		**0.30**	**0.29**	**0.30**
2001	01	0.44	0.26	0.40
	02	0.25	0.25	0.25
	03	0.21	0.09	0.20
	04	0.11		0.11
	05	0.25	0.26	0.25
	06	0.15	0.59	0.31
	07	0.59	0.07	0.54
	08	0.36	0.38	0.37
	09	0.21	0.23	0.22
	10	0.30	0.15	0.28
	11	0.65	0.13	0.49
	12	0.19	0.26	0.20
2001 Total		**0.32**	**0.32**	**0.32**
2002	01	0.30	0.07	0.28
	02	0.31	0.29	0.31
	04	0.31	0.53	0.38
	05	0.14	0.57	0.26
	06	0.26	1.00	0.40
	07	0.36	0.19	0.31
	08	0.44	0.56	0.47
	10	0.12	0.27	0.18
	11		0.17	0.17
	12	0.20	0.23	0.21
2002 Total		**0.29**	**0.41**	**0.32**
Grand Total		**0.32**	**0.34**	**0.33**

Table D8: The number of samples collected for Mine1 – Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine1

Count of SampleTWA		Vent district HEG		
		VD4		VD4 Total
YEAR	MONTH	HEG1	HEG2	
1999	02	8	2	10
	10	5	1	6
	11	5	1	6
	12	4	1	5
1999 Total		**22**	**5**	**27**
2000	01	4		4
	02	7	3	10
	05	6	1	7
	06	9	2	11
	07	7	3	10
	08	7	2	9
	09	8	2	10
	10	5	1	6
	11	9	3	12
	12	5	2	7
2000 Total		**67**	**19**	**86**
2001	01	6	2	8
	02	9	2	11
	03	11	1	12
	04	2		2
	05	9	4	13
	06	11	6	17
	07	10	1	11
	08	8	3	11
	09	1	1	2
	10	8	1	9
	11	7	3	10
	12	8	1	9
2001 Total		**90**	**25**	**115**
2002	01	10	1	11
	02	9	2	11
	04	8	4	12
	05	8	3	11
	06	8	2	10
	07	7	3	10
	08	9	3	12
	10	3	2	5
	11		1	1
	12	5	5	10
2002 Total		**67**	**26**	**93**
Grand Total		**246**	**75**	**321**

Table D9: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine1 - Ventilation District 5 per year over the years 1999 – 2002

Mine	Mine1

Average of SampleTWA		Vent district	HEG
		VD5	VD5 Total
YEAR	MONTH	HEG3	
1999	02	0.07	0.07
	10	0.51	0.51
	11	1.33	1.33
	12	0.14	0.14
1999 Total		**0.57**	**0.57**
2000	01	0.13	0.13
	03	0.23	0.23
	10	0.12	0.12
	11	0.20	0.20
	12	0.14	0.14
2000 Total		**0.16**	**0.16**
2001	01	0.20	0.20
	02	0.18	0.18
	03	0.21	0.21
	04	0.43	0.43
	05	0.28	0.28
	06	0.17	0.17
	07	0.19	0.19
	08	0.13	0.13
	09	0.06	0.06
	10	0.30	0.30
	11	0.45	0.45
	12	0.36	0.36
2001 Total		**0.24**	**0.24**
2002	01	0.17	0.17
	02	0.50	0.50
	03	0.27	0.27
	04	0.48	0.48
	05	0.16	0.16
	06	0.15	0.15
	07	0.30	0.30
	08	0.32	0.32
	10	0.22	0.22
	11	0.33	0.33
	12	0.35	0.35
2002 Total		**0.29**	**0.29**
Grand Total		**0.26**	**0.26**

Table D10: The number of samples collected for Mine1 – Ventilation District 5 per year over the years 1999 – 2002

Mine	Mine1

Count of SampleTWA		Vent district	HEG
		VD5	VD5 Total
YEAR	MONTH	HEG3	
1999	02	2	2
	10	1	1
	11	2	2
	12	1	1
1999 Total		**6**	**6**
2000	01	1	1
	03	2	2
	10	12	12
	11	15	15
	12	14	14
2000 Total		**44**	**44**
2001	01	13	13
	02	16	16
	03	13	13
	04	4	4
	05	10	10
	06	17	17
	07	11	11
	08	10	10
	09	1	1
	10	11	11
	11	9	9
	12	8	8
2001 Total		**123**	**123**
2002	01	14	14
	02	11	11
	03	2	2
	04	17	17
	05	18	18
	06	15	15
	07	15	15
	08	18	18
	10	10	10
	11	17	17
	12	5	5
2002 Total		**142**	**142**
Grand Total		**315**	**315**

Table D11: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine1 - Ventilation District 6 per year over the years 1999 – 2002

Mine	Mine1

Average of SampleTWA		Vent district	HEG
		VD6	VD6 Total
YEAR	MONTH	HEG5	
1999	02	0.20	0.20
	11	0.25	0.25
1999 Total		**0.21**	**0.21**
2000	01	0.35	0.35
	02	0.06	0.06
	03	0.14	0.14
	10	0.14	0.14
	11	0.29	0.29
	12	0.16	0.16
2000 Total		**0.22**	**0.22**
2001	01	0.32	0.32
	02	0.31	0.31
	03	0.12	0.12
	04	0.11	0.11
	05	0.13	0.13
	06	0.28	0.28
	07	0.47	0.47
	08	0.09	0.09
	09	0.19	0.19
	10	0.21	0.21
	11	0.21	0.21
	12	0.17	0.17
2001 Total		**0.24**	**0.24**
2002	01	0.31	0.31
	02	0.19	0.19
	03	0.07	0.07
	04	0.23	0.23
	05	0.34	0.34
	06	0.31	0.31
	07	0.27	0.27
	08	0.34	0.34
	10	0.14	0.14
	11	0.26	0.26
	12	0.39	0.39
2002 Total		**0.27**	**0.27**
Grand Total		**0.25**	**0.25**

Table D12: The number of samples collected for Mine1 – Ventilation District 6 per year over the years 1999 – 2002

Mine	Mine1

Count of SampleTWA		Vent district	HEG
		VD6	VD6 Total
YEAR	MONTH	HEG5	
1999	02	4	4
	11	1	1
1999 Total		**5**	**5**
2000	01	1	1
	02	1	1
	03	2	2
	10	4	4
	11	12	12
	12	6	6
2000 Total		**26**	**26**
2001	01	12	12
	02	13	13
	03	2	2
	04	2	2
	05	3	3
	06	8	8
	07	2	2
	08	3	3
	09	3	3
	10	15	15
	11	18	18
	12	9	9
2001 Total		**90**	**90**
2002	01	19	19
	02	24	24
	03	1	1
	04	8	8
	05	8	8
	06	8	8
	07	7	7
	08	10	10
	10	5	5
	11	11	11
	12	5	5
2002 Total		**106**	**106**
Grand Total		**227**	**227**

Table D13: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine1 - Ventilation District 8 per year over the years 1999 – 2002

Mine	Mine1

Average of SampleTWA		Vent district	HEG
		VD8	VD8 Total
YEAR	MONTH	HEG4	
1999	02	0.23	0.23
	10	0.69	0.69
	11	0.44	0.44
	12	0.65	0.65
1999 Total		**0.45**	**0.45**
2000	01	0.37	0.37
	02	0.31	0.31
	03	0.06	0.06
	05	0.22	0.22
	06	0.08	0.08
	07	0.35	0.35
	08	0.45	0.45
	09	0.31	0.31
	10	0.15	0.15
	11	0.25	0.25
	12	0.36	0.36
2000 Total		**0.31**	**0.31**
2001	01	0.48	0.48
	02	0.14	0.14
	03	0.29	0.29
	04	0.14	0.14
	05	0.19	0.19
	06	0.10	0.10
	07	0.21	0.21
	08	0.25	0.25
	09	0.82	0.82
	10	0.11	0.11
	11	0.29	0.29
	12	0.06	0.06
2001 Total		**0.21**	**0.21**
2002	01	0.16	0.16
	02	0.17	0.17
	03	0.20	0.20
	04	0.42	0.42
	05	0.19	0.19
	06	0.21	0.21
	07	0.20	0.20
	08	0.25	0.25
	10	0.09	0.09
	11	0.17	0.17
	12	0.25	0.25
2002 Total		**0.21**	**0.21**
Grand Total		**0.26**	**0.26**

Table D14: The number of samples collected for Mine1 – Ventilation District 8 per year over the years 1999 – 2002

Mine	Mine1

Count of SampleTWA		Vent district	HEG
		VD8	VD8 Total
YEAR	MONTH	HEG4	
1999	02	14	14
	10	8	8
	11	8	8
	12	7	7
1999 Total		**37**	**37**
2000	01	6	6
	02	11	11
	03	1	1
	05	4	4
	06	3	3
	07	4	4
	08	10	10
	09	4	4
	10	4	4
	11	7	7
	12	7	7
2000 Total		**61**	**61**
2001	01	6	6
	02	12	12
	03	7	7
	04	2	2
	05	11	11
	06	10	10
	07	7	7
	08	11	11
	09	3	3
	10	10	10
	11	8	8
	12	10	10
2001 Total		**97**	**97**
2002	01	9	9
	02	11	11
	03	4	4
	04	9	9
	05	11	11
	06	9	9
	07	14	14
	08	11	11
	10	4	4
	11	10	10
	12	5	5
2002 Total		**97**	**97**
Grand Total		**292**	**292**

Table D15: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine2 - Ventilation District 1 per year over the years 1999 – 2002

Mine	Mine2

Average of SampleTWA		Vent district HEG			
		VD1			VD1 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	0.16	0.34	0.45	0.29
	02	0.30	0.48	0.30	0.33
	06	0.07			0.07
	10	0.34	0.43		0.36
	11	0.25	0.42	0.26	0.31
	12		0.12	0.25	0.19
1999 Total		**0.26**	**0.37**	**0.32**	**0.30**
2000	01	0.51	0.13		0.45
	02	0.38	0.56		0.41
	03			0.08	0.08
	05	0.39	0.56	0.10	0.38
	06	0.39	0.13	0.63	0.41
	07	0.56	0.58	0.14	0.40
	08	0.82	0.17	0.36	0.60
	09	0.24		0.44	0.29
	10	0.27	0.35	0.21	0.28
	11	0.27	0.30	0.06	0.19
2000 Total		**0.43**	**0.32**	**0.29**	**0.38**
2001	01	0.28	0.24		0.26
	02	0.34	0.12		0.29
	03	0.12	0.25	0.19	0.17
	04	0.22	0.23	0.54	0.30
	05	0.20		0.30	0.23
	06	0.27	0.24	0.12	0.21
	07	0.22	0.41		0.25
	08	0.24	0.11	0.46	0.29
	09		0.36	0.44	0.41
	10	0.61		0.21	0.53
	11	0.09	0.08	0.44	0.15
	12	0.17		0.06	0.11
2001 Total		**0.26**	**0.22**	**0.30**	**0.26**
2002	01	0.23	0.05	0.83	0.40
	02	0.07	0.25	0.07	0.13
	03	0.37	0.06		0.26
	04	0.26	0.18	0.42	0.28
	05	0.10	0.11	0.49	0.20
	06	0.16	0.40	0.40	0.25
	07	0.18		0.18	0.18
	08	0.17	0.30	0.62	0.29
	09	0.32			0.32
	10	0.59	0.04		0.40
	11	0.32	0.43	0.23	0.31
	12	0.46	0.41	0.61	0.47
2002 Total		**0.26**	**0.24**	**0.42**	**0.29**
Grand Total		**0.31**	**0.29**	**0.33**	**0.31**

Table D16: The number of samples collected for Mine2 – Ventilation District 1 per year over the years 1999 – 2002

Mine	Mine2

Count of SampleTWA		Vent district HEG			
		VD1			VD1 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	4	4	2	10
	02	10	2	2	14
	06	2			2
	10	4	1		5
	11	3	3	3	9
	12		1	1	2
1999 Total		**23**	**11**	**8**	**42**
2000	01	5	1		6
	02	5	1		6
	03			1	1
	05	7	1	1	9
	06	5	2	3	10
	07	2	1	2	5
	08	3	1	1	5
	09	3		1	4
	10	1	1	1	3
	11	2	1	2	5
2000 Total		**33**	**9**	**12**	**54**
2001	01	1	1		2
	02	4	1		5
	03	5	2	4	11
	04	2	1	1	4
	05	4		2	6
	06	1	1	1	3
	07	5	1		6
	08	3	1	2	6
	09		1	2	3
	10	4		1	5
	11	2	2	1	5
	12	1		1	2
2001 Total		**32**	**11**	**15**	**58**
2002	01	3	1	2	6
	02	1	1	1	3
	03	2	1		3
	04	3	1	1	5
	05	2	1	1	4
	06	3	1	1	5
	07	3		2	5
	08	3	2	1	6
	09	1			1
	10	2	1		3
	11	4	1	2	7
	12	1	2	1	4
2002 Total		**28**	**12**	**12**	**52**
Grand Total		**116**	**43**	**47**	**206**

Table D17: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine2 - Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine2

Average of SampleTWA		Vent district HEG			
		VD2			VD2 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	0.10	0.02	0.11	0.08
	02	0.30	0.21	1.16	0.49
	10	0.21		0.08	0.14
	11	0.06	0.13	0.06	0.09
	12	0.07			0.07
1999 Total		**0.18**	**0.12**	**0.45**	**0.24**
2000	01	0.61			0.61
	02	0.41	0.09	0.15	0.27
	03		0.22	0.07	0.14
	05	1.44		0.15	0.80
	06	1.07		0.51	0.93
	07	0.32		0.09	0.20
	08	0.11		0.08	0.09
	10			0.11	0.11
	11	0.25		0.08	0.19
2000 Total		**0.60**	**0.15**	**0.15**	**0.39**
2001	01	0.26			0.26
	02	0.35		0.30	0.33
	03	0.41		0.16	0.32
	04			0.16	0.16
	05	0.27	0.10	0.22	0.21
	06	0.14	0.23	0.11	0.18
	07		0.41		0.41
	08	0.19		0.07	0.16
	09	0.15		0.23	0.18
	10	0.14	0.63		0.38
	11	0.16		0.05	0.09
2001 Total		**0.27**	**0.32**	**0.15**	**0.24**
2002	01	0.12		0.13	0.12
	02	0.10	0.72	0.25	0.41
	03	0.25	0.26		0.26
	04	0.18			0.18
	05	0.35			0.35
	06	0.42			0.42
	07	0.21			0.21
	08	0.08			0.08
	09	0.22			0.22
	10	0.15			0.15
	11	0.03			0.03
	12	0.38			0.38
2002 Total		**0.24**	**0.45**	**0.21**	**0.26**
Grand Total		**0.31**	**0.27**	**0.21**	**0.28**

Table D18: The number of samples collected for Mine2 – Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine2

Count of SampleTWA		Vent district HEG			
		VD2			VD2 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	2	2	2	6
	02	4	2	2	8
	10	1		1	2
	11	2	2	1	5
	12	1			1
1999 Total		**10**	**6**	**6**	**22**
2000	01	2			2
	02	3	1	2	6
	03		1	1	2
	05	1		1	2
	06	3		1	4
	07	2		2	4
	08	1		1	2
	10			1	1
	11	2		1	3
2000 Total		**14**	**2**	**10**	**26**
2001	01	2			2
	02	2		1	3
	03	6		3	9
	04			1	1
	05	2	1	1	4
	06	2	3	1	6
	07		2		2
	08	3		1	4
	09	2		1	3
	10	1	1		2
	11	1		2	3
2001 Total		**21**	**7**	**11**	**39**
2002	01	3		1	4
	02	1	2	2	5
	03	1	3		4
	04	2			2
	05	6			6
	06	3			3
	07	3			3
	08	3			3
	09	3			3
	10	2			2
	11	1			1
	12	2			2
2002 Total		**30**	**5**	**3**	**38**
Grand Total		**75**	**20**	**30**	**125**

Table D19: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine2 - Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine2				
Average of SampleTWA		Vent district HEG			
		VD4			VD4 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	0.29	0.28	0.06	0.26
	02	0.57	0.50	0.27	0.52
	10	0.29	0.25	0.13	0.24
	11	0.33	0.44	0.06	0.33
	12	0.12	0.31	0.54	0.32
1999 Total		**0.41**	**0.37**	**0.20**	**0.37**
2000	01	0.09	0.09	0.19	0.10
	02	0.29	0.24		0.27
	03	0.25	0.06	0.07	0.17
	05	0.44	0.50	0.35	0.43
	06	0.87	0.12	0.42	0.70
	07	0.41	0.18	0.42	0.33
	08	0.33	0.38	0.23	0.33
	09	0.61	0.38		0.50
	10	0.40		0.10	0.34
	11	0.48		0.25	0.42
	12	0.15			0.15
2000 Total		**0.41**	**0.24**	**0.26**	**0.35**
2001	01	0.26			0.26
	02	0.49			0.49
	03	0.25		0.34	0.28
	04	0.31	0.45	0.36	0.37
	05	0.44	0.35	0.37	0.41
	06	0.19	0.25	0.25	0.21
	07	0.27	0.34	0.24	0.27
	08	0.49	0.27	0.81	0.51
	09	0.18	0.38	0.40	0.22
	10	0.35	0.24	0.62	0.42
	11	0.30	0.16	0.32	0.29
	12	0.34	0.69		0.43
2001 Total		**0.33**	**0.34**	**0.41**	**0.35**
2002	01	0.31	0.45	0.23	0.33
	02	0.24	0.25	0.21	0.24
	03	0.29	0.24	0.23	0.25
	04	0.29	0.18	0.41	0.30
	05	0.46	0.25	0.29	0.39
	06	0.39	0.21	0.51	0.39
	07	0.49	0.21	0.38	0.39
	08	0.43	0.26	0.42	0.40
	09	0.26	0.06	0.76	0.31
	10	0.63	0.27	0.30	0.48
	11	0.25	0.08	0.25	0.22
	12	0.20	0.33	0.37	0.27
2002 Total		**0.36**	**0.26**	**0.33**	**0.34**
Grand Total		**0.36**	**0.31**	**0.34**	**0.35**

Table D20: The number of samples collected for Mine2 – Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine2				
Count of SampleTWA		Vent district HEG			
		VD4			VD4 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	8	10	2	20
	02	12	8	2	22
	10	2	2	1	5
	11	5	3	1	9
	12	1	1	1	3
1999 Total		**28**	**24**	**7**	**59**
2000	01	3	3	1	7
	02	8	4		12
	03	3	1	1	5
	05	6	2	2	10
	06	5	1	1	7
	07	3	2	1	6
	08	3	2	1	6
	09	1	1		2
	10	4		1	5
	11	6		2	8
	12	1			1
2000 Total		**43**	**16**	**10**	**69**
2001	01	4			4
	02	7			7
	03	5		3	8
	04	7	5	5	17
	05	14	4	4	22
	06	9	3	3	15
	07	10	5	6	21
	08	9	4	4	17
	09	8	1	1	10
	10	6	3	5	14
	11	10	2	5	17
	12	6	2		8
2001 Total		**95**	**29**	**36**	**160**
2002	01	14	7	5	26
	02	16	3	3	22
	03	5	2	6	13
	04	11	2	3	16
	05	17	6	4	27
	06	11	3	4	18
	07	10	5	2	17
	08	14	4	6	24
	09	4	1	1	6
	10	8	3	3	14
	11	11	3	4	18
	12	4	2	2	8
2002 Total		**125**	**41**	**43**	**209**
Grand Total		**291**	**110**	**96**	**497**

Table D21: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine2 - Ventilation District 6 per year over the years 1999 – 2002

Mine	Mine2

Average of SampleTWA		Vent district HEG		
		VD6		VD6 Total
YEAR	MONTH	HEG1	HEG3	
1999	01	0.82	0.43	0.63
	02	0.03	1.47	0.99
	10	0.11	0.58	0.34
	11	0.07		0.07
	12	0.63		0.63
1999 Total		**0.33**	**0.99**	**0.66**
2000	01	0.12		0.12
	02	0.13	0.11	0.12
	03	0.33	0.70	0.52
	05	0.15	0.09	0.13
	06	0.53	0.23	0.39
	07	0.68	0.41	0.63
	08	0.44	0.20	0.41
	09	1.12		1.12
	10	0.78	0.10	0.61
	11	0.16	0.06	0.14
	12	0.45		0.45
2000 Total		**0.46**	**0.22**	**0.40**
2001	01	0.26		0.26
	02	0.38	0.57	0.41
	03	0.26	0.52	0.33
	04	0.38		0.38
	05	0.34	0.10	0.27
	06	0.26	0.19	0.21
	07	0.21	0.56	0.38
	08	0.38		0.38
	09	0.35		0.35
	10	0.27	0.22	0.25
	11	0.77		0.77
	12	0.26	0.20	0.22
2001 Total		**0.35**	**0.31**	**0.34**
2002	01	0.40	0.06	0.34
	02	0.24	0.31	0.27
	03	0.24		0.24
	04	0.46	0.10	0.37
	05	0.73	0.22	0.56
	06	0.44	0.06	0.34
	07	0.15		0.15
	08	0.09	0.08	0.08
	09	0.30	0.41	0.34
	10	0.03	0.11	0.07
	11	0.36	0.31	0.35
	12	0.18		0.18
2002 Total		**0.33**	**0.18**	**0.30**
Grand Total		**0.38**	**0.39**	**0.38**

Table D22: The number of samples collected for Mine2 – Ventilation District 6 per year over the years 1999 – 2002

Mine	Mine2

Count of SampleTWA		Vent district HEG		
		VD6		VD6 Total
YEAR	MONTH	HEG1	HEG3	
1999	01	2	2	4
	02	2	4	6
	10	2	2	4
	11	1		1
	12	1		1
1999 Total		**8**	**8**	**16**
2000	01	1		1
	02	3	2	5
	03	1	1	2
	05	2	1	3
	06	5	4	9
	07	5	1	6
	08	7	1	8
	09	2		2
	10	3	1	4
	11	5	1	6
	12	1		1
2000 Total		**35**	**12**	**47**
2001	01	5		5
	02	8	2	10
	03	3	1	4
	04	1		1
	05	5	2	7
	06	1	2	3
	07	1	1	2
	08	6		6
	09	2		2
	10	2	1	3
	11	2		2
	12	1	2	3
2001 Total		**37**	**11**	**48**
2002	01	5	1	6
	02	1	1	2
	03	3		3
	04	3	1	4
	05	2	1	3
	06	3	1	4
	07	3		3
	08	1	1	2
	09	2	1	3
	10	1	1	2
	11	3	1	4
	12	3		3
2002 Total		**30**	**9**	**39**
Grand Total		**110**	**40**	**150**

Table D23: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine2 - Ventilation District 8 per year over the years 1999 – 2002

Mine	Mine2

Average of SampleTWA		Vent district HEG			
		VD8			VD8 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	0.24	0.44	0.83	0.44
	02	0.49	0.26	0.34	0.37
	10	0.12		0.07	0.09
	11	0.21		0.38	0.30
	12	0.07			0.07
1999 Total		**0.26**	**0.35**	**0.47**	**0.34**
2000	01	0.08		0.35	0.21
	02	0.10		0.39	0.29
	05	0.44	0.43	0.39	0.42
	06	0.24	0.54	0.44	0.45
	07	0.18	0.41		0.32
	08	0.65	0.61	0.15	0.58
	09	0.20		0.15	0.17
	10	0.68	0.29	0.60	0.50
	11	0.41	0.38	0.28	0.37
	12		0.14		0.14
2000 Total		**0.43**	**0.41**	**0.34**	**0.40**
2001	01	0.31	0.76	0.09	0.43
	02	0.18	0.45	0.35	0.36
	03	0.11	0.15	0.21	0.15
	04	0.64	0.66	0.08	0.46
	05	0.37	0.33	0.33	0.34
	06	0.07	0.06		0.06
	07	0.53	0.16	0.27	0.30
	08			0.24	0.24
	09	0.53	0.27	0.08	0.33
	10	0.33		0.54	0.40
	11	0.54	0.29	0.10	0.34
	12	0.35	0.50	0.49	0.45
2001 Total		**0.33**	**0.41**	**0.25**	**0.34**
2002	01	0.41	0.06	0.26	0.24
	02	0.39	0.30	0.32	0.35
	03	0.13		0.19	0.16
	04	0.70	0.48	0.33	0.55
	05	0.40	0.50	0.15	0.41
	06	0.21	0.38	0.05	0.22
	07	0.35	0.13	0.19	0.24
	08	0.83	0.37	0.09	0.57
	09	0.70			0.70
	10	0.10	0.49		0.29
	11	0.41	0.22		0.34
	12	0.34	0.55		0.47
2002 Total		**0.45**	**0.35**	**0.20**	**0.37**
Grand Total		**0.39**	**0.39**	**0.29**	**0.37**

Table D24: The number of samples collected for Mine2 – Ventilation District 8 per year over the years 1999 – 2002

Mine	Mine2

Count of SampleTWA		Vent district HEG			
		VD8			VD8 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	4	2	2	8
	02	2	2	2	6
	10	1		1	2
	11	1		1	2
	12	1			1
1999 Total		**9**	**4**	**6**	**19**
2000	01	1		1	2
	02	1		2	3
	05	6	5	4	15
	06	2	5	2	9
	07	3	5		8
	08	5	3	1	9
	09	1		2	3
	10	4	4	1	9
	11	5	8	3	16
	12		2		2
2000 Total		**28**	**32**	**16**	**76**
2001	01	5	6	4	15
	02	5	10	4	19
	03	4	5	2	11
	04	1	1	1	3
	05	1	1	1	3
	06	1	1		2
	07	2	3	2	7
	08			2	2
	09	2	2	1	5
	10	2		1	3
	11	4	1	3	8
	12	2	1	3	6
2001 Total		**29**	**31**	**24**	**84**
2002	01	2	2	2	6
	02	2	1	1	4
	03	2		2	4
	04	2	1	1	4
	05	3	3	1	7
	06	1	1	1	3
	07	3	3	1	7
	08	5	4	1	10
	09	1			1
	10	2	2		4
	11	3	2		5
	12	2	3		5
2002 Total		**28**	**22**	**10**	**60**
Grand Total		**94**	**89**	**56**	**239**

Table D25: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine2 - Ventilation District 9 per year over the years 1999 – 2002

Mine	Mine2

Average of SampleTWA		Vent district	HEG	
		VD9		VD9 Total
YEAR	MONTH	HEG2	HEG3	
1999	01	0.38	0.66	0.52
	02	0.30	0.76	0.53
	10	0.07	0.23	0.15
	11	0.19	0.19	0.19
	12	0.14	0.10	0.12
1999 Total		**0.25**	**0.48**	**0.36**
2000	01	0.06	0.31	0.18
	03	0.14	0.12	0.13
	05	0.21	0.29	0.24
	06	0.41	0.59	0.50
	07	0.22	0.36	0.31
	08	0.78	0.31	0.51
	10	0.26	0.46	0.36
	11	0.25		0.25
2000 Total		**0.35**	**0.36**	**0.36**
2001	01	0.53	0.63	0.57
	02	0.21	0.41	0.30
	03	0.20	0.50	0.32
	04	0.11		0.11
	06	0.23	0.21	0.22
	07	0.58	0.59	0.58
	08	0.07	0.05	0.06
	09	0.22		0.22
	10	0.61		0.61
	11	0.39	0.22	0.35
2001 Total		**0.33**	**0.42**	**0.36**
2002	01	0.17	0.81	0.49
	02	0.30		0.30
	03		0.13	0.13
	05	0.23	0.10	0.16
	06	0.27	0.20	0.24
	07	0.06	0.13	0.09
	08	0.06		0.06
	09		0.13	0.13
	10	0.07		0.07
	11	0.03	0.25	0.18
	12	0.19	0.17	0.19
2002 Total		**0.16**	**0.27**	**0.21**
Grand Total		**0.29**	**0.37**	**0.33**

Table D26: The number of samples collected for Mine2 – Ventilation District 9 per year over the years 1999 – 2002

Mine	Mine2

Count of SampleTWA		Vent district	HEG	
		VD9		VD9 Total
YEAR	MONTH	HEG2	HEG3	
1999	01	2	2	4
	02	2	2	4
	10	1	1	2
	11	1	1	2
	12	1	1	2
1999 Total		**7**	**7**	**14**
2000	01	1	1	2
	03	1	1	2
	05	2	1	3
	06	2	2	4
	07	2	4	6
	08	3	4	7
	10	1	1	2
	11	3		3
2000 Total		**15**	**14**	**29**
2001	01	4	2	6
	02	4	3	7
	03	6	4	10
	04	1		1
	06	2	2	4
	07	3	2	5
	08	1	1	2
	09	1		1
	10	1		1
	11	3	1	4
2001 Total		**26**	**15**	**41**
2002	01	2	2	4
	02	2		2
	03		2	2
	05	1	1	2
	06	1	1	2
	07	1	1	2
	08	2		2
	09		2	2
	10	1		1
	11	1	2	3
	12	2	1	3
2002 Total		**13**	**12**	**25**
Grand Total		**61**	**48**	**109**

Table D27: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine3 - Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine3

Count of SampleTWA		Vent district HEG			
		VD2			VD2 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	14	6	2	22
	02	12	4	6	22
	10	3	2	1	6
	11	6	2	1	9
	12	5	3		8
1999 Total		**40**	**17**	**10**	**67**
2000	01	4	3	1	8
	02	4	5	3	12
	03	1	1		2
	05	17	6	3	26
	06	6	3	1	10
	07	7	3	1	11
	08	10	2		12
	09	7		1	8
	10	6	1		7
	11	7	2	2	11
	12	2			2
2000 Total		**71**	**26**	**12**	**109**
2001	01	15	3	2	20
	02	6	3	6	15
	03	3			3
	04	7	3	1	11
	05	5	2	3	10
	06	8	3	2	13
	07	7	1	1	9
	08	5	1		6
	10	6	1	1	8
	11	5	2	3	10
	12	2		1	3
2001 Total		**69**	**19**	**20**	**108**
2002	01	3	3	2	8
	02	9	3	3	15
	03	2			2
	04	3	2	1	6
	05	4	2	3	9
	06	4	1	1	6
	07	3	1	2	6
	08	6	1	2	9
	09	1			1
2002 Total		**35**	**13**	**14**	**62**
Grand Total		**215**	**75**	**56**	**346**

Table D28: The number of samples collected for Mine3 – Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine3

Average of SampleTWA		Vent district HEG			
		VD2			VD2 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	0.66	0.34	0.15	0.52
	02	0.59	0.90	0.23	0.55
	10	0.13	0.28	0.30	0.21
	11	0.28	0.11	0.20	0.23
	12	0.23	0.48		0.33
1999 Total		**0.49**	**0.46**	**0.22**	**0.44**
2000	01	0.24	0.68	0.11	0.39
	02	0.25	0.33	0.09	0.24
	03	0.18	1.16		0.67
	05	0.34	0.34	0.52	0.36
	06	0.26	0.23	0.24	0.25
	07	0.15	0.31	0.31	0.21
	08	0.26	0.78		0.35
	09	0.35		0.60	0.38
	10	0.18	0.07		0.16
	11	0.27	0.37	0.08	0.25
	12	0.17			0.17
2000 Total		**0.27**	**0.42**	**0.27**	**0.30**
2001	01	0.35	0.46	0.10	0.34
	02	0.20	0.57	0.13	0.25
	03	0.17			0.17
	04	0.11	0.15	0.12	0.12
	05	0.22	0.08	0.15	0.17
	06	0.46	0.61	0.21	0.46
	07	0.22	0.06	0.07	0.18
	08	0.34	0.13		0.30
	10	0.28	0.20	0.23	0.27
	11	0.21	0.40	0.19	0.24
	12	0.06		0.13	0.08
2001 Total		**0.27**	**0.35**	**0.15**	**0.26**
2002	01	0.09	0.08	0.06	0.08
	02	0.18	0.25	0.08	0.18
	03	0.07			0.07
	04	0.65	0.44	0.39	0.54
	05	0.48	0.52	0.08	0.36
	06	0.21	0.09	0.06	0.17
	07	0.24	0.06	0.08	0.16
	08	0.40	0.94	0.31	0.44
	09	0.23			0.23
2002 Total		**0.29**	**0.31**	**0.13**	**0.26**
Grand Total		**0.31**	**0.39**	**0.18**	**0.31**

Table D29: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine3 - Ventilation District 3 per year over the years 1999 – 2002

Mine	Mine3

Average of SampleTWA		Vent district HEG			
		VD3			VD3 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	0.60	0.34	0.13	0.43
	02	0.39	0.43	0.27	0.39
	10	0.16	0.19	0.17	0.17
	11	0.47	0.25	0.07	0.36
	12	0.30		0.49	0.32
1999 Total		**0.41**	**0.35**	**0.20**	**0.36**
2000	01	0.06	0.71	0.08	0.28
	02	0.24	0.94	0.07	0.27
	03	0.51			0.51
	05	0.11	0.27	0.20	0.17
	06	0.49	0.07	0.23	0.31
	07	0.48	1.14	0.05	0.70
	08	0.60	0.44	0.10	0.44
	10	0.15	0.82		0.32
	11	0.82	0.33	0.27	0.46
	12	0.23			0.23
2000 Total		**0.31**	**0.57**	**0.15**	**0.36**
2001	01	0.32	0.15	0.19	0.22
	02	0.22	0.13		0.19
	03	0.11	0.25	0.10	0.15
	04	0.27	0.37		0.31
	05	0.52	0.45	0.46	0.49
	06	0.36	0.35	0.46	0.38
	07	0.31	0.24	0.19	0.27
	08	0.41	0.37		0.39
	09	0.56			0.56
	10	0.21	0.32	0.12	0.22
	11	0.28	0.33	0.41	0.33
	12	0.57	0.06		0.47
2001 Total		**0.36**	**0.29**	**0.32**	**0.33**
2002	01	0.31	0.09	0.06	0.21
	02	0.10	0.08	0.65	0.30
	03	0.24	0.14		0.21
	04	0.29	0.06	0.33	0.26
	05	0.45	0.72	0.67	0.55
	06	0.28	0.38	0.48	0.34
	07	0.25	0.17	0.23	0.24
	08	0.51	0.63	0.47	0.50
	09	0.79	0.68	0.09	0.52
2002 Total		**0.31**	**0.26**	**0.46**	**0.34**
Grand Total		**0.34**	**0.36**	**0.34**	**0.35**

Table D30: The number of samples collected for Mine3 – Ventilation District 3 per year over the years 1999 – 2002

Mine	Mine3

Count of SampleTWA		Vent district HEG			
		VD3			VD3 Total
YEAR	MONTH	HEG1	HEG2	HEG3	
1999	01	10	6	4	20
	02	8	8	2	18
	10	5	2	1	8
	11	5	2	1	8
	12	6		1	7
1999 Total		**34**	**18**	**9**	**61**
2000	01	4	3	2	9
	02	7	1	2	10
	03	3			3
	05	5	3	1	9
	06	3	2	1	6
	07	3	3	1	7
	08	2	5	1	8
	10	3	1		4
	11	2	1	3	6
	12	1			1
2000 Total		**33**	**19**	**11**	**63**
2001	01	5	5	4	14
	02	4	2		6
	03	2	2	2	6
	04	2	1		3
	05	10	4	5	19
	06	7	3	3	13
	07	6	2	2	10
	08	6	3		9
	09	1			1
	10	7	2	1	10
	11	4	6	3	13
	12	4	1		5
2001 Total		**58**	**31**	**20**	**109**
2002	01	7	3	2	12
	02	9	3	7	19
	03	6	3		9
	04	9	2	3	14
	05	10	2	5	17
	06	10	1	4	15
	07	7	1	4	12
	08	8	1	5	14
	09	1	1	1	3
2002 Total		**67**	**17**	**31**	**115**
Grand Total		**192**	**85**	**71**	**348**

Table D31: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine3 - Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine3

Count of SampleTWA		Vent district	HEG
		VD4	VD4 Total
YEAR	MONTH	HEG4	
1999	01	6	6
	02	10	10
	10	2	2
	11	2	2
	12	3	3
1999 Total		**23**	**23**
2000	01	3	3
	02	5	5
	05	2	2
	06	2	2
	07	3	3
	08	2	2
	09	2	2
	10	2	2
	11	2	2
2000 Total		**23**	**23**
2001	01	4	4
	02	4	4
	05	3	3
	06	3	3
	07	3	3
	08	2	2
	10	3	3
	11	3	3
	12	1	1
2001 Total		**26**	**26**
2002	01	4	4
	02	5	5
	05	5	5
	06	2	2
	07	2	2
	08	1	1
	09	1	1
2002 Total		**20**	**20**
Grand Total		**92**	**92**

Table D32: The number of samples collected for Mine3 – Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine3

Average of SampleTWA		Vent district	HEG
		VD4	VD4 Total
YEAR	MONTH	HEG4	
1999	01	0.07	0.07
	02	0.36	0.36
	10	0.21	0.21
	11	0.07	0.07
	12	0.07	0.07
1999 Total		**0.21**	**0.21**
2000	01	0.14	0.14
	02	0.38	0.38
	05	0.08	0.08
	06	0.36	0.36
	07	0.07	0.07
	08	0.07	0.07
	09	1.18	1.18
	10	0.40	0.40
	11	0.08	0.08
2000 Total		**0.30**	**0.30**
2001	01	0.19	0.19
	02	0.08	0.08
	05	0.07	0.07
	06	0.46	0.46
	07	0.40	0.40
	08	0.22	0.22
	10	0.71	0.71
	11	0.39	0.39
	12	0.07	0.07
2001 Total		**0.30**	**0.30**
2002	01	0.07	0.07
	02	0.15	0.15
	05	0.54	0.54
	06	0.06	0.06
	07	0.18	0.18
	08	0.42	0.42
	09	0.06	0.06
2002 Total		**0.23**	**0.23**
Grand Total		**0.26**	**0.26**

Table D33: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine4 - Ventilation District 1 per year over the years 1999 – 2002

Mine	Mine4

Average of SampleTWA		Vent district HEG		
		VD1		VD1 Total
YEAR	MONTH	HEG3	HEG4	
1999	02	0.12		0.12
	10	0.58	0.29	0.43
	11	0.20	0.49	0.27
1999 Total		**0.21**	**0.39**	**0.24**
2000	01	1.16	0.20	0.68
	02	0.06	0.16	0.10
	05	0.54	0.15	0.28
	06	0.23	0.75	0.52
	07	0.22	0.19	0.21
	08	0.07	0.10	0.09
	09	0.11	0.06	0.07
	10	0.31		0.31
	11		0.07	0.07
	12	0.06		0.06
2000 Total		**0.29**	**0.24**	**0.26**
2001	01	0.14	0.62	0.38
	02	0.24	0.41	0.35
	03	0.14	0.13	0.13
	04		0.15	0.15
	05	0.07	0.66	0.56
	06	0.25	0.06	0.14
	07	0.13	0.07	0.09
	08	0.07	0.24	0.22
	09	0.20	0.06	0.10
	10		0.21	0.21
	11		0.11	0.11
	12		0.06	0.06
2001 Total		**0.17**	**0.24**	**0.22**
2002	01	0.15	0.57	0.45
	02	0.27	0.36	0.34
	03	0.05		0.05
	04	0.11	0.51	0.31
	05	0.18	0.20	0.19
	06	0.14	0.36	0.25
	07	1.56	0.27	0.70
	08	0.31	0.16	0.21
	09	0.86		0.86
	10	0.03	0.04	0.03
	11	0.27	0.24	0.26
	12	0.42	0.05	0.17
2002 Total		**0.28**	**0.33**	**0.31**
Grand Total		**0.25**	**0.26**	**0.26**

Table D34: The number of samples collected for Mine4 – Ventilation District 1 per year over the years 1999 – 2002

Mine	Mine4

Count of SampleTWA		Vent district HEG		
		VD1		VD1 Total
YEAR	MONTH	HEG3	HEG4	
1999	02	4		4
	10	1	1	2
	11	3	1	4
1999 Total		**8**	**2**	**10**
2000	01	1	1	2
	02	3	2	5
	05	4	8	12
	06	4	5	9
	07	4	5	9
	08	1	2	3
	09	1	3	4
	10	1		1
	11		3	3
	12	1		1
2000 Total		**20**	**29**	**49**
2001	01	2	2	4
	02	3	6	9
	03	4	4	8
	04		2	2
	05	1	5	6
	06	3	4	7
	07	2	4	6
	08	1	6	7
	09	1	2	3
	10		5	5
	11		6	6
	12		4	4
2001 Total		**17**	**50**	**67**
2002	01	2	5	7
	02	2	6	8
	03	1		1
	04	3	3	6
	05	2	2	4
	06	2	2	4
	07	1	2	3
	08	1	2	3
	09	1		1
	10	2	2	4
	11	3	3	6
	12	1	2	3
2002 Total		**21**	**29**	**50**
Grand Total		**66**	**110**	**176**

Table D35: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine4 - Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine4

Average of SampleTWA		Vent district VD2	HEG		VD2 Total
YEAR	MONTH	HEG2	HEG3	HEG4	
1999	01	0.10			0.10
	02	0.79	1.54		0.94
	10	0.20	0.07	1.45	0.57
	11	1.52	0.36	0.33	0.74
	12		0.28		0.28
1999 Total		**0.69**	**0.68**	**0.89**	**0.71**
2000	01	0.07	0.18	0.75	0.36
	02	1.04	1.52	0.94	1.17
	06		0.07		0.07
	07		0.07		0.07
	08	0.40	0.28	0.10	0.24
	09	0.41		0.33	0.38
	10			0.06	0.06
	11		0.15	0.06	0.10
	12	0.08	0.85	0.06	0.33
2000 Total		**0.38**	**0.38**	**0.33**	**0.36**
2001	01	0.18	0.10	0.06	0.14
	02	0.18	0.11	0.22	0.17
	03	1.13	0.07		0.60
	04	0.51			0.51
	05			1.09	1.09
	06	0.05		0.22	0.14
	07	0.41		0.22	0.36
	08	0.08			0.08
	09			1.10	1.10
	10	0.35	0.41		0.38
	11		0.15	0.95	0.55
	12	0.08	0.06	0.06	0.06
2001 Total		**0.27**	**0.15**	**0.42**	**0.29**
2002	01	0.11	0.14	0.27	0.16
	02	0.41	0.30	0.35	0.34
	04	0.14	0.16	0.18	0.15
	05	0.22	0.05	1.42	0.48
	06		0.20	0.10	0.15
	07			0.19	0.19
	10		1.04		1.04
	11	0.34	0.11	0.08	0.19
	12	0.07	0.34	0.20	0.20
2002 Total		**0.19**	**0.29**	**0.35**	**0.26**
Grand Total		**0.37**	**0.36**	**0.39**	**0.37**

Table D36: The number of samples collected for Mine4 – Ventilation District 2 per year over the years 1999 – 2002

Mine	Mine4

Count of SampleTWA		Vent district VD2	HEG		VD2 Total
YEAR	MONTH	HEG2	HEG3	HEG4	
1999	01	2			2
	02	8	2		10
	10	1	1	1	3
	11	1	1	1	3
	12		2		2
1999 Total		**12**	**6**	**2**	**20**
2000	01	2	1	2	5
	02	1	1	1	3
	06		1		1
	07		2		2
	08	2	3	3	8
	09	6		4	10
	10			1	1
	11		1	1	2
	12	1	1	1	3
2000 Total		**12**	**10**	**13**	**35**
2001	01	3	1	1	5
	02	4	1	1	6
	03	1	1		2
	04	1			1
	05			1	1
	06	2		2	4
	07	3		1	4
	08	2			2
	09			1	1
	10	1	1		2
	11		1	1	2
	12	1	1	2	4
2001 Total		**18**	**6**	**10**	**34**
2002	01	2	1	1	4
	02	1	2	1	4
	04	2	1	1	4
	05	2	1	1	4
	06		1	1	2
	07			1	1
	10		1		1
	11	2	2	1	5
	12	3	3	1	7
2002 Total		**12**	**12**	**8**	**32**
Grand Total		**54**	**34**	**33**	**121**

Table D37: The arithmetic mean respirable dust concentrations in mg/m³ for Mine4 - Ventilation District 3 per year over the years 1999 – 2002

Mine	Mine4

Average of SampleTWA		Vent district HEG			
		VD3			VD3 Total
YEAR	MONTH	HEG2	HEG3	HEG4	
1999	01			0.16	0.16
	02			0.12	0.12
	10	0.40			0.40
	11			0.20	0.20
	12		0.13		0.13
1999 Total		**0.40**	**0.13**	**0.13**	**0.16**
2000	01	1.06	0.68	0.29	0.77
	02	0.13	0.15	1.77	0.54
	03		0.07	0.44	0.25
	05	0.34	0.16	0.20	0.25
	06	0.38	0.50	0.15	0.37
	07	0.84	0.44	0.07	0.50
	08	0.09		0.14	0.12
	09			0.39	0.39
	10	0.06			0.06
	11	0.31	0.07	0.56	0.27
	12	0.44	0.40		0.42
2000 Total		**0.43**	**0.34**	**0.38**	**0.38**
2001	01	0.57	0.15	0.06	0.35
	02	0.21	0.33	0.25	0.26
	03	0.48	0.26	0.08	0.36
	04	0.41			0.41
	05	0.63		0.69	0.64
	06	0.30		0.09	0.23
	07	0.64			0.64
	08	0.33		0.61	0.42
	09	0.38		1.37	0.71
	10	0.34			0.34
	11	0.33		0.59	0.37
	12	0.13		0.13	0.13
2001 Total		**0.41**	**0.25**	**0.37**	**0.38**
2002	01	0.23		0.20	0.22
	02	0.22		0.78	0.33
	04	0.25	0.17	0.64	0.30
	05	0.23	0.09	0.41	0.19
	06	0.11	0.06	0.08	0.08
	07	0.26	0.36	0.29	0.30
	08	0.18	0.44	0.47	0.36
2002 Total		**0.22**	**0.19**	**0.41**	**0.25**
Grand Total		**0.37**	**0.28**	**0.29**	**0.33**

Table D38: The number of samples collected for Mine4 – Ventilation District 3 per year over the years 1999 – 2002

Mine	Mine4

Count of SampleTWA		Vent district HEG			
		VD3			VD3 Total
YEAR	MONTH	HEG2	HEG3	HEG4	
1999	01			2	2
	02			14	14
	10	2			2
	11			2	2
	12		1		1
1999 Total		**2**	**1**	**18**	**21**
2000	01	2	1	1	4
	02	2	1	1	4
	03		1	1	2
	05	4	3	2	9
	06	2	5	3	10
	07	2	4	1	7
	08	1		1	2
	09			3	3
	10	1			1
	11	3	2	1	6
	12	1	1		2
2000 Total		**18**	**18**	**14**	**50**
2001	01	3	2	1	6
	02	3	2	1	6
	03	6	2	2	10
	04	1			1
	05	4		1	5
	06	4		2	6
	07	4			4
	08	4		2	6
	09	2		1	3
	10	1			1
	11	6		1	7
	12	3		2	5
2001 Total		**41**	**6**	**13**	**60**
2002	01	2		1	3
	02	4		1	5
	04	2	2	1	5
	05	3	3	1	7
	06	2	2	1	5
	07	3	2	1	6
	08	1	1	1	3
2002 Total		**17**	**10**	**7**	**34**
Grand Total		**78**	**35**	**52**	**165**

Table D39: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine4 - Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine4

Average of SampleTWA		Vent district HEG			
		VD4			VD4 Total
YEAR	MONTH	HEG2	HEG3	HEG4	
1999	11	1.12	0.31	0.51	0.74
1999 Total		**1.12**	**0.31**	**0.51**	**0.74**
2000	01		0.44	0.33	0.41
	02	0.83	0.12	0.45	0.54
	03		0.07		0.07
	06	0.40	0.26	0.22	0.27
	07	1.10	0.31	0.32	0.54
	08		0.66	0.33	0.55
	09	0.27	0.79	0.25	0.32
	10			0.57	0.57
	11	0.06	0.06	0.15	0.09
	12	0.06		0.43	0.18
2000 Total		**0.44**	**0.35**	**0.32**	**0.37**
2001	01	0.52	0.61	0.06	0.46
	02	0.13	0.83	0.48	0.48
	03	0.53	1.69		0.82
	04		0.08	0.31	0.19
	05	0.67	0.11	0.86	0.42
	06	0.71	0.16	0.76	0.59
	07	0.54	1.07	0.76	0.79
	08	0.25	0.23	0.11	0.21
	09		1.24		1.24
	10	0.46	1.26	0.35	0.67
	11	0.12	0.06	0.34	0.25
	12	0.15	0.06	0.24	0.15
2001 Total		**0.45**	**0.57**	**0.42**	**0.48**
2002	01		0.10	0.41	0.34
	02	0.68	0.05	0.77	0.64
	04	0.22	0.82		0.52
	05	0.63	0.29		0.56
	06	0.37		0.43	0.40
	07		0.12	0.05	0.07
	08		0.06	0.06	0.06
	10	0.08			0.08
	11	0.19	0.07	0.16	0.16
	12	0.09	0.21	0.70	0.30
2002 Total		**0.34**	**0.29**	**0.42**	**0.36**
Grand Total		**0.45**	**0.41**	**0.40**	**0.42**

Table D40: The number of samples collected for Mine4 – Ventilation District 4 per year over the years 1999 – 2002

Mine	Mine4

Count of SampleTWA		Vent district HEG			
		VD4			VD4 Total
YEAR	MONTH	HEG2	HEG3	HEG4	
1999	11	3	2	1	6
1999 Total		**3**	**2**	**1**	**6**
2000	01		2	1	3
	02	2	1	2	5
	03		1		1
	06	1	3	2	6
	07	2	3	2	7
	08		2	1	3
	09	5	1	3	9
	10			1	1
	11	1	1	1	3
	12	2		1	3
2000 Total		**13**	**14**	**14**	**41**
2001	01	2	2	1	5
	02	1	1	1	3
	03	3	1		4
	04		1	1	2
	05	2	3	1	6
	06	3	2	3	8
	07	1	1	1	3
	08	4	1	2	7
	09		1		1
	10	1	2	3	6
	11	1	1	4	6
	12	1	1	1	3
2001 Total		**19**	**17**	**18**	**54**
2002	01		2	7	9
	02	2	1	4	7
	04	3	3		6
	05	4	1		5
	06	2		2	4
	07		1	2	3
	08		2	1	3
	10	4			4
	11	2	1	2	5
	12	1	2	1	4
2002 Total		**18**	**13**	**19**	**50**
Grand Total		**53**	**46**	**52**	**151**

Table D39: The arithmetic mean respirable dust concentrations in mg/m^3 for Mine4 - Ventilation District 5 per year over the years 1999 – 2002

Mine	Mine4

Average of SampleTWA		Vent district	HEG
		VD5	VD5 Total
YEAR	MONTH	HEG5	
1999	11	0.89	0.89
1999 Total		**0.89**	**0.89**
2000	01	0.05	0.05
	02	0.22	0.22
	03	0.14	0.14
2000 Total		**0.14**	**0.14**
2001	05	0.10	0.10
	06	0.15	0.15
	07	0.06	0.06
	08	0.07	0.07
	09	0.06	0.06
	10	0.08	0.08
	12	0.08	0.08
2001 Total		**0.09**	**0.09**
2002	01	0.19	0.19
	02	0.18	0.18
	03	0.05	0.05
	04	0.11	0.11
	05	0.33	0.33
	06	0.18	0.18
	07	0.09	0.09
	08	0.16	0.16
	10	0.12	0.12
	11	0.18	0.18
	12	0.82	0.82
2002 Total		**0.25**	**0.25**
Grand Total		**0.22**	**0.22**

Table D40: The number of samples collected for Mine4 – Ventilation District 5 per year over the years 1999 – 2002

Mine	Mine4

Count of SampleTWA		Vent district	HEG
		VD5	VD5 Total
YEAR	MONTH	HEG5	
1999	11	1	1
1999 Total		**1**	**1**
2000	01	1	1
	02	1	1
	03	2	2
2000 Total		**4**	**4**
2001	05	4	4
	06	1	1
	07	1	1
	08	1	1
	09	1	1
	10	3	3
	12	1	1
2001 Total		**12**	**12**
2002	01	4	4
	02	2	2
	03	1	1
	04	4	4
	05	3	3
	06	5	5
	07	4	4
	08	4	4
	10	3	3
	11	5	5
	12	5	5
2002 Total		**40**	**40**
Grand Total		**57**	**57**