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Silicosis, Tuberculosis (tb) And Hiv/aids: The Triple Epidemic Among Gold Mineworkers In South Africa (literature Review And Policy Analysis)

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Literature Review and Policy Analysis

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Epidemiology of Microbial Diseases and Global Health

Yale School of Public Health

This thesis is dedicated to all mineworkers in South Africa fighting for health equity and justice.

You inspire me!

Executive Summary

The scourge of the triple epidemic of silicosis, tuberculosis (TB) and HIV/AIDS has plagued the South African gold mineworkers, with black mineworkers in particular, for over two decades now. Factors such as oscillating migration patterns, hazardous working conditions, and crowded living arrangements allow for the perfect conditions needed to sustain and amplify the epidemic within this population. The objective of this thesis is to provide a detailed review of the epidemiological literature regarding the different aspects of the epidemic, followed by an in-depth analysis of the current policy response and its implications for directing the next phase of the response to the silicosis, TB and HIV epidemic in South Africa.

Review of the epidemiological literature provides strong and cogent evidence for the rapid and concomitant increase in the incidence and prevalence of silicosis and TB among gold mineworkers in South Africa over the last two decades. Moreover, the literature shows that silica dust exposure is an independent risk factor for TB even among gold mineworkers without silicosis, and significantly increases the risk for TB even after exposure to silica dust has ceased. There is also convincing evidence regarding the fact that the Occupational Exposure Limit (OEL) of 0.1 mg/m^3 currently recommended by the South African government for the silica dust exposure in gold mines is not sufficient to prevent new cases of silicosis among mineworkers.

Policy analysis provides evidence for the fact that there are serious gaps in research, policy and implementation of the approach and strategy to address the epidemic so far. There has been a steady decline in research expenditure on mining-related occupational health and safety research over the last few years, especially with regard to studying the health implications of silica dust exposure among mineworkers. There has also been a wide-ranging failure to reduce silica dust exposure levels in mines to below the OEL level of 0.1 mg/m^3, resulting in the failure to prevent new cases of silicosis among mineworkers. Poor active surveillance of silicosis and TB, especially among former mineworkers, has also contributed to the failure to develop a robust response since the real extent of the epidemic is still unknown.

Moreover, both the South African government and the mining companies share responsibility for the poor administration and the inadequate functioning of the compensation process, leading to the failure to successfully compensate mineworkers eligible for compensation. Lack of awareness among mineworkers and the absence of primary healthcare infrastructure is rural areas are other contributing factors that act as barriers for mineworkers from accessing their compensation benefits. Lastly, the policy analysis shows that silicosis and other occupational lung diseases are largely absent from the global health agenda, thereby resulting in lack of research funding and push from the global health community to demand action on this issue. While academics and local NGOs in South Africa have played a key role in mobilizing a response to the epidemic, there is an urgent need for a broader response and collaboration within the global health community to address the epidemic more robustly and effectively.

ACKNOWLEDGMENTS

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Introduction

The scourge of the triple epidemic of silicosis, tuberculosis (TB) and HIV/AIDS has plagued the South African gold miners, with black mineworkers in particular, for over two decades now. Factors such as oscillating migration patterns, hazardous working conditions, and crowded living arrangements allow for the perfect conditions needed to sustain and amplify the epidemic within this population.

Although both the mining industry and the South African government have acknowledged the severity of this epidemic, and have taken important measures to address the issue, a large proportion of attention, efforts and resources have been directed mainly towards the prevention and treatment of TB and HIV. While these initiatives deserve recognition and must continue, there is also an urgent need to address the 'hidden epidemic' of silicosis (Roberts 2009), with the proportion of gold miners with silicosis having increased dramatically over the last three decades (Nelson 2010).

Several epidemiological research studies have found strong and cogent evidence for the fact that prolonged exposure to silica dust predisposes both current and ex- gold miners to silicosis and TB, while presence of silicosis is a strong independent risk factor for TB within this population. Moreover, in the context of the HIV epidemic, silicosis further multiplies the risk of TB infection, thereby adding to the risk profile and disease burden of gold mineworkers' population. Therefore, it is imperative to control and manage the silicosis epidemic among gold miners, especially if we are to achieve the goal of preventing and controlling the exploding TB epidemic within this population.

Moreover, it's important to realize that in addition to the hazardous working conditions and lack of safety precautions in mines, the current epidemic is also partly a result of the combination of political and economic policies that existed in South Africa during the apartheid regime that lasted from 1948-1991, as well as those that exit today in post-apartheid South Africa. The South African mining industry has traditionally relied on migrant workers, with most mineworkers before 1970s belonging to neighboring countries in Southern Africa. The reliance on cross-border migrant workers was mainly because of the availability of surplus labor in these countries, and also because local South Africans despised mining-related jobs (Marks 2006). This distaste for the mining sector was essentially a symbol of the conflict between two different forms of economic production—the capitalist mode of production that originated from the mining sector versus the social mode of production that viewed families as responsible for control and production of resources (Wolpe 1972).

As a result, cross-border migration was used to support the capitalist mode of production, thereby establishing a strong reliance on migration that characterizes much of the labor force in the mining industry

even today, although most of it has now been replaced by rural-urban migration of mining labor-force within South Africa (Breckenridge 2010). Moreover, the politics of the apartheid regime in South Africa further propagated the reliance on migration of work-force in the mining industry. Under the apartheid regime, the cross-border migrant mineworkers were segregated from white mineworkers, and not allowed to build permanent living quarters, thereby giving rise to a circular migration pattern (Basu et al. 2009), which continues to add significantly to the risk of HIV and TB infection within this population (Rees et al. 2010).

After 1970s, however, there was a dramatic shift in the recruitment pattern of labor in the mining industry, with the apartheid state pressuring the mining industry to recruit more local South Africans from rural areas along with the industry's self-interest to build a more skilled workforce (Marks 2006). In fact, the policies of the apartheid regime fueled the collapse of the social model of economic production, and directed the unemployed local labor force in South Africa to the mining industry (Breckenridge 2010). As a result, local unemployed black men from rural areas were now taking up jobs in the mining sector. Moreover, while black mineworkers were still largely recruited on a contract-basis unlike the white mineworkers, the duration of the contract increased significantly, with average duration of a mine contract having increased to 13.4 months compared to 4.5 months that existed before 1970s for cross-border migrant mineworkers (Marks 2006).

Therefore black mineworkers were now employed for longer durations in high-risk job functions in the mines, thereby putting them at a higher risk of contracting silicosis and other occupational lung diseases compared to the white labor force. Moreover, black mineworkers during the apartheid regime were rarely informed of their eligibility for compensation benefits in case they developed silicosis, and even if they were informed many of them believed that reporting the disease and filing for compensation could result in the termination of their employment contract (Marks 2006). As a result, many never reported cases of silicosis and TB, thereby resulting in the burgeoning silent epidemic of silicosis and TB within this population.

However, even after the fall of the apartheid establishment in 1991, the powerful nexus between the mining industry, the post-apartheid government, and the mineworkers' union has largely sustained the migration of labor-force in this sector, although it is now mostly characterized by in-country migration of workers from rural areas to the mining sites (Breckenridge 2010). Moreover, with the shift towards a more high-skilled modern capitalistic economy since the 1990s there has been a steady decline in employment in the mining sector, especially with regard to low-skilled labor intensive jobs (Seekings and Nattrass 2002). This has created a power differential within this population, and recently led to the case of anger directed by the low-skilled migrant miners towards the relatively well-paid and high skilled officials of the National Union of

Mineworkers (NUM) (Breckenridge 2010). As a consequence of all these factors, the incentive and urgency to address health and compensation issues faced by the low-skilled miners who are most likely to develop silicosis and TB has taken a backseat, thereby further fueling the silent epidemic of silicosis and TB in this population.

Objectives

The objectives of this thesis are, therefore, threefold. The first section provides an in-depth literature review of the epidemiological research and findings pertaining to the incidence and prevalence trends of silicosis, TB and HIV among white and black gold mineworkers, with special emphasis on the relationship of silicosis and silica dust exposure as independent risk factors for TB, both in the presence and absence of HIV. The review will also look at the role of oscillating migration in fueling and sustaining the triple epidemic among black gold mineworkers.

The second section focuses on the policy environment in South Africa with regard to this epidemic, and discusses the evolving role of the state, the mining industry, and the miners and their representatives in addressing this epidemic over the last two decades. This will be followed by the third and last section that summarizes the gaping holes in the present response to this epidemic, and discusses policy implications for establishing effective and long-term measures for strengthening and streamlining the future efforts to address the epidemic. This section will also identify the key stakeholders in this process, the different levels of intervention, and barriers to implementation of suggested reforms.

Literature Review

I. Incidence and Prevalence Trends

i. The Silicosis Epidemic:

Silicosis has been rightly called the 'hidden' (Roberts 2009) and 'silent' (Marks 2006) epidemic. Although historically, the burden of silicosis and other occupational lung diseases had been borne by both white and black mineworkers, political, social and economic factors at play during the early decades of the 20th century dramatically skewed the proportion of burden of silicosis towards black miners (Marks 2006).

Factors such as the encouragement of a migrant labor system among black miners, differences in job function (with black miners often working as underground miners and thus exposed to higher levels of dust), and lack of similar employment benefits for black miners as compared to their white counterparts (Marks 2006), all contributed significantly towards shifting the burden of silicosis and other occupational lung diseases disproportionately on the population of black mineworkers.

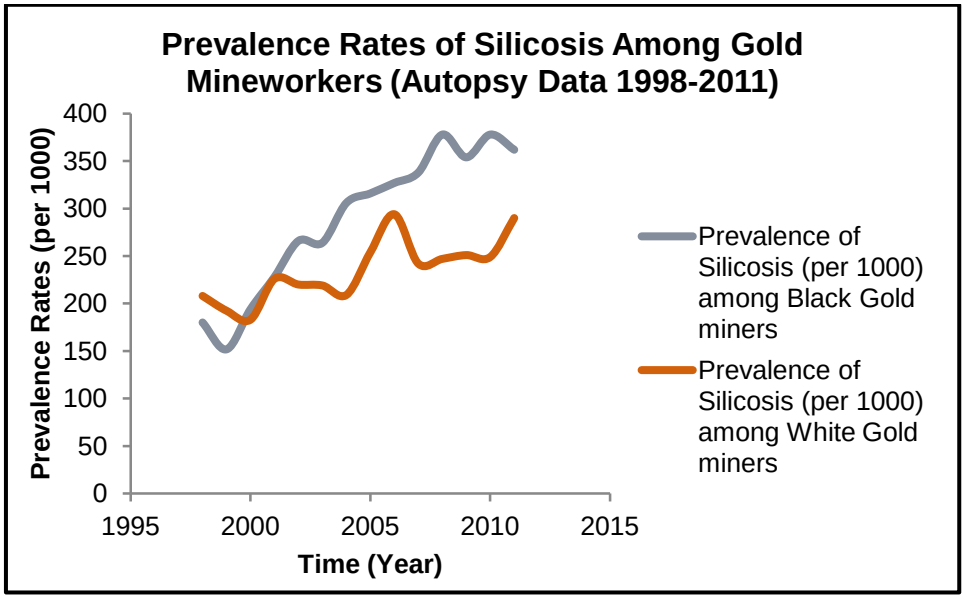

Figure 1(Source: Pathology Division Surveillance Data: 1998-2011)

Moreover, few black miners participated in research studies that were undertaken at the time to quantify the prevalence of silicosis among South African mineworkers (Roberts 2009 and Nelson 2010). With changes in employment patterns of black mineworkers in the late 1980s and early 1990s, there was a considerable increase in the number of epidemiological studies conducted to measure the burden of silicosis in this population (Nelson 2010).

Although no definitive data exist on the prevalence estimates of silicosis among black miners, a 2004 report from the Safety in Mines Research Advisory Committee (SIMRAC) estimated the prevalence of silicosis among current in-service miners to be around 24 percent, while also cautioning that this figure was quite possibly an underestimate (Roberts 2009). In fact, two earlier studies, both conducted among ex-

miners, one in 1997 in Thamage village, Botswana (Steen et al. 2007), and the other in1998 in Libode, Eastern Cape Province, South Africa (Trapido et al. 1998), found the prevalence rates of silicosis in the range of 26-31 percent and 22-37 percent respectively (Roberts 2009).

Epidemiological research conducted in the last decade has provided a deeper insight into the prevalence of silicosis, particularly among black mineworkers. A study published in 2004 found a high prevalence (18.9-19.9 percent) of radiologically diagnosed silicosis among older in-service black miners (Churchyard et al. 2004). Another study found the prevalence of silicosis to be nearly 25 percent among older Basotho ex-mineworkers, 18 months after they had been terminated from their work at a South African gold mine (Girdler-Brown et al. 2008).

Therefore, both age and duration of service are important risk factors for silicosis among black mineworkers working in gold mines. For instance, a study by Churchyard and others found that for mineworkers with duration of service ranging from 20.1-25 years, the prevalence rate of silicosis was 22 percent, and even higher for those with 30+ years of duration of service (Churchyard et al. 2004).

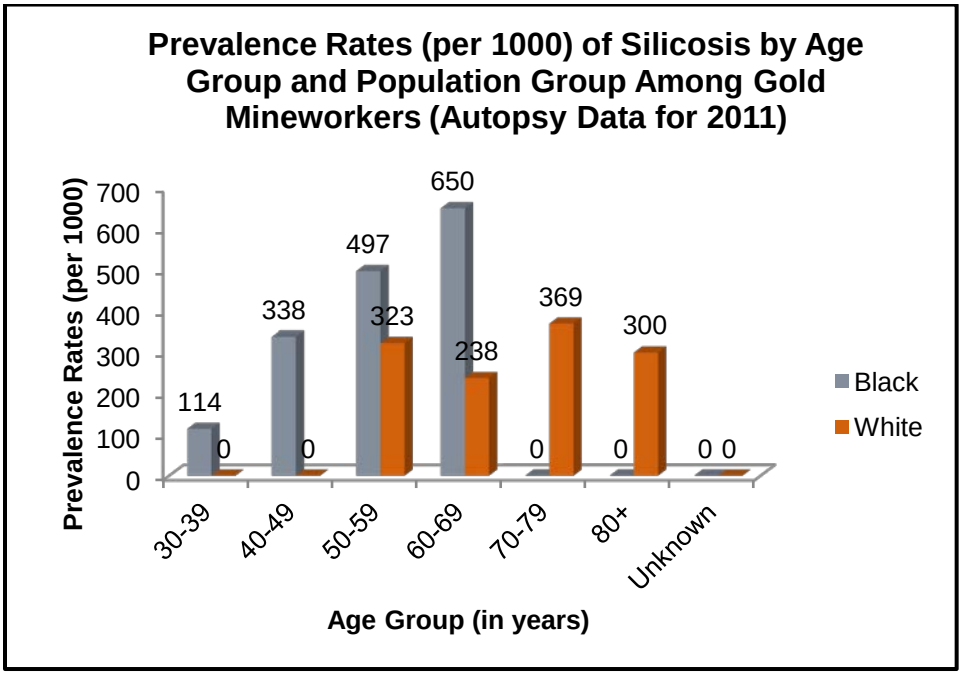

Figure 2 (Source: Pathology Division Surveillance Report 2012)

However, while prevalence estimates are an important measure of the burden of silicosis at a given time, they provide little information regarding the prevalence trend over time. A 17 year study (1975-1991) published in 1996 was one of the first to document the changes over time in prevalence of silicosis among a cohort of deceased black gold miners (Nelson 2010). The study documented a significant increase in the prevalence of silicosis over the study period (9.3 percent in 1975 to 12.8 percent in 1991), and also found that prevalence of silicosis increased with age and duration of service (Murray et al. 1996).

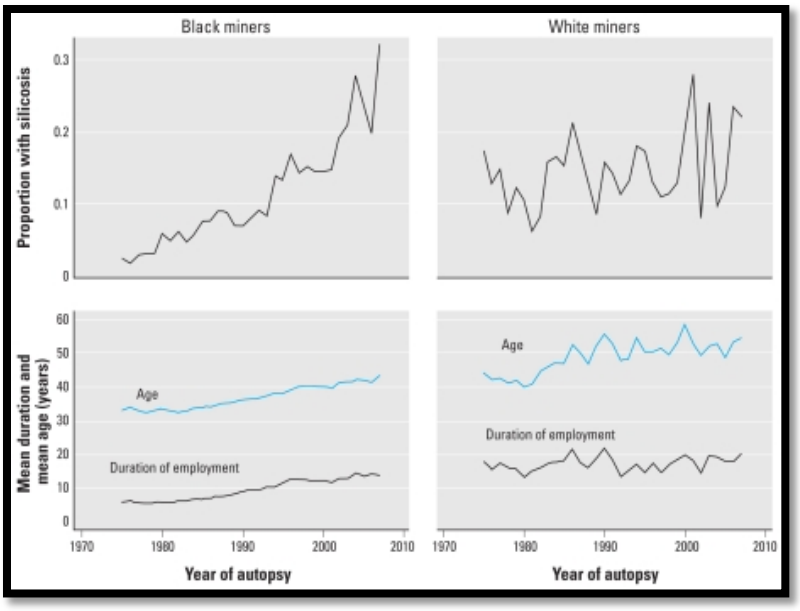

Figure 3 (Source: Nelson et al. 2010)

A recent study replicated these findings, and found that although the burden of silicosis has increased among both black and white South African gold miners over the last three decades (Nelson et al. 2010), the increase in proportion of black mineworkers with silicosis was almost twice compared to the increase among white mineworkers, even though white mineworkers, on average, are older and have a longer duration of service (20.1 years compared to 13.4 years among black gold miners) (Nelson et al. 2010).

However, in addition to age and duration of service, two interrelated and important risk factors that put black mineworkers at a higher risk of silicosis compared to white mineworkers are differences in job function within the mining occupation (Kleinschmidt and Churchyard 1997), and the level of silica dust that the black mineworkers are exposed to in these job functions (Sluis-Cremer 1980, Hnizdo and Murray 1998, and Churchyard et al. 2004). Mineworkers working in job functions such as drilling, stoping and mining teams are at a higher risk of developing silicosis compared to mineworkers working in low dust exposure job functions (Kleinschmidt and Churchyard 1997).

ii. Silica Dust Exposure and Silicosis:

While few studies have looked directly at the relationship between dust exposure levels and silicosis, and even fewer studies have tried to quantify the dust exposure levels associated with onset of silicosis, there is strong evidence that prevalence of silicosis among older black mineworkers increases linearly with increase in different exposure variables such as duration of service, cumulative exposure to respirable dust and cumulative exposure to quartz in gold mines (Churchyard et al. 2004).

With regard to the level of dust at which risk of silicosis increases, an earlier study reported silicosis prevalence of nearly 25 percent among white South African miners at a cumulative exposure to respirable

dust level of 9 mg.years/m^3 (Hnizdo and Sluis-Cremer 1993). The study by Churchyard and others had similar findings, where prevalence of silicosis was estimated to be around 23 percent among older black in-service gold mineworkers at a cumulative exposure to respirable dust level between 8.6-10.4 mg.years/m^3 (Churchyard et al. 2004).

More importantly, the study also found that the mineworkers in the cohort used for the study developed silicosis despite the fact that they were exposed to a quartz concentration below the recommended South African occupational exposure limit (OEL) of 0.1 mg/m^3 (Churchyard et al. 2004). Although 90 percent of mineworkers in the study cohort had exposure quartz levels in the range (0.029-0.075 mg/m^3) well below the recommended OEL of 0.1 mg/m^3, nearly one out of five still developed silicosis (Churchyard et al. 2004). The authors of the study also noted that an increasing amount of evidence shows that the present quartz OEL limit of 0.1 mg/m^3 is "not protective against silicosis" (Churchyard et al. 2004), and that an OEL limit of 0.05 mg/m^3 "may not be protective against silicosis either" (Churchyard et al. 2004).

In fact, a more recent cross-sectional study that evaluated the exposure-response relationship between respirable dust, respirable quartz and loss of lung function among a cohort of older black gold miners (aged>37 years) through directly obtained gravimetric exposure measurements (Ehrlich et al. 2010) also found that significant loss of lung function among this population is associated with a mean respirable dust concentration below 0.4 mg/m^3 and mean respirable quartz concentration below 0.1 mg/m^3 i.e. below the recommended South African OEL (Ehrlich et al. 2010). Notably, the study also found that the presence of silicosis, even after controlling for dust exposure, is associated with substantial loss of lung function particularly among black gold miners, thereby highlighting the independent effects of silica dust exposure and silicosis on lung function within this population (Ehrlich et al. 2010).

While most of the epidemiological research regarding exposure levels to dust has been conducted among in-service gold mineworkers, there is also strong evidence that the risk of developing silicosis persists even after the exposure to silica dust has ceased (Sluis-Cremer 1980, Hnizdo and Murray 1998). A longitudinal study that followed a cohort of white South African in-service and ex-miners from 1968-1971 found that even though the average age at the end of the dust exposure among the cohort was 53.1 years, the average age of onset of silicosis was around 53.5 years, thereby demonstrating that silicosis is a progressive disease that can develop even after the exposure to dust has ceased (Hnizdo and Murray 1998).

Other studies have also shown the prevalence of silicosis to be high among ex-miners (Steen et al. 1997, Trapido et al. 1998, Girdler-Brown et al. 2008 and Park et al. 2009), with one longitudinal study that followed a cohort of Basotho ex-gold miners documenting the prevalence of "progressive silicosis" and lower grades of silicosis among the cohort to be nearly 23 and 18 percent respectively (Park et al. 2009).

iii. The HIV epidemic:

Over the last two decades, South Africa has been ravaged by the HIV epidemic, and with nearly 5.6 million people estimated to be living with HIV according to data from 2009, it has the biggest HIV epidemic in the world (UNAIDS Report 2011). However, compared to the general population, South African gold miners have been hit particularly hard by HIV. Data show that HIV prevalence has increased dramatically in this population from a mere 1.3 percent in 1990 to 24 percent in 1999, and to stunning 27 percent in 2000 (Rees et al. 2010), which is almost twice the average of HIV prevalence in general adult population (Delva 2011).

One of the main risk factors for the rapid spread of HIV among black gold miners is the migrant labor system, which causes miners from rural areas to leave their homes and live away from their spouses and families for long periods of time. In fact, a cross-sectional study published in 2003 that compared the rates of HIV prevalence among migrant gold mineworkers and non-migrant men in KwaZulu Natal province in South Africa found that the HIV prevalence among migrant miners was more than twice that among non-migrant men (Rees et al. 2010). Moreover, as the turnover rate among black gold mineworkers continues to decline (Murray et al. 1996), rates of HIV incidence and prevalence within this population are expected to increase over the next few years.

However, while younger in-service miners are at an increased risk of HIV infection, rates of new HIV infection are also high among older ex-miners. A study that followed a cohort of older Basotho ex-miners for a period of one year found that the HIV incidence among this cohort was almost twice compared to the incidence rates among a group of South African black males in the ages 30-59 surveyed in 2005 (Park et al. 2009).

The evidence that HIV rates are higher among both black in-service and ex-miners compared to the HIV rates among the general population of South African black men also has another very important implication. Several studies have established the fact that HIV is a strong independent risk factor for TB, especially within the population of black gold mineworkers (Corbett et al. 1999, Corbett et al. 2000, and Park et al. 2009). A case-control study of South African in-service gold mineworkers with TB (cases) and without TB (controls) found HIV prevalence to be significantly higher among mineworkers with TB compared to controls (Corbett et al. 1999). In another longitudinal study of in-service black gold mineworkers, not only was TB incidence reported to be significantly higher among HIV-positive miners compared to HIV-negative miners, but the HIV-positive cohort also showed a significant increase over time in TB incidence, increasing from 2.2 to 5.8 per 100 person-years (Corbett et al. 2000).

Moreover, TB incidence is also found to be higher among ex-mineworkers compared to in-service mineworkers due to high rates of HIV prevalence in this population (Girdler-Brown et al. 2008 and Park et

al. 2009). Compared to in-service mineworkers, ex-miners are at a higher risk of undiagnosed active TB infection because of lack of compensation benefits and limited access to TB treatment services once they leave and return to their homes, often in remote rural areas with little to no healthcare infrastructure in place (Park et al. 2009).

iv. The TB epidemic:

South Africa has the third highest TB prevalence in the world, with nearly 0.4-0.59 million South Africans estimated to be living with TB (National Strategic Plan 2012-2016), while around 1 percent of the total South African population develops TB infection every year (National Strategic Plan 2012-2016). South African gold mine workers are characterized as a high-risk group for TB since TB incidence has been reported to be traditionally higher within this population, by nearly three times compared to the national average (Aggregate Report June 2012).

Moreover, TB prevalence has increased within this population by more than twice, from 806 per 100,000 mineworkers in 1991 to 1,914 per 100,000 mineworkers in 1998, and to 3,821 per 100,000 mineworkers in 2004, again a nearly twofold increase (Rees et al. 2010). However, according to a recent report from an external source that reviewed the TB control program in gold mines for the South African Chamber of Mines, there has been a decline in the number of new TB cases reported in gold mines (Aggregate Report 2012), dropping from 2,581 new TB cases per 100,000 mineworkers to around 2,267 TB cases per 100,000 mineworkers in 2008 (Aggregate Report 2012). Although the authors of the report conclude that these findings are in accordance with official figures from Chamber's Sustainability Report from 2005-2007, these data could not be corroborated with other published findings.

Racial disparity also exists in TB rates among gold mine workers, with black mineworkers at a considerably higher risk of contracting TB compared to their white counterparts (Hnizdo and Murray 1998). This disparity can be attributed mainly to the differences in the work profile of black and white gold miners. Black mine workers have traditionally worked as underground miners, in job functions that required prolonged exposure to high dust-levels, such as drilling and stoping. On the other hand, white miners are usually employed in managerial and maintenance positions, with little exposure to silica dust (Nelson et al. 2010).

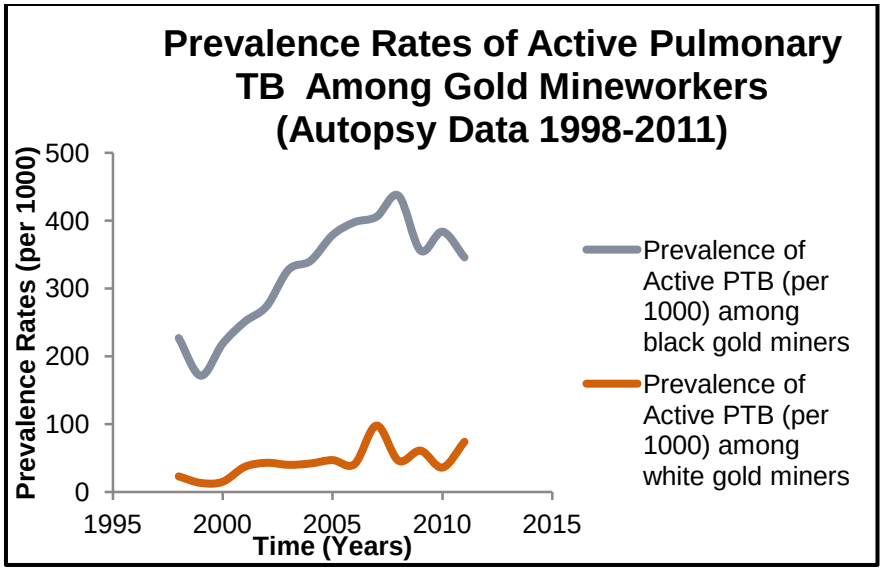

Figure 4 (Source: Pathology Division Surveillance Data: 1998-2011)

However, evidence regarding the racial disparity in TB rates among black and white gold miners started building up only in the 1990s, due to an increase in the number of public health studies with mine workers as the study population, as well as due to changes in employment patterns of the black mineworkers. Before the 1990s, a majority of black miners were short-term contract workers, who were migrants from rural areas. Unlike their white counterparts who built their careers in mining, black miners had a high turnover rate and constantly changed their employers (Nelson et al 2010).

As a result, even limited studies that followed this population rarely included black miners in their study population since they were at a higher risk of 'loss to follow-up'. However, owing to the changes in the employment pattern in the 1990s, there has been an increase in the duration of service years of black miners. In fact, according to one study (Murray et al. 1996) that followed a large cohort of black miners from 1975-1991, the proportion of black miners that were employed at the same mine for ten years or longer nearly tripled from 10.7 to 29.5 percent (Murray et al. 1996). This dramatic increase in the total years of service among black miners in gold mines has severely impacted the TB rates, thereby increasing both the TB incidence and prevalence within this population.

II. Silicosis, HIV and TB

Several epidemiological research studies have identified silicosis and HIV as key risk factors for the explosion of the TB epidemic among black mineworkers over the last two decades (Corbett et al. 1999, Corbett et al. 2000, Churchyard et al. 2000, Park et al. 2009 and Rees et al. 2010). A case-control study that compared the prevalence of silicosis and HIV among gold miners with TB and without TB found that controlling for other factors such as age, type of job function and duration of service, mineworkers with TB were 4.5 times as likely to be HIV-positive as mineworkers without TB (Corbett et al. 1999). In other

words, the prevalence of HIV was significantly higher among mineworkers with TB compared to those without TB. Moreover, mineworkers with TB were also more likely to have higher grades or severity of silicosis compared to those without TB (Corbett et al. 1999).

Combined presence of HIV infection and silicosis also increases the likelihood for in-service black miners to develop TB, with HIV-positive miners with silicosis 15 times more likely to develop TB compared to HIV-negative miners with no silicosis (Corbett et al. 2000). However, it's important to emphasize that both silicosis and HIV are independent risk factors for TB, and each increases the risk for TB even in the absence of one or the other, i.e. they demonstrate a multiplicative effect rather than an additive effect (Corbett et al. 2000).

In addition to increasing the likelihood of developing TB among gold mineworkers, combined presence of HIV and silicosis also significantly increases the likelihood of mortality among mineworkers with TB (Churchyard et al. 2000). According to a retrospective cohort study of gold mineworkers with pulmonary TB (PTB) and of known HIV status, a higher case-fatality rate from pulmonary TB (i.e. number of deaths due to PTB /number of diagnosed cases of PTB) in the overall study sample was significantly associated with HIV-positive status, presence of silicosis and self-presentation of symptoms by the mineworkers (Churchyard et al. 2000).

Interestingly, the study found that TB-associated case-fatality rates among mineworkers in the cohort were lower compared to the case-fatality rate from TB in the general population, mainly because with increase in TB incidence and prevalence, the gold mining industry compared to the general South African population has better access to healthcare, higher treatment completion rates and active case detection (Churchyard et al. 2000). Moreover, mineworkers are usually healthier compared to general population, i.e. the healthy worker effect could have biased the findings in this study (Churchyard et al. 2000). However, these findings also indicate that while the mining industry has directed considerable efforts towards reducing mortality from TB among mineworkers, especially among in-service mineworkers, little has been done with regard to preventing the rates of new TB cases from accelerating, both among in-service and ex-mineworkers.

III. The Role of Migration in the Silicosis, TB and HIV epidemic

i. Oscillating Migration and HIV:

Several studies have identified oscillating migration as one of the driving factors of the silicosis, HIV and TB epidemic among black gold mineworkers' population in South Africa (Marks 2006, Basu et al. 2009, Park et al. 2009, Rees et al. 2010). The mining industry in South Africa is characterized by both in-country migration, as well as cross-border migration from neighboring countries such as Lesotho and Swaziland,

with black miners, in both forms of migration, often migrating from rural areas to the mining sites for work (Lurie 2004, Marks 2006, Rees et al. 2010 and Corno and Walque 2012). In fact, cross-border migration of black mineworkers has been identified as one of the most important factors for the size and rapid spread of HIV in Southern Africa (Basu et al. 2004, Corno and Walque 2012).

However, according to a recently published World Bank study, it is migration-associated mining and not mining by itself that is a significant risk factor for rapid transmission of HIV within this population (Corno and Walque 2012). However, as Mark Lurie has noted, even migration by itself is not a risk factor for HIV; instead it is the social and economic factors that characterize and influence migration patterns that make it a risk factor for HIV within a population (Lurie 2004). The regulations imposed on the movement of black miners under the Apartheid regime until the 1990s encouraged circular migration (Marks 2006 and Basu et al. 2009), and forced miners to live in crowded single-sex hostels for long durations, thereby giving rise to a thriving prostitution industry and increased incidence and prevalence of sexually transmitted infections (STIs) within this population, thus putting them at a higher risk of contracting HIV (Lurie 2004, Basu et al. 2009 and Corno and Walque 2012).

In fact, according to the World Bank study, which analyzed data from the Demographic and Health Survey (DHS) from Swaziland and Lesotho, being a migrant miner is significantly associated with engaging in risky sexual behaviors, with migrant miners less likely to use condoms during extra-marital relationships compared to within marriage (Corno and Walque 2012). Moreover, the study also concluded that being a migrant miner in the age group 30-44 years increases the risk of being HIV-positive by 15 percentage points (Corno and Walque 2012). Another study that looked at in-country migration among miners and factory workers (i.e. rural to urban migration within South Africa), also found that migrant men were more likely to have regular sex partners at their migration destination and less likely to use condom during casual sexual encounters (Lurie 2004).

However, while it is usually assumed that the risk of HIV flows from migrant miners to their partners and communities back at home, studies have shown that the directionality of the flow of HIV risk is not unidirectional, and is in fact quite complex (Lurie 2004, Corno and Walque 2012). While the World Bank study on cross-border migration among miners found that women whose partners are migrant miners are at an increased risk of HIV infection by nearly 8 percentage points (Corno and Walque 2012), the study also demonstrated that women with migrant miners as partners are more likely to engage in extra-marital relationships themselves in the absence of their spouses/partners (Corno and Walque 2012). Moreover, female spouses of migrant miners are less likely to use a condom within marriage compared to women not married to miners (Corno and Walque 2012), and are also more likely to have experienced symptoms of STIs than female partners of non-migrants (Lurie 2004).

Therefore, while both migrant miners and their partners are at an increased risk of contracting HIV, the directionality of the flow of risk is complex and influenced by various factors. There is some evidence, however, that migrant men and their partners are both more likely to get infected with HIV from outside of the long-term relationship, rather than from their spouse or long-term partner (Lurie 2004). In fact, according to the study that examined HIV incidence and prevalence among rural migrants and their spouses in South Africa, migrant men were almost 26 times more likely to contract HIV from outside the relationship than from their spouses, while female partners of migrant men were nearly twice more likely to contract HIV from outside of the relationship than from their spouses (Lurie 2004).

However, while the flow of HIV risk among migrant miners and their partners is complex and multidimensional, there is little doubt that both migrant miners and their partners are at an increased risk of HIV, with the transmission occurring both within rural communities in South Africa as well as the neighboring countries that send migrant workers to the mining sites located in South Africa. These findings have important implications, both in terms of policies required for better HIV surveillance and prevention efforts not only at the mines but also in the rural communities, as well as the need for further research to better understand the dynamics of HIV transmission among migrant miners and their partners.

ii. Oscillating Migration and its Impact on the silicosis and TB epidemic:

Although oscillating migration has further fueled the HIV epidemic among black miners, it has also had an important impact on propagating the silicosis and TB epidemic within this population. Migration causes miners to live in crowded accommodation facilities, thereby providing conditions amenable for TB transmission (Rees et al. 2010). Moreover, with declining turnover rates of black miners at the gold mines, longer duration of employment in the mines has increased the risk of both silicosis and TB within this population, which is further amplified by the crammed and crowded living conditions of miners (Basu et al. 2009 and Rees et al. 2010).

Moreover, for former black migrant miners, who often have little knowledge of the compensation benefits, or for whom the distance is a barrier to accessing compensation, the costs of addressing silicosis and TB is externalized to their rural communities (Rees et al. 2010). There is also an added risk of transmission of TB among families and communities of former migrant miners, especially in cases of untreated TB, a result of lack of adherence to treatment and/or lack of access to treatment once the former miners are back in their communities (Basu et al. 2009, Rees et al. 2010). In fact, TB resistance has been increasing within this population over the last few years, with one study reporting the incidence of new multi-drug resistance TB (MDR-TB) and extensively drug resistance TB (XDR-TB) cases to be nearly 25 percent among migrant miners from Lesotho (Basu et al. 2009).

IV. Silicosis as an Independent Risk Factor for TB among mineworkers

While both HIV and silicosis together increase the risk of TB among gold mineworkers significantly, silicosis is also an independent risk factor for TB, thereby increasing the risk of TB among mineworkers even in the absence of HIV (Corbett et al. 2000). However, while HIV prevention and treatment has taken a center stage in the efforts to combat the growing HIV epidemic and the HIV-associated TB among this population, and rightly so, the important link between silicosis and occupational TB has been sidelined.

According to the latest estimates compiled from the autopsy results of deceased mineworkers, there has been only a slight decrease in the prevalence rates of silicosis among black gold miners, from 378 per 1000 in 2010 to 362 per 1000 in 2011 (Pathology Division Surveillance Report 2011). In fact, as is evident from the epidemiological study from 2010, there has been a sharp increase in the proportion of black miners with silicosis over the last three decades (Nelson et al. 2010), thus putting the mineworkers at higher risk of TB compared to mineworkers without silicosis.

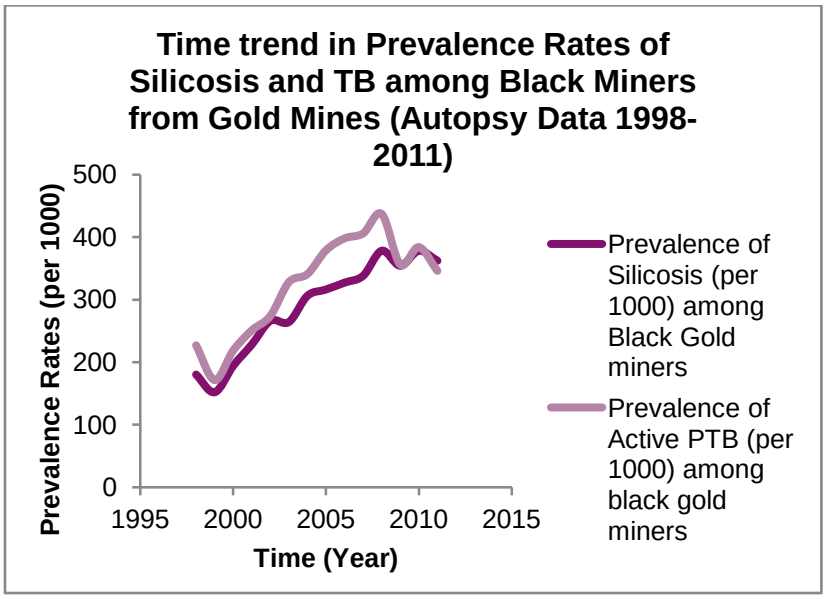

Figure 5 (Source: Pathology Division Surveillance Data: 1998-2011)

Moreover, even though there has been a decline in prevalence rates of pulmonary TB (PTB) among the overall population of mineworkers from all commodities (Pathology Division Surveillance Report 2011), the PTB prevalence rate continues to remain high among black miners working in gold mines, which was around 346 cases of PTB per 1000 deceased black miners, compared to PTB prevalence among black miners working in platinum mines, which was far lower at 262 cases of PTB for every 1000 deceased black platinum miners (Pathology Division Surveillance Report 2011). The higher prevalence of PTB among black miners working in gold mines can be partly attributed to higher rates of silicosis within this population, along with higher rates of HIV prevalence, which further amplifies the risk of PTB (Corbett et al. 2000).

These statistics are indicative of the fact that preventing and managing the rates of silicosis is the key towards reducing the added risk of occupational PTB among gold mineworkers. Several epidemiological studies have time and again shown that silicosis increases the risk of PTB significantly, with black mineworkers with silicosis nearly three times more likely to develop pulmonary TB than black mineworkers without silicosis even after controlling for factors such as age, duration of service, and home and work environment (Cowie 1994, and Kleinschmidt and Churchyard 1997). In fact, some studies have shown that gold miners with silicosis are also at an increased risk of developing extra-pulmonary TB (Cowie 1994) and nontuberculous pulmonary mycobacterial (NTM) disease (Corbett et al. 1999).

Although both silicosis and TB share certain common risk factors such as age, duration of service and type of occupation (Cowie 1994, Murray et al. 1996, Kleinschmidt and Churchyard 1997, and Hnizdo and Murray 1998), presence of silicosis remains a significant and independent risk factor for pulmonary TB among black miners (Cowie 1994, and Kleinschmidt and Churchyard 1997). However, as some studies have documented, the independent association between silicosis and TB might be weakened as a result of the fact that TB is more easily diagnosable compared to silicosis, which is often not detectable during radiological examination because of its long latency period (Murray et al. 1996, Kleinschmidt and Churchyard 1997, and Hnizdo and Murray 1998).

Epidemiological evidence also shows that risk of TB among gold mineworkers also increases with increase in severity of silicosis (Hnizdo and Murray 1998, Corbett et al. 1999, and Corbett et al. 2000). In fact, evidence shows that a considerable increase in the risk for TB is associated even with silicosis cases of minor severity (Murray et al. 1996). According to one longitudinal study that followed a cohort of white South African gold miners for over two decades, even negligible degree of silicosis i.e. < 5 silicotic nodules in the lungs, was also found to be associated with an increased risk of developing TB compared to the risk among mineworkers without silicosis (Hnizdo and Murray 1998).

Although the emergence of the HIV epidemic in the 1990s has further increased the risk of TB among gold mineworkers, epidemiological research shows that prevalence of higher grades of silicosis is a significant risk factor for new TB infections among both HIV-positive and HIV-negative miners (Churchyard et al. 2000, Corbett et al. 1999 and Corbett et al. 2000). While the incidence of TB among HIV-positive miners is generally higher than among HIV-negative miners due to the combined presence of both silicosis and HIV infection (Corbett et al. 1999 and Corbett et al. 2000), there is strong evidence that silicosis is a strong risk factor for both HIV-associated TB and TB among HIV-negative mineworkers, both at the population- and individual-level (Corbett et al. 2000).

Epidemiological evidence also suggests that silicosis is associated with increased risk of death from TB among both HIV-positive and HIV-negative gold miners (Churchyard et al. 2000). Moreover, according to

the study by Churchyard and others, not controlling for factors such as age, HIV status, extent of TB, and type of TB treatment, gold miners with silicosis were nearly eight times as likely to die from TB as gold miners without silicosis (Churchyard et al. 2000). This provides evidence for the fact that similar to HIV, presence of silicosis accelerates the progression of TB among mineworkers, thereby resulting in higher case-fatality from TB compared to case-fatality from TB among miners without silicosis (Churchyard et al. 2000 and Corbett et al. 2000).

V. Silica Dust Exposure and Risk of TB among Gold Mineworkers

Strong epidemiological evidence suggests that silica dust exposure is a significant risk factor for TB among gold miners even in the absence of silicosis (Sluis-Cremer 1980, Cowie 1994, Murray et al. 1996, Hnizdo and Murray 1998, Park et al. 2009). One of the earliest studies on this issue compared the prevalence rates of pulmonary TB among black miners from gold, asbestos and coal mines, and found concurrent cases of silicosis and TB not only in gold miners, but also in asbestos and coal miners, which the author noted had prior employment history of working in gold mines, and thus been exposed to silica dust (Sluis-Cremer 1980). The study concluded that previous exposure to silica dust even after the exposure has ceased can still increase the risk of both silicosis and TB among mineworkers.

Although it's difficult to disentangle the effects of silica dust and silicosis on the incidence of TB among mineworkers since silicosis and silica dust are highly correlated (Hnizdo and Murray 1998), a study of white South African gold miners showed that both silicosis and silica dust are independent risk factors for TB among this population (Hnizdo and Murray 1998). The study had two important findings− first, even after controlling for the cumulative dust exposure, presence of radiologically diagnosed silicosis increased the risk for pulmonary TB by nearly four times among gold miners with silicosis compared to those without silicosis (Hnizdo and Murray 1998), and second, that the risk of PTB was increased even among miners without silicosis, indicative of the effect of silica dust exposure on risk of PTB (Hnizdo and Murray 1998).

The study also found similar evidence for silicosis detected through necropsy procedure for deceased gold miners, thus confirming that exposure to silica dust is a significant risk factor for PTB even after controlling for severity of silicosis detected at necropsy (Hnizdo and Murray 1998). Moreover, there exists a dose-response relationship between exposure to silica dust and risk for TB, with increase in exposure to silica dust directly related to increase in the risk for TB, even in the absence of silicosis (Hnizdo and Murray 1998). An earlier study reported similar findings for a population of black mineworkers, where risk for PTB was found to be high even among miners without silicosis, although this risk was lower than among miners with silicosis (Cowie 1994), thereby emphasizing the importance of the relationship between silica dust exposure and TB.

These findings have important implications for minimizing and managing the risks of silicosis and TB, both among in-service and ex-gold miners. Strong epidemiological evidence for the fact that there is considerable risk for development of silicosis among ex-gold miners even after exposure to silica dust has ceased (Sluis-Cremer 1980, Hnizdo and Murray 1998, Park et al. 2009), and that development of TB among ex-gold miners can occur both after exposure to silica dust has ceased and in the absence of silicosis (Cowie 1994, Hnizdo and Murray 1998, Park et al. 2009), indicates that absence of silicosis among current and former gold mineworkers does not necessarily reduce their risk for developing TB, especially with increase in age, longer duration of service and type of job function. While silicosis and HIV remain significant risk factors for TB among black mineworkers, prolonged exposure to silica dust significantly contributes to the risk of both silicosis and TB, even after the exposure to silica dust has ceased.

Policy Analysis of the Response to the Silicosis, TB and HIV Epidemic in South Africa

The increasing severity of the HIV epidemic among gold miners in South Africa in the 1990s also generated attention and efforts to address the concomitant epidemic of silicosis and TB within this population. Although a number of policies and initiatives have been instituted both by the state and the mining industry, little has changed on the ground for black mineworkers, attributable largely to the weak and flawed implementation of these policies. I use the 'Deadly Mineral Triangle' (depicted below) model proposed by *Stuckler et al*. to discuss the different policies that have been instated to address the combined epidemic of silicosis, TB and HIV in this population so far.

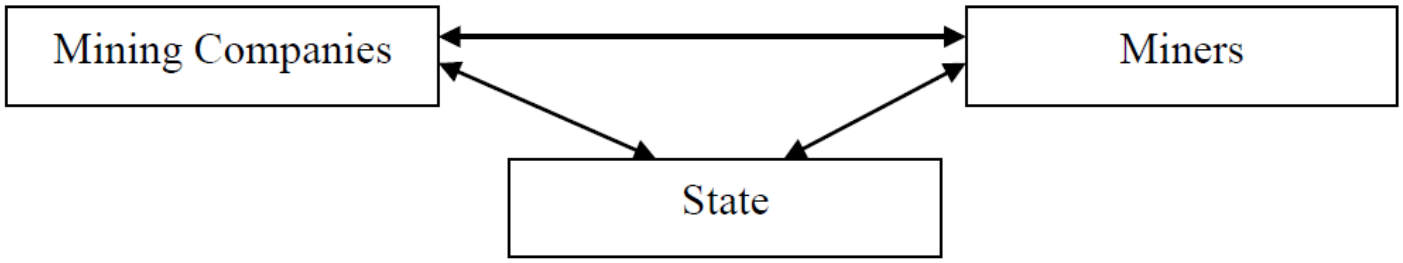

Figure 6 (Source: Stuckler et al. 2010)

Based on the 'Deadly Mineral Triangle' model, *Stuckler et al*. have identified three key stakeholders in addressing the current epidemic of silicosis, TB and HIV among gold mineworkers in South Africa-- the mining companies, the state, and the miners and their representatives such as the current miners' union, the ex-mineworkers' association, academic and non-governmental organizations (NGOs) (Stuckler et al. 2010).

I. The Mining Companies:

Although the big mining companies have taken note of the seriousness of the epidemic among gold mineworkers, they have been lacking in terms of implementing any effective measures to address the issue. The 1995 Leon Commission report called for the stricter enforcement of laws and regulatory bodies to ensure the health and safety of mineworkers, and led to the legislation of the Mine Health and Safety Act and the consequent establishment of the Mine Health and Safety Council (MHSC) in 1996, a tripartite body which mandates equal representation of the mining industry, the state (Department of Minerals and Resources) and the mineworkers (Stuckler et al. 2010). However, there is evidence that interests of the mining industry, represented by the Chamber of Mines, the main lobby group for the mining industry, often undermine the interests of the state and the mineworkers, thereby paralyzing the effective implementation of the objectives of the MHSC (Vogt 2011). The failure to achieve any of the three targets set by the MHSC at the Mine Health and Safety Summit in 2003, i.e. zero fatalities and injuries by 2013 in the gold mining sector,

elimination of silicosis by December 2013, and elimination of noise-induced hearing loss (NIHL) by December 2013 reflects the lackluster efforts of the industry to implement effective measures necessary to achieve these targets (Vogt 2011).

While strong and convincing research has consistently demonstrated the need for reducing the quartz exposure levels in gold mines to below the present recommended OEL level of 0.1 mg/m^3, the mining industry missed the primary target of reducing 95 percent of all respirable crystalline silica or quartz measures to below the OEL level by December 2008 (Nelson et al. 2010). In fact, according to the Mine Health Report of 2010-2011, the proportion of mines complying to the above guideline actually declined from 94 percent in 2006 to 85 percent in 2010 (Nelson et al. 2010).

There has also been some evidence that in order to avoid the levy imposed by the South African government on the mines, which is dependent on the dust measurements as mandated under the Occupational Diseases in Mines and Works Act (ODMWA), the mining industry has regularly 'estimated' silica dust levels in the mines, rather than actively measure them (Nelson et al. 2010). While there have recently been changes in the factors that dictate the nature of levies imposed on the mines, their terms and conditions haven't been made publicly available.

There is also a shroud of secrecy that covers the undertakings of the mining industry with regard to data collection concerning incidence and outcome of occupational diseases among their employees, with the industry not required to make its reports publicly available (Basu et al. 2009). Moreover, while the reports are made available to the government, these reports are kept secret (Basu et al. 2009). This lack of transparency obscures the true extent of the silicosis and TB among the mineworkers employed in gold mines (Basu et al. 2009).

One of the chief failures of the mining industry has been its non-compliance with ODMWA, which mandates the mining industry to compensate both black and white current and former mineworkers suffering from occupational lung diseases such as silicosis. However, the complex process of compensation is burdensome for many mineworkers (Stuckler et al. 2010) and their families, requiring evidence of second degree TB or permanent lung damage, and often covers only work shifts lost due to hospitalization (Basu et al. 2009). Moreover, in cases of deceased mineworkers, the mining industry requires the family to send the miner's heart and lungs for an autopsy to ensure lung damage for further processing of the compensation claim (Basu et al. 2009). This is often culturally objectionable for many families, especially for those from rural areas (Stuckler et al. 2010).

The task of navigating through the compensation process is especially difficult for former migrant mineworkers from rural areas, who often have no access to healthcare facilities for a medical diagnosis of silicosis or TB. Moreover, few former mineworkers are even aware of their eligibility for compensation, given

the lack of initiative on the part of the mining industry to inform mineworkers of their rights and benefits (Marks 2006 and Stuckler et al. 2010). The fact that silicosis can take years before it develops also causes many former mineworkers to become disillusioned with the idea of compensation or to forget about it.

However, even if the former mineworkers are aware of their rights, and are able to get a medical diagnosis, they often lack the means to travel to cities to file a compensation claim (Stuckler et al. 2010 and Murray et al. 2011). Lastly, the long wait for a compensation claim to get through also acts as a deterrent for many former mineworkers and prevents them from filing the compensation claim in the first place (Stuckler et al. 2010 and Murray et al. 2011). In fact, only a mere 2 percent of former gold miners with compensable silicosis in Eastern Cape have been estimated to receive their compensation benefits (Stuckler et al. 2010). These problems are even further exaggerated for former mineworkers from neighboring countries, with lack of coordination between countries and institutions regarding procedures and protocol for filing of compensation claims by non-South African former mineworkers (Stuckler et al. 2010).

In addition to the cumbersome compensation process, there are some concerns regarding the solvency of the compensation fund (Basu et al. 2009 and Stuckler et al. 2010). According to some estimates, there are approximately 280,000 men in Southern Africa eligible for occupational health compensation, which totals to an amount of greater than US$ 6 billion in compensation (Stuckler et al. 2010). Several studies have cited a 2005 report by Deloitte that outlined the imminent bankruptcy of the compensation fund (Basu et al. 2009 and Stuckler et al. 2010), and the fact that the mining industry will be able to compensate all the pending claims only if it dramatically increases the funding of compensation fund from the current funding levels (Basu et al. 2009).

With regard to the medical services provided to in-service gold miners, most big mining companies conduct annual physical examination of their employees, along with X-rays for preliminary diagnosis of active TB followed by lab testing for confirmation of TB (Basu et al. 2009). The healthcare facilities at the mining premises also provide STI and HIV testing, along with increasing awareness about HIV through information and education sessions (Basu et al. 2009). However, there is little evidence that the industry has invested in any other long-term structural changes in order to address silicosis, TB or HIV among gold miners, such as dust control measures or improving living conditions of the miners (Basu et al. 2009 and Stuckler et al. 2010).

Stuckler and others have attributed this failure to the current economic system, which doesn't provide the mining companies any strong financial incentives to address the health concerns of their employees through effective preventive measures (Stuckler et al. 2010). This is due to two main reasons−first, the surplus labor available to the mining industry from the rural areas within South Africa and the neighboring countries over the last few decades has not only kept the wages low, but also prevented the companies from investing in

long-terms measures to protect their employees because of high rates of turnover among black mineworkers (Marks 2006 and Stuckler et al. 2010). Second, even the recent changes in the employment patterns, with more and more black mineworkers working at one mine for a longer duration, are accompanied by an increase in use of technology and shrinking of the gold mining industry, thereby leading to downsizing of labor, and hence further disincentivizing the need for the mining industry to invest in their employees' health and safety (Marks 2006 and Stuckler et al. 2010).

II. The State:

Different departments within the South African government have been delegated the responsibility for addressing the epidemic of silicosis, TB and HIV among the gold mineworkers. While Department of Mineral Resources (DMR) is responsible for advancing the objectives of the Mining Charter adopted by the department in 2004, which includes regulatory reforms on issues such as housing and nutrition requirements of miners (Stuckler et al. 2010), the Department of Health (DOH) is mainly delegated with the responsibility of surveillance, overseeing the compensation fund and successful implementation of the compensation benefits for the eligible miners (Stuckler et al. 2010). Recently, the Department of Labor also assumed some responsibility, with the establishment of the National Programme for the Elimination of Silicosis in1998, which in accordance with the goals of the International Labor Organization (ILO) and the World Health Organization (WHO), aims to reduce the prevalence of silicosis by 2015 and completely eliminate silicosis in the workplace by 2030 (Stuckler et al. 210 and Murray et al. 2011).

As evident, the fragmented delegation of responsibilities spread across different government departments acts as a major barrier towards effective implementation of policies and regulatory measures, especially since different departments have different goals and objectives, thus resulting in conflict of interests (Stuckler et al. 2010). Moreover, the widespread corruption has also led to poor implementation of otherwise well-formulated policies (Stuckler et al. 2010, Murray et al. 2011). For instance, there are accusations that both the DOH and DMR failed to take any action against the mining industry even though they were well aware of the risks posed towards the health and safety of the miners from high levels of the silica dust exposure in the gold mines (Stuckler et al. 2010).

Even with respect to the present measures in place to control dust levels in the mines, which are voluntarily agreed upon rather than strictly enforced, the government has no independent oversight regarding the evaluation of reported dust levels, or no independent body in place to corroborate the results that are reported by the mining industry (Stuckler et al. 2010).

There is also concern regarding the effective functioning and oversight of the compensation fund under the auspices of the Department of Health (Stuckler et al. 2010). As per ODMWA, compensation to an

eligible mineworker (whether in-service or former mineworker) is only provided if a state inspector or examiner mandated by the Department of Health (DoH) finds sufficient evidence of a compensable disease. Moreover, the DoH commissioner approves the pay out of claims, while a separate reviewing committee is in-charge of any appeals (ODMWA Fact Sheet 2013). ODMWA also requires the state to pay for the ongoing medical care of a mineworker who can no longer afford to work in the mines. Therefore, there is a considerable need of personnel and resources required by the DoH for smooth functioning and processing of compensation claims (Stuckler et al. 2010)

Moreover, while families of deceased mineworkers are eligible to apply for compensation benefits, they are required to obtain and submit autopsy results of heart and lungs of the deceased mineworker to the DoH in order to verify the presence of silicosis or TB (ODMWA Fact Sheet 2013). While this requirement might be culturally insensitive for some families to adhere to (Stuckler et al. 2010), even families that wish to follow this requirement face a number of barriers, especially since ODMWA mandates that heart and lungs of the deceased miner must be sent to Johannesburg for autopsy (Stuckler et al. 2010). This is especially difficult for families of cross-border migrant mineworkers since they require a special permission from the DoH to send the organs into South Africa, and this permission document is often difficult to obtain (ODMWA Fact Sheet 2013). Therefore, the bureaucratic complexity and the fact that the DoH is already overstretched regarding resources and administrative capacity result in long waiting times for processing of compensation claims (Stuckler et al. 2010 and Murray et al. 2011), which often prevents miners from filing claims and obtaining their compensation benefits.

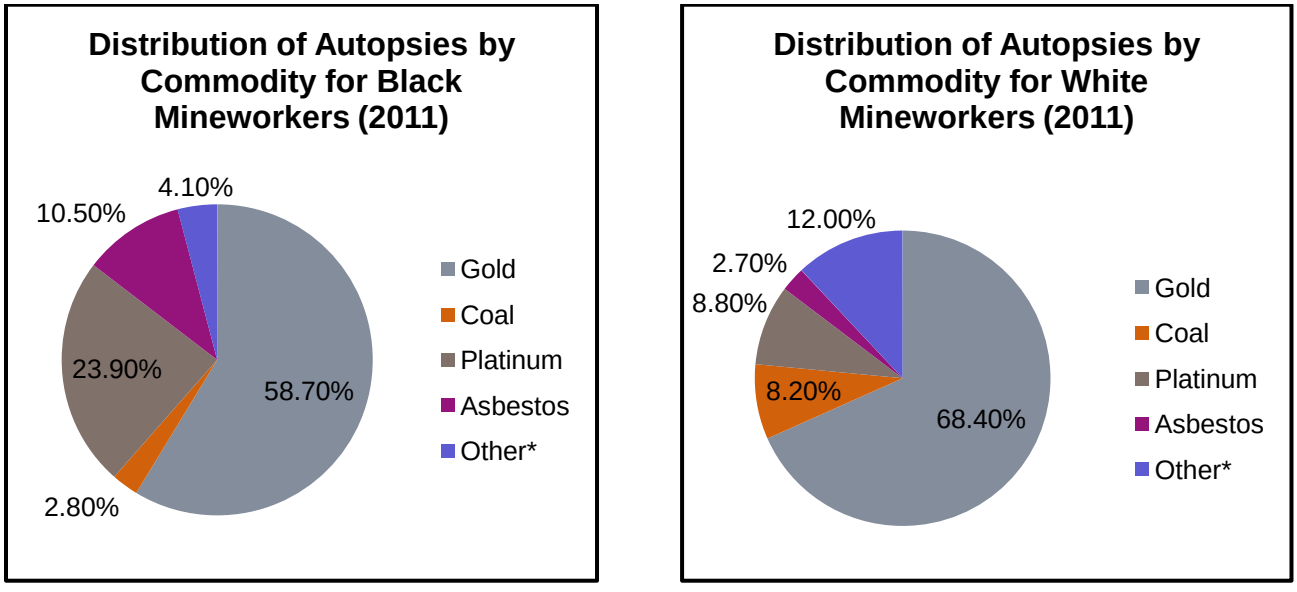

Figure 7 (Source: Pathology Division Surveillance Report: 2011)

III. Miners and their Representatives:

Miners have an important role to play in terms of getting their voices and concerns heard by the relevant authorities. Although white mineworkers have had a strong tradition of unionization under the apartheid regime, with white mineworkers calling for better wages and living conditions, as well as compensation through trade-union organization and strikes as early as 1920s (Marks 2006), black mineworkers were at a disadvantage with the refusal of the apartheid regime to guarantee equal benefits to both white and black mineworkers (Marks 2006).

In fact, while white mineworkers received more in compensation as well as a pension after their retirement, black mineworkers received far less in compensation and were not eligible for any retirement benefits (Marks 2006). Moreover, as more black mineworkers began filling in jobs previously undertaken by white miners, both the mining industry and the apartheid government became less interested in addressing issues concerning the health and safety of the mineworkers (Marks 2006).

At present, the National Union of Mineworkers, which represents around 500,000 current in-service miners, works to protect the rights of the black mineworkers, along with an Ex-Mineworkers' Union that represents several million former mineworkers (Stuckler et al. 2010). However, these unions are relatively weak in comparison to the powerful lobby group of the mining industry, the Chamber of Mines. While there are speculations that some union leaders are in cahoots with the mining industry, several other factors also contribute to the failure of the unions to challenge the mining industry and the government (Stuckler et al. 2010). The fact that mineworkers are often from remote rural areas from within and outside of South Africa leads to organizational difficulties, with few mineworkers actively involved in the unions' proceedings (Stuckler et al. 2010).

Moreover, there are also disagreements and differences within the union, which has led to the formation of different factions and sub-groups, representing and fighting for different goals and agendas (Stuckler et al. 2010). For instance, while some miners within the union strongly advocate for better compensation benefits, others are hesitant and skeptical of the excessive focus on compensation, fearing its negative effects on the employment levels and wages. This issue has in fact led to a deep rift between the current miners' union and the ex-mineworkers' union, with leaders of the current miners' union more interested in addressing issues of injuries and other safety concerns for in-service miners, rather than taking up the cause of compensation for silicosis, a condition which takes years to develop and is more likely to affect miners that have already left the workforce, and is therefore not viewed as an issue that requires urgent attention with respect to current in-service mineworkers (Stuckler et al. 2010).

In addition to the politics and power differentials within and between the unions, lower literacy levels among mineworkers also acts a barrier towards raising awareness on a variety of issues, ranging from the

information contained in their employment contracts to information regarding silicosis, TB, and HIV, and related issues of healthcare services and compensation eligibility and benefits (Basu et al. 2009). The additional burden of cost, travel, time and immigration issues for former migrant mineworkers further deters them from taking advantage of the compensation benefits even if they are aware of their rights and eligibility for benefits. Moreover, the lack of support services for the former mineworkers, both in their respective home countries as well as from the South African government or the mining industry makes navigating through the compensation process a nightmare for former miners and their families (Basu et al. 2009, Stuckler et al. 2010, Murray et al . 2011).

IV. The Role of Academics, NGOs and International Agencies:

In addition to these three pillars of response to the silicosis, TB and HIV epidemic , Stuckler and others posit a fourth pillar, representing academics, NGOs and international organizations, which have become active participants in the fight for justice for the black mineworkers. While the academics have long played an important role in advancing the research and policy on silicosis and TB within this population, with credible and strong evidence available on the role of oscillating migration, silicosis, silica dust exposure and HIV in advancing the TB epidemic among South African mineworkers, NGOs and international agencies have only recently begun to play an active role in addressing this epidemic (Stuckler e al. 2010).

While the earliest efforts by the UN to address the issue of silicosis were when the ILO and the WHO, in conjunction with the South African government and the Chamber of Mines, established the program to eliminate silicosis in 1998, the program has failed to achieve any of its set targets owing to the weak implementation of the outlined guidelines, and virtually no monitoring and evaluation mechanism in place (Stuckler et al. 2010, Murray et al. 2011).

Moreover, WHO and UNAIDS have mostly failed to take any concrete measures to address the mining-related risks of TB and HIV among mineworkers (Stuckler et al. 2010). While much attention has been paid in the literature and reports published by the WHO, UNAIDS and the World Bank on the role of HIV in advancing the TB epidemic among mineworkers in South Africa, silicosis has been virtually ignored even though cogent peer-reviewed literature exists on both the independent and combined effect of silicosis in advancing the TB epidemic within this population (Stuckler et al. 2010). In fact, only recently has UNAIDS partnered with the ILO and WHO to formulate guidelines on controlling the TB-HIV epidemic in workplaces, including mines (Stuckler et al. 2010). However, despite these new measures, there is further need for the UN to highlight silicosis as an important and urgent public health issue that needs to be addressed not only in South Africa but also in other countries with active mining industries.

Another international agency that has been a key player in addressing this issue is the Southern African Development Community or SADC, an inter-governmental agency established to encourage cooperation and integration on socio-economic issues in Southern Africa (Stuckler et al. 2010). While SADC has a *Protocol on Mining* in place, with similar goals and objectives as the Mining Charter which was adopted by the DMR in 1994, the document is voluntary and hence lacks any mechanism of strong enforcement (Stuckler et al. 2010). While the trade department of SADC promotes cross-border employment throughout Southern Africa, it has done little to find solutions to address barriers related to availability and access to healthcare services, or streamlining the process of filing compensation claims for former migrant mineworkers with silicosis, TB and HIV (Basu et al. 2009). Therefore, while there are protocols and policies in place, SADC has failed in its leadership role to promote and ensure their effective implementation.

In contrast to the international agencies, NGOs and health activists have played a significant role in advancing public awareness and mobilization regarding the silicosis and TB epidemic among black mineworkers in South Africa. Several AIDS activists and NGOs, such as AIDS and Rights Alliance South Africa (ARASA) have been instrumental in bringing the issue of silicosis and TB epidemic among mineworkers into the public domain (Stuckler et al. 2010). The focus of these NGOs is not only on evidence-based policy making, with many of them collecting and compiling qualitative and quantitative data and publishing annual reports, but also on promoting health and economic equity, thereby advancing the issue through the lens of human rights and social justice. However, while their efforts are commendable and much needed, issues remain surrounding funding and collaboration required for such projects, along with the struggle to sustain public attention and momentum on this issue.

V. Mining-related Research and Funding:

While the 'Deadly Mineral Triangle' model provides a useful way to look at the role of different stakeholders involved in this issue, I would also like to reflect on the state of research and funding with regard to issues relevant to the mining industry, whether it's devising new methodologies for dust control measures, or funding resources for academics and researchers to better characterize the biology and epidemiology of silicosis and TB, and to quantify and study the dynamics of silica dust exposure.

a) The Leon Commission Report and SIMRAC:

Mining-related research had traditionally been the responsibility of the South African mining industry, with most of the research in the 1960s carried out by the Chamber of Mines Research Organization (COMRO) (Vogt 2011). However, a number of factors such as declining prices of gold, conflict within the organization regarding its research priorities and general neglect for research led to the closure of COMRO

in 1992 (Vogt 2011). However, the collapse of COMRO was accompanied by a new legislation that mandated the formation of a safety research account funded by the levy paid by mines based on their safety performance, consequently leading up to the creation of the Safety in Mines Research Advisory Committee (SIMRAC) (Vogt 2011).

While the creation of SIMRAC was an important step towards ensuring the safety of mineworkers, it had no oversight regarding the health status of miners, thus rendering it futile in terms of ensuring medical or compensation benefits for in-service or former mineworkers with occupational diseases such as silicosis or TB. However, the unveiling of the Leon Commission Report in 1995, which drew attention to the urgent need for regulation of health and safety in mines, brought dramatic changes in the structure and function of SIMRAC (Vogt 2011). The Leon Commission findings led to the establishment of the Mine Health and Safety Council (MHSC), with SIMRAC adjudicated as a sub-committee to the MHSC (Vogt 2011). Like MHSC, SIMRAC was also restructured as a tripartite body, with equal representation of the industry, state and the labor, and was designated as the main source of funding for health and safety research under the guidance of the MHSC (Vogt 2011).

Although the Leon Commission made a number of important recommendations regarding the objectives and functioning of MHSC and SIMRAC, few of these have actually been implemented. While the Leon Commission was cautious of the dangers of the interference of industry interests with the fairness and objectivity of the research, which they envisioned to be 'needs driven' (Vogt 2011), industry interests have dominated the functioning of both MHSC and SIMRAC (Stuckler et al. 2010, Murray et al. 2011 and Vogt 2011). In fact, even though the Leon Commission recommended the creation of an independent review panel that would be responsible for reviewing the objectives and progress of research undertaken by SIMRAC, there has been a failure to strictly enforce this recommendation (Vogt 2011).

b) Inadequate Funding for Research:

While the MHSC focuses on a range of research topics, ranging from mining technology to occupational diseases and airborne pollutants, and each with their respective levels of funding, there has been a steady decline in the overall expenditure on research funding since the creation of SIMRAC in the early 1990s (Vogt 2011). Though some of it could be attributed to the expansion of SIMRAC, from focusing just on safety measures to inclusion of occupational health research following the Leon Commission findings (Vogt 2011), the decline in funding has also been a result of incompetence and passiveness of the mining industry and the government to a certain extent, with their failure to acknowledge the importance of research in advancing evidence-based policy regarding the health and safety concerns of the mineworkers (Basu et al. 2009, Stuckler et al. 2010 and Murray et al. 2011).

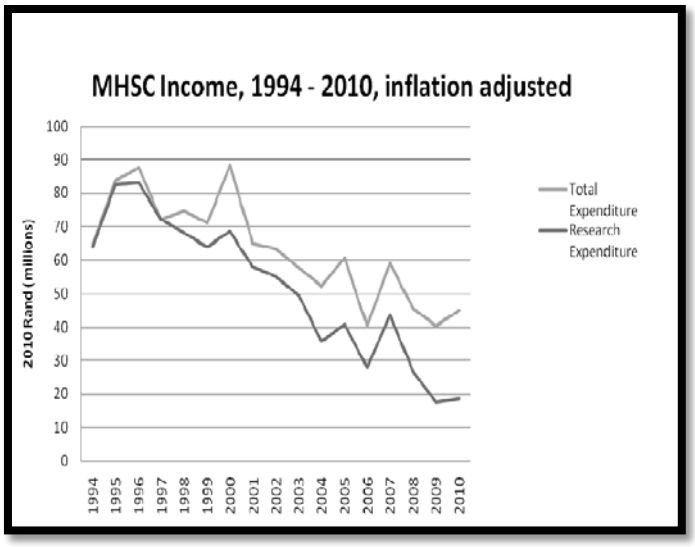

Figure 8(Source: Vogt 2011)

In fact, the lack of sufficient funding has made it extremely difficult for researchers and academics to rely on MHSC funding for longer than a year, which in turn has affected funding for graduate students interested in pursuing research either in occupational health or other mining-related research areas (Vogt 2011). Such uncertainty and unreliability regarding funding has also paralyzed the progress of other important projects such as investigation and quantification of appropriate and safe silica dust exposure levels and rockburst research, thereby derailing the achievement of targets set by MHSC regarding elimination of injuries/fatalities, silicosis and hearing loss among mineworkers (Vogt 2011).

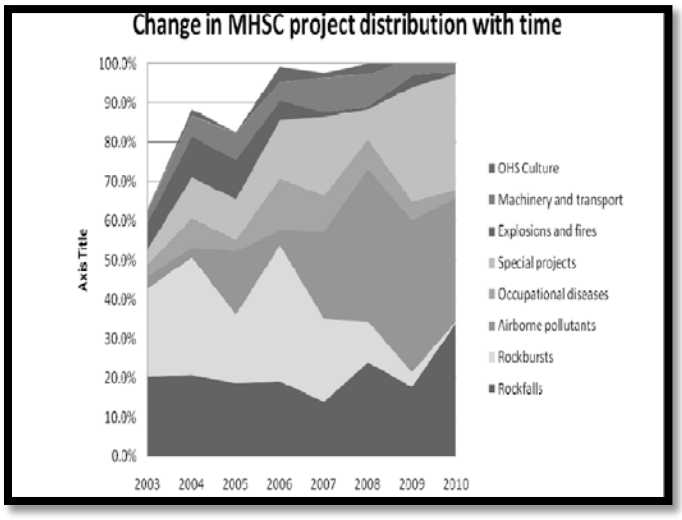

Figure 9 (Source: Vogt 2011)

c) The Role of the Government in Mining-related Research:

Although the MHSC provides equal representation to the government, along with the industry and labor, the government has failed to adequately utilize this role, either to improve funding or provide an impetus for more research. However, the government has also failed to take an independent initiative to encourage research on mining-related activities such as dust control measures that can directly or indirectly address the health and safety issues related to mining. In fact, while the Department of Mineral Resources (DMR) has no published policy directive on research (Vogt 2011), the Department of Science and Technology has also failed to include mining-related research in its 10 year plan of 2008 (Vogt 2011). Mining-related research is also not viewed as an important area of focus by the Department of Trade and Industry, which has also failed to make any substantial commitment to the mining sector so far (Vogt 2011).

d) The Role of CSIR in Research Funding:

At present, the Council for Science and Industrial Research (CSIR) is the largest funder of mining-related research in South Africa, and oversees the independent Center for Mining Innovation (CMI), which conducts research on a number of issues ranging from risk management and technological innovation to development of novel tools to address health hazards in mining (CSIR 2007). In addition to the CMI initiative, CSIR is also working with the mining industry and the government to revive and build research capacity through the establishment of the *Centre of Excellence*, which in accordance with the recommendations made by the Leon Commission would aim to develop and undertake research in important mining-related issues, with particular focus on occupational health and hygiene (Vogt 2011).

e) Failure to Translate Research into Practice:

There has also been a failure to use the available research to guide policy and practice to address the silicosis, TB and HIV epidemic among mineworkers. While there is some research available on measures to reduce silica dust exposure in gold mines, along with research on ways to minimize risks for silicosis and TB, these findings have not been disseminated efficiently by the MHSC, the trade unions or the mining industry (Murray et al. 2011). Moreover, even if research findings have been incorporated into government's recommendations and initiatives to address the epidemic, the slow and weak enforcement mechanism in place have obstructed the progress on this issue at each and every step (Murray et al. 2011). Lastly, even if the recommendations have been implemented, there is no effective monitoring and evaluation system in place to measure the effectiveness of the programs/initiatives, thus failing to provide guidance on the needs of future research and/or modifications and improvements needed in current policies and programs (Stuckler et al. 2010 and Murray et al. 2011).

f) Encouraging the Next Generation of Public Health Researchers and Academics:

Although funding is a major barrier, there is also a need to encourage the next generation of researchers and academics to pursue research in occupational health in order to fill in the gaps that currently exist in the literature. Public health professionals and occupational health physicians who have been involved in this field, therefore, have an important responsibility to create awareness among public health and medical students regarding the magnitude of the problem of occupational diseases that plague mineworkers.

While no data currently exists on the number of students that are actively involved or who plan on pursuing research in occupational health and safety in South Africa, anecdotal evidence reflects the need for more students and young researchers to carry out the next phase of epidemiological, medical and technological research to prevent control and treat silicosis, TB and other occupational lung diseases that affect thousands of mineworkers each year. Therefore both economic and human capital is required in order to advance future research and policy that can ensure the health and safety of this marginalized population.

Policy Implications

As evident from the policy analysis of the current state of response to the silicosis, TB and HIV epidemic among gold mineworkers in South Africa, there are notable gaps in research, policy and implementation in the approach and strategy to address this epidemic (Basu et al. 2009, Stuckler et al. 2010 and Murray et al. 2011). This section summarizes the key problems responsible for an inadequate response to the epidemic so far, and also provides suggestions for overcoming these barriers by describing the role of main actors and stakeholders imperative for implementing a successful response to the silicosis, TB and HIV epidemic among gold mineworkers in South Africa.

I. *Inadequate and lax implementation of measures to control silica dust levels in gold mines*

The wide-ranging failure to reduce silica dust levels in mines to below OEL level of 0.1 mg/m^3 has been a major barrier towards adequate prevention and control of silicosis among mineworkers. Even though a number of strong and convincing academic studies have unequivocally stated that silica dust levels equal to or higher than currently accepted OEL level are detrimental to the health of miners, especially those working in drilling and stoping, there has been a lack of serious effort on part of both the mining industry and the government to reduce the dust levels. This has also resulted in failure to achieve the target set by MHSC to eliminate any new cases of silicosis by 2013.

Both the mining industry and the government should take a joint initiative to address this issue with urgency. While the mining industry should implement current WHO and ILO guidelines in place to prevent silicosis, and enforce stricter preventive measures to reduce the exposure to silica dust, the government should seek to put a mechanism in place to review and verify the dust levels that are reported by the mining industry. The fact that currently there is no independent oversight and evaluation of the reported dust levels has prevented mining companies from taking any strict measures to address this problem.

II. *Lack of sufficient funding for mining-related occupational health and safety research*

As discussed in the previous section, there has been a steady decline in the amount of funding for mining-related occupational health and safety research in the last decade. Investment in research is important to develop new and innovative methods to control and reduce dust exposure in mines. Moreover, the funding should also be directed to academic research to better understand the epidemiology and biology of silicosis and TB, dynamics of HIV and migration, and more importantly to measure and quantify safe levels of silica dust exposure.

Addressing this issue requires commitment of the mining industry, the state as well as the miners and the mineworkers' unions. With equal representation mandated to all three stakeholders within the MHSC, they should work together to ensure adequate funding for mining-related occupational health and safety research. Moreover, NGOs and health activists can contribute significantly in addressing this barrier by mobilizing the community, especially students interested in pursuing a career in occupational health research, to demand an increase in funding in this sector. Therefore, a joint collaboration and effort would be necessary for overcoming this barrier.

III. *Poor active surveillance of silicosis and TB among both in-service and former mineworkers*

Although peer reviewed literature provides an estimate of the incidence and prevalence of silicosis and occupational TB among mineworkers, the true extent of the epidemic is still unknown. This is mainly due to the poor surveillance systems in place to track and record the actual number of cases of these diseases among miners. While autopsy still remains the only sure way of knowing the extent of the epidemic in this population, it conveys nothing about the extent of the epidemic among in-service and former mineworkers who are alive. This greatly underestimates the true nature of the epidemic, thereby also preventing an adequate and effective response to address the epidemic.

While the mining companies have records of the incidence and outcome of these diseases in their employees, the government can play a vital role in setting up a separate surveillance system to monitor the incidence and prevalence of silicosis and TB in this population. The South African government, in collaboration with the governments of neighboring countries, can also set up joint surveillance system to monitor silicosis and TB trends among cross-border migrant mineworkers, especially former mineworkers. This is especially important because evidence shows that silicosis can take years to develop, and former mineworkers can develop silicosis even after exposure to silica dust has ceased, thereby putting them at a higher risk of TB.

IV. *Lack of primary healthcare services to address the needs of migrant mineworkers in rural areas*

Absence of primary healthcare services remains an acute problem for mineworkers from rural areas, since they often lack the means and resources to access healthcare facilities in cities. Since silicosis and TB can develop even years after exposure to silica dust has ceased, mineworkers must have regular access to healthcare facilities that can monitor and evaluate their health. However, primary healthcare services are defunct or absent in rural areas, both in South Africa and in the neighboring home countries of migrant

mineworkers. The government and international agencies such as SADC can play a key role in addressing this issue by jointly funding essential primary healthcare services in rural communities for migrant miners.

V. *Poor administration of compensation fund and inadequate functioning of the compensation process*

The complex bureaucratic procedures have inhibited the smooth filing and processing of the compensation claims. In fact, these barriers not only delay the processing of the claims, but also prevent miners and their families from even exercising their right to compensation in the first place. This is especially true for migrant mineworkers who often don't have access to a healthcare facility to get a medical certificate or lack resources to travel to a South African city to get a medical certificate and file a claim. Moreover, for families of deceased mineworkers the strict rules under ODMWA for getting an autopsy often prevent families from filing for compensation benefits.

In addition, lack of enough administrative personnel and resources also delays the processing of claims, while the lack of an independent oversight of the administering of the compensation fund results in further delay of processing of compensation claims. Therefore, there is an urgent need for the government to adopt measures to make the process more accessible and user-friendly for mineworkers and their families. While ODMWA guarantees certain rights and privileges to the mineworkers, it's the government's responsibility to ensure that mineworkers are able to receive the compensation benefits.

VI. *Absence of silicosis from the global health agenda*

While the WHO and ILO have guidelines in place to prevent silicosis, most occupational health diseases including silicosis are largely absent from the global health agenda. With no group lobbying for occupational lung diseases, there is a lack of urgency on this issue, including the need for more funding and research needed in this field. Moreover, there is little awareness regarding silicosis and occupational TB not only among the general population, but also among public health professionals, with public health students in particular. The occupational health professionals and academics along with health activists and international agencies like the UN and SADC can play a key role in advancing awareness on this issue by highlighting the intertwined issues of HIV/AIDS, human rights and social justice in the South African context.

VII. *Fragmented coordination and communication regarding enforcement and implementation of effective measures to address the silicosis, TB and HIV epidemic among gold mineworkers*

Lack of coordination is a barrier to effective implementation of remedies to address the silicosis and TB epidemic at two levels – the state and the mineworkers and their unions. While fragmented coordination between different departments of the government inhibits any cohesive response to the epidemic, and also affects the administration and functioning of the compensation process, the lack of coordination and differences in the objectives and goals of mineworkers' unions (for in-service and former mineworkers respectively) prevents mineworkers from coming together and collectively demand the mining industry to enforce and implement an effective response to address the silicosis and TB epidemic.

Therefore, while the different government departments must make an effort to coordinate an effective response to the epidemic, the unions should also seek to sort out their differences and assist all mineworkers, whether in-service or ex-miners, in filing of compensation claims. Moreover, the unions should also take an initiative to make the mineworkers aware of the risks involved in mining, along with increasing their awareness regarding their rights and benefits that they are entitled to as employees of the mining industry.

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