

# Occupational health, occupational illness: tuberculosis, silicosis and HIV on the South African Mines<sup>1</sup>

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## Introduction

In this chapter we discuss tuberculosis, silicosis and HIV in the context of the South African gold mining industry in order to assess the current state of these diseases on the mines and to suggest areas in which more research needs to be done. Although these diseases are probably the most pressing and urgent in terms of the threat to the health of mine workers, we will also mention briefly some of the other diseases that are of particular relevance to the mining industry in general. While there are excellent tertiary health care facilities on the mines, more attention needs to be paid to primary health care but in order to plan and implement this effectively better surveillance methods need to be developed. Both mine management and the unions are increasingly concerned about such issues and there is reason to hope that improved systems of disease management can be developed.

South Africa and gold have long been synonymous and mining plays a key role in the economy. Gold contributes about 4% of the gross domestic product directly, twice as much if indirect multipliers are included, and provides almost 30% of foreign exchange earnings (Baxter, 1996). The industry employs about 350 000 workers. About ninety percent of the workers are black, the ten percent who are white occupy mainly supervisory positions (Hnizdo, 1991; COM, 1994). With some gold mines reaching depths of more than three kilometres, in seams that may be only one to two metres deep, gold mining remains labour intensive and working conditions are dangerous and stressful. In 1993 out of every 100 000 gold miners 113 died in accidents, 2000 suffered a reportable injury (COM, 1994), 1100 developed active tuberculosis and of these 25 died (Goldfields, 1993); in 1990 about 500 were certified as having silicosis (MBOD, 1990). The majority of mineworkers in South Africa are migrant labourers, either from within South Africa or from neighbouring states under a labour recruiting system which has been in place for more than a century (Crush, Jeeves and Yudelman, 1991). Each contract of employment lasts for one year, but may be renewed many

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<sup>1</sup> *Occupational Lung Disease: An International Perspective* Daniel E. Banks and John E. Parker (editors). (Chapman and Hall, 1998)

times and 90% of mineworkers spend more than ten years on the mines (Leon, Davies, Salomon and Davies, 1995). A large proportion of black mineworkers are still housed in single men's hostels living and working under conditions that put them at high risk of disease, trauma and death. Increasing duration of service on the mines (Murray, Kielkowski and Reid, 1996) will lead to increased lifetime exposure to dust, radiation, noise and other contaminants. The long delay between exposure and the onset of many occupational diseases means that illnesses may develop long after men have left the mines and returned to their rural homes where even the most rudimentary medical services are often lacking.

Tertiary health care on the mines is, however, excellent: the industry operates 41 hospitals offering 7000 beds with approximately 350 full time doctors and 3500 health care staff (Fourie, 1996). While these facilities provide a valuable national resource, we argue below that existing biomedical interventions are inadequate for containing diseases such as silicosis, tuberculosis and HIV in the particular social context of the mines, and that greater attention needs to be paid to early case detection, evaluation of service delivery, the development of innovative approaches to primary health care, as well to the social and living conditions in which such diseases flourish.

Unfortunately there is little publicly available data on the incidence, prevalence or mortality due to work-related and other diseases on the mines. Gold Fields of South Africa publishes an annual report which contains basic health statistics; the other five major mining houses have discontinued the publication of annual medical reports (Leon, Davies, Salomon and Davies, 1995). The health department of the Chamber of Mines of South Africa collects morbidity and mortality data but does not make them publicly available (Leger, 1992). The Medical Bureau for Occupational Diseases, under the National Department of Health, publishes data on claims for compensatable diseases and from these and some other sources researchers have produced proxy rates of work-related respiratory diseases in the mining industry (Leger, 1992). It must be stressed that not only are the available numerator data poor, good denominator data are also lacking and most rates are aggregated over workers in different mines, in different jobs and at different levels of exposure and risk.

### **History of silicosis and tuberculosis on the mines**

In mines where the concentration of silica in the ore is high, silicosis has long been responsible for high levels of mortality and morbidity among gold miners and continues to take a heavy toll. Very little is known about the history or levels of silicosis amongst black mine workers beyond the fact that, as Katz (1994) notes, during the first decades of this century, silicosis among black mine workers was largely ignored, with doctors arguing, for example, that black workers who contracted simple silicosis were restored to health by rests at their rural homes. However, more is known about silicosis amongst white mine workers. Early in this century when the annual mortality from 'phthisis', including silicosis, among white miners was estimated to be 1100 per 100 000 underground workers (Katz, 1994) leading a mining journal to note that 'phthisis has killed such a large number of young, strong labourers, that many miners in Europe and America prefer to stay in their own countries, earn

lower wages, and live, rather than come to the Rand, earn a higher wage, and die' (Katz, 1994).

Before the nineteenth century there seems to have been little tuberculosis amongst people living in southern Africa (Anderson, 1990). During that century, however, many Europeans suffering from tuberculosis came to South Africa to take advantage of the climate, and the arrival of large numbers of infectious people combined with the social changes associated with the discovery of minerals, especially the need to recruit migrant labour on a large scale, provided ideal conditions for the spread and increase of tuberculosis (Anderson, 1990; Packard, 1989). The increased risk of tuberculosis amongst those with silicosis (Cowie, 1994) meant that mine workers were particularly vulnerable.

In the 1920s, a confidential report by the mine inspectorate noted that the mines were returning an average of 1000 new cases of tuberculosis to the rural areas each year (Anderson 1990). The tuberculosis rates among gold miners were then extremely high, particularly among men from Botswana, Lesotho and southern Mocambique with annual incidences of 2350, 1340 and 1490 per 100 000, respectively (DOPH, 1990). The impact on rural communities was highlighted by a study of 112 patients who had returned to the Transkei and the Ciskei after being diagnosed as having tuberculosis on the mines: within five years 65 had died and of the 47 still alive, nearly half were incapable of working again (Allan, 1924).

In the early decades of this century the crowded and unsanitary living conditions combined with the stressful working conditions lead to very high rates not only of silicosis and tuberculosis but also of pneumonia (Gorgas, 1913) on the mines and, combined with the high levels of migrancy, probably contributed to the high rates of these diseases in rural areas of southern Africa. Living conditions continue to be problematic. In 1995 the assessors of a judicial commission of enquiry, set up by the government and Chaired by Justice Ramon Leon, to investigate the regulation of occupational health and safety in the mining industry, visited three hostels on two mines (Leon, Davies, Salomon and Davies, 1996). Each room was occupied by between 12 and 20 men, giving an average of just over five square metres per person. The assessors were 'shocked by the conditions in which food was prepared' and by ablution facilities 'so squalid as to shock the most hardened'.

## **Tuberculosis**

Tuberculosis has long been a major cause of morbidity and mortality in the general population of South Africa and in 1980 accounted for an estimated 7% of all deaths among black people between 15 and 64 years of age (Yach, 1987) and the most recent review of tuberculosis in South Africa concluded that in 1994 the overall incidence was 311 per 100 000 per year (DOH, 1996b). After trauma, tuberculosis claims the largest number of lives amongst working miners, with a mortality rate of 25 per 100000 in 1993; the industry wide incidence of tuberculosis in the same year was 1100 per 100 000 (COM, 1994). There is evidence that the incidence of tuberculosis on the mines is increasing (Murray, Kielkowski and Reed, 1996). HIV enhances the spread of tuberculosis but other factors, including the high prevalence of silicosis, longer periods of service in mining and the associated increase in the

age of the work-force, the physical stress of long shifts under conditions of high humidity and heat, as well as the living conditions, are all risk factors for tuberculosis in mineworkers.

As a result of the high incidence of tuberculosis in the mining industry, the Mines Phthisis act of 1916 made provision for the compensation of tuberculous miners, who were then repatriated to their place of origin (Katz, 1980). However, in 1977 a study to evaluate the regulations that prevented men with tuberculosis from continuing to work as gold miners was initiated by Cowie (1987) who subsequently argued that tuberculous mine workers on suitable short-course chemotherapy could safely return to work underground. In 1984, the regulations were changed and men who were under treatment for pulmonary tuberculosis with an approved regimen were allowed to return to work (Cowie, 1987). In 1994, the Occupational Disease in Mines and Works Act was revised in a way that reduced miners entitlement to compensation and since then miners with tuberculosis are only compensated for shifts lost when they are hospitalised, are found to have second degree tuberculosis, or have evidence of permanent lung damage (ODMWA, 1994).

As noted above, the mining industry has excellent medical facilities using modern drugs and following treatment regimes recommended by the World Health Organization. Mine medical clinics are close to the compounds or hostels where miners live. On one typical group of mines, workers have an annual fitness examination; miniature X-rays are used to screen miners for tuberculosis and all suspected cases are confirmed bacteriologically. Nevertheless, a number of questions arise concerning tuberculosis case detection. Sluis-Cremer (1980) observed that it was not unusual to see men with advanced pulmonary tuberculosis less than nine months after their X-rays appeared entirely normal and it may be that the policy of screening miners once a year is inadequate. The hearts and lungs of miners who die while in employment are examined at the National Centre for Occupational Health for evidence of occupational diseases including tuberculosis and a post mortem study of black mineworkers showed that of those who were shown to have tuberculosis at autopsy, 40% were not detected in life (Lowe and Murray, 1994).

There is an urgent need to improve tuberculosis control on the mines. From the beginning of 1996, the mining industry has followed the new National Tuberculosis Control Programme guidelines (DOH, 1996a), adopted from the World Health Organization Global Tuberculosis Programme. The emphasis is on treating smear positive cases under Directly Observed Therapy, Short Course Treatment (DOTS). While DOTS is now accepted and followed, a recent study on one group of mines (Mqoqi *et al.* 1996) showed that while the apparent rate of compliance, assessed from clinic records, is 99.8% the actual rate of compliance, as assessed by random urine tests, was only 85% among the 40% of patients who returned to give urine samples. In this study it was found that 21% (s.d.  $\pm 6\%$ ) of patients whose treatment regime did not include Isoniazid gave positive urine tests for Isoniazid and 35% (s.d.  $\pm 7\%$ ) not on Rifampicin gave positive urine tests for Rifampicin.

The epidemic of HIV complicates the problem of tuberculosis control. In a study in Kinshasa, for example, extending tuberculosis treatment among HIV-positive patients from six to twelve months reduced the relapse rate at two years from 9% to 2% (Perriens, *et al.*

1995). On one group of South African mines, acquired Isoniazid and multi-drug resistance have both increased since 1985 and now occurs in 7% and 0.8% of tuberculosis patients, respectively (Churchyard, 1996).

### **Silicosis**

The relationship between exposure to dust containing silica and the occurrence of silicosis has been thoroughly investigated in the South African mining industry (Beadle, 1971). The Leon Commission (Leon, Davies, Salomon and Davies, 1996) concluded that a person working for twenty years or more in high dust areas, such as drilling or shaft sinking, has a 20–30% chance of developing simple silicosis. Silicosis compounds the problem of tuberculosis: in one autopsy study, even a slight degree of silicosis not detected radiologically in life was significantly associated with an increased prevalence of pulmonary tuberculosis compared to gold miners without silicosis (Sluis-Cremer, 1980). In a cohort study of South African gold miners the annual incidence of tuberculosis was 1% among those without silicosis but increased to 2.2%, 2.9% and 6.3% for those with categories 1, 2 and 3 silicosis, respectively (Cowie, 1994). The association with silicosis increases the need to ensure early case detection and high levels of compliance for tuberculosis.

A retrospective cohort study of over 2000 white South African gold miners with an average of 24 years of service was used to examine the relationship between exposure to dust and risk of silicosis (Hnizdo and Sluis-Cremer, 1993). The risk of silicosis increased exponentially with cumulative dust dose. For this group of white miners, at the highest exposure level of 15 mg/m<sup>3</sup>-years, which represents approximately 37 years of gold mining at an average respirable dust concentration of 0.4 mg/m<sup>3</sup>, the cumulative risk for developing silicosis reached 77%. In a large proportion of the miners radiological signs of silicosis developed only after they had left the mines.

An autopsy study of black miners found a prevalence of silicosis of nearly 12% in gold miners (Sluis-Cremer, 1980) although only 3% of these were ‘moderate’ or ‘marked’ in severity. A more recent study confirms the prevalence of silicosis diagnosed at autopsy and reports an increasing trend over the last fifteen years (Murray, Kielkowski and Reid, 1996). For comparison, the prevalence of silicosis diagnosed in life in a cohort of black gold miners was 1.4% (Cowie, 1987). A study of silicosis comparing radiological findings in life with pathological findings at autopsy found that only one-third of the pathologically confirmed cases were diagnosed from X-rays, taken on average 2.7 years earlier, with International Labour Organization category 1/1 used to define a positive diagnosis of silicosis. The sensitivity of the radiological findings improved with increasing degree of silicosis at autopsy but, even among those with a moderate or marked degree of silicosis, a large proportion were not diagnosed radiologically (Hnizdo, Murray, Sluis-Cremer and Thomas, 1993).

Simple, chronic silicosis does not appear to impair lung function (Irwig, 1978), but more advanced silicosis does, even after controlling for the effects of smoking (Cowie and Mabena, 1991; Cowie, Hay and Thomas, 1993). Studies on white South African miners have shown that smoking acts synergistically with silica dust on respiratory impairments (Hnizdo,

Baskind and Sluis-Cremer, 1990). There are no studies on the effect of silicosis on life expectancy of black South African mine workers, but it is likely to be substantial in view of the resulting increase in the life-time risk of tuberculosis.

The jobs done by black workers generally involve higher levels of dust exposure than those done by white workers and this is reflected in the fact that the average length of service before certification of silicosis is 15 years for black workers, and 26 years for white workers (Leger, 1992). That silicosis has been a serious problem amongst black mine workers is shown by studies of former mine workers. In a study in Botswana of men who had worked on mines in South Africa more than one-quarter had pneumoconiosis and 6% had progressive massive fibrosis (Steen, et al. 1996). According to preliminary results of a recent study in the Libode District of the Transkei, among a random sample of retired miners, recruited between 1969 and 1980, 32% were diagnosed as having pneumoconiosis, 13% as having tuberculosis and 23% as having both (Trapido *et al.* 1996).

## **HIV**

In a country with already very high levels of tuberculosis, there is now a rising epidemic of HIV infection. The only available statistics on the nation-wide burden of HIV in South Africa are those kept by antenatal clinics: between 1990 and 1994 the nation-wide prevalence of HIV infection among women attending antenatal clinics rose from less than 1% to 7.4% with a mean doubling time of 15 months although with wide provincial variations (Swanevelder, 1996).

The most important factors associated with severe epidemics of HIV/AIDS are well known and include high rates of sexually transmitted diseases, migrancy, social instability, disruption of social support mechanisms and family structures, and opportunistic infections, especially tuberculosis (Campbell and Williams, 1996). The extent of migrancy and the lack of social support amongst miners as well as the high levels of tuberculosis have been noted above. The high sexually transmitted disease (STD) rates are indicated by data from a clinic serving one group of mines where the annual incidence of new STD cases is 16 100 per 100 000 miners (Ballard, 1996). As in the rest of Africa, the main mode of HIV transmission is heterosexual. A recent pilot study suggested that in a culture of masculinity which promotes high levels of sexuality amongst male migrant workers, most of whom live some distance from their wives and families, multiple sexual encounters with a range of partners are common. Furthermore levels of condom use appear to be low. Within such a context, it is likely that the impact of HIV/AIDS on the mines will be substantial.

The heterosexual epidemic of HIV/AIDS in South Africa began to take off in the 1990s. Unfortunately there are no published data on the current overall prevalence of HIV on the mines in South Africa. In 1987 HIV testing was done on workers on the South African gold mines in which correlations were made between HIV status and country of origin. The prevalence amongst mine-workers from Malawi was 4%, among those from other countries, including South Africa, it was about 0.03% (Brink, B. and Clausen, L. 1987). As a result the Chamber of Mines stopped recruiting novices from Malawi (James 1992) and the number of

Malawians employed on the South African mines was reduced from 13090 in 1988 to 2212 in 1989 (Crush, Jeeves and Yudelman, 1991). Since then no further prevalence studies have been published. Using the 1987 prevalence of 0.03% amongst non-Malawian workers, and assuming a doubling time of 15 months, as in the ante-natal clinic surveys, the prevalence of HIV amongst mine-workers could now be as high as 15% and informal estimates by mine medical officers put the current prevalence at between 15 and 20%. In 1994, 19% of tuberculosis patients on one group of mines were HIV positive (Churchyard, 1996).

The potential impact of HIV infection when prevalence reaches these levels is shown by a study of a mature epidemic in Uganda (Mulder *et al.* 1994) where the prevalence of infection among adults was 8%; in this rural population adult mortality was increased 15 times by HIV-infection. Against this background, the lack of an appropriate surveillance system on the mines is particularly worrying given that such data are essential for monitoring the trend of the epidemic and planning adequate health care services in the future.

The association between tuberculosis and HIV is well established. Studies in other African countries show that the relative risk of developing active tuberculosis may be increased by 8 to 12 times among those with HIV-infection and 30–40% of all cases of tuberculosis may be attributed to HIV (Van den Broek *et al.*, 1993; Richards *et al.* 1995). In many countries where tuberculosis was thought to be under control it is now becoming epidemic. Increased levels of HIV infection on the mines are likely to reduce immunity and resistance to tuberculosis making it more difficult to treat those patients who are diagnosed (Packard and Coetzee, 1995). Between 1990 and 1992 the annual incidence of tuberculosis on one group of mines was steady at about 600 per 100 000 but had increased to about 1000 per 100 000 in 1994 (Churchyard, 1996) and at least part of this increase may be attributable to HIV infection.

### **The social context of disease**

Against the background of the lack of success in stemming the tide of STDs, including HIV, and tuberculosis in southern Africa using conventional biomedical interventions, there is a growing argument that unless miners understand the nature of the disease transmission and are actively involved in programmes to manage both HIV and tuberculosis there is little hope that the levels of transmission will be significantly reduced (Campbell 1996). In a recent study of mine workers perceptions of health (Campbell, 1997) very few mine workers had any first hand experience of AIDS. This made it difficult for them to regard the disease as a threat to their own lives. Living in a dangerous and stressful environment with few opportunities for intimacy and little social support, reinforced a macho notion of sexuality in which regular sex, often with commercial sex workers, and involving ‘flesh-to-flesh contact’ is regarded as essential. This continued to place them at high risk of acquiring HIV. While all of them were aware of tuberculosis and many had experienced the diseases themselves, few of them knew that tuberculosis is an infectious disease. Indeed, the association with silicosis led them to say that tuberculosis was caused by the dust.

Evidence suggests that miner's understandings of illnesses such as tuberculosis and HIV may often be at variance with those of the medical profession and that such variances may play a role in the failure of excellent biomedical facilities to make an impact on the growing incidence of these diseases. Furthermore miners conceptualised notions of health and illness in a plurality of healing systems that embraced both traditional and modern views of healing, and the vast majority of them consult both biomedical practitioners and traditional healers when they are ill. Attempts to deal with STDs, HIV and tuberculosis on the mines need to involve a far more active dialogue between mineworkers, traditional healers and those who are part of the formal medical structures (Abdool Karim, Ziqubu-Page and Arendse 1994).

### **Other diseases**

There are a number of other diseases, some of which are associated with mines other than gold mines, and this section provides a brief overview of these.

Asbestos mining in South Africa has created an epidemic of asbestos related disease (White, 1994; Felix, 1994) amongst asbestos workers as well as in the broader community due to large scale environmental contamination. Although very few people are still employed in the asbestos industry tens of thousands of people have been occupationally or environmentally exposed and a proportion will develop diseases such as mesothelioma in the future. Between 1980 and 1990 about 400 cases were certified annually and it is expected that the health effects will continue to be felt well into the next century. Since the asbestos industry has all but disappeared and it is not clear who will pay for the cost of rehabilitation and compensation (White, 1994).

While asbestos mining has declined greatly, coal mining remains important in the economy. Certifications for coal workers' pneumoconiosis have declined from approximately 600 per 100 000 workers in 1980, to around 400 per 100 000 in 1989, which is similar to the silicosis rate for gold miners (White, 1994). Unfortunately separate data are not available for silicosis and coal workers pneumoconiosis after 1989. Routine post mortems of black coal miners (White 1994) gave a prevalence of coal workers pneumoconiosis of approximately 7%.

Apart from the diseases discussed above, there were 60 certifications for chronic obstructive pulmonary disease per 100 000 workers in the mining industry generally (MBOD 1993) and smaller numbers of workers are also affected by platinum salt sensitivity, scleroderma, hard metal pneumoconiosis as well as hearing loss (Leon, Davies, Salomon and, 1996). Much larger numbers of workers are affected by non-occupational, but arguably work-related, diseases such as pneumonia (817 incident cases and 20 deaths per 100 000 workers) and neoplasms (200 incident cases and 21 deaths per 100 000 workers). The Chamber of Mines also reports 62 deaths per 100 000 workers as due to 'ill defined diseases and disorders' (Goldfields, 1993).

## Conclusions

Probably the most important diseases currently facing miners are tuberculosis, especially through its association with silicosis, and the rising epidemic of HIV/AIDS. However, tuberculosis is treatable, silicosis is preventable and there are interventions that may reduce the incidence of HIV/AIDS (Grosskurth *et al.* 1995). It is important to find ways to manage these diseases in the future.

There is an urgent need to set up proper surveillance systems for the most important diseases (Leon, Davies, Salomon and Davies, 1996). It is important to know considerably more about the distribution and determinants of disease. Improving the compilation and reporting of existing health records would be an important first step but epidemiological surveys and monitoring should be carried out on a regular basis in order to identify risk situations and factors for the most important diseases. Such surveys will require agreement between labour and employers to establish an effective and ethical approach. If the disease problems are to be addressed effectively, it is important to be able to monitor and assess the effectiveness of any interventions so that those involved in disease control on the mines know if they are succeeding and can try alternative strategies if they are failing.

The mining industry has good medical facilities, well trained medical personnel and access to the most modern drugs. The tertiary interventions that are in place tend to address the clinical rather than epidemiological causes of disease. Good primary health care interventions are needed that focus on prevention and early detection of problems. This will not only be more cost effective but will also create links between the medical aspects of disease and the social context of disease transmission on the mines. It will also provide a basis for more effective participation by labour in health interventions on the mines.

The prevention of silicosis requires the monitoring and reduction of dust levels (Murray, Kielkowski and Reed, 1996) which is primarily a technical problem but again it is important that the control of disease is addressed jointly by the mine management, the mine medical services and the trade unions. The control of tuberculosis is closely linked to the containment of HIV. HIV is as much a social as a biomedical disease and the management of HIV depends critically on bringing about changes in people's sexual behaviour. There is no evidence that traditional information-based HIV education programmes, favoured by many of the mines, have succeeded in promoting large scale behaviour change (Crisp, 1996). There are a number of initiatives being planned to develop more innovative and participatory 'peer education' programmes for the mining context. These are health education programmes which aim to take account of the fact that health behaviours are governed not only by factual information and individual choice, but by the cultural construction of health and illness, group norms and the routine organization of everyday life (Dube and Wilson, 1996).

The World Health Organization suggests that if 85% of people who contract tuberculosis comply fully with their treatment, the incidence of tuberculosis should decline. Unfortunately, it is often the case that non-compliance is blamed on the patients; the study by Mqoqi *et al.* (1996) shows that the primary failure may be a failure of the medical programme. For a disease in which compliance and early case detection are the most

important determinants of successful control, the active participation of the workers in addressing the control of the disease will be essential.

The Leon Commission of Enquiry into the Health and Safety of Mineworkers (Leon, Davies, Salomon and Davies, 1996) felt justified in concluding that 'there is no evidence to indicate a decline in the prevalence or severity of any occupational disease in the mining industry during the past twenty years ... radical steps are required to deal with the serious occupational health problems described in the evidence presented to the Commission.' The challenge is not only to manage the current problems and to deal with the consequences of past neglect but to ensure that in the future the levels of disease are substantially reduced.

## References

- Abdool Karim, S., Ziqubu-Page, T. and Arendse, R. (1994) *Bridging the Gap: Potential for a Health Care Partnership between African Traditional Healers and Biomedical Personnel in South Africa* (Medical Association of South Africa, Pinelands, South Africa)
- Allan, P. (1924) *Report of Tuberculosis Survey of the Union of South Africa* (Government Printer, Cape Town, UG 18–24) cited in Anderson (1990).
- Anderson, N. (1990) 'Tuberculosis and social stratification in South Africa' *International Journal of Health Services* **20** 141–165.
- Ballard, R. (1996) 'STDs on the mines: the nature of the problem' in *HIV/AIDS management in South Africa: Priorities for the Mining Industry*. Williams, B.G. and Campbell, C.M. (editors) (ERU, Johannesburg) 111–114.
- Baxter, R. (1996) 'The economics of the South African mines' in *HIV/AIDS management in South Africa: Priorities for the Mining Industry*. Williams, B.G. and Campbell, C.M. (editors) (ERU, Johannesburg) 42–50.
- Beadle, D.G. (1971) 'The relationship between the amount of dust breathed and the development of radiological signs of silicosis: an epidemiological study of South African gold miners' in Walton, W.H. (editor) *Inhaled particles III*. (Oxford, Pergamon Press, 1971) 953–966.
- Brink, B., and Clausen, L. (1987) 'The acquired immune deficiency syndrome' *Journal of the Mine Medical Officers Association* **63** 10–17.
- Campbell, C.M. (1996) 'The psychosocial context of HIV transmission on the gold mines: implications for HIV education programmes' in *HIV/AIDS management in South Africa: Priorities for the Mining Industry*. Williams, B.G. and Campbell, C.M. (editors) (ERU, Johannesburg) 77–91.
- Campbell, C.M. (1997) 'Migrancy, masculine identities and AIDS: the psychosocial context of HV transmission on the South African gold mines' *Social Science and Medicine* **45**, 273–281.

- Campbell, C.M. and Williams, B.G. (1996) 'Academic research and HIV/AIDS in South Africa' *South African Medical Journal* **86** 55–60.
- Churchyard, G. (1996) 'Of Soil and Seed: HIV related TB on the Mines' in *HIV/AIDS Management in South Africa. Priorities for the Mining Industry* Williams B.G. and Campbell C.M. (editors). (ERU, Johannesburg) 117–119.
- COM (1994) *Chamber of Mines Statistical Tables, 1993* (Chamber of Mines, Johannesburg)
- Cowie, R.L. (1987) *Pulmonary Tuberculosis in South African Gold Miners. Determinants of Relapse after treatment*. M.Sc. thesis, McGill University, Montreal.
- Cowie, R.L. (1994) 'The epidemiology of tuberculosis in gold miners with silicosis' *American Journal of Respiratory and Critical Care Medicine* **150** 1460–1462.
- Cowie, R.L. and Mabena, S.K. (1991) 'Silicosis, chronic airflow limitation, and chronic bronchitis in South African gold miners' *American Review of Respiratory Disease* **143** 80–84.
- Cowie, R.L., Hay, M., and Thomas, R.G. (1993) 'Association of silicosis, lung dysfunction, and emphysema in gold miners' *Thorax* **48** 746–749.
- Crisp, J. (1996) 'AIDS programmes in the mining industry: an overview' in *HIV/AIDS management in South Africa: Priorities for the Mining Industry*. Williams, B.G. and Campbell, C.M. (editors) (ERU, Johannesburg) 91–93.
- Crush, J., Jeeves, A. and Yudelman, D. (1991) *South Africa's Labour Empire: a History of Black Migrancy to the Gold Mines*. (Westview Press, Boulder)
- DOH (1996a) *The South African Tuberculosis Control Programme. Practical Guidelines*. (Department of Health, Pretoria).
- DOH (1996b) *Draft Report of the Review of the Tuberculosis Control Programme of South Africa*. Unpublished.
- DOPH (1990) *Department of Public Health: Annual Report* cited in Anderson (1990).
- Dube, N. and Wilson, D. (1996) 'Peer education programmes among HIV-vulnerable communities in southern Africa' in *HIV/AIDS management in South Africa: Priorities for the Mining Industry*. Williams, B.G. and Campbell, C.M. (editors) (ERU, Johannesburg) 30–40.
- Felix, M.A., Leger, J. and Ehrlich, R. (1994) *The Identification and Control of Environmental and Occupational Diseases* (Princeton Scientific, New Jersey)
- Fourie, I. 'Health care in the mining industry' in *HIV/AIDS management in South Africa: Priorities for the Mining Industry*. Williams, B.G. and Campbell, C.M. (editors) (ERU, Johannesburg) 53–58.
- Goldfields (1993) *1993 Annual Report of the Medical Division of Gold Fields of South Africa Limited* (Goldfields, Johannesburg)

Gorgas, W.C. (1914) 'Recommendation as to sanitation concerning employee of the mines on the Rand made to the Transvaal Chamber of Mines' *Report to the Transvaal Chamber of Mines*.

Grosskurth, H., Mosha, F., Todd, J., Mwijarubi, E., Klokke, A., Senkoro, K., Mayaud, P., Changalucha, J., Nicoil, A., ka-Gina, G., Newell, J., Mugeye, K., Mabey, D. and Hayes, R. (1995) *The Lancet* **346** 530–536.

Hnizdo, (1991) *Combined effects of dust exposure and tobacco smoking on the occurrence of lung diseases in South African gold miners* Ph. D. Thesis, University of the Witwatersrand, 1991.

Hnizdo, E., Baskind, E., Sluis-Cremer, G.K. (1990) 'Combined effect of silica dust exposure and tobacco smoking on the prevalence of respiratory impairments among gold miners' *Scandinavian Journal of Work, Environment and Health* **16** 411–422.

Hnizdo, E., Murray, J., Sluis-Cremer, G.K. and Thomas, R.G. (1993) 'Correlation between radiological and pathological diagnosis of silicosis: An autopsy population based study' *American Journal of Industrial Medicine* **24** 427–445.

Hnizdo, E., Sluis-Cremer, G.K. (1993) 'Risk of silicosis in a cohort of white South African gold miners' *American Journal of Industrial Medicine* **24** 447–457.

Irwig, L.M. and Rocks, P. (1978) 'Lung function and respiratory symptoms in silicotic and non-silicotic gold miners' *American Review of Respiratory Disease* **117** 429.

James, W.G. (1992) *Our Precious Metal: African Labour in South Africa's Gold Industry, 1970–1990* (David Philip, Cape Town,)

Katz, E. (1980) 'Silicosis on the South African gold mines' in Wilson, F. and Westcott, G. (editors) *Economics of Health in South Africa: Hunger, Work and Health*. (Ravan Press, Johannesburg) pp. 187–244.

Katz, E. (1994) *The White Death: Silicosis on the Witwatersrand Gold Mines 1886–1910* (Witwatersrand University Press: Cape Town)

Leger, J.P. (1992) 'Occupational diseases in South African mines—A neglected epidemic?' *South African Medical Journal* **81** 197–201.

Leon, R., Davies A., Salomon, M. and Davies J. (1995). *Leon Commission of Enquiry into Safety and Health in the Mining Industry*. (Government Printers, Pretoria)

Lowe, R. and Murray, J. (1994). 'Tuberculosis at autopsy in Black Mine Workers' National Centre for Occupational Health, NCOH Report No. 6/94, Johannesburg.

MBOD (1990) Report of the Medical Bureau for Occupational Disease for the period 1 April 1989 to 31 March 1990 (Government Printers, Pretoria).

MBOD (1993) Report of the Medical Bureau for Occupational Disease for the year 1992 (Government Printers, Pretoria).

- Mqoqi, N., Churchyard, G., Kleinschmidt, I. and Williams, B.G. (1996) 'Attendance versus compliance with TB treatment in an occupational setting: a pilot study' *South African Medical Journal* (1997) **87** 1517–1521.
- Mulder, D.W., Nunn, A.J., Kamali, A., Nakiyingi, J., Wagner, H.U. and Kengeyakayondo, J.F. (1994) 'Two-year HIV-1-associated mortality in a Ugandan rural population' *Lancet* **343** 1021–1023.
- Murray, J., Kielkowski, D. and Reed, P. (1996) 'Occupational disease trends in black South African gold miners' *American Journal of Respiratory Critical Care Medicine* **153** 706–710.
- ODMWA (1994) *Occupational Disease in Mines and Works Act, 1973 (Act No. 78 of 1973) and Regulations*. Issue No.1 (Aquila Publications CC)
- Packard, R.M. (1990) *White Plague, Black Labour: Tuberculosis and the Political Economy of Health and Disease in South Africa* (James Currey, London)
- Packard, R.M. and Coetzee, D. (1995) 'White plague, black labour revisited: TB and the mining industry' in *Crossing Boundaries: Mine Migrancy in a Democratic South Africa* Crush, J. and James, W. (editors) (Creda Press, Cape Town) pp. 101–115.
- Perriens, J.H., St. Louis, M.E., Mukadi, Y.B., Brown, C., Prignot, J., Pouthier, F., Portaels, F., Willame, J.C., Mandala, J.K., Kaboto, M., Ryder, R.W., Roscigno, G. and Piot P. (1995) 'Pulmonary tuberculosis in HIV-infected patients in Zaire—a controlled trial of treatment for either 6 or 12 months' *New England Journal of Medicine* **332** 779–784.
- Richards, S.B., St. Louis, M.E., Nieburg, P., Coulibaly, I.M., Coulibaly, D., Abouya, L., Gayle, H.D. and De Cock, K.M. (1995) 'Impact of the HIV epidemic on trends in tuberculosis in Abidjan, Côte d'Ivoire' *Tubercle and Lung Disease* **76** 11–16.
- Sluis-Cremer, G.K. (1980) 'Active pulmonary tuberculosis discovered at post-mortem examination of the lungs of black miners' *British Journal of Diseases of the Chest* **74** 374–378.
- Steen, T., Gyi, K. White, N., Gabosianelwe, T., Ludick, S., Mazonde, G., Mabongo, N., Ncube, M., Monare, N., Ehrlich, R. and Schierhout, G. (1996) 'Prevalence of occupational lung disease amongst Botswana men formerly employed in the South African mining industry' submitted for publication.
- Swanevelder, R. (1996) 'The national HIV antenatal surveillance programme: spatial and temporal trends in South Africa' in *HIV/AIDS management in South Africa: Priorities for the Mining Industry*. Williams, B.G. and Campbell, C.M. (editors) (ERU, Johannesburg) 61–66.
- Trapido, A.S.M., Mqoqi, N.P., Macheke, C.M., Williams, B.G., Davies, J.C.A. and Panter, C. 'Occupational lung disease in ex-mineworkers—sound a further alarm!' (1996) *South African Medical Journal* **86** 559.
- Van den Broek, J., Borgdorff, M.W., Pakker, N.G., Chum, H.J., Klokke, A.H., Senkoro, K.P. and Newell, J.N. (1993) 'HIV-infection as a risk factor for the development of

tuberculosis—a case-control study in Tanzania’ *International Journal of Epidemiology* **22**  
1159–1165

White, N. (1994) *Health Hazards in the mining industry: an overview* Report submitted to the  
Leon Commission of Enquiry into the Health Hazards in the Mining Industry; June 1994.

Yach, D. (1987) ‘Tuberculosis deaths in South Africa, 1980’ *South African Medical Journal*  
**72**, 149–151.