Methodology in assessing long-term respiratory risk in longwall miners

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Abstract

A study to examine respiratory disorder risk in longwall miners is being considered. The method to be used in examining this issue is the correlation of long term cumulative exposure with changes in respiratory symptoms and functions. Measurement of respiratory dust, assessment of cumulative exposure is considered in the context of method and statistical validity. The method of estimating cumulative exposure considers structured interviews with longwall mine workers with more than ten years experience.

The process of estimating change in respiratory function involves accessing and analysing medical records obtained as part of the Coal Workers Health Scheme. Factors that may adversely distort results such tobacco smoking are identified and treated separately. The longer term objective is to establish parameters for interventions when elevated risk is identified.

Introduction

The recent Senate Community Affairs References Committee, 'Inquiry into workplace exposure to toxic dust' (2006) has called on government and industry to re-evaluate their mechanisms for controlling adverse effects from toxic dusts in the workplace. The perception of dust related health risk in the coal mining industry has largely been dispelled by a number of Australian studies that sought to monitor dust related disease known as Coal Workers Pneumoconiosis. Since the mechanisation of coal mines in the 1960s, the levels of coal dust to which coal miners have been exposed has been relatively low until the advent of longwall mining systems in Queensland in the late 1980's. Longwall face operators are exposed to dust levels that are elevated and may exceed the statutory limits in about 15% of samples taken.

Given that these longwall operations have been operating in Queensland for 20 years, some re-assessment of dust disease risk is warranted. Studies in the United Kingdom (Rudd, 1998), have established that coal mining dust related disease extends beyond Coal Workers Pneumoconiosis to include silicosis, chronic bronchitis, congestive obstructive airways disease (COAD) and emphysema. The latter three disorders occur in small numbers in the general population, but as indicated in the UK coal industry studies, they are more prevalent in coal mine workers.

Aim and Objectives

A research project is being developed to examine whether there is any evidence that the respiratory health of longwall miners is being adversely affected by exposure to dust in longwall operations.

In order to achieve the study aim, it is necessary to:

a) Review previous studies in terms of method and findings;
b) Estimate the exposure of workers at various face positions at each Queensland longwall mine;
c) Identify the cumulative dust exposure of a sample of longwall miners,

d) Correlate the exposure against miner's change in respiratory function and respiratory symptoms,
e) Determine the nature of the dose-response characteristics of dust related reduction in respiratory function and
f) Assess trigger levels of cumulative exposure that might be associated with unacceptable health outcomes.

Review of Previous Studies
Rathus and Abrahams (1984) identified coal miner's pneumoconiosis as a serious occupational health issue faced by coal miners who had been in the Queensland coal mining industry through the 40's, 50's and 60's by identifying 75 cases of dust related respiratory disorders showing on a chest x-ray study. Ham (2000) reported no new cases of coal mining related respiratory disorders requiring an ILO pneumoconiosis classification from x-ray screening from 1993 to 1998. This study identified between 20 and 30 cases of congestive obstructive airways disease that may have been caused or exacerbated by dust exposure. The study also showed that the respiratory function of underground coal miners was generally better than would be expected in the general population (shown as predicted values). There was however one exception which was one of the older longwall mines (Mine E) where reduced respiratory function was demonstrated as shown in table 1.

Table 1 Spirometry of Non-Symptomatic Non-Smokers - Underground Mines (FEV1/FVC%) (after Ham, 2000)

Mine		E	B	C	F	E	A	U/G	AllMines
Workers		157	218	112	62	150	157	836	2953
Observed Values	Av.	81.10	83.42	85.53	85.97	84.90	84.07	83.88	83.34
	Std Dev	5.33	6.52	6.80	5.78	6.49	8.19	6.84	6.59
Predicted Values	Av.	82.62	82.56	82.82	82.78	82.69	82.19	82.58	82.02
	Std Dev.	2.33	2.15	1.88	1.79	2.21	2.00	2.08	2.28

In relation to environmental monitoring, Bofinger, Cliff and Tiernan (1995) identified that underground operations had respirable dust levels that exceed the exposure standards in about 15% of the samples for some work groups.

Analysis of mortality data by Bofinger and Ham (2002) identified that 232 coal miners (and ex miners) from New South Wales had been reported as dying from respiratory disease from 1980 to 2000. Further analysis showed that this represented 10% of deaths where, in the general population, only 6.4% of died from this disorder. Analysis by Ham (2004) showed that the average at death from respiratory disease in coal miners was 73, compared with the expected average age of 77 for respiratory disease in the general population. Further work by Ham (2006) expressed these results in terms of burden of disease – life years lost. The result was that the 232 respiratory related deaths represented a loss of 820 life years. This can also be expressed as a risk of 0.3 life years lost across the whole mining industry (1980 to 2000 data set).

Kizil and Donoghue (2001) examined the New South Wales respiratory dust exposure data. Their analysis considered the respiratory health risk based on and average exposure of 1.5 mg/m^3. Using this value, they considered dose-response studies from the United Kingdom and the United States to predict New South Wales health outcomes for pneumoconiosis and massive progressive fibrosis. They also estimated the average loss of forced expiry volume for 1 second (FEV1) to be 73.7 ml over 40 years. At an average level of 1.5 mg/m^3 exposure over a working career, the study concluded that 1 in 500 longwall miners may die from progressive massive fibrosis.

Dust Emission Data

An analysis was undertaken of samples collected by the Department of Natural Resources and Mines from 1995 to 2000 to assess the validity of the sampling frequency (Ham 2002) as shown in Table 2.

Table 2: Dust and Silica failures and percentage failures

	Dust			**Silica**		
Position	No of Samples	No of Failures	% of Failures	No of Samples	No of Failures	% of Failures
Bolter	180	11	**6.1**	161	16	**9.9**
Cablehand	82	9	**11.0**	73	5	**6.8**
Chocks	205	31	**15.1**	199	33	**16.6**
Continuous miner	158	13	**8.2**	142	22	**15.5**
Maingate	54	6	**11.1**	48	5	**10.4**
Shearer	187	23	**12.3**	171	15	**8.8**
Shuttle Car	129	5	**3.9**	117	3	**2.6**
All positions	1,076	105	**9.8**	986	103	**10.4**

The high variability of the concentrations of respirable dust was identified as an issue that might adversely impact on a reliable estimation of cumulative exposures. The study identified that quarterly respiratory dust levels in surveys were generally related to mine production but did not otherwise fluctuate over time. This finding provided an opportunity to improve the previous estimate of the average variance. The power calculation was undertaken to estimate the number of samples that would be required to provide an reliable estimate of the mean exposure for each position at various mines. Given the long term nature of the exposure, it is argued that for the purpose of a safety management system, should allow an assessment of dose related change in the two of the five yearly health screening cycle at a reliability of 20% in the estimate of the mean. Using this approach, and considering the variability in dust measures at various mines, Table 3 makes recommendations as to sampling frequency. The key issue is that low variability leads to a more reliable estimate of exposure for a set number of samples. High variability may also be associated with less that adequate dust control.

Table 3 Mean exposure of coal miners to respirable dust and recommended sampling

Mine	Position	Mean	Variance	Sample Number required given variability		Samples/year
				10%	20%	20% variability
A	Shearer	1.79	1.442	475	119	12
B	Chocks	1.88	0.617	184	46	4
B	Shearer	2.05	1.497	375	94	9
C	Bolter	1.02	0.287	288	72	8
C	Cable	1.40	0.626	337	84	9
C	Cont. Miner	1.59	2.215	916	229	23
C	Shuttle Car	0.93	0.155	188	47	5
D	Bolter	0.78	0.046	79	20	2

Estimation of Exposure

The strategy planned for the estimation of dust exposure of individuals is to conduct structured interviews with longwall miners who volunteer to participate in the study. Data that will be collected includes:

- Face positions undertaken including data on mines and years,
- Type and frequency of respiratory protection used,
- Smoking history and
- A respiratory symptoms survey.

The participants will also be required to complete a Coal Industry Medical Release form to allow access to the participants' confidential medical information.

By correlating the exposure to respiratory dust and length of exposure, the cumulative dose will be estimated by applying a standard respiratory rate factor (Seixas et al., 1991).

Acquisition of respiratory and related data

The signed Coal Industry Medical Release forms will assist in obtaining the medical information from either the relevant medical practitioner or the Health Surveillance Unit of the Department of Natural Resources and Mines (Ham 2000). The change in respiratory function will be extracted with other relevant information needed for validity checks and to identify factors that have potential to impact on the validity of the analysis. This will include factors such as smoking habits, previous work in high dust environments and previous respiratory conditions.

Analytical Approach

The aim of the analysis is to separate out sub-groups with confounding factors such as tobacco smoking, previous dust exposure, previous respiratory disorders. Each of these sub-groups will be analysed separately provided the sub group is of a statistically valid size and the individuals identity cannot be determined by persons who do not have authorised access to confidential health information.

The analysis comprises four components comprising the following:

1 Estimate the dose for each longwall position in each mine over the study period.

2. From structured interviews, determine the period that each subject spent in each longwall position,
3. Determine the cumulative dose of each of the study subjects,
4. Determine the change in respiratory function for each study subject over the study period,
5. Correlate the cumulative dose against the change in respiratory function,
6. Determine the level of dose that becomes a significant predictor of an adverse health outcome.
7. Determine how other factors such as smoking habits, previous dust exposure and medical conditions such as asthma cause variance from predicted results

Method Issues

The data used for exposure data is based in quarterly dust surveys undertaken by the Department of Natural Resources and Mines as described by Bofinger, Cliff and Tiernan (1995). In order to reduce the variance of the estimates of average variance, the data has been further analysed to take into account variation caused by fluctuations in production and variation over time.

The monitoring procedures collect only respirable dust but research by Jennings and Flahive (2005) suggest that the coarser inhalable dust may have a contribution to certain respiratory disorders. Given that the mining operations are in similar geological conditions, the respirable dust is a reasonable proxy for the total respiratory dust burden

The use of personal protective equipment is expected to have a significant impact on long term respiratory health outcomes. Protection practice should be recorded in the structured interview and considered as a study variable. The reliability of this self-reported factor is of some concern, but some of this error may be reduced by clustering the groups from each mine. The use of respiratory protection is required as a part of the mines' health and safety management systems, but variation in application between mines and mining crews may be a cultural issue in the longwall mining environment. This might be reflected in differences in health outcomes appearing between mines that are otherwise very similar.

Assessment of Risk

Soutar, Hurley and Miller (2004) reported that the epidemiological work undertaken as a part of the study into dust concentrations and respiratory risks in coal miners as a part of the British Pneumoconiosis Field Research Project confirmed numerically that respiratory disease is an indicator of reduced life expectancy. More importantly, the study also determined that cumulative exposure in the absence of clinical symptoms was also a significant indicator of reduced quality of life and reduced life expectancy. The outcome of the current project is to use a dust related decline in respiratory function or the advent of respiratory symptoms as an indicator of the increased risk of an adverse health outcome.

Statistical Issues

In order to reduce the variance of the estimates of average dust exposure, the data has been analysed to take into account variation caused by fluctuations in production and variation over time. Previous work in a Coal Services Project indicated that in some, but not all mines, there was a strong correlation between dust and production. Because the variation in dust levels was not shown to be time dependent, the variance of the mean exposure can be influenced by data points peripheral to the time periods in question. This will have the effect of narrowing the variance of the estimate of the mean exposure estimate and improving the confidence as to whether or not there is a statistically significant relationship.

Further Work

The concepts discussed in this paper have been developed as part of a pilot study to test issues of methodology and data variability. A pilot programs needs to be undertaken and critically reviewed as a part of developing a far wider comprehensive study that provided the necessary evidence to demonstrate the risk associated with exposure to dust in coal mines is effectively managed.

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