

# **Respiratory Health and Silica Dust Levels in the Extractive Industry**

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# Foreword

The Extractive Industry Study 1999/2000 had as its main purpose to identify whether dust levels in this diverse industry posed a risk to health. That is was the dust a significant hazard as defined in the Health and Safety in Employment Act 1992.

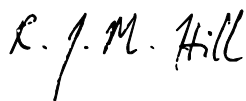
To answer this question the results of dust sampling carried out as part of the National Dust Project (1995-1999) were reviewed together with the results of the Respiratory Symptoms and Lung Function Survey carried out as part of the Extractive Industry Strategy 1999/2000.

The National Dust Project targeted those operations where high dust levels and particularly quartz based rock were present and as a consequence are not representative of average dust levels in the industry.

The Respiratory System Survey results were based in general on workers at sites which were easily accessible to the OSH branch staff and were as representative as possible.

The results indicated that 13% of the work sites sampled for dust had levels of respirable silica in excess of the current New Zealand workplace exposure limit. The lung function results showed a non statistically significant decline in the mean expiratory flow, a sensitive indicator of diffuse airway disease, with increasing years of dust exposure among workers who had never smoked.

The two separate studies indicate the need for improved dust control, health surveillance and respiratory protection in this industry.



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# Contents

Foreword .....	2
Contents .....	3
Introduction .....	4
Background History on Health Effects in the Extractive Industries in New Zealand .....	5
The Extractive Industry.....	9
The National Dust Project 1995 - 1999 .....	10
The Respiratory System Survey 1999 / 2000.....	12
Discussion.....	16
Recommendations .....	19
A Case Study : Lung Fibrosis in a Quarry Worker.....	20
References .....	22
Appendix 1.....	23

# Introduction

In 1998 the Mining and Quarrying Inspectorate moved from the Ministry of Commerce to Occupational Safety and Health (OSH) in the Department of Labour. The result of this move was that an industry that had been separated from the day to day practice and experience of OSH, now became an integral part of OSH's responsibility, including its health focus.

With the move of the Inspectorate there also came their experience and their excellent database of dust levels in this industry. The National Dust Project initiated in 1995, had produced a wealth of such information. To supplement this environmental information, it was recognized that there should also be some health data, and while some of the larger private industries had been carrying out lung function testing, overall in this industry it was the exception.

In late 1998 a decision was made to establish an extractive industry strategy. A health strategy team was convened which included George Munro, Chief Inspector of Mines, Quarries and Tunnels, Les Heads, a Health and Safety practitioner from the mining industry, Louisa Thomas, a Business Advisor from OSH, and Bill Glass, a Senior Departmental Medical Practitioner, also from OSH.

A decision was made to carry out a respiratory symptom questionnaire and lung function assessment in those OSH districts where Mines Inspectors were located. Five districts were included - Dunedin, Nelson, Hamilton, Palmerston North and Auckland.

# Background History on Health Effects in the Extractive Industries in New Zealand

There have been only four major studies in New Zealand in this area in the 20th century.

## 1938<sup>1</sup>

In 1938 the Government printer published a report of an Inter-Departmental Committee on Silicosis. This report, Bulletin No. 57 of the Department of Scientific and Industrial Research (DSIR) was prepared as a consequence of a request by the Hon. Mark Fagan to the DSIR to develop some information on the incidence of the disease in the Dominion. At this time silicosis was not a notifiable disease and medical examination of workers in the industry did not take place. Thus the Inter-departmental Committee set up to comment on this condition had recourse primarily to pensions granted under the Miners Phthisis Act. Data from the Pensions Office showed that since this Act came into force in 1915, 1576 pensions had been granted to miners "said to suffer from silicosis", and of these 1508 were described as gold and quartz miners and 68 as coal miners. In another section of this report the sources of dust in this industry were considered and listed as mining for gold and coal, quarrying and shaping building stones, rock breaking, together with brick, tile and pottery making, pumice insulation making, and block and pipe making.

## 1961<sup>2</sup>

The first investigative study was carried out by Dr Francis de Hamel of the Department of Health and became known as the Grey Valley Survey, Special Report Series No. 3. This study arose out of a demonstrated need by Dr. De Hamel for a large film radiographic survey of a coal mining area in order to demonstrate the incidence of coal workers pneumoconiosis. The survey took place in 1958 in the Grey Valley on the West Coast of New Zealand.

1525 miners and ex-miners and 228 non-miners from the Grey Valley were examined. Occupational histories, smoking habits, symptoms, chest X-rays and lung function tests were recorded for each subject.

The attendance rate for underground miners was 93.2% It was shown to be unlikely that the non-attenders significantly affected the results.

Analyses of occupational histories indicated that most underground miners had not worked as much as 40 years underground.

The smoking habits of the surveyed population were analyzed and compared with the Dominion habit. Miners smoked more frequently than non-miners. Cigarette smoking diminishes maximum breathing capacity and there is some evidence that the greatest depression of maximum breathing capacity in miners in the Grey Valley was caused by cigarette smoking rather than by coal dust. However coal dust combined with heavy cigarette smoking caused a more marked loss of lung function than either factor alone.

No marked difference in the effect upon lung function or upon cough rates could be found between commercially packeted and self-rolled cigarettes. Both cigarette smoking and coal dust gave rise to increased cough. Cigarette smokers had a lower chest X-ray normality rate than non-smokers. There was some evidence that only respiratorily fit men smoked cigarettes heavily.

Miners more frequently had phlegm than non-miners and this was more than would be accounted for by their greater smoking habit.

Complaints of dyspnoea amongst miners were more commonly due to causes other than pneumoconiosis and were frequently confirmed by a lower maximum breathing

capacity even in the absence of radiological emphysema. It was suggested that a finding of less than 70% of forced vital capacity expired in the first three-quarters of a second at any age is indicative of some pulmonary dysfunction.

Nearly two-thirds of those subjects with a history of wet pleurisy showed no evidence of radiological pleural thickening.

Symptoms arising from mining were analyzed according to the mines worked in. Increased phlegm was a common concomitant from working in the mines in the Grey Valley.

Miners had a lower chest X-ray normality rate than non-miners and this is probably more than can be accounted for by their greater smoking rates.

Only 32 cases of pneumoconiosis were found, half of which were in category 1. One case undoubtedly arose from working in New Zealand coalmines but a number of others may well have so arisen. It seemed unlikely that coal workers' pneumoconiosis will occur before about 30 years underground coal work in this country. 5 cases of progressive massive fibrosis were found, 4 of whom had worked in overseas mines previously and the fifth for many years in West Coast quartz mines.

### 1978<sup>3</sup>

In 1978 Dr de Hamel and Mr P de Souza published a follow up study "The Second Grey Valley Survey" which looked at chronic bronchitis and lung function as well as X-ray changes. Because of the importance of this follow up study and the fact it has been out of print for over 20 years the full summary and conclusions are presented.

### Summary and Conclusions

Five hundred and ninety eight men, who were originally examined during a study of 1753 residents of a coal mining area in 1958, were re-examined exactly 14 years later. Changes in the answers to an occupational and respiratory questionnaire have been examined in relation to radiological appearances and lung function tests.

During the intervening 14 years more than 300 of the original subjects had died and more than 550 were known to have moved at least 200 km from the area. The reason for the large exodus was the decline of the coal industry between the two studies. It is shown that the high lapse rate in the follow-up study has not materially affected the results given here. The non-attenders did not differ significantly from the attenders in any measured parameter except that the non-attenders were largely from the top and bottom of the original age-range whereas the 598 tended to consist largely of the middle-aged men, including those with greater mining experience. The reasons for these selection factors are discussed.

Among the 598 men studied, 80 percent had been coal miners at the time of the original study. Just under half of these miners were still mining 14 years later and one-third had taken up non-mining employment in the area. Five percent of the employed miners examined had worked for more than 40 years underground in New Zealand coalmines. A much larger proportion of the retired miners than current miners had worked in overseas mines (mainly in the United Kingdom), reflecting the inter-war immigration of experienced miners to New Zealand.

The quantity of tobacco consumed by the smokers tended to increase over time. The proportion of heavy smokers tended to fall among those who had smoked for long periods and this finding is considered to be largely due to the effect of respiratory symptoms. The publication of the results of the first study did not cause smokers to abandon the habit. The association between the occupation of coal mining and excess cigarette smoking, suggested in the 1958 study, has been confirmed. The smoking habits acquired while in the coal mining industry were carried over into subsequent occupations by the ex-miners.

Thirteen men were found to have possible or probable pneumoconiosis (categories 0/1 or 1/0). Eleven men had definite pneumoconiosis (category 1/1 or greater), five of whom had worked solely in New Zealand. Four of these latter five men had worked in quartz mines or in tunneling and only one solely in coalmines. Very little information is available about coal dust concentrations in state coalmines and none in private mines.

Chronic respiratory symptoms of cough, phlegm or wheeze were present in more than one-third of those examined. Such symptoms occurred in more than one in 10 of those who had never smoked. The prevalence of these symptoms in never smokers did not increase with age, except in the old men.

The prevalence of these symptoms among the smokers increased markedly with age, a finding which is thought to be due to duration of smoking rather than age itself. Smoking cigarettes increased the liability to multiple respiratory symptoms. Our findings suggest that the admission of chronic phlegm production is a more sensitive index of early respiratory damage than chronic cough. The prevalence of symptoms of cough, phlegm and wheeze in cigarette smokers increased with the quantum of tobacco smoked, but the latter rose with smoking duration. A similar prevalence of symptoms were found in those who had smoked heavily for shorter periods as in those who had smoked less heavily but for longer periods. A reduction in the amount of tobacco smoked tended to cause a lessening of previous symptoms, in particular the symptom of cough.

The prevalence of symptoms of cough, phlegm and wheeze in ex-smokers rose with age and appeared to be related to the duration of smoking in the past but not clearly with the quantum smoked. Giving up smoking reduced substantially the symptom of cough, somewhat reduced the symptom of phlegm, but appeared not to affect the symptom of wheeze. We concluded that wheeze was not usually reversible, phlegm partially reversible and cough frequently reversible upon stopping smoking. The evidence from the ex-smokers supported an hypotheses that the ex-smoking population falls into three groups: the tobacco-susceptible group which gives up smoking because of symptoms after less than about 15 years of smoking, a tobacco-insusceptible group which gives up smoking for non-symptomatic reasons usually before 30 years of smoking, and a tobacco-insusceptible group which gives up smoking when symptoms supervene after 30 or more years of smoking. The effect is to produce a skewed bimodal symptom-incidence over smoking duration in the population. This hypothesis has been tested upon a different whole-population cross-sectional study and appears to fit the data.

We present evidence that coal mining, both currently or in the past, caused an increase in the prevalence of cough, but not of phlegm or wheeze, among cigarette smokers. Coal mining did not cause an increase of any of these symptoms amongst miners who had never smoked. Chronic cough was therefore associated with coal mining only in the presence of smoking.

Both the FVC and the FEV I were depressed by smoking and the greater the tobacco consumption the greater the depression of the FEV I. Only when smoking had been abandoned for a number of years did the FEV I of the younger ex-smokers become similar to the FEV I of those who had never smoked. Among the older ex-smokers we found no evidence

of recovery of the FEV I following cessation of smoking.

Both FVC and FEV I regressions upon age and height were significantly improved by including smoking and symptoms in the formula. We have briefly studied whether a power of height, or an age-height interactive term, was an improvement upon the generally used simple linear relationships of lung function to height and we have confirmed the overseas finding that a non-linear function of height in the regression of lung function is rather better than a linear function. But we observe that this difference is very small in comparison with the great improvement obtained by including symptoms and smoking in the linear regression of FEV I upon age and height.

No evidence was found that mining coal in New Zealand, even for long periods, affected either the FVC or FEV I. No significant depression of lung function was found in the few cases of pneumoconiosis discovered.

The FVC and FEV I of the men who had died during the period between the two studies were lower than those of the men who had survived, after taking age, weight and smoking into account. This is in conformity with the recent findings of both European and United States workers.

Over the 14 years the FVC did not fall as much as the FEV I at any age. While FEV I fell at all ages as would have been predicted from the regression of the 1958 cross-sectional study, the FVC did not fall as much as would have been predicted. Thus, in the ratio of FEV I to FVC (i.e. FEV%), the denominator fell less than, and at a rate independent of, the numerator. Since this can only be interpreted as signifying that the FEV I percentage for a man of a given age and height at one point in time will differ from the FEV% for a similar man of the same age and height several years later, the FEV I percentage was considered to be an unsatisfactory index. The relationship of each cohort to the others, with respect to the ratio of FEV I to FVC, was maintained over the 14 years. Our finding that the FVC fell less than, and independently of, the FEV I over time would appear to have occurred in some published overseas studies but does not appear to have given rise to comment outside New Zealand previously.

By means of discriminate analysis it has been found possible to separate our population very adequately into two categories in respect of lung function. For the purposes of this paper we have termed these two categories "Fit" and "Unfit", though fully realising the inadequacy of such terms.

The Unfit comprised those with chronic respiratory symptoms as well as all symptomless cigarette smokers who smoked 10 or more cigarettes a day.

The average annual fall over the 14 years in the FVC and FEV I was notably greater in the Unfit than in the Fit. In the Unfit the relationship of FVC with age and height changed significantly between 1958 and 1972. This was not found to be true of the Fit. We believe that "unfitness" has a greater effect upon FVC as age increases. Possible reasons for these findings are considered.

For those of the same age and height, the higher the initial FVC the greater was the fall over the study period. This applied to both the Fit and Unfit categories. The FVC appeared to be a less sensitive indicator of respiratory disease than the FEV I and adequate separation of the Fit from the Unfit could be made at an earlier age by means of the FEV I.

Separation of a population into two "fitness" categories, by means of the criteria we have used here, appears to be a useful preliminary to predicting lung function both cross-sectionally as well as longitudinally.

The change in FEV I over the 14 years was not related to the standing height, nor to the cube of height, in either the Fit or the Unfit. The starting value of the FEV I in the Fit was higher than it was in the Unfit. In the Fit there was a significant regression of FEV I change on the starting value but this could not be confirmed in the Unfit.

We have considered various alternative explanations for our findings but no explanation at this stage can be more than hypothetical. The FEV I decreases with increasing age. The actual drop in the FEV I over any given period is greater in some people than in others. We have shown that this excess fall in the FEV I cannot be accounted for solely by long-term tenure of respiratory symptoms because this excess fall occurs in symptomless men who have been subjected to heavy smoking over many years.

It is plausible to suggest that repeated acute respiratory infections, which could reasonably be expected to be most frequent in our Unfit group, is the most probable explanation for the excess fall in the FEV I in the group. However a number of overseas studies have demonstrated that the FEV I is not permanently depressed as a result of bouts of respiratory infection.

We have shown in this paper that this depression of the FEV I is not related to the chronic occupational inhalation of coal dust. Since our study was confined to one topographical area the probability of local exogenous geographical influences being important is minimal. There is no evidence to suggest that general air pollution - that obvious potential chronic exogenous assault - is likely to have had any marked, or more importantly, differential, effect upon our survey population in the Grey Valley.

We have, however, shown that symptoms depress the FEV I by an amount which is largely independent of age, whereas smoking depresses the FEV I by an amount which is markedly age-related (the older the subject the greater the depression). Thus we believe that symptoms depress the FEV I but barely affect the rate of fall with age, while smoking both depresses the FEV I and also results in the rate of fall increasing with age. This is perhaps the most reasonable explanation of the differences we have found in the FEV I fall.

#### 1998 <sup>4</sup>

The most recent study was that by Mr Les Heads on the "Effect of an Underground Mine Environment on Respiratory Function in a Greenfields Workforce"

The purpose of this study was to review spirometry measurements over a 7 year period among a group of greenfields underground miners to determine whether there was evidence of higher than expected annual reduction in lung function measured as forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV I).

Forty-four underground miners and 33 surface miners were included in the study.

The results showed that surface miners had a marginally greater loss in percent predicted FVC and FEV I, with time than underground miners. Smoking was not a factor in the analysis.



# The Extractive Industry

The extractive industry consists essentially of coal mining, gold mining and quarrying. Coal mining involves both open cast and underground activities, gold mining includes open cast, hard rock and alluvial sources and quarrying encompasses a range of sand and rock quarries for building, roading and dam construction, limestone for agriculture, roading and cement manufacture and special rocks such as Oamaru stone used in building.

Most New Zealand rocks contain some quartz and with the effects of erosion and quarrying the resulting quartose sands – because of the resistant nature of quartz – tend to contain a higher content of quartz than the parent material<sup>5</sup>.

A range of rock types are quarried including rhyolite, diatomaceous clays, serpentine, bentonite, perlite, basalt, greywacke and zeolite. Overall there are some two hundred and fifty quarries and sixty-three lime works throughout New Zealand ranging in employee size from less than five to more than twenty.

One of the occupational health nurses involved in the study recorded the following

“The quarriers” work in gangs moving to quarry sites over a wide area and dependent largely on roading contracts. The tendering process is cut throat and employment can be “temperamental”. The gangs usually work up to fifteen hours daily or from daylight to dusk. They work on crushers, mobile machinery, driving front end loaders and dump trucks. Their lunch rooms are huts or a caravan on site. Down time costs money with crews staggering meal breaks and I was aware of that when it came time to down tools for the testing to be done. There was a high incidence of smoking among workers. The long hours of work equate to a high exposure rate to the dusts.”

She summed up the issues as she saw them as:-

- Isolation of work places
- Itinerant nature of work
- Small contractors in a competitive market
- Irregular health checks
- Distance worked from home base
- Limited availability of health providers

# The National Dust Project 1995 - 1999

The main aim of the project was to determine dust levels at those operations where people may be at risk from high concentrations and especially where quartz is present in the rock mass. It should be noted that this targeting of potentially high risk areas means that the resulting statistics do not represent average conditions in the industry.

The most serious effect of exposure to airborne rock dust is lung damage caused by the inhalation of respirable dust over a long period of time. It was therefore decided to use a size selective sampling method and concentrate on measuring the respirable fraction. At the same time the monitoring equipment allowed for collection of the over

size dust fraction, providing a good indication of total air-borne dust.

The method of gravimetric determination of respirable dust used complies with Australian Standard 2985:1987.

Mining inspectors have been trained in the use of portable personal dust sampling units that are equipped with a cyclone for separating the respirable fraction. Capital Environmental Services Ltd processed the samples. Their Gracefield laboratory has TELARC registration and provides both gravimetric and quantitative (XRD) quartz analysis.

**Table 1**

## Summary of Results to March 1999

	<b>Total Dust</b>	<b>Respirable Dust</b>	<b>Respirable Quartz Dust</b>
Number of results	86	102	87
Number exceeding WES*	23	11	11
Percent exceeding WES	27%	11%	13%

**Table 2**

## Percentage of Dust Samples Exceeding New Zealand Workplace Exposure Standards (WES) at the Time of Sampling

<b>Industry</b>	<b>Total Dust</b>	<b>Respirable Dust</b>	<b>Respirable Quartz</b>
Quarries	20	10	11
Lime Works	60	15	9
Gold Mines	5	0	5
Tunnels	11	11	44
Gold Testing Rooms	60	20	60

Note: WES is expressed as an 8-hour time weighted average. For total dust the WES was 10mg/m<sup>3</sup>, for respirable dust it was 5 mg/m<sup>3</sup> and for respirable quartz dust it was 0.2 mg/m<sup>3</sup>.

**Table 3**  
**Dust Levels According to Type of Industry**

Type of Industry	Number of Sites Tested	Total Dust Levels (mg/m <sup>3</sup> )				Total Respirable Dust (mg/m <sup>3</sup> )				Total Respirable Silica (mg/m <sup>3</sup> )			
		Number of Samples	Geometric Mean	Geometric Standard Deviation	Range	Number of Samples	Geometric Mean	Geometric Standard Deviation	Range	Number of Samples	Geometric Mean	Geometric Standard Deviation	Range
Quarries	21	26	2.34	6.66	0.09 to 14.8	31	0.66	3.61	0.06 to 12.5	27	0.05	3.45	.007 to 0.57
Lime Works	9	15	9.59	4.25	0.45 to 65.0	19	1.08	3.97	0.09 to 11.9	11	0.08	1.90	0.03 to 0.27
Gold Mines	3	18	0.96	3.67	0.19 to 10.5	18	0.25	2.05	0.03 to 0.3	18	0.08	2.57	0.02 to 0.45
Tunnels	5	9	1.28	3.38	0.25 to 11.0	9	1.00	4.00	0.1 to 10.0	9	0.09	5.03	0.01 to 1.29
Gold Testing Rooms	2	5	9.03	6.98	0.65 to 59.0	5	1.27	3.07	0.43 to 6.4	5	0.26	5.45	0.05 to 2.62

## Comments

Tables 1 and 2 show the percentage of dust samples in excess of the New Zealand Workplace Exposure Standards (WES) at the time of sampling. The only change in those standards since the sampling was carried out is a lowering of the total respirable dust from 5mg/m<sup>3</sup> to 3mgm/m<sup>3</sup> for an 8 hour day.

The main features of these results apart from their variability, are the high levels of total dust in lime works and gold testing rooms and the high levels of respirable quartz in tunnels and quarries.

Table 3 confirms this variability in more detail.

# The Respiratory System Survey 1999 / 2000

## Study Method

The respiratory symptom questionnaire and lung function testing procedures were carried out by OSH Occupational Health Nurses in the five OSH Districts where mines inspectors were located : Dunedin, Nelson, Hamilton, Palmerston North and Auckland.

The sites selected for the survey were determined on the basis of willingness to participate, accessibility, size and type. The owner/manager of each plant was phoned and an explanation given about the project. The numbers of sites visited were limited by the time available to the OSH branch staff. On average the occupational health nurse interviewed and tested fifty workers each and in all sites visited there was full cooperation and participation. No workers refused the testing procedure. On visiting the site each participant signed a consent form.

A standard questionnaire (Appendix 1) was administered by the Occupational Health Nurses to the 301 participants. This questionnaire recorded occupational exposure

to quarry dust, smoking history, respiratory symptoms and past respiratory history.

Spirometry was carried out using a Microspiro 3300 electronic spirometer. Each Occupational Health Nurse had a similar instrument which was calibrated prior to the project.

The nurses were trained to ATS (American Thoracic Society) standard by Ms Maureen Swanney of the Christchurch Respiratory Unit. Forced Vital Capacity (FVC), Forced Expiratory Volume, 1 second (FEV1) and MEF were recorded.

The participants recorded three consecutive blows, the best blow was utilized in the study. An assessment of the results indicated that 99% were within a 3% variation, a highly acceptable figure for a field-based investigation.

On completion of each site visit the occupational health nurse sent a copy of the lung function results to the participants and thanked them for their cooperation.

## Results

### 1. Spirometry

Table 4 shows the crude spirometric data according to years of exposure. There is a non statistical trend in the mean MEF only with increasing years of exposure.

Fig 1 shows the spirometric data corrected for smoking habit. This figure indicates a non statistically significant decline in MEF among never smoked quarry workers with years of exposure to quarry dust. There is no pattern for FEV1, FVC or FER.

A comparison between the mean differences for MEF for never and ever

smoked groups show a contraction in this difference with an increase in years of exposure.

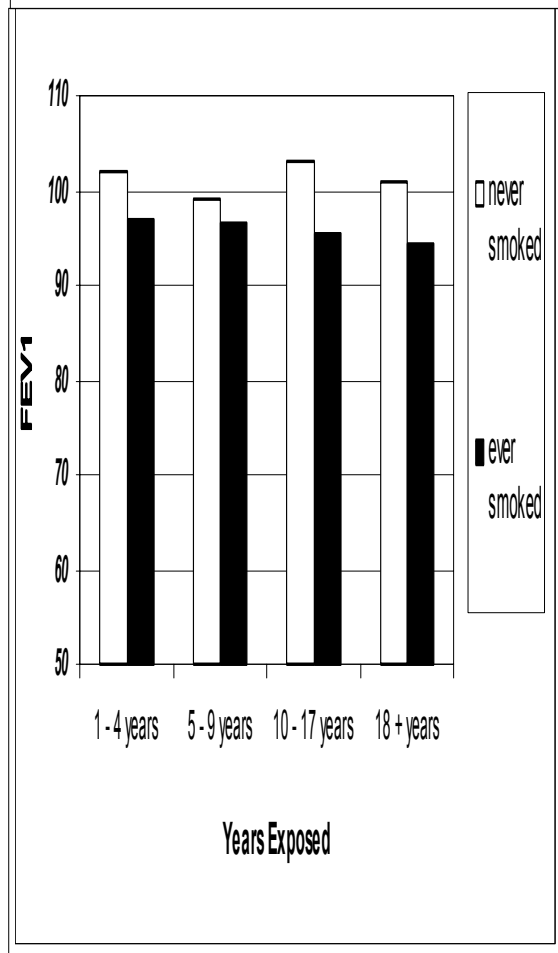
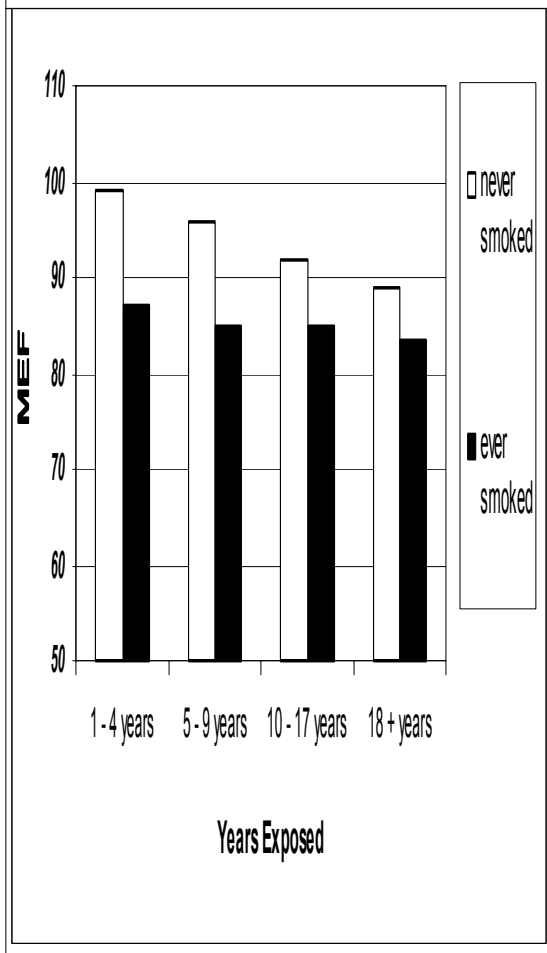
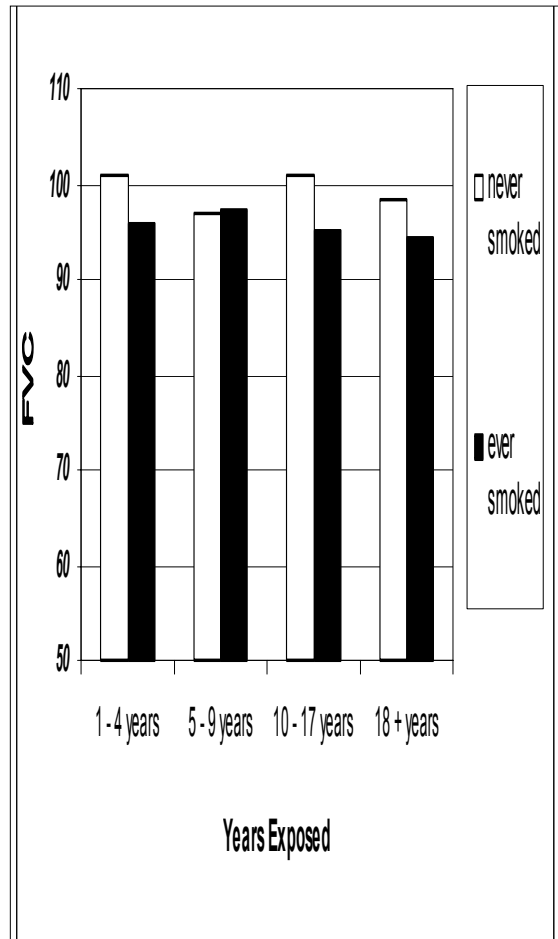
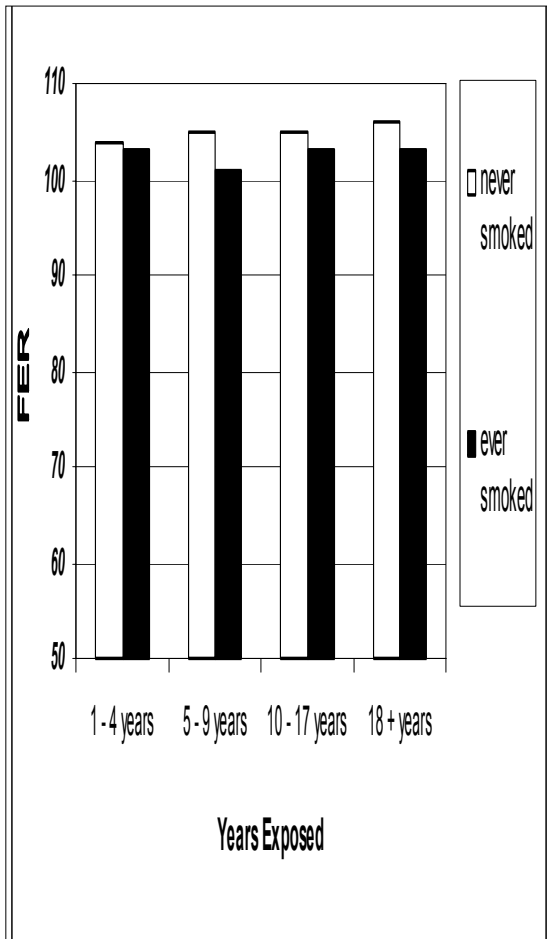
### 2. Respiratory Symptoms – cough, shortness of breath (SOB) and asthma

Table 5 shows a difference in the prevalence of cough and shortness of breath between the ever smoked and never smoked quarry workers. There is no trend in symptom prevalence with years of exposure. There is no difference in asthma prevalence between the ever and never smoked groups.

**Table 4**  
**Crude Spirometric Data**

<b>Variable</b>	<b>Years of Exposure</b>	<b>Numbers</b>	<b>Mean</b>	<b>Lower 95% CL for Mean</b>	<b>Upper 95% CL for Mean</b>
FER	1-4	75	103.2	101.6	104.7
	5-9	74	102.4	100.2	104.6
	10-17	74	103.6	102.0	108.2
	18+	78	103.5	101.0	105.9
FEV <sub>1</sub>	1—4	75	98.1	95.3	101.0
	5-9	74	96.6	93.0	100.2
	10.-17	74	98.1	94.8	101.4
	18+	78	96.0	91.8	99.1
FVC	1-4	75	97.4	94.3	100.5
	5-9	74	96.8	93.2	100.3
	10-17	74	97.2	94.0	100.5
	18+	78	95.4	91.8	99.1
MEF	1-4	75	90.0	85.1	94.9
	5-9	74	87.8	81.5	93.7
	10-17	74	87.3	80.9	93.7
	18+	78	85.0	78.6	91.4

Figure 1 : Mean lung function results according to smoking habit and years of exposure.



**Table 5****Respiratory Symptoms, Work Exposure, Smoking Habit**

Years of Exposure	Numbers	Ever Smoked			Numbers	Never Smoked		
		Cough (%)	SOB (%)	Asthma (%)		Cough (%)	SOB (%)	Asthma (%)
1-4	54	5 (9)	14 (26)	6 (11)	18	0 (0)	2 (11)	2 (11)
5-9	47	2 (4)	10 (21)	3 (6)	24	0 (0)	1 (5)	1 (5)
10-17	54	9 (17)	20 (37)	7 (13)	20	1 (5)	2 (10)	3 (15)
18+	56	5 (9)	17 (32)	4 (7)	21	1 (5)	2 (10)	3 (15)
Total (Percent)	211	21 (10)	61 (29)	20 (9)	83	2 (2)	7 (7)	9 (9)

# Discussion

This report brings together two separate but related investigations, the National Dust Project and the Respiratory System Survey, each of which were carried out as part of the day to day work of OSH. There were thus inevitable constraints on the numbers of sites visited and tested and the number of individuals surveyed.

## The National Dust Project

This project targeted high risk areas at quarry sites, gold mines, lime works and tunnels. Lime works were, in general, more dusty than quarries as were the total respirable dust levels although there was little difference in respirable quartz levels. Gold mines had lower total dust and respirable dust levels but similar respirable quartz levels. The highest respirable quartz levels were present in the tunneling operations tested and in the gold analysis rooms. Long term exposure to respirable quartz dust has been associated with the development of silicosis and more recently it has been shown that exposure to crystalline silica (quartz) can result in an increased risk of developing lung cancer.

## The Respiratory System Survey

The respiratory health of the group of extractive industry workers investigated showed that cough and shortness of breath were a consequence of smoking habit rather than years of exposure to quarry dust.

Spirometry results indicated a non-statistical response of Mean Expiratory Flow to increasing years of exposure to quarry dust among non smoking quarry workers.

Lung function is usually measured in terms of volume and time, giving measurements of FVC (forced vital capacity), FEV<sub>1</sub> (forced expiratory volume in 1 second) and FEV<sub>1</sub>/FVC ratio.

Using flow measurements generates information which includes FVC, FEV<sub>1</sub>, and FEV<sub>1</sub>/FVC ratio, but also gives a peak flow reading, and flow rates at 25%, 50% and 75%

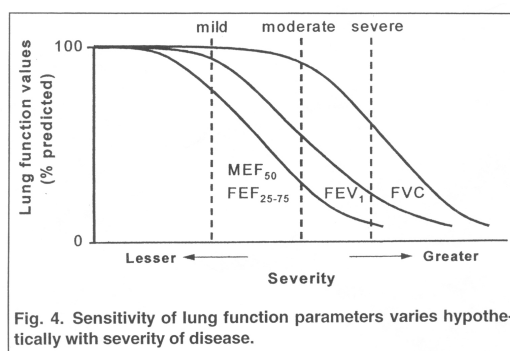
of the way through the vital capacity manoeuvre.

In addition, a mean expiratory flow can be calculated using the average flow over the time taken from 25 to 75% of the flow volume loop. This is known as MEF (mean expiratory flow) or FEF<sub>25/75</sub> (forced expiratory flow 25/75).

Peak flow measurements have been used with variable airflow obstruction, but in fact are more indicative of muscle strength than lung function.

FEV<sub>1</sub>, a sensitive marker of airflow obstruction, whilst FVC is the most sensitive marker of restrictive lung pathology.

Mean and mid flow rates provide more information in early disease states including airflow obstruction, and the mean expiratory flow may reflect the most important physiological variable as it is during this time phase that most of the respiratory flow occurs. MEF and FEF<sub>25/75</sub> reflect the impact of diffuse airway disease before changes in FEV<sub>1</sub> and therefore provide the earliest index of diffuse small airway disease.



(Ref: Data from European Epidemiologic Registry of Cystic Fibrosis)

Although, observational field data using mean expiratory flow as a marker of airflow obstruction is not prevalent in the literature, it may become so in the future.



## **Overseas studies among quarry workers**

A study of dust exposure and respiratory health was carried out among hard rock quarry workers and ex-workers in Scotland<sup>6</sup>. This 1992 report confirmed that dust concentrations were highest at crushers and screens and that dust concentrations in winter were half those in summer. A point of interest was that overall dust and quartz concentrations were of the same order of magnitude during compliance and research surveys and that “with appropriate precaution” the use of compliance monitoring data for epidemiological research purposes was appropriate. The range of dust sample results was wide with respirable quartz concentrations in many cases exceeding the current occupational exposure limits for quartz of 0.1mgm per cubic metre. As far as the worker health response was concerned, 8.2% of 1,117 male workers had a median profusion of small opacities of 0/1 or greater, 4.7% had a category of 1/0 or greater. For ex-workers comparable figures were 11.7% and 6.8%.

Another study of interest by Sanderson et al<sup>7</sup> in 2000 reported on 4,269 respirable quartz samples collected at 18 plants over 22 years from 1974 to 1996. A geometric mean of 1.03 mg/m<sup>3</sup> with a range from <0.001 to 11.7 mg/m<sup>3</sup> was recorded with 51% exceeding the NIOSH recommended exposure of 0.05 milligrams per cubic metre.

## **Silica and Lung Cancer**

An IARC monograph<sup>8</sup> on this issue summarised the situation as follows:-

“there is sufficient evidence in humans for carcinogenicity of inhaled crystalline silica in the form of quartz or cristobalite from occupational sources”.

The working group also noted that “carcinogenicity in humans was not detected in all industrial circumstances studied. Carcinogenicity may be dependent on inherent characteristics of the crystalline silica or on external factors affecting its biological activity or distribution of its polymorphs”.

Thus crystalline silica inhaled in the form of quartz or cristobalite from occupational sources is carcinogenic to humans (Group 1).

With reference to quarries and granite works, six cohort studies were reviewed in which the working environment were generally free of radon – a lung carcinogen – and all six studies revealed lung cancer excesses.

In 2002 NIOSH issued a Hazard Review.

Health Effects of Occupational Exposure to Respirable Crystalline Silica –

In the abstract to this review, the following points were made:

1. Occupational exposures to respirable crystalline silica are associated with the development of:-

Silicosis

Lung cancer

Pulmonary tuberculosis

Airways diseases

2. Such exposures may also be related to the development of:-

Autoimmune disorders

Chronic renal disease

3. Recent epidemiological studies have demonstrated that workers have a significant risk of developing chronic silicosis when exposed to respirable crystalline silica over a working lifetime at current OSHA permissible exposure limits, or the NIOSH recommended exposure limit of 0.05 mg/m<sup>3</sup> as a time weighted average (TWA) for up to a 10 hour workday, during a 40 hour work week.

4. However, until improved sampling and analytical methods are developed for respiratory crystalline silica NIOSH will continue to recommend an exposure limit of 0.05 mg/m<sup>3</sup> as a time weighted average for up to a 10 hour workday during a 40 hour work week, over a working lifetime.

## **Workplace Exposure Standards and Hazard Management in the Extractive Industries**

Reference has been made to workplace exposure standards (WES) when commenting on the dust levels measured, whether it is total dust, respirable dust or respirable quartz. It is also clear that the standards vary with the length of time of the work shift. Current New Zealand standards are in line with Australian standards which are not as rigorous as those recommended by some authorities in some overseas countries, notably the United States.

Currently the ACGIH recommendation for respirable quartz is  $0.05\text{mg}/\text{m}^3$  and the NIOSH Recommended Exposure Limit is similar. However, environmental standards are only part of hazard management. Mastromatteo<sup>9</sup> at Minesafe International 1990 – an international conference on occupational health and safety in the mineral industry made the following important points when introducing his paper on Threshold Limit Values and the Development of Regulatory Exposure Standards for the Workplace.

1. The control of workplace health hazards involves a multidisciplinary team and an integrated approach.
2. The development of exposure limits represents but one facet of the control programme.
3. An integrated approach includes:
  - i appropriate application of process control measures
  - ii administrative control measures
  - iii health surveillance and monitoring of exposed workers
  - iv the use of personal protective equipment
  - v the substitution of hazardous chemicals by less toxic chemicals
  - vi monitoring of the workplace environment

Further, when referring to exposure standards in the workplace environment Mastromatteo makes this point.

“Throughout their development and history, TLV’s were intended as guidelines for use by occupational health professionals. They were never intended to define fine lines between safe and unsafe exposures.” They “refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect” but that “a small percentage may experience discomfort from some substances at or below the threshold limit; a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness”.

It is important, therefore, to see TLV’s now designated WES’s in perspective, as an important part of a total hazard management package and not to see them as the only basis of determining the presence or absence of hazard and not attaching undue importance to the WES level itself as a measure of safety at work.

However, where the impact on health of a workplace hazard is long term, as it is with exposure to silica dust then the best measure of both the hazard and its significance (ie health risk) is regular environmental monitoring. It is of concern therefore that some 13% of the respirable quartz levels were above the WES at the time of sampling. This figure increases to 61% when current US exposure level recommendations are applied.

## **Conclusion**

This report has obvious limitations such as the cross sectional nature of the results and the possibility that the lung function results were measured on a survivor population. Nevertheless both the dust levels and health findings are reasons for concern in this industry.

# Recommendations

1. That the New Zealand standard for respirable quartz for an 8 hour day exposure be reduced to  $0.05 \text{ mg/m}^3$  and that workplace monitoring be carried out 3 monthly.
2. That all employees in the extractive industry have a medical examination at the commencement of employment which will include a chest x-ray and a lung function test using spirometry which includes a measure of the mean expiratory flow rate. The person carrying out the spirometry must be trained to ATS standards.
3. That all employees have an annual respiratory questionnaire and lung function test and a regular two yearly chest x-ray.
4. That dust extraction methods be introduced where practicable.
5. That personal respiratory protection be provided when dust levels cannot be controlled against inhalation of respirable quartz.

# A Case Study :

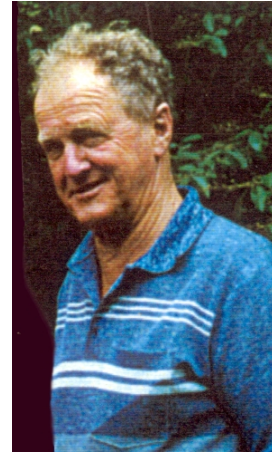
## Lung Fibrosis in a Quarry Worker

### Work History

Mr Eggers left school at 16 doing farm work for five years before beginning his lifelong job as quarryman/crusher/operator/loader driver. His work included working in gravel crushing plants all over the South Island, both at quarries and riverbeds. The plant was usually run dry and was very dusty. He was not given respiratory protection until 1985.

He stopped work in 1988, aged 55, because of increasing shortness of breath.

Mr Eggers died of respiratory failure in 2002.



### Medical History

He first noticed shortness of breath on exertion about 1981 and at that time it was recorded in the physician's report that a chest x-ray reported right basal pleural fibrosis.

In 1988 the physician noted a steady deterioration in effort tolerance such that he was breathless moving around during normal activities. He had no acute respiratory events such as infection nor did he have bronchospasm, pleural pain, cough or phlegm.

Mr Eggers was an ex-smoker of 25 pack years, stopping in 1978.

On his final admission to hospital in November 2002 following a collapse and loss of consciousness the following clinical diagnoses were made: chronic respiratory failure, obstructive lung disease, pulmonary hypertension, arterial sclerotic circulatory disease and a history of interstitial pulmonary fibrosis. It was also recorded that one year prior to death Mr Eggers was found to have a grossly enlarged right auricle and ventricle.

### Investigations

#### Chest X-Ray

A review of x-rays since 1988 noted bilateral apical pleural thickening, lesser pleural thickening laterally both costophrenic recesses, linear shadowing both mid zones consistent with parenchymal fibrosis.

#### Lung function

	1988	2000
FEV1	1.59 (3.77)	1.23 (3.09)
FVC	2.43 (4.78)	1.88 (3.99)
DLCO	17mL/min (54% N)	

# Post Mortem Examination

A chest only post mortem examination was carried out.

Lungs: The pleural space was obliterated bilaterally by dense fibrous adhesions. All pleural surfaces were covered by large thick white plaques with a similar patch over the left pericardial sac. Microscopically the pleural plaques were composed of nearly avascular bundles of collagen covered by a thin membrane of serosal cells. There was interstitial thickening of the alveolar walls. No silica-anthracotic nodules were identified, no ferruginous bodies were shown although there were excessive numbers of iron filled macrophages throughout the lung. Polarisation studies revealed silica particles distributed within the perivascular and peribronchial aggregates of anthracotic macrophages.

## Acknowledgement

Mrs June Eggers expressed willingness to see public recognition of the consequences of Mr Eggers' work on his health.

ID:   
 Sex: Male   
 Height: 175 cm   
 Date: 05/04/80   
 Age: 67   
 Time: 15:10   
 Face: CAUCASIAN

### All Spirometry Results

TEST	BASE		
	1	2	3
FEV1	1.23	1.17	1.15
FVC	1.88	1.85	1.86
PEF	257	247	203
UAR	0	-2	-3

Best Spirometry Result: Base = 1

	Base	%Pred	PostBD	%Pred	%Chs	Normal			
						Min	Pred	Max	
FEV1	1.23	40				2.25	3.09	3.93	L
FVC	1.88	47				2.99	3.99	4.99	L
PEF	257	54				361	480	600	L/M
FEV1%	65	87				63	75	87	%
F50	0.77	18				2.03	4.20	6.37	L/S
F25	0.27	18				0.20	1.48	2.76	L/S
MEF	0.69	21				1.50	3.21	4.92	L/S
I50	3.85								L/S
R50	20								%
PIF	4.34								L/S
MVV	46								L
FET	8.43								S

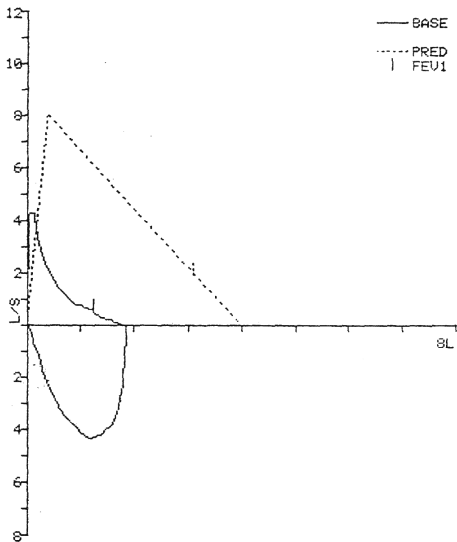
Micro Medical Ltd.

Cat No. PSA 1600

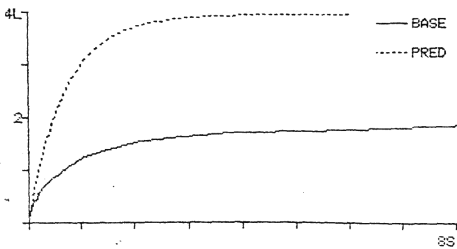
Lung Age: More than 100 years.

Interpretation: Severe Restriction.

### Flow/Volume



### Volume/Time



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3. de Hamel FA, de Souza P. *Lung function and chronic bronchitis in New Zealand*. 1978 Department of Health Special Report Series 52. Occupational Health and Toxicology Branch, Department of Health on behalf of the Department of Preventive and Social Medicine, University of Otago.
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8. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Vol 68 1997 Silica [14808-60-7] crystalline (inhaled in the form of quartz or cristobalite from occupational sources) Lyon International Agency for Research on Cancer.
9. Mastromatteo E *Threshold limit values and the development of regulatory exposure standards for the workplace*. J Occup Health Safety – Aust NZ 1990; 6(8):503-508

# Appendix 1

## *Extractive Industry Study 1999/2000*

### Personal Details of Person Investigated

1. Surname
2. Given Names
3. Home Address
4. Telephone Numbers     Home: \_\_\_\_\_  
   Work: \_\_\_\_\_
5. Date of Birth? \_\_\_\_\_
6. Gender Male          Female
7. Ethnic Origin?     European                           
   Maori                                           
   Pacific Island                                   
   Other       
If other please specify below \_\_\_\_\_
8. Name and Address of Family Doctor? \_\_\_\_\_
9.     **Occupational History**  
Current Employment \_\_\_\_\_  
Who do you work for? \_\_\_\_\_  
How long have you worked in this industry? \_\_\_\_\_  
How long as a minor/quarryman \_\_\_\_\_  
If you have had previous employment as a minor/quarryman, where? \_\_\_\_\_  
How long? \_\_\_\_\_  
Daily Exposure – What is your average daily exposure?  
Very Little              About half a Day                      All day
10.    **Smoking**  
Have you every smoked for as long as a year?     Yes          No   
At what age did you begin smoking? \_\_\_\_\_  
On average, how many cigarettes did you/do you smoke each day? \_\_\_\_\_  
If you no longer smoke, how old were you when you stopped smoking? \_\_\_\_\_

## 11. Chest Symptoms

	Yes	No		Yes	No
Do you wheeze?	<input type="checkbox"/>	<input type="checkbox"/>	Does it occur walking up hills?	<input type="checkbox"/>	<input type="checkbox"/>
Does it come on at work?	<input type="checkbox"/>	<input type="checkbox"/>	Does it occur walking on the flat?	<input type="checkbox"/>	<input type="checkbox"/>
Does it come on after work?	<input type="checkbox"/>	<input type="checkbox"/>	Do you wake up at night short of breath	<input type="checkbox"/>	<input type="checkbox"/>
Does it improve away from work?	<input type="checkbox"/>	<input type="checkbox"/>	Are you an asthmatic?	<input type="checkbox"/>	<input type="checkbox"/>
Do you have chest tightness?	<input type="checkbox"/>	<input type="checkbox"/>	Are you on treatment?	<input type="checkbox"/>	<input type="checkbox"/>
Does it come on at work?	<input type="checkbox"/>	<input type="checkbox"/>	List type of treatment:		
Does it come on after work?	<input type="checkbox"/>	<input type="checkbox"/>	1.		
			2.		
			3.		

## 12. Past Respiratory History

Does it improve away from work?	<input type="checkbox"/>	<input type="checkbox"/>	Have you had asthma?	<input type="checkbox"/>	<input type="checkbox"/>
Do you cough?	<input type="checkbox"/>	<input type="checkbox"/>	Is there a family history of asthma?	<input type="checkbox"/>	<input type="checkbox"/>
It is present for 3 months or more for 2 years?	<input type="checkbox"/>	<input type="checkbox"/>	Have you had hayfever?	<input type="checkbox"/>	<input type="checkbox"/>
Do you bring up phlegm	<input type="checkbox"/>	<input type="checkbox"/>	Have you had eczema?	<input type="checkbox"/>	<input type="checkbox"/>
Do you bring up phlegm for 3 months or more for 2 years?	<input type="checkbox"/>	<input type="checkbox"/>	Have you had pleurisy?	<input type="checkbox"/>	<input type="checkbox"/>
Do you get short of breath?	<input type="checkbox"/>	<input type="checkbox"/>	Have you had any other chest condition?	<input type="checkbox"/>	<input type="checkbox"/>
			List other Chest Conditions:		
			1.		
			2.		
			3.		



**13. Spirometry**

	Predicted	Sample 1	Sample 2	Sample 3
FEV 1				
FVC				
FEV 1 %				

Date of Test

Type of Spirometer

Date Calibrated

Name of Nurse

**14. The Worksite**

How many miners/quarrymen are employed?

Type of quarry/mine

Any dust tests done?

When?

How many?

Are results available