Silicosis and Tuberculosis in Zambian Miners

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Silicosis and tuberculosis (TB) are significant mining-related illnesses in developing countries. The purpose of this study was to examine annual cases of these diseases in Zambian miners, including comparison of periods before (1960–1970) and after (1992–2002) the arrival of the HIV/AIDS pandemic. The Occupational Health and Safety Research Bureau of Zambia reported 2,114 cases from 1945 to 2002. Of these, 22.7% were silicosis, 65.4% TB, and the remaining 11.9% silicotuberculosis. While silicosis cases decreased from 28.6% to 12.4% with the arrival of HIV/AIDS, there was a large increase in tuberculosis cases (37.1% to 86.1%), with a corresponding decrease in silicotuberculosis cases (34.3% to 1.6%). Although silicosis remains an occupational health issue in Zambian miners, the most significant problem appears to be the marked increase in cases of TB. *Key words*: silicosis; tuberculosis; HIV; AIDS; Zambia.

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Silicosis is a chronic respiratory disease primarily associated with exposure to free crystalline silica.[1] This disease is sometimes asymptomatic.[2] Particle size, the crystalline nature of the silica, the duration of dust exposure and the time from first exposure to diagnosis are important factors in the development of nodular pulmonary fibrosis.[3–5] Workers in occupations such as mining, tunneling, quarrying, and foundry casting are at high risk for developing silicosis.[6] There is additional evidence that freshly crushed silica is the most toxic form of free crystalline silica.[7]

With increasing lung dust burden, the risk of pulmonary tuberculosis (TB) increases, and this risk is highest in individuals with established silicosis.[7] Between 1950 and 1959, Zambian copper miners with silicosis developed TB at the rate of 3% per year.[8] The annual new-case rate in this study was 30 times greater among miners with silicosis than among miners without it. HIV infection is an independent risk factor for the development of TB in miners. Silicosis and HIV infection together confer a multiplicative risk for the development of TB. HIV prevalence in the general population of Zambia is currently estimated to be 28% in the 15–49-year age group for urban areas, with an adult prevalence of 14% in rural areas.[9] When considering social and economic conditions, rates among miners may be even higher.

The main objective of this study was to examine the trends in the numbers of new cases of silicosis, TB, and silicotuberculosis from data obtained from the Occupational Health and Safety Research Bureau (OHSRB) of Zambia. The specific goals were to assess the relative percentages of silicosis, TB, and silicotuberculosis cases before and after the arrival of the HIV/AIDS epidemic and to determine the mean ages at which these occupational diseases were diagnosed.

MATERIALS AND METHODS

Zambian miners who develop silicosis or TB are compensated through the statutory requirement of the Workers Compensation Act (10) 1999. This act supersedes the former Pneumoconiosis Act (217). Under the Workman's Compensation Act, a worker seeking compensation must have been working in a designated "pneumoconiosis scheduled area." The OHSRB database contains information about each miner compensated under this act, including date of birth, date of death, date of disease certification, disease (silicosis, TB, or silicotuberculosis), and stage of silicosis. The OHSRB occupational physician uses the International Labor Organization (ILO) standards in interpreting annual chest radiographs and certifying the conditions present. Miners whose radiographs are seen as abnormal during annual medical examinations and are in category 1/1 and above according to the ILO standards are diagnosed as having silicosis. Diagnoses of TB and silicotuberculosis are determined by the occupational physician based on radiographic findings combined with consistent clinical history. Miners are compensated only once, and thus each entry in the OHSRB database represents a unique miner.

The present silicosis study evaluated the records of Zambian miners who were compensated from 1945 to 2002 for occupational diseases. It was possible only to determine the number of new cases of silicosis and TB in a given time period, and not the incidence rate, due to limitations in the database associated with ascertain-

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TABLE 1 Distribution of Ages at Onset of Disease among Miners (1945–2002)

	Cases No. (%)	Age Mean ± SD.	Age Range
Silicosis	542 (22.7)	52.4 ± 9.1	18–82
Stage 1	119 (22.0)	49.4 ± 7.5	34–72
Stage 2	309 (57.1)	53.0 ± 9.2	18–82
Stage 3	114 (21.0)	54.0 ± 9.7	29–78
Tuberculosis	1,563 (65.4)	42.2 ± 7.6	17–79
Silicotuberculosis	284 (11.9)	51.4 ± 8.4	27–76

ing worker populations in which the cases occurred. The OHSRB does not collect employment statistics or the numbers of individuals deemed at risk. The database also does not provide information about the HIV status of the miners.

RESULTS

An analysis of the OHSRB database indicates that 2,114 Zambian miners received compensation for silicosis, TB, or silicotuberculosis from 1945 to 2002. These reported cases stem from data recovered from nine mines operating in Zambia. These are major mines in the Copperbelt and Central provinces, and include both underground and open pit mines. The distributions of diseases and ages of onset are shown in Table 1. Ages of these miners ranged from 17 to 82 years. The average age for onset of disease was lowest for TB, followed by silicotuberculosis and silicosis.

When divided into five-year intervals, the number of new cases of silicosis appears cyclical, with large growth in 1965–70, 1981–85, and 1991–95 (Figure 1). With the exception of a recent decline, the total number of reported cases of TB increased drastically over this period. Interestingly, the data indicate a concurrent decrease in the number of cases of silicotuberculosis. For a single mine, available employment information included the total number of miners employed by year. This allowed for an analysis of the incidence rates of silicosis, TB, and silicotuberculosis for this operation over a nine-year period (Figure 2). In the last two years for which data were complete (1999–2000), there was an apparent decrease in the incidence of TB.

The pre-HIV/AIDS era was defined as the ten-year period from 1960 to 1970, in which no HIV/AIDS case is known to have been recorded. The post-HIV era was defined as the ten-year period from 1992 to 2002, when there was a high prevalence of HIV/AIDS in Zambia. This analysis was performed to determine the possible effects of HIV/AIDS on the relative percentages of the diseases diagnosed. Figure 3 shows the occurrences of silicosis, TB, and silicotuberculosis before and after the arrival of the HIV epidemic. Prior to the HIV epidemic, 133 cases (38.2% of the total) were silicosis, 99 cases (28.4%) were TB, and 116 cases (33.3%) were silicotuberculosis. After the arrival of HIV/AIDS, 114 cases (11.8% of the total) were silicosis, 835 cases (86.5%) were TB, and only 16 cases (1.7%) were silicotuberculosis.

Categorical analysis of the proportions of disease according to age categories (30s, 40s, and 50s) was done for the periods before and after the onset of the HIV epidemic (Table 2). Although the percentage of tuberculosis cases was highest for miners in their 30s both before and after the arrival of HIV/AIDS, the per-

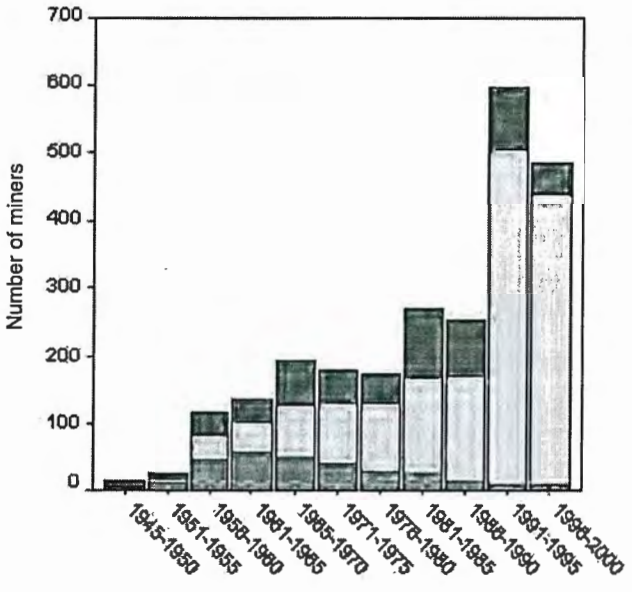

Figure 1—Silicosis (black bars), tuberculosis (light grey bars), and silicotuberculosis (dark grey bars) cases by five-year periods of disease onset (1945–2000).

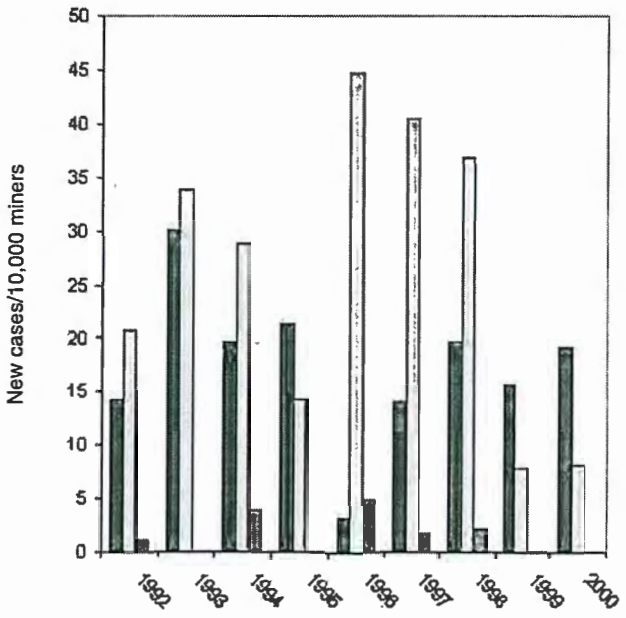

Figure 2—Silicosis (black bars), tuberculosis (light grey bars), and and silicotuberculosis (dark grey bars) rates for a single mine.

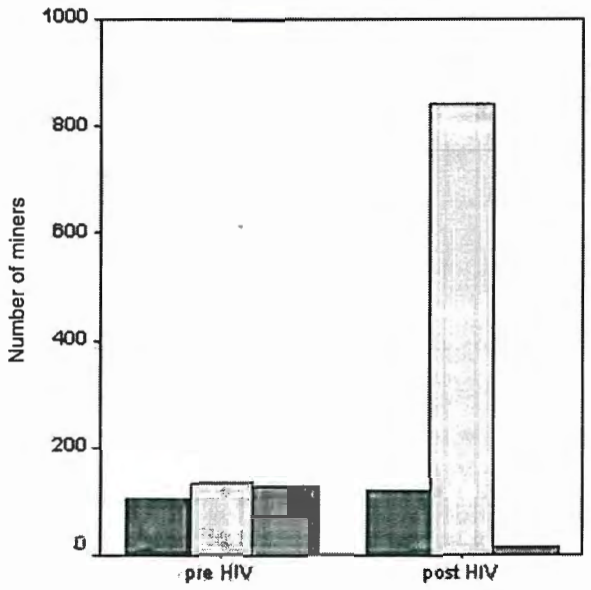

Figure 3—Cases of silicosis (black bars), tuberculosis (light grey bars), and silicotuberculosis (dark grey bars) in the pre- (1960–1970) and post-HIV (1992–2002) eras.

centage increase was most marked for miners in their 40s and 50s. The mean ages at which silicosis, TB, and silicotuberculosis were diagnosed are illustrated in Figure 4. No major change over time in the ages of diagnosis was observed for these diseases.

DISCUSSION

No studies of Zambian miners compensated for having silicosis, TB, or silicotuberculosis have been published for over 40 years. Compared with other developing nations, Zambia has benefited from having a centralized location for diagnosis and compensation of mining-related diseases. While no information about the annual employment statistics for miners is available, this study demonstrates that new cases of silicosis have not markedly changed over the study period. TB has become a much more significant problem in the post-HIV era, while cases of silicotuberculosis have been on the decline.

Given the generally held belief that the number of miners has decreased in Zambia over the years, it is likely that there was an increased rate of silicosis among miners at least until the mid-1990s. Despite the absence of employment data, copper production in Zambia is known to have decreased each year since the late 1970s, continuing a two-decade decline in output due to poor re-investment and unstable copper prices on the world market. Copper is by far the most significant mineral mined in Zambia, still accounting for 80% of foreign exchange earnings and 9% of the gross domestic product (GDP). Even with diminished production, it is estimated that the Zambian copper industry provides employment to more than 40,000 people. Silicosis continues to be a problem in Zambian mines. Dust monitoring by the Mines Safety Department (MSD) of Zambia routinely uses konimeters. The permissible exposure limit (PEL) for total dust, mandated by the MSD, is 350 parts per cubic centimeter. The spot samples collected using konimeters are highly variable and dependent upon the skill of the technician to count the particles on the slide. Elsewhere in the world, gravimetric sampling using personal pumps is the primary method of assessing dust-exposure levels. Gravimetric sampling tends to give a more representative estimate of workers' exposures, since it is an integrated time-weighted average (TWA) of the workers' duration of work. It should be noted that since privatization of the mines (1999/2000), some individual mining companies have been using gravimetric sampling to monitor adherence to their own internal occupational standards. While the need to regulate exposures to respirable dust and silica is well established by the MSD, there are inadequate resources to conduct exposure assessments and install expensive control technologies. Although air-purifying respirators are commonly available in large companies, they are often used improperly (e.g., the use of "mutton cloth" over the mouth and nose to improve the comfort of using the respirator).

As previously described, new cases of TB have increased markedly since 1945. The HIV epidemic has almost certainly contributed to this increase. HIV infection is a risk factor for tuberculosis in miners. Treatment for HIV infection is not available in Zambia through the Workers' Compensation System. Workplace prevention programs are also used, although a survey conducted by one of the Zambian copper mines in 2000 found that 18% of its 8,523 employees were HIV-positive.[10] This could relate to the marked decrease in silicotuberculosis in our study. The corre-

Table 2 Age-specific Comparison of Cases Pre- and Post-HIV Epidemic

	1960–1970			1992–2002		
	Silicosis No. (%)	TB No. (%)	SilicoTB No. (%)	Silicosis No. (%)	TB No. (%)	SilicoTB No. (%)
Age 30–39 years	2 (5.4)	31 (83.8)	4 (10.8)	7 (1.9)	370 (97.6)	2 (0.5)
Age 40–49 years	16 (13.7)	67 (57.3)	34 (29.1)	33 (8.7)	341 (90.2)	4 (1.1)
Age 50–59 years	61 (40.1)	29 (19.1)	62 (40.8)	43 (25.6)	117 (69.6)	8 (4.8)
TOTAL	79 (25.8)	127 (41.5)	100 (32.7)	93 (9.0)	828 (89.5)	14 (1.5)

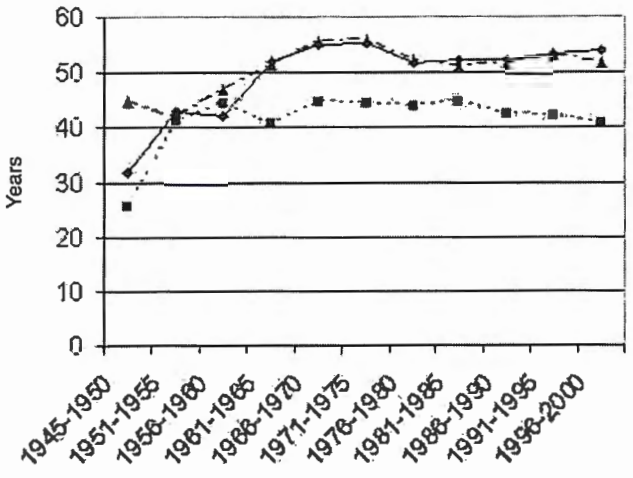

Figure 4—Mean ages to onset of silicosis, tuberculosis, and silicotuberculosis in five-year periods. —♦— silicosis; --■-- TB; --▲-- silicotuberculosis.

sponding increase in the percentage of compensated miners with TB suggests that miners may not be surviving long enough to develop silicotuberculosis.

There are a number of important limitations to this study that extend beyond the lack of employment information about the number of miners. Although the classification of miners as to their disease status is done by skilled occupational physicians, diagnosis uses chest radiographs only. This is a potential source of bias involving the misclassification of study subjects by disease status.[11] The data analyzed in this study also did not show the smoking status of individual subjects. In a mining community, smoking is an important risk factor for respiratory impairment. However, according to a report from the U.S. Surgeon General,[12] cigarette smoking has no significant causal role in the etiology of silicosis.

Given the adverse effects of silica exposure,[13–16] it is highly recommended that properly designed ventilation systems be installed in areas where substantial dust exposures occur. More importantly, educational efforts should be made to ensure that workers understand the importance of respiratory protection. It has been shown that workers are more willing to attempt to change worksite conditions following training and their efficacy in making changes is greater after training.

Since TB is a major cause of death and morbidity among Zambian miners, and silicosis is a risk factor for the development of TB, a program to eliminate silicosis should be advocated as an integral part of a campaign to eradicate TB. Special attention should also be given to training workers in the proper use of disposable respirators to minimize the potential TB transmission from worker to worker. There is also the need for workplace HIV prevention programs.

In conclusion, silicosis continues to be a significant problem in Zambia. The number of new cases of TB has grown rapidly, particularly since arrival of the HIV epidemic. There is a continuing need for improvement of health and safety programs that focus on dust control, TB treatment, and the prevention of HIV infection.

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