The geo-epidemiology of hepatocellular and oesophageal carcinomas in southern Africa using gold mining industry records

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ABSTRACT
Over 33 years, the labour force statistics of the employees of a single occupational group in the gold mining industry have provided invaluable examples of constructive and analytic studies using stochastic and specialised cartography, based upon some 6000 cancer cases and a population-at-risk of 13 million man-years of gold miners’ labour. Two examples are provided here; one in the temporal mode showed consistent and unchanging distributions of hepatocellular carcinoma over time. Second, in a comparative mode, distributions of oesophageal cancer provided evidence that both resident and gold miner fatalities came from similar home areas. Such mapping had practical utility in providing viable hypotheses for the causes of hepatocellular carcinoma in Mozambique and oesophageal cancer in the Eastern Cape (formerly the Transkei) of South Africa. At the time of this work, these cancers occurred in these localities at rates among the highest in the world and so explanation of international significance might be expected.

INTRODUCTION
In terms of statistics, the epidemiology of cancer research in the less developed world has traditionally been hampered by the absence of even the most basic numerical data on births and deaths. Even in countries with recorded knowledge of births, cause-specific information on mortality has been lacking as has information on the occupations of individuals. Researchers on cancer occurrence have therefore needed to fall back on other approaches to data collection.

A major step forward was recognised when occupational statistics for black gold miners from several disparate countries and regions across southern Africa (Figure 1) were first used by researchers such as Beyers in 1927, Fischer in 1932 and Berman in 1935. Such studies rely on the cooperation of major employers of labour who agree, possibly for paternalist reasons, to make available for humanitarian research their records of the numbers, ages, occupations and dates of employment of all their employees and then, at a later stage, the ill health record of each employee compiled by professional medical staff.

In this present review of studies published from 1964 to 1996, the gold mines’ industry of South Africa employed only men (until very recently) so that no information was forthcoming on female cancers. Black recruits were often attracted from rural home areas. Even then two difficulties were encountered. Most frequently, they had no firm record of date of birth, in which case estimated age had to be utilised. Second, a man diagnosed with potentially lethal cancer often preferred to forsake his employment to return to die among his own folk. In such cases, these men were included in lists of mortality.

Against these disadvantages, two counter points should be made. Diagnoses were made and recorded via some of the best medical and hospital services in the country and recruits came from far-flung territories represented by several distinct population or ethnic groups.

The purpose then of this paper is to present comparative findings of 33 years of studies of cancer among one particular, but enormously numerous, body of employees – almost 13 million man-years – in one well-recorded occupation. The cumulative information from these studies led to greatly increased understanding of cancer occurrence
CANCER AMONG THE LABOUR FORCE OF THE GOLD MINES

Much was already known in the 1960s of the numbers of men employed and their territories of origin since the discovery of gold in 1886. Miners usually worked for an average of 9–12 months of each contract before taking leave at home. Their employment records each year became the data for the population-at-risk which were compiled in Johannesburg by the Employment Bureau of Africa, the central organisation for recruitment for all of southern Africa. Excellent continuing medical care was assured and almost all cases of cancer recorded were histopathologically confirmed.

In the earliest study of these employees Robertson et al found 925 cancers of all sites in the five years from 1964 to 1968. This established a starting point for study and found that of all the cancers, 52.6% were hepatocellular carcinoma (HCC), 13% were oesophageal cancer and 5% cancer of the bladder. The dominant position of HCC was no surprise, as liver cancer had already been recognised as extremely common in African patients, regardless of their occupation. Similarly, the high incidence of oesophageal cancer among men from the Eastern Cape (formerly Transkei) was not unexpected.

The next major advance in defining cancers in the gold mining industry was by Harington et al in 1975 for the period 1964-71. They also reviewed the causes and consequences for epidemiological study of the uncertainty caused by an absence of birth certificates among the populations of sub-Saharan Africa. This affected their ages both at recruitment and at diagnosis of cancer. Estimates of age, mainly by European officials, might well be in error by up to ten years, either over or under. Add to this, the uncertainty...
(in 1975) about the quality of diagnoses of HCC used in earlier studies that led to the view that over-diagnosis had been occurring fairly generally. In contrast, it was now claimed that the diagnoses were correct for most cases included in this study. Of all the cancers, 710 (52.8%) were HCC, 162 (12.1%) oesophageal cancer, 73 (5.4%) respiratory and 65 (4.8%) bladder, proportions well concurring with Robertson’s earlier work. At that time, 23.9% of the total labour force were recruited from Mozambique, a proportion to be severely reduced (for political reasons) to 9.8% by 1979.

Studies of men in this single broad occupation group were extended, eventually to 33 years, with ever-increasing clarity regarding both geographical distributions and aetiological implications. For some sites of cancer there were increases over the period and for some decreases. For some territories, most notably Mozambique and Transkei with their high numbers of recruits, gross numbers of diagnoses for HCC and oesophageal cancer permitted analysis by home area down to magisterial district (or Mozambican equivalent). Moreover, these spatial variations were mapped by significance under the Poisson distribution for rational investigation of potential environmental causes. A logical start was to seek aetiology in the home areas, whether this would prove elusive or obvious. For less common or rare sites of cancer it would take over thirty years for numbers of deaths to build and even then these did not suffice for analysis.

Out of this huge body of occupation-based mortality data (Table 1) two numerically major examples are provided to illustrate in greater detail two specific facets of these analyses; consistency of place through time and comparisons of place between places of miners’ recruitment and the resident male non-miners’ populations.

**Liver cancer in the miners’ labour force**

It had long been established that hepatocellular carcinoma was a major scourge in some of the populations of southern Africa. Now researchers demonstrated a major difference in susceptibility to liver cancer between black gold miners from Mozambique, where rates were significantly high and men from southern Africa’s other recruitment areas, where they were much lower. This disparity had already attracted international attention because of the rarity of the condition in Western countries and the unusually large number of Mozambican cases. Indeed it was eight times more common in black residents of the capital city of Mozambique, than it was in Johannesburg.

Figure 2 provides an example in the temporal domain and compares two similar data sets, hepatocellular cancers (HCC) in migrant male gold mine workers absent from their residential homeland in southern Mozambique. In two time periods up to 25 years apart, 687 cases occurred in 16 years and 65 in 8 years respectively. Eighteen locations show areas whose crude incidence rates are individually similar over time at a correlation coefficient of r = 0.48 and a significance level of p <0.05. This clearly supports an hypothesis of causative factors being constant through time with, especially, the high incidence areas clustering among miners recruited from the coastal regions of south-eastern Mozambique. The maps also illustrate a major and lasting contrast of HCC occurrence with high case numbers to the east, changing to low in the west at or near to the mouth of the Limpopo River — a feature yet to be explained.

These findings have led to useful follow-up. Van Rensburg et al., basing their field studies on the 1975 geographical indicators, later reported that the ingestion of aflatoxins, powerful hepatocarcinogens in poorly stored mouldy groundnuts, a staple food, was a telling cause of liver cancer in Mozambique. This agent is also strongly associated with chronic endemic HBV hepatitis. By 1996, a striking decrease in liver cancer had taken place among miners from Mozambique — 78.1 cases per 100 000 in 1964-68 to 16.9 in 1989-96. More recent evidence from the cancer registry in Maputo concurs that HCC is decreasing in formerly endemic areas in Mozambique. Similarly, the incidence of HCC in Shanghai and Singapore, both formerly high-risk regions, has declined by about one-third over the last two decades, perhaps due to decreasing exposure to dietary aflatoxin. Possibly some progressive decrease in activity of one or other of the co-determinants of HCC, or in their interaction has occurred.

### Table 1. Temporal analyses of major cancers in black gold miners from 1964 to 1996 by crude incidence rate (CIR)

<table>
<thead>
<tr>
<th>Period</th>
<th>Population-at-risk (in man-years of employment)</th>
<th>Number of cancers diagnosed</th>
<th>Liver (HCC)</th>
<th>Oesophagus</th>
<th>Respiratory</th>
<th>Bladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964 – 71†</td>
<td>2 926 461</td>
<td>1344</td>
<td>24.3</td>
<td>12.1</td>
<td>2.5</td>
<td>2.2</td>
</tr>
<tr>
<td>1972 – 79‡</td>
<td>2 910 506</td>
<td>903</td>
<td>14.1</td>
<td>6.2</td>
<td>3.5</td>
<td>0.8</td>
</tr>
<tr>
<td>1980 – 89§</td>
<td>4 405 949</td>
<td>1704</td>
<td>8.8</td>
<td>8.0</td>
<td>4.4</td>
<td>1.8</td>
</tr>
<tr>
<td>1989 – 96†</td>
<td>2 561 720</td>
<td>1745</td>
<td>8.7</td>
<td>7.7</td>
<td>9.4</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>12 804 636</strong></td>
<td><strong>5698</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Crude incidence rates per 100 000 years of employment.
† In this final analysis, 235 cancers related to HIV infection had a pooled CIR of 9.2, second by rank only to respiratory cancer among the 31 site-specific cancers listed (see Reference 9).
An alternative explanation might be, in some unrecognised way, connected with the AIDS epidemic.9 One would expect that the number of children or young people dying would reduce life expectancy and thereby, possibly by competition between diseases, reduce the numbers liable to suffer from HCC. This might equally apply if an increase of deaths were to be occurring from malaria or other infectious diseases, particularly pneumonia known to be endemic among the young.

That some major naturally-occurring act of prevention has taken place contemporaneously with times of severe disruption marked by 30 years of war, massive population displacement, famine and flood13 seems beyond doubt. All these disasters occurred in a country where the life expectancy of both males and females is 40 years. To identify the cause(s) of this major decrease in HCC locally could provide southern Africa had by 1964 witnessed an increase over a 12-year period that appeared to be greater than that in lung cancer over the half-century.10 The most secure evidence of the increase had come from data concerning the black gold miners.6,9 In the 1975 study,6 67% of cases of cancer of the oesophagus came from miners from Transkei, and just as

**CANCER OF THE OESOPHAGUS AMONG THE MINES’ LABOUR FORCE**

This cancer in the Eastern Cape (previously known as Transkei) experienced a remarkable increase first recognised among the Xhosa people in Johannesburg in 19519 and then elsewhere. An even greater increase was reported in 1962 by Burrell in the former Transkei.16,17,18 Some areas in

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**“Gold miners from widely differing areas of recruitment work under conditions of similar environment and yet experience quite various sites of cancer.”**

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**Figure 2. Significant variations of hepatocellular carcinoma among absentee gold miners from home areas in Mozambique at contrasted time periods”9**
the causes of liver cancer were demonstrated to occur in Mozambique, so it was in Transkei that the aetiology of oesophageal cancer was later to be detected.

Figure 3 compares the incidence of confirmed cases of oesophageal cancer among the absentee gold miners in the period 1964-79 with those among the resident male populations in the 26 locations of Transkei. The numbers of deaths portrayed, 154 in the miners against 884 in the residents, underlines why there is a greater number of areas reaching a significantly high or low level of case numbers in the residents in the period under review. The correlation of crude incidence rates (CIR) values by location at $r = 0.71$ ($p < 0.01$) supports the contention that the overall distribution of this cause of mortality is extremely unlikely to have occurred by chance. This, in turn, was the basis for the claim that the gold miners’ patterns of cancer mortality provided surrogate measures of what can be expected to occur in the residents of their respective homelands. This is of especial usefulness in territories that have no available cancer registry.

This similarity of pattern between the resident non-miners and the gold miners also showed clearly that mining as an occupation has little to do with the causes of this disease in the miners. The origins needed to be found in the environment from which the miners had been recruited.

The spatial analyses of oesophageal cancer over 1964-71,6 and 19827 and later confirmed in 20039 showed little change and led to independent field studies.19,20 These showed that the customary use of home-grown and commercial pipe tobacco, especially in the form of hand-rolled cigarettes, was a principal causative determinant of the disease in both males and females, young and old. A much lower correlation was found with the drinking of either home-brewed beer or spirits.19,20 The most compelling finding was that the effect of both habits together was multiplicative, with relative risk raised by six- to eleven-fold. A Johannesburg case control study of oesophageal cancer patients some 20 years earlier had found much the same, although multiplicative effects had not then been tested.10

The consistent pattern of this neoplasm in peoples of the Eastern Cape may reflect the effect of deeply held cultural customs with regard to alcohol and tobacco abuse which are very difficult to combat even in the face of well-known understanding of their ill effects. This extends to the local name, umhlaza wombiza, (the sore that does not heal) for the early stages of the disease and its invariably lethal outcome.17

**Conclusions**

This series of studies in a single industry’s multi-ethnic labour force ran, in total and on a consistent basis, for 33 years and analysed records of nearly 6000 cases of various sites of cancer among nearly 13 000 000 man-years of mining labour. In territories where clear records of date of birth and/or of cause of death are not yet routinely and nationally recorded, the records of other major occupations should be similarly reviewed. In Africa, for example, these might include the major copper industry of Katanga.

![Figure 3. Significant variations of oesophageal carcinoma from locations of Eastern Cape (formerly Transkei) contemporaneously compared between absentee gold miners and resident male populations](image-url)
or the sugar industry of Zimbabwe. However, the potential for the use of National Cancer Registries both in South Africa and in the recently independent countries to the north cannot be sufficiently emphasised.

The geographical distributions of liver and oesophageal cancer in miners from Mozambique and the Eastern Cape respectively serve as surrogate or substitute patterns of the same cancers in the home areas of the miners. This further suggests that, in the absence still of cancer registries in many of the home territories examined, the occupational data of site-specific cancer as assessed by the gold miners’ distribution for those same distributions in their homeland provide authorities locally with valuable practical information (and their only guide) to cancer occurrence in the males, and sometimes also the females, of their home territories.

At the outset of these studies it had been expected that gold mining might provide evidence of excess numbers of occupation-specific cancer. In fact, as the data accumulated, it became clear that the place or area of recruitment carried greater risks than those related to mining employment. Gold miners from widely differing areas of recruitment work under conditions of similar environment and yet experience quite various sites of cancer.

Since the Chamber of Mines no longer keeps employee records in the pre-1996 form, the possibility of continuing analyses of these changing patterns and of utilising them to afford clues to aetiology is now closed off. Far-reaching changes in the make-up of the labour force and different bases of information are now forthcoming on matters of health.

This review therefore brings to a close a comprehensive investigation of cancer incidence among the black employees of the gold mines in southern Africa. The present article, based on routine industrial labour statistics, highlights both enduring and new geographical and temporal patterns of cancer experience. These offer fresh aetiological opportunities for several different cancers in different areas that have been shown to be of particular concern, and invite further explanatory study of the distributional patterns shown.

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One of the authors, Dr J.S. Harington, has long received support from the University of the Witwatersrand and this further suggests that, in the absence still of cancer registries in many of the home territories examined, the occupational data of site-specific cancer as assessed by the gold miners’ distribution for those same distributions in their homeland provide authorities locally with valuable practical information (and their only guide) to cancer occurrence in the males, and sometimes also the females, of their home territories.

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