Silicosis Compensation in Western Australian Gold Miners Since the Introduction of an Occupational Exposure Standard for Crystalline Silica

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Received 22 January 2002; in final form 15 July 2002

Occupational exposure limits for crystalline silica are under review worldwide because of the large numbers of exposed people and, especially, because of the recent International Agency for Research on Cancer classification of silica as a human carcinogen.

Objectives: The aims of this study were to (i) re-examine the incidence of silicosis in Western Australian gold miners and, using estimates of the total population at risk, (ii) estimate the upper confidence limit for the risk of silicosis in Western Australian gold miners since 1974, when the current exposure standard for crystalline silica was implemented.

Methods: Work histories of cases compensated for pneumoconiosis after 1974 were examined. Numbers of workers in the total workforce likely to be exposed to crystalline silica in Western Australia were estimated as the population at risk.

Results: There were no cases of compensated silicosis in Western Australian miners whose first dust exposure began during or after 1974. The upper 95% confidence interval for this zero rate was estimated to be 4.8 per 100000 person-yr.

Conclusions: There have been no compensated cases of silicosis in Western Australia among miners first exposed to crystalline silica after introduction of the current exposure standard. A rate of compensated silicosis higher than five cases per 100000 person-yr is unlikely.

Keywords: exposure standards; occupational exposure; silicosis

INTRODUCTION

In Western Australia, the current occupational exposure standard for crystalline silica is 0.20 mg/m³. This standard was introduced to allow for an ‘acceptable’ lifetime risk of silicosis. In 1974, the Western Australian Ventilation Board was set up to regulate the implementation of this exposure standard throughout the mining industry. In 1999, an analysis of records of cases applying to the Western Australian Pneumoconiosis Medical Panel (PMP) for compensation for silicosis reported that no cases of silicosis had occurred among Western Australian workers first employed in the industry since 1974 (Wan and Lee, 1999). It was concluded that with the current silica exposure standard, workplace practices were adequate to protect the health of workers in the mining industry. However, there are several issues that need to be considered before such an assumption can be justified.

The PMP compensation data contain some information regarding occupational history, the presence of disease and the level of disability where applicable. However, it does not collect any denominator data that provide information on the number of subjects at risk, to permit the calculation of disease rates. The confidence interval for this observed zero value is therefore unknown, but is required for risk assessment. If any cases do occur, it is clear that the exposure standard is not a “no observed adverse effect
level’ (NOAEL). In order to assess the reliability of the previously observed NOAEL or zero rate of silicosis (compensated) an estimate of the population at risk is required, so that an upper confidence interval can be placed on the zero value (analogous to a detection limit in industrial hygiene dust sampling). A simple estimate of the annual net workforce is not sufficient, because the risk of silicosis increases with both duration and intensity of exposure to silica and also with time since exposure started. Thus, rather than reducing the risk of disease by reducing the exposure, the risk since 1974 might appear to be reduced by increasing staff turnover rather than by reducing levels of exposure in the workplace. Some information on staff turnover and its association with age and duration of employment is therefore needed.

The extent to which people awarded compensation for silicosis represent all exposed subjects with the disease in a defined area is not known. It is widely acknowledged that compensated silicosis tends to represent the more severe cases and not incident silicosis, which can only be determined fully by the complete radiographic screening of a population at risk. Previous work has suggested that Western Australian gold miners with concomitant diseases and symptoms (especially from smoking-related airway disease) are more likely to apply for silicosis compensation (de Klerk and Musk, 1998). On the other hand, simple silicosis can be asymptomatic and have no significant effect on lung function. Therefore, an unknown number of people could have diagnosable silicosis without experiencing symptoms to warrant seeing a doctor and obtaining a chest X-ray. Consequently, unknown numbers of undiagnosed cases of silicosis may exist.

However, the rate of applications for compensation made to the PMP by Western Australian gold miners has traditionally been very high. The majority of Western Australian gold miners in the past were familiar with the PMP because of the social cohesiveness of the industry and the strict health surveillance system required by the Mines Regulation Act prior to 1996. It is believed that many regarded silicosis compensation as a pension for which there was no penalty for applying. Therefore, many would have been screened by the PMP when they retired. In other industries, similar screening has not been conducted and the tendency to make an application at the time of leaving the industry is almost certainly less. Yet, it is generally well known that the majority of workers exposed to crystalline silica in Australia work outside the mining industry (Nurminen et al., 1992). With the repealing of the Mines Regulation Act and privatization of health surveillance in the Western Australian mining industry in 1996, however, regular radiographic screening of mine workers in this state has disintegrated.

The primary aims of this study were therefore:

1. to determine if any new cases of silicosis have occurred among Western Australian gold miners whose exposure to crystalline silica began after 1974 when the current exposure standard was implemented;
2. to estimate an approximate denominator for the number of cases (i.e. the numbers of gold miners exposed);
3. hence, to estimate the upper confidence limit for the observed rate of silicosis at the current exposure standard for crystalline silica in Western Australia.

MATERIALS AND METHODS

Identification of claimants and their work histories

The PMP is a panel of physicians appointed under the Workers’ Compensation and Rehabilitation Act of 1981 to assess all applications for compensation for disability resulting from pneumoconioses, mesothelioma and lung cancer acquired through occupational exposures. The assessment involves a review of the applicant’s medical and occupational histories, a physical examination, a plain chest X-ray and pulmonary function tests, supplemented with any CT scans, histopathology and additional tests or reports where indicated. Data retained by the PMP include demographic information, a comprehensive occupational history, the medical examination and the Panel’s determination.

Because of a legal ruling brought in after action from lawyers representing former asbestos producers, the PMP has not been permitted to make a diagnosis of ‘silicosis’ or ‘asbestosis’ since June 1992, but has been required to record ‘pneumoconiosis’ to conform with the working of the Act. PMP records were searched for all subjects awarded compensation for either silicosis or pneumoconiosis from the end of 1998, working backwards chronologically through the records. The occupational history in the PMP record for each case was examined to ascertain if the applicant’s occupational exposure to silica dust occurred prior to 1974. Work histories were also sought from miners’ record cards held at the Perth Chest Clinic, which document previously compulsory chest X-ray screenings in the mining industry. These include details of dates of employment at each mine, job descriptions and other clinical information which had been entered each time a subject attended for the issue or renewal of a mine worker’s health certificate.

Exposure assessment

Gravimetric dust sampling of various mines throughout Western Australia has been undertaken by the Western Australian Government’s Department of Minerals and Energy since 1974, and the results recorded in the Department’s ‘CONTAM’ database.
since 1976. The crystalline silica content of these samples has been estimated using either X-ray diffraction or infra-red spectroscopy. How well actual measures of silica levels conform with the standard could be assessed on a job-specific basis and each claimant’s job history could be assigned a ‘post-standard’ estimate of exposure. However, this information was not available for subjects who had not applied for compensation nor a sample of these. Therefore, estimates of overall levels of compliance with the existing standard and how these have changed over time were used as surrogates for their exposures. Such estimates have been comprehensively estimated up until 1993 by Hewson (1993), but exposures after 1993 are not currently available.

**Estimation of person-yr at risk**

Estimates of the numbers of gold miners in the Western Australian workforce each year were obtained by regression smoothing using data from published cross-sectional surveys of the Western Australian gold mining industry (Holman et al., 1987; Musk et al., 1992; de Klerk and Musk, 1998). The mean age in each sub-group was similarly obtained.

The ‘eligible’ workforce consisted of all subjects known to have been occupationally exposed to dust as gold miners and required to undergo periodic chest X-rays for disability due to dust, who are therefore eligible to apply for compensation. Such regular, compulsory surveillance was superseded by privatized cross-sectional surveys (Miner’s Health Surveillance Surveys) occurring irregularly since 1996. In the 1996 Miners’ Health Surveillance Survey, 14% of the 46216 workers in Western Australian mining industries were required to undergo X-ray screening based on their job title (unpublished data). This number was considered the ‘eligible’ workforce in Western Australia at that time. Similarly, in 1975, 19% of all gold industry employees attended for X-ray and in 1989, 10% of all gold industry employees attended for an X-ray. Therefore, an average of 14% for the whole period was thought to be a reasonable estimate of the ‘eligible’ workforce, despite changes in work practices over that time.

**Statistical methods**

To estimate the number of person-yr at risk of silicosis, life-table methods using Western Australian mining industry workforce data for each year were applied with the following assumptions: the population at risk (eligible workforce) each year was 14% of the total Western Australian mining industry workforce, age was the mean interpolated age in each duration of exposure sub-group, age-specific death rates for all males living in Western Australia in 1991 were applied to adjust for natural attrition in the workforce and those leaving the workforce died at the same rate as those who stayed. Person-years were then summed over all the age period groups within each of four exposure duration categories (0–9, 10–19, 20–29 and 30+ yr of exposure).

Assuming cases occur randomly with a Poisson distribution, then zero cases will occur 5% of the time if three cases are expected. Therefore, 3 divided by the person-yr observed can be interpreted as an upper 95% confidence limit for the true rate of compensated silicosis when observing zero cases.

**RESULTS**

**Implementation of the occupational exposure standard**

According to estimations by Hewson, average silica exposure levels have been maintained below 0.2 mg/m³ since 1977 and have steadily declined each year; even exposure in ‘high exposure jobs’ is thought to have been kept below this level since 1989 (Hewson, 1993). There is no reason to believe that they have not either continued the steady decline reported or at least remained constant.

**Compensated silicosis cases**

After working backwards from 1998, the search for silicosis cases in PMP records stopped at 1978, as no cases recognized in 1978 or 1979 commenced their exposures after 1974 and it became evident that cases diagnosed between 1974 and 1977 would not have done so either. Cases termed ‘asbestosis’ or with asbestos recorded as the cause were excluded. There were 408 compensation applications between 1979 and 1998, with a fairly rapid decline in these numbers over time (Fig. 1). There were no cases whose first ever dust exposure occurred in the Western Australian mining industry (or anywhere else) during or after 1974.

**Person-yr at risk of silicosis**

According to cross-sectional surveys of Western Australian gold miners in 1974 (de Klerk and Musk, 1998), 1985 (Holman et al., 1987) and 1989 (Musk et al., 1992) and Western Australian Miners’ Health Surveillance data from 1996 the duration of employment in gold mining was greatest in 1974, with staff turnover increasing in the industry after 1974 (Table 1). Whereas the total mining industry workforce has steadily increased, the mid 1970s saw the least number of people employed in gold mines in the previous 100 yr (Fig. 2). Thus, while the proportion of new starters in the total Western Australian mining industry workforce has increased necessarily with increasing overall staffing levels, the proportion of workers employed for under 10 yr has increased markedly and there have been concomitant declines in long-stay employees (Table 1). The mining industry...
workforce as a whole also appeared to be getting older (Table 1). Between 1979 and 1993, a total of 61910 person-yr at risk of silicosis was estimated (Table 2). This excluded the first 5 yr spent after first joining the workforce to allow for disease latency.

Upper confidence limit for zero observed cases

Based on the observation of zero cases and the estimate of 61910 person-yr at risk, an upper 95% confidence limit for the rate of compensated silicosis in Western Australian gold miners under current workplace practices is estimated at 4.8 cases per 100000 person-yr (3 ÷ 61910).

DISCUSSION

We have examined the rate of compensated silicosis since the implementation of an occupational exposure standard for crystalline silica among miners known to routinely apply for compensation and for whom exposure and workforce data were known. Our findings support previous results reporting that no compensated cases of silicosis have been observed in Western Australia since the introduction of the occupational exposure standard for silica in 1974. However, given the number of people in Western Australia who are employed in the total mining industry (and therefore at risk of silicosis) and the 95% confidence interval about the zero cases observed, we cannot rule out the possibility of up to nearly five cases per 100000 person-yr under current exposure conditions.

Our analysis is limited to compensated silicosis cases, as silicosis is currently identifiable only through compensation records. Those gold miners applying for compensation may not, however, be the only workers with silicosis. Numerous cases of simple pneumoconiosis could exist undetected, because they have not developed symptoms and/or made a claim for compensation. However, gold miners represent a highly suitable group in which to examine the effects of a crystalline silica exposure standard, because of their distinct exposures to crystalline silica and, historically, they have often been dedicated to employment within the gold mining industry. We
believe that the high rates of applications for compensation in Western Australian miners and the availability of exposure and workforce data on Western Australian gold miners, in the absence of data on radiographic silicosis, justify the use of compensated silicosis in this study.

Errors may exist in the data used for our analysis that are related to the estimate of person-yr and silica exposure levels, but it is not possible to identify how large or in which direction these errors might be. The methods used to estimate the person-yr at risk (from which zero cases arose) were probably the most problematical. This strongly suggests that monitoring of the numbers of workers joining, leaving and remaining in the industry and their work histories, in addition to exposure monitoring, is necessary for adequate industry surveillance to take place in Western Australia. Knowledge of historic levels of measured exposure to silica is also important. If workplace hygiene conditions are such that the exposure standard is often exceeded, only intermittently maintained or the standard is never even approached, these findings and their generalizability to other industries are questionable.

Silicosis (excepting acute silicosis after intense exposure) usually takes many years to develop after silica exposure has begun and, therefore, may not occur until long after a subject has left the industry where the relevant exposure occurred (Glover et al., 1982). An earlier study of Western Australian gold miners surveyed in the 1970s found that no subject was compensated within 5 yr of commencing exposure, but after 5 yr the rate increased rapidly to a maximum at approximately 30 yr (de Klerk et al., 2002). This current study of more recently employed Western Australian gold miners has a maximum follow-up period of only 26 yr since the occupational exposure standard was introduced and the rate of silicosis may not have peaked yet, even in those workers who started as early as 1974, with the rate in the more numerous later starters (Fig. 2) still to peak after that.

Crystalline silica (the most abundant form of silica) has been classified as a human carcinogen by the International Agency for Research on Cancer (IARC, 1997) and as such, no level below which there is no risk of lung cancer is likely to exist. There is therefore a need to minimize exposures to the lowest sustainable level. Previous studies of Western Australian gold miners and other occupational cohorts exposed to crystalline silica have shown increased lung cancer rates (Steenland et al., 2001) and the detection of early silicosis is one way of monitoring silica exposure in the mining industry prior to the emergence of lung

Table 2. Estimated person-yr at risk of silicosis for gold miners in Western Australia, 1979–98

<table>
<thead>
<tr>
<th>Years of exposure</th>
<th>Person-yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–9</td>
<td>54917</td>
</tr>
<tr>
<td>10–19</td>
<td>6818</td>
</tr>
<tr>
<td>20–29</td>
<td>175</td>
</tr>
<tr>
<td>30+</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>61910</td>
</tr>
</tbody>
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Subjects with more than 5 yr since first exposure, first exposed after 1974.
cancer. However, unlike asbestos exposure, for which the elevated risk of lung cancer has been consistently shown to be increased irrespective of the presence of asbestosis, it is not yet confirmed whether the risk of lung cancer in workers exposed to silica is increased irrespective of the presence of silicosis (de Klerk and Musk, 1998; Checkoway and Franzblau, 2000; Finkelstein, 2000). It will be necessary to determine if further (uncompensated) cases of silicosis exist among Western Australian gold miners in order to pursue this issue further.

Acknowledgements—The authors wish to thank Mrs Nola Olsen for searching the PMP records and miners’ record cards for this study. This project was approved by the University of Western Australia’s Human Research Ethics Committee and the Western Australian Health Department’s Confidentiality of Health Information Committee and was funded by the National Occupational Health and Safety Commission (NOHSC) of Australia, as part of a review of the National Occupational Exposure Standard for Crystalline Silica.

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