ABSTRACT

This thesis examines historical and contemporary artisanal and small-scale gold mining (ASGM) in Kadoma-Chakari, Zimbabwe in order to identify effective strategies to reduce mercury loss and exposure and to increase miners’ incomes by improving gold recoveries. Cyanidation of mercury-rich tailings and the use of nitric acid to leach mercury from cathode sludge and amalgams are identified as significant pathways for losses of mercury into the environment in Zimbabwe. Indirect evidence suggests that as much as 90% of the mercury contained in amalgamation tailings at mills in Kadoma-Chakari is dissolved during passive vat cyanidation. Mercury traps placed after copper amalgamation plates and centrifuges could reduce the amount of mercury subjected to cyanidation, but mercury can be kept out of cyanidation circuits altogether by replacing whole ore amalgamation with vinyl loop carpets. The optimal cyanide concentration for passive vat leaching is between 0.1 to 0.15%. Better management of nitric acid waste solutions can also significantly reduce mercury losses. The current political and socio-economic crisis significantly limits the effectiveness of ASGM programs in Zimbabwe. Nevertheless, strategies for more effective management of ASGM interventions are suggested by a review of the history of didactic theatre (Theatre for Development) in Africa. Theatre used as an awareness building tool is exemplified by “Nakai”, a drama produced in Kadoma-Chakari to increase knowledge of the hazards of mercury use. Theatre can also be a means to ensure horizontal communication between donors and project beneficiaries if it is used to stimulate discussions that give communities a real voice in development programs. It is proposed that community participation in project design, implementation and evaluation increases the likelihood of project success and sustainability because community-identified problems and solutions are more realistic than those defined by donors, and because community “buy in” and ownership increases pressure on project administrators to deliver the services communities need.
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DEDICATION

For my wonderful wife and partner, Daniela Fiess, and our lovely son, Emil.
1 INTRODUCTION

1.1 Problem statement

As many as 15 million people in the world are currently mining alluvial and primary gold ores at the smallest scale (Veiga and Baker, 2004). Up to 300,000 of these miners are active in Zimbabwe. In Kadoma-Chakari, located about 2 hours drive southwest of Harare, some 20,000 artisanal and small-scale gold miners (ASGMs) are taking considerable environmental and personal health risks in order to earn, with a few exceptions, only subsistence livings. The collapse of the national economy and soaring inflation in recent years has added huge stresses to Kadoma-Chakari’s gold mining communities, while the owners of the region’s milling facilities (“custom milling centers”) are prospering due to inequitable milling charges. Lack of knowledge and access to more efficient low-cost equipment are among the chief barriers to Kadoma-Chakari’s ASGMs adopting more productive and safer practices.

While the past 35 years have seen a growth in knowledge and concern about the working conditions of ASGMs worldwide, there have been relatively few practical attempts to introduce safer and more efficient mining and mineral processing alternatives. The lessons learned from these attempts have been poorly shared, and the focus of many ASGM interventions has been on researching the scope of the problem, rather than on working directly with mining communities to solve the technical and socioeconomic challenges they face (Walls and D’Souza, 2000; Hilson et al., 2007).

UNIDO’s Global Mercury Project (GMP) made a commitment to working directly with mining communities, in addition to researching the scope of the problems miners
face in its 6 pilot programs. This thesis examines these efforts in Kadoma-Chakari, Zimbabwe, where it looks closely at mining and mineral processing practice in order to identify opportunities and strategies to reduce mercury exposure and to increase incomes by improving gold recoveries. The potential of theatre to communicate awareness messages to mining communities and to stimulate sustainable community-directed development is revealed by a discussion of the history of “Theatre for Development” in Africa and by an analysis of a play written to illustrate the hazards of mercury use by ASGMs.

1.2 Objectives

- Summarize the history of artisanal and small-scale mining and mineral processing in Zimbabwe
- Review present-day ASGM mineral processing practice in Kadoma-Chakari
- Identify the major pathways of mercury loss at milling centers in Kadoma-Chakari
- Review the GMP’s interventions in Kadoma-Chakari
- Recommend better mineral processing practices for custom milling centers
- Summarize the history of Theatre for Development in Africa
- Review the characteristics of the two main types of Theatre for Development—awareness-focused and community-focused theatre
- Review the accomplishments of the GMP’s theatre program in Kadoma-Chakari
- Identify ways to make ASGM interventions more effective.
1.3 Justification/Rationale

It is necessary to understand the historical, economic, political and geological determinants of local mining and mineral processing practice if ASGM interventions are to introduce realistic mineral processing alternatives and facilitate policy change that supports mining community development. ASGM technology transfer programs are not well studied.

Inappropriate choice of stakeholders leads to poor consultation with project beneficiaries prior to and during implementation, and favors the interests of the most powerful institutional stakeholders, especially government and local academic institutions. It is imperative to develop strategies that ensure that the least powerful members in mining communities benefit from interventions.

1.4 Thesis Structure

Chapter 2 summarizes the extent of ASGM worldwide, its roots in the growing numbers of poor in many developing countries, and the need for intervention. The environmental and human health problems associated with ASGM are due in large part to a lack of knowledge of risks and alternatives on the part of miners. The limitations of ASGM programs include development institutions’ preference for research over practical field interventions and their withholding the full story of their interventions—the failures as well as the successes. Development institutions also need to refine their relationships with host governments and country partners, who in turn need to demonstrate their commitment to advancing the status of mining communities.
Chapter 3 seeks an understanding of the reluctance of the ASGM sector to accept safer and more efficient methods by reviewing the history of gold mining in Zimbabwe from pre-historic times to the present day. Contemporary ASGM practices are outlined, and the mineral processing methods of two small-scale milling operations are examined in detail. About two thirds of the gold produced at these operations is recovered by cyanidation. Because they rely on the status quo for their profits, “custom milling centers” resist the introduction of more efficient, mercury free recovery methods which they believe will lower the grade of their cyanidation feed. In addition, the present methods have been long practiced in Zimbabwe and are considered to be more transparent and reliable than new alternatives. Nitric acid is used to remove most of the residual mercury from amalgams before burning and to digest cathode sludge after cyanidation. Mercury rich nitric waste solutions are then discarded on the ground or in unlined tailings dumps (a serious problem because mercury in acidic solutions can be easily methylated).

The GMP conducted assessments of the socio-economic, environmental and health impacts of ASGM in the Kadoma-Chakari region in 2003 and 2004, and reviewed financing opportunities and the national mercury trade in 2005 and 2006. Chapter 4 summarizes the strengths and weakness of these reports, clarifying and bringing the story of ASGM activities in Zimbabwe and Kadoma-Chakari up-to-date.

Chapter 5 examines the efforts of the GMP to address the economic, health and mineral processing needs of miners in the Kadoma-Chakari project area. Over 30 ASGM trainers were trained and a “Transportable Demonstration Unit” (TDU) was commissioned in 2006. Other initiatives included introducing and testing the efficiency
of vinyl loop carpets, addressing the environmental impacts of milling centers by establishing the optimum cyanide concentration for passive leaching, and funding a national training program that introduced retorts and better gravity recovery methods to miners throughout the country.

The GMP’s awareness program in Zimbabwe centered on the play “Nakai” which was collaboratively written by local community-based organizations to teach mining communities about the dangers of mercury use. Chapter 6 evaluates the effectiveness of “Nakai” in light of the rich history of didactic drama in Africa, and concludes that theatre is most effective when it supports a self-directed process of community development. Rather than relying on itinerant troupes of actors, community members themselves can play the roles of villagers exploring possible solutions to self-identified problems.

Chapter 7 explores various possibilities for improved and safer practices, such as minimizing mercury in cyanidation circuits by using vinyl loop carpets instead of amalgamation plates or mercury-charged centrifuges, ensuring proper ventilation during elution and electrowinning, and recovering mercury contained in waste nitric acid solutions.

Chapter 8 summarizes the key findings of the thesis, and Chapter 9 identifies a number of possible research directions that have come to light as a result of this research.
2 ARTISANAL AND SMALL-SCALE GOLD MINING: THE GLOBAL CONTEXT

2.1 Worldwide Poverty and Artisanal and Small-scale Mining

Even though there are indications that growing economies in some parts of the world are leading to an overall decline in poverty, more than 1 billion people still earn less than USD 1 per day (Bloomberg, 2007). The World Bank (2004a) reports that extreme poverty (as indexed by incomes of less than USD 1 per day) declined from 28% in 1990 to 19% in 2002, led by growing economies in countries such as China. Poverty data can be misleading however. For example, while the percentage of people in sub-Saharan Africa living on USD 1 per day increased only 2% from 1990 to 2001 (44.6% in 1990 to 46.4% in 2001), the numbers of people extremely poor people actually grew by 87 million (from 231 million to 318 million people), due to population increase (World Bank, 2004b; Osberg and Xu, 2006; Independent, 2007).

The rate of population increase is outpacing economic growth in many developing countries, especially in Sub-Saharan Africa where per capita GNP was 17.6 % of the global per capita GNP in 1975, but dropped to 10.5 % in 1999 (Arrighi, 2002). In Africa, there is strong evidence that poverty and the current artisanal and small-scale mining (ASM) gold rush have their roots in the economic structural adjustment and privatization programs driven by the World Bank (Marquette, 1997; Banchirigah, 2006; Bush, 2007).

It is estimated that the global population will exceed 9 billion people in 2050, up about 50% from today’s 6.6 billion (US Census Bureau, 2008). Growing numbers of poor people are turning to ASM activities for their livelihoods. As many as 30 million
people (or 1.5% of the global population) participate directly in mining metals and industrial minerals, benefiting up to 100 million people indirectly (Veiga and Baker, 2004; Hinton, 2006).

2.2 The need for ASGM interventions

Artisanal and small-scale gold mining (ASGM) is practiced by up to 15 million people who produce between 350 to 800 tonnes of gold/annum, or about 20 to 30% of the total global gold output (Veiga and Baker, 2004; Telmer and Veiga, 2008). ASGM is clearly a “golden opportunity” for the world’s poor, but it often brings unwanted social, environmental and human health challenges (Appendix 1). This requires support of affected populations through awareness building, introduction of more environmentally friendly and safer mining and mineral processing techniques, and appropriate policy initiatives.

ASGM often leads to severe environmental stresses, especially to aquatic systems due to siltation and improper disposal of process chemicals. ASGM’s effect on water supplies is especially critical because global water supplies are quickly becoming insufficient for ecological and human services such as food production (Rockström et al., 1999; Rockström, 2003). Lack of reclamation contributes to deforestation and an increase of malaria vectors while leaving behind physical hazards for humans and livestock.

Mining activities often increase the labor burden of women in mining communities and disrupt traditional family structures due to migration, diminishing the quality of life of children, especially when children themselves engage in mining activities. Work force mobility has contributed to the increase in sexually transmitted
infections, and many miners and their families are exposed to hazardous process chemicals, including mercury (Hinton, 2006).

Mercury use is perhaps the most publicized of the environmental and human health risks associated with ASGM. Total mercury losses from ASGMs are between 640 to 1,350 tonnes/annum, assuming 1 to 3 grams of mercury are required per gram of gold produced (Spiegel et al., 2005; Telmer and Veiga, 2008). For gold miners, the primary mercury exposure pathway is breathing mercury vapors during the distillation of gold-mercury amalgam, but consumption of methylmercury containing fish constitutes a secondary exposure pathway in some places (Swain et al., 2007).

2.3 Challenges facing ASGM interventions

2.3.1 Lack of knowledge of alternatives

In spite of the importance that ASGM has become for so many of the world’s poor, miners still have limited access to appropriate mining and mineral processing knowledge and technology. In most jurisdictions, policy and legal frameworks tend to favor environmental protection and the interests of large concession holders, but do not promote the introduction of more efficient and safer ASGM work practices that lead to the development of more stable mining communities.

Program designers and field workers have limited knowledge of best practices because the lessons learned during the past 3 decades of ASGM interventions have not been well shared. Today, for example, designers of development programs cannot refer to any comprehensive overview of past microcredit schemes for ASMs when they contemplate establishing finance programs to eliminate the access-to-capital
hurdles that prevent miners from adopting cleaner technologies. A further challenge is the lack of commitment to test work that realistically replicates field conditions. This can lead to introduction of alternative processing methods that are not properly tested before introduction to program beneficiaries, and which fail in practice.

2.3.2 ASM interventions need to be better documented

In 2000, Great Britain’s Department for International Development (DfID) identified the impacts of poorly sharing ASM intervention experiences, and pointed hopefully to the 2001 launch of the World Bank’s Communities and Small-scale Mining (CASM) initiative which promised to develop an intervention database (Walls and D’Souza, 2000). Unfortunately CASM has since made little progress—its documentation of completed and ongoing ASM interventions contains mostly thumbnail sketches, and is generally out of date (CASM, 2008). International development agencies supporting ASM training still do not freely share their critical reflections on their ASM interventions. The Mining Minerals and Sustainable Development’s review of ASM research is only 2 ½ pages long (Hentschel et al., 2004). Leading providers of ASM training programs such as Projekt-Consult and the Intermediate Technology Development Group (now called Practical Action) only offer short summaries of projects on websites that do not reveal the shortcomings of their programs.

2.3.3 Lack of donor commitment to practical interventions

The work of a handful of development organizations and researchers during the past 35 years has led to an increased awareness of the socioeconomic, health and
environmental impacts of ASGM. Unfortunately, much of the development work in the ASGM sector has focused on environmental and health impact analysis, especially on the impact of mercury use in ASGM gold extraction. Relatively few programs have attempted to build the kind of relationships with mining communities that are essential to transfer the knowledge and technologies that can improve ASGM efficiency and work conditions, lessen environmental impacts, and facilitate the establishment of legal frameworks that protect mining communities’ futures (Veiga and Hinton, 2002; Hilson et al, 2006).

Only a fraction of the funding dedicated to the ASGM programs is spent on practical field interventions, in part due to the bureaucratic nature of international donor organizations and the relative high cost of expatriate trainers and program managers. Insufficient spending at the practical level has led to a shortage of skilled managers and trainers because of the discontinuous nature of employment contracts.

2.4 Limitations of ASGM interventions

Problems facing ASGMs do not exist in isolation. Gender is an underlying dynamic that is often overlooked. Poor health arising from inadequate water and sanitation, communicable diseases, and inadequate nutrition limits miners’ ability to work effectively. Clearly, ASGM interventions need to take holistic approaches, but addressing a diversity of challenges can quickly dilute a program’s focus and funding.

ASGM programs typically fall under the umbrella of the local Ministry of Mines and lack coordination with Ministries of Environment and Health. In addition, ASGM programs often do not coordinate well with the activities of other international organizations serving the same populations. For example, the UNIDO’s GMP
interacted only to a limited extent with the UN’s environmental agency (the United Nations Environmental Program), and did not exploit synergies with the UN’s food, agricultural, health and children’s agencies.

Global large-scale ASGM programs tend to be driven by donor-identified concerns, and lack the flexibility to respond to needs identified at the local level. The well-funded nature of large-scale initiatives invites opportunism by managers and participants at all levels. Locally driven small-scale ASGM programs, on the other hand, can be more flexible and effective. Management of small grants (USD 10,000--20,000) by project beneficiaries promotes buy-in and sustainability of programs, but small programs require narrow focus and are insufficient to meet the scale of miners’ needs.

2.4.1 Stakeholder engagement

Participation of program beneficiaries in program design ensures that program objectives reflect the real needs of communities, and secures essential support for the various stages of program. Participation at this level promotes community “ownership” of programs which in turn leads to more sustainable implementation (Kidd, 1994; GTZ, 1998). Large-scale ASGM interventions are typically designed by donors in consultation only with government and other stakeholders who do not sufficiently understand the realities facing mining communities.

2.4.2 Commitment of host governments

National and local governments must see ASGMs as future contributors to economic and social development. Without this perspective, governments will not be
committed to the success of ASGM programs. Interventions will not eventually become self-sustaining, and project assets may become little more than toys for participating stakeholder institutions.
3 ARTISANAL AND SMALL-SCALE GOLD MINING IN ZIMBABWE

3.1 The importance of links between historic and present day ASGM practices

There are strong links between Zimbabwe’s historical mining and mineral processing practices and present day environmental, economic and political realities. Those wishing to influence today’s environmentally unsound practices need to know how these practices evolved. Whole ore amalgamation and cyanidation of amalgamation tailings is releasing tonnes of mercury annually into the Zimbabwe’s aquatic systems, but ASGMs are reluctant to embrace new technologies because they have confidence in the old, well-established practices. This chapter describes the country’s custom milling system, which evolved during the last 100 years of adaptation to geological and economic realities. In the context of Zimbabwe’s social and economic crisis, the “custom milling” system (where itinerant miners process their ore for a fee) has become a significant structural obstacle to adopting more environmentally friendly mineral processing practices.

Gold in Kadoma-Chakari occurs mostly in narrow, discontinuous quartz veins in the exposed Archean core of the 100 km long NE-SW trending Kadoma anticline. The host rocks are primarily fine-grained chloritic hornblende schists (former basaltic pillow lavas, or so-called “greenstones”) and similarly altered coarser coeval intrusives (epidiorites). Gold bearing quartz veins are also hosted in overlying quartz-mica schists (former felsic sediments) found on the limbs of the anticline (Dirks et al., 2002; Mhlanga, 2002, Shoko and Veiga, 2004). Most of the ASGM ore in Kadoma-Chakari is
free milling, but some refractory ores are encountered at depth (Singo, 2006). Refractory ores are more abundant 100 km to the southwest in the Kwekwe region (Kevin Woods, 2008—Small Mining Supply, Harare, Zimbabwe). While much of the ore produced by ASGMs in Kadoma-Chakari is extracted from the oxide layer (Appendix 2), some ores contain accessory sulfides that can foul the mercury coating of copper amalgamation plates, reducing recovery efficiency.

About 95% of ancient gold workings were in quartz veins and associated zones of secondary enrichment at depths to about 6 to 10 meters. The average Shona mine was likely mined out in a single dry season (Phimister, 1975).

Zimbabwe’s robust small-scale gold mining and milling industry was born in the late 19th Century when Cecil Rhode’s British South Africa Company (BSAC) received charters from the British Crown to administer Southern Rhodesia (territories between the Limpopo and Zambezi Rivers) in 1889 and Northern Rhodesia (territories between the Zambezi River and Lake Tanganyika) in 1890 (and 1895). The BSAC liberally supported small-scale gold mining activities in the early 20th Century. In 1923 and 1924 respectively, Britain reclaimed administrative control of Southern and Northern Rhodesia from the BSAC, but gold production remained a priority of the colonial administration. During the African independence era that followed World War II, Southern Rhodesian unilaterally declared independence (UDI) from Britain (1965) in an attempt to ensure white political and economic domination. The new UDI government, however, was confronted with UN sanctions and an armed resistance that successfully toppled the new Rhodesian regime. Free elections were held in 1979, and “Zimbabwe” became the name of independent Rhodesia in 1980. Robert
Mugabe has been the sole ruler of Zimbabwe since 1980, but his economic policies (especially his chaotic land reform program) have impoverished the country and led to a dramatic increase in ASGM activities (CIA, 2008).

Few large-scale mines (i.e., mines with outputs exceeding roughly 300 kg Au/annum) were able to make a profit in early Rhodesia because pre-colonial indigenous miners had depleted most of the region’s easily mined, high grade oxidized gold deposits. Smaller operations were more flexible and could mine the region’s discontinuous vein systems more efficiently. With some relatively minor technological improvements, today’s small-scale operators use the same methods practiced by indigenous and early colonial miners and mineral processors (Phimister, 1975).

Limited capital was available to the early Rhodesian gold mining industry, as most foreign investment found its way to Johannesburg and the Witwatersrand in South Africa and other more profitable goldfields. Profitability in Southern Rhodesia often depended on cheap African labor, and the unpredictability of narrow, discontinuous quartz vein deposits favored small-scale over large-scale mining operations. During periods of inflation when the costs of mining supplies rose, “smallworkers” (as colonial small scale gold miners were called) were able to suspend operations, while at times of rising gold prices or when subsidies were provided by government, they were able to mobilize operations quickly. These flexible smallworkers, able to make do with limited capital and relying more heavily on lower African wages than larger mines, tended to flourish in Southern Rhodesia, but were not able to benefit from the mechanization and economies of scale available to large-scale mines (Phimister, 1975).
Following the early 20th Century “smallworker” model, colonial farmers began gold mining in large numbers during the Great Depression in the 1930s. Gold mining and milling became an important second source of income for these farmers, some of whose descendants eventually managed to retain ownership of their mining and milling operations, even as they forfeited their farms during Zimbabwe’s recent land re-distribution programs. The boom in artisanal mining activities caused by the collapse of the Zimbabwean economy in the 1990s brought a demand for custom milling\(^1\) services which mill owners supplied in exchange for the right to extract the gold left in the miners’ tailings.

3.2 Pre-colonial gold mining and milling

Summers (1969) and Phimister (1975) detail the region’s pre-historic and historic mining and milling practices. ASGM is not new to Zimbabwe. Indeed, indigenous populations mined the region between the Limpopo and Zambezi rivers for nearly 2000 years. Thousands of ancient indigenous underground and alluvial gold mining sites dot Zimbabwe, but production had dwindled considerably even before the colonial era, owing to the depletion of high-grade gold ores. Ancient miners were only able to mine easily accessible, shallow ores with grades above about 30 g/tonne. Depletion of the high-grade gold ore close to the surface by indigenous miners accounts for the general failure of early European efforts to exploit the region’s relatively small, discontinuous quartz vein deposits. While only a few large-scale gold mines were successful in Zimbabwe, thousands of small deposits were developed by

\(^1\) Custom milling centers are milling operations that grind the ore of itinerant miners on a fee for service basis. The mill receives between USD 1 to 3 per hour, in addition to ownership the tailings which contain much unliberated gold.
small-scale European operators who were able to flexibly adapt to the cycles of inflation, recession and varying demand for gold that marked the 20th Century (Summers, 1969; Phimister, 1975).

Between 1000 and 1200 AD, Shona tribes migrating from the north slowly displaced the region’s Bantu tribes who had been mining iron deposits to make hoes and other implements for agricultural use from about 100 to 1000 AD. Based on carbon dating of artifacts found in ancient workings, it is estimated that the Shona began mining gold rich quartz veins sometime between 1100 and 1300 AD, and the prosperity of the Shona Great Zimbabwe kingdom in the Fourteenth Century was likely due to gold trade with Swahili trading towns along what is now the Mozambique coast (McEvedy, 1995).

It is thought that quartz vein deposits were discovered by tracing alluvial deposits to their source by panning with wooden and clay bowls, by identifying soil and vegetation anomalies, or by accidentally uncovering gold rich material during farming activities. For the pre-colonial Shona, gold panning and underground mining were generally not year around activities, but were usually secondary to farming as sources of income. As today, the best time for mining was during the dry months of August, September and October when the plowing of the next year’s fields took place, and when underground development was favored by low water tables. Miners could also best access gold rich alluvial deposits when river levels were low (Summers, 1966).
3.2.1 Pre-colonial depletion of surface ores

Ancient prospectors and miners successfully managed to deplete most of the region’s surface and easily discovered shallow vein deposits. Estimates of total pre-colonial gold production range from 250 to 900 tonnes (from year 1200 to about 1800) (Phimister, 1975; Summers, 1969), while colonial and post-colonial gold production has exceeded 1,700 tonnes (1890 to the present) (Bartholomew, 1990).

Most of the ancient Shona workings exploited vertical or sub-vertical veins by open-cutting “V” shaped workings. Occasionally such pits followed an outcrop for up to 500 meters. When the vein systems were relatively flat, miners sunk 6 to 25 meter shafts that they expanded laterally underground a meter or so at the vein intersection. Excavated material was passed up the shaft in wooden bowls (Summers, 1969; Phimister, 1975).

In the early 15th century, Portuguese gold traders observed the Shona’s extensive systems of shafts and adits following vein systems. Narrow shafts and adits (50-80 cm) were also driven in alluvial deposits, and divers weighted with stones would sometimes recover sediments from pools in streams. As the easily exploitable underground deposits became exhausted, riverbed panning was typically practiced to supplement incomes during farming slack seasons. In some areas, alluvial mining was a collective summer activity for large groups who would relocate to rivers where they would reside for several months at a time during the dry months of September and October (Summers, 1969; Phimister, 1975).
3.2.2 Mining Methods

Surface and underground rock breaking was done with stone hammers and iron hoes, chisels, and picks. When the rock was too hard for manual breaking, fires would be built underground and then carefully quenched with cold water, shattering the quartz or exfoliating blocks of country rock (a similar technique was used to exfoliate granite blocks for building stone “zimbabwe”). Fire setting, however, had limited effect on harder rocks beneath the oxidized zone, and without ventilation, this technique could only be carried out close to the surface (Summers, 1969).

Haulage, ventilation and underground water were the biggest problems faced by pre-colonial Shona miners. The ore was brought to surface by passing ore in wooden bowls up the shaft, but in deeper operations it is likely that ore was hoisted by rope in leather buckets. Ventilation is thought to have been provided by simple convection or by fanning with softened hides, but in some instances, shafts were connected by crosscutting adits, with local backfilling used to direct the replacement air to the working area. The rainy season, typically beginning in November, invariably flooded the mines and prevented mining activity until the water table dropped months later. Rarely did pre-colonial workings extend below the water table (Summers, 1969).

3.2.3 Mineral Processing

Once on the surface, ore was ground with pestles in small (10-15 cm) mortars carved in nearby country rock. 30 to 40 of these grinding holes were commonly sited near ancient workings. Sometimes the ore would be roasted between alternating
layers of wood, presumably to aid in crushing. In the 1870s, the British explorer Thomas Baines made an engraving depicting natives in Matabeleland operating a large stone rocker mill or “quimbalete” (estimated at 1m x1m x 1.5m) in the company of several European (possibly Portuguese) gold panners, and another engraving depicting natives tending a fire used to roast gold bearing quartz ore (Summers, 1969; Baines, 1872).

Once milled, the ore was concentrated by panning in square or elongate wooden bowls (30 x 45 cm) with 2.0 cm x 0.25 cm deep holes cut in the center to collect the gold. In some communities, panning was done only by women, but in others only adult men panned for gold. Final concentration was sometimes done in small, smooth ceramic bowls. It appears that sluicing was also practiced, at least from the 17th Century onwards, as there is evidence of carved stone riffles. Summers (1969) concluded that amalgamation was not practiced, but his reasoning may be faulty as it was based on the lack of archeological evidence of iron retorts or mined local mercury deposits. Amalgamation, however, was commonly practiced in West Africa by the 17th Century, and the process was well understood by Portuguese gold traders--mercury could have been imported from India, and retorts, as it is well known, are not essential to evaporate mercury from gold amalgam.

3.2.4 Pre-colonial gold trading

Wealth for ancient miners was more commonly held in the form of cattle, rather than gold. Gold was traded for beads and cloth, as well as for guns, but by the 16th and 17th Centuries, the high profit margins taken by Portuguese traders and the
increasing hazards and challenges associated with deeper underground operations due to the depletion of rich deposits close to surface led to the decline of underground mining activities. In the 19th Century, gold was exchanged for guns, caps and gunpowder, coarse calico cloth, salt, or beads. Gold could also ransom women captured in raids or be used to pay “lobolo” (the bridal purchase fee) (Summers, 1969; Phimister, 1974).

3.3 Mining during colonial rule

Phimister (1975) details the history of colonial mining during from 1890 to 1950 in his PhD dissertation at the University of Rhodesia. European miners during the Rhodesian gold rush of the 1890s did not have access to modern mining and milling equipment such as dewatering pumps and windlasses that were necessary to exploit deposits beneath the water table. At the beginning of the 20th Century however, a new railroad was available to transport needed heavy equipment (windlasses, underground pumps, boilers, stamp mills and copper amalgamation plates), and the introduction of cyanide technology allowed profitable mining of the region’s relatively low-grade ore. Since then over 6000 mines, most of them small-scale, have been in operation in Zimbabwe. Only 28 of these mines, however, produced more than 10 tonnes each in total, collectively accounting for about 60% of the nation’s total output since the beginning of the Rhodesian gold rush in 1890 (Bartholomew, 1990).

With no easily mined surface or near-surface gold, investment capital was essential for extensive underground development. At the time however, European capital was more likely to be invested in the goldfields of Australia or South Africa where the surface deposits were still relatively untouched, and where larger deposits
promised more profits to investors. Even when development capital was found for Rhodesian mines, the size of underground deposits in Southern Rhodesia was usually too small to support heavily capitalized mining development. Thus large-scale mining ventures capable of outputs exceeding 300 kg/annum had limited success in the first decade of colonial rule, producing only 6 tonnes/annum by 1902. What successes large operations eventually achieved came from introduction of machinery and mining supplies transported by the rail line newly completed from the south, and by exploiting poorly paid African workers (Phimister, 1976; van Onselen, 1976).

3.3.1 The rise of the “smallworker”

Southern Rhodesia’s small-scale mining industry evolved considerably in the wake of the Anglo Boer War (1899 to 1901) and the global economic depression of 1903 and 1904 when flexible “smallworker” operations began to successfully exploit the small deposits that were not profitable for large-scale mining, relocating their small, easily transported milling operations as needed. During to the global depression of 1903-1904, struggling larger mining ventures made tailings available to smallworkers at very low rates (about 10% of the nominal value of the gold recovered), and leased already developed but unprofitable mines on a tribute basis. Typically owned by a single person or by a few partners who personally managed operations at the mine, smallworkers kept operating costs low by exploiting African workers, even more so than larger mining companies. In 1906, there were 254 “smallworkers” in Southern Rhodesia. Their numbers grew to over 500 in 1909, compared with only 9 large-scale operations (Norris, 1933; Phimister 1975).
As indicated, these small-scale operations were more flexible than larger ventures. Their equipment (a boiler, a pump, a stamp mill, amalgamation plates, and sometimes cyanidation equipment) could be moved from site to site, and the low capital costs permitted suspension of milling and mining during adverse geological or economic conditions. In 1908, a miner could set up a stamp mill for USD 10,000, an amount that could be readily borrowed from the British South Africa Company or from local banks (Phimister, 1975).

Operating costs for smallworkers were much less than for large mining operations. In 1908, for example, operating cost per tonne of ore mined and processed was about 25% that of large mines. Smallworkers saved money because the owners worked at their mines, eliminating the costs of hired white managers. They also benefited from colonial government policies that allowed liberal access to fuel (wood) and water. Dangerous mining also practices reduced costs, but most of the competitive advantage of smallworkers came from the low cost of African labor (Phimister, 1975).

Smallworkers paid lower wages than bigger mines, sometimes paying nothing at all when operations were unsuccessful. Low wages and bad working conditions sometimes required sourcing of African mine workers by force through compulsory programs. From 1904 to 1910, for example, indigenous peasants were rounded up by the Native Commissioner’s African agents on behalf of the Rhodesian Native Labour Board who transferred them to the gold mines. Those who resisted would be whipped and their grain stocks burned. Once at the mines, workers guilty of “loafing” could be
imprisoned in stocks and whipped (in one instance at least, a miner was whipped 56 times) (Phimister, 1975; van Onselen, 1976; Johnson, 1992).

Large-scale mining operations expanded in the lead-up to World War I, when investment capital from South Africa flowed into Southern Rhodesia to develop deposits proven by smallworkers. In 1912, 10 large mines produced 10 tonnes of gold, or 53% of Southern Rhodesia’s total output, while 394 small operations yielded 2.3 tonnes; the industry as a whole operated 1803 stamp mills and employed 34,494 Africans (Norris, 1933, and Phimister, 1975).

3.3.2 The decline of the Southern Rhodesian gold industry

With the onset of World War I, Southern Rhodesia’s gold mining industry began a slow decline, which persisted through the 1960s, due to ever-increasing operating costs and the relatively static price of gold\(^2\). In 1915, the colony’s production peaked at 28 tonnes, but output had dropped to 17 tonnes in 1930. Production at the end of the 1960s was only 12 tonnes/annum (Norris, 1933; Bartholomew, 1990).

During and just after World War I, inflation caused by the war was offset by the benefits of an increased labor supply from displaced African farmers seeking work in the mining sector due to falling farm commodity prices. The cost of new mining equipment and replacement parts rose between 20% to 50% from 1914 and 1920. By the mid 1920s, however, machinery, explosives and cyanide prices had dropped substantially, enabling smallworkers to restart operations. Total gold production continued to fall however, and large-scale mines progressively increased their share

\(^2\) Britain suspended its gold standard during World War I, and later during the Great Depression and World War II. In 1944, however, the Bretton-Woods system fixed international currency exchange rates by establishing a gold standard price of USD 35/oz.
of the colony’s output, producing 75% of the total in 1930. Labor shortages developed in the late 1920s as commercial farming expanded and the Northern Rhodesian copper belt developed, leading to higher wages for both white and black workers. Blacks constituted about 96% of the work force while whites held the skilled, semi-skilled, and supervisory positions (Norris, 1933; Phimister, 1975).

International gold prices increased when England and other European countries abandoned the gold standard in 1931, making gold mining more profitable. Consequently, gold production in Southern Rhodesia increased by 50% by 1938. Higher gold prices made lower grades economic, reducing the average ore grade from about 12 grams/tonne to 6 grams/tonne. Profits were boosted by lower wages caused by unemployment in the agricultural and base metal sectors. Reacting to the decline in agricultural commodity prices during the Great Depression (the global economic downturn from 1928 to 1939), Southern Rhodesian farmers became more actively involved in gold mining, working small deposits in their farms with “smallworker” technologies. The number of mines increased from 286 in 1930 to 722 in 1932, while the number of Africans employed in Southern Rhodesia’s gold sector increased 3 times to 60,000. On average, 5 tonnes of ore were mined and processed per native worker per month\(^3\) (Phimister, 1975).

At this time, the colonial government expanded programs begun in the 1920s to support small-scale gold miners, financing a roasting plant to process refractory gold ores near Kwekwe, and providing reliable low cost electricity and a government loan fund. Mines that produced less than 15 kg of Au/annum (90% of smallworkers)

\(^3\) This is roughly the same as today’s artisanal primary ore output per month.
received government assistance premiums equal to about one third of the value of their gold production, and royalty assessments were eliminated, making it profitable for small workers to mine and process ores containing 6 g Au/tonne by 1935 (Phimister, 1975).

3.3.3 World War I

World War II again brought inflated costs of mining machinery and supplies. By 1942, small operators paid 31% more for supplies than before the war. These increased operating costs led to a decline in output of about 30% from pre-war levels. After the war, inflation continued to push the cost of supplies even higher, with costs in 1950 running 70% more than in 1939. African wages also rose dramatically during this period, and the gold industry was not able to successfully compete for workers with the expanding base metal and secondary manufacturing sectors. In 1952, for example, wages in the Northern Rhodesian copper belt were twice as high as in the Southern Rhodesian gold sector (Anonymous, 1943; Phimister, 1973).

Large mines lowered costs by introducing new levels of mechanization. Small mines could mechanize to only a limited degree, but some were able to improve efficiency through better organization of mine layouts. Even though the Southern Rhodesian government introduced temporary gold pricing subsidies in 1948, by 1953 the amount of gold produced in Southern Rhodesia was less than 1906 production levels of 16 tonnes/annum. While base metal output rapidly increased, gold production stayed low. By the 1960s, only 100 of the 1,600 gold mines operating in 1939 were

Profitability increased in the mid-1970s, shortly after the US dropped the gold standard, leading to a dramatic rise in the number of gold mining operations. Fifty new mines opened in 1975 alone, stimulated in part by increased government subsidies. While the mining industry per-se was not the focus of the liberation war strategy, gold mines and commercial farmers known for their cruel or harsh working conditions were attacked by the liberation fighters. Social and economic disruptions during the war of independence, however, had a negative impact on the mining industry, causing shortages of skilled labor, raw material and mining equipment, and exacerbating inflation (B. Ngwenga, 2007—Department of Economic History, University of Harare, pers. comm.).

Historically, most milling operations have been white owned. This trend continued after independence when a number of commercial farmers, foreseeing the loss of their farms in the inevitable land redistribution process, established residences in the vicinity of mines and milling operations (or set up stamp mills close to their residences). This permitted continued ownership of milling facilities after their farms were seized. Growing numbers of ASGMs in the 1990s have provided millers with large quantities of tailings for cyanidation from which they recover up to two thirds of the gold in the miner’s ore (Shoko and Veiga, 2004). Present day reluctance of millers to embrace new technologies may have its roots in commercial farmers’ historical lack

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4 Subsidies were implemented to increase mineral exports. Rhodesia’s unilateral declaration of independence from Britain in 1965 (an attempt to maintain white minority rule) led to UN economic sanctions in 1966 which were circumvented by the illegal sale of Rhodesian minerals on the world market.
of mining and milling knowledge and experience. Observers believe that many millers currently sell their gold on the black market as foreign exchange currencies provide a convenient hedge against inflation and an easy way to transfer funds to foreign bank accounts. In addition, some observers have suggested that majority ownership of custom milling centers is sometimes nominally transferred to trusted African associates of the white owners to create the illusion of black empowerment.

3.4 Present day artisanal and small-scale gold mining and milling

3.4.1 Gold mining and milling in Kadoma-Chakari

The Kadoma-Chakari mining district (Figure 1) hosts numerous gold deposits in its near-surface Archean greenstone complexes. During the colonial era, a few the region’s large-scale mines (e.g., Dalney, Golden Valley, and Patchway mines) successfully exploited deeper gold deposits but these shut down about 20 years ago. Many of today’s ASGMs exploit mine tailings and commercially uneconomic showings in the vicinity of these larger colonial-era operations (Shoko and Veiga, 2004). In Kadoma-Chakari, primary gold ore is extracted from narrow discontinuous quartz veins and zones of enrichment in the oxidized layer, and manually hauled up through narrow workings. Alluvial ores are also mined by non-mechanized methods.

Shoko and Veiga (2004) refer to those who extract semi-weathered gold ores from underground or surface deposits as “miners”, those who work at custom milling centers as “millers”, and those who concentrate alluvial and eluvial deposits and re-work old tailings as “panners.” In reality however, the terms “panner” and “miner” are often used interchangeably in Zimbabwe, referring to artisanal gold miners in general.
Panners can be legal, working on a tribute basis on a miner’s claim, or illegal, surreptitiously exploiting river deposits, old workings and new-found deposits without permission. In some instances, the term “miner” refers specifically to large claim owners, or to the operators of small-scale mines. For the sake of clarity and simplicity, this thesis refers to all artisanal miners (whether working on the surface or underground) as “miners”, to custom milling center owners as “millers.” In 2004, there were about 20,000 miners in Kadoma-Chakari, and about 70 active millers employing as many as 2,000 mill workers.

Figure 1 — Map of Zimbabwe showing the location of Kadoma-Chakari
Mineral processing relies heavily on technologies introduced over 100 years ago: *stamp mills, amalgamation plates and cyanidation circuits*. The old methods are very well established and trusted, and Kadoma-Chakari’s miners and millers are reluctant to switch to new technologies, even if the old technologies may be inefficient or toxic⁵. Mercury is an integral part of ore processing in Zimbabwe and is broadly not believed to be a serious human health or environmental hazard.

### 3.4.2 Alluvial mining

As reported by Shoko and Veiga (2004), as many as 15,000 of the 20,000 miners in Kadoma-Chakari were exploiting alluvial deposits along the Muzveze River and its tributaries during the dry season when low water levels expose the river sediments. Alluvial mining is not mechanized, but miners can process up to 2 tonnes per day, recovering about 0.2 g of gold/tonne. Gravel is screened through 1 cm perforated steel sheets and the fines are concentrated on makeshift, blanket-lined earthen sluices called “James Tables.” Sudden releases of irrigation water from the reservoir up-stream on the Muzveze River has led to the drowning of a number alluvial miners (18 miners drowned in one instance in July, 2003). The mercury used to recover the gold is burned without retorts, and amalgamation tailings are discarded locally, creating numerous small zones of elevated mercury concentration (Shoko and Veiga, 2004).

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⁵ Former commercial farmers may not have the mineral processing skills necessary to operate efficient milling operations—future training of millers should be based an inventory of their technical shortcomings.
3.4.3 Surface and underground mining

Tools for digging gold-rich eluvial or “rubble” deposits range from shovels, picks and bars to small sticks and fragments of metal for scraping rain-softened surface material. Primary ore is extracted from shallow surface pits and from primitive underground workings reaching to the water table, which can be 20 meters deep, using hammers, chisels and picks. When possible, underground operations utilize rented compressors and explosives to advance workings. Ore is hauled to the surface in buckets by rope or steel cable with manual windlasses. Mine shafts are narrow, typically a meter in diameter. Workings, whether open pits or underground, are not backfilled and wasted dumps are not reclaimed. This has proven to be a considerable hazard for livestock as well as people in many areas. Protective clothing and mechanical underground ventilation are rarely used. Ground collapse is common in the Kadoma area, especially when miners are removing pillars from abandoned large-scale workings. Mining accidents claim the lives of as many as 50 people each year in Kadoma-Chakari (Boese-O’Reilly et al., 2004).

Miners sometimes work in small syndicates, mining in shifts, 24 hours a day. A syndicate/team of 4 miners can produce 20 tonnes of ore/month. If the miners recover 30% of the gold during gravity concentration, their gross income would be about 60 g Au/month, assuming a total recovery of about 10 g Au/tonne of ore. Arrangements vary, but miners and miners’ syndicates pay a tribute to the claim owner for the right to mine. In the Kadoma-Chakari area, tribute is typically 5%, but the Zimbabwe Women in Mining Association reports that their members have paid tributes of 20% (Ellen Ncube, 2007—President, Mashonaland West Women in Mining, pers. comm.). In
some cases, ambitious African ASGMs are claiming mineral rights on the formerly white-owned commercial farms where they grew up, using the knowledge of the huge estates gained as children to focus their prospecting efforts.

3.4.4 Milling and gravity recovery at custom milling centers

Owners of milling operations provide milling services to itinerant miners who require milling of low-grade gold ores. This kind of “custom milling” service in Zimbabwe is a post-independence phenomenon. Because much of the best farming land in Zimbabwe is situated on the NE-SW trending high plateau which exposes the gold bearing Archean basement complex (Bartholomew, 1990), many large commercial farms contained gold showings that yielded supplementary incomes for their white owners during the Rhodesian era. Today’s custom milling operations are often owned by white farmers who, foreseeing the loss of their farms in the inevitable land redistribution process, are said to have established residences in the vicinity of their mines and milling operations (or moved stamp mills close to their residences). This permitted continued ownership of their milling facilities after their farms were seized.

When custom millers lack sufficient feed from their own mines, they grind the ore of itinerant miners for a nominal fee plus ownership of the miners’ tailings. Custom millers have flourished with the growing numbers of ASGMs in the 1990s because stamp mills and whole ore amalgamation pass much unliberated gold to cyanidation. Even though millers rely on the poor liberation of stamp mills and the low recovery rates of amalgamation plates and centrifuges to maximize the gold content in their
cyanidation circuits, they must be sufficiently competitive with neighboring mills to ensure a constant supply of feed to their cyanidation tanks. A few milling centers in Kadoma-Chakari offer ball milling, and some millers attempt to attract high quality ore by providing miners with legal and technical support, and loans for equipment and permitting fees.

Altogether, there are about 1000 milling sites in Zimbabwe. In September 2007, however, there were only 243 operating “custom” or “toll” milling centers selling gold to Fidelity Printers and Refiners, the only legal gold buyer in the country (Paul Musuka, 2007—Director of Gold Operations, Fidelity Printers and Refiners, pers. comm.). There are currently 117 registered custom milling centers in the Kadoma-Chakari area, but at any given time, less than half of these are likely to be operating. A given milling center usually has multiple mills. At the M+K custom milling center in 2007, for example, there were 46 workers operating 6 mills and attendant cyanidation circuits. More milling centers are operating in the dry season when the water table is lowest and underground mining output is greatest. Ore grade, gold recovery and mercury inputs and loss at custom milling centers are summarized in Appendix 2.

3.4.5 Milling

High-grade ore is separated from the run of mine material and processed by hand in villages using steel mortars and pestles and concentrated on blanket-lined earthen sluices, amalgamated in pans, and roasted on open fires. Low-grade ore (usually between 5 and 10 mg Au/kg ore) is processed at custom mills where it is

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6 High grade ore is usually contains more than 15 g Au/tonne. The coarseness of the gold makes visual identification of high grade ore relatively easy.
concentrated on mercury amalgamation plates or in mercury containing centrifuges. Miner’s hand-crush their low-grade ore to about -10 cm and transport it in hired trucks or tractor-trailers to custom milling centers where the miner pays a nominal fee for the milling, typically between USD 1 and 3 per hour. Once milled, the miner receives the gold that is amalgamated on copper plates or concentrated in centrifuges. Centrifuge concentrates are usually subjected to manual pan amalgamation, but sometimes amalgamation barrels and elutriators are used.

Typically, a miner or member of the mining syndicate accompanies the ore to the milling center where they ensure that the milling, concentration and amalgamation are accomplished as efficiently as possible. Unless prohibited by their tribute arrangements, miners are free to chose where they mill their ore, allowing the option to use a ball mill if one is located suitably close to the mine site.

3.4.6 Stamp mills

Large electrically driven belts turn 50 cm diameter eccentric cams that lift and drop tall vertical steel shafts attached to 25 cm diameter stamps. Mill employees shovel the ore into a narrow mortar box where the ore is mixed with water and crushed between 250 to 800 kg stamps and fixed anvils. Water flow is adjusted to flush the crushed ore through the discharge screen at a pulp density of about 20% solids. Mills should stamp at the rate of 90 to 100 times per minute. Output can be up to 1.0 tonne/hour for a 3-stamp mill, depending on the hardness of the rock. The discharged pulp flows to either a Knudsen bowl type centrifuge, or to a mercury-
coated copper amalgamation plate which is usually one meter wide and 1 ½ meters in length (Singo, 2006).

Typically 50 to 70% of the gold in the miners’ ore reports to the tailings and is recovered through cyanidation by the miller (Shoko and Veiga, 2004). Gravity recovery is poor because stamp mills are fitted with coarse screens that pass <1mm particles that often contain unliberated gold which is not easily caught by amalgamation plates or centrifuges. Miners receive only what is recovered on the amalgamation plate or in the centrifuge, but at some mills they also collect the mortar box’s heavy fraction.

3.4.7 Ball mills

Ball mills are available at only 5 custom milling centers in Kadoma-Chakari, but operate in open circuit (no classification) which limits control of grain size and gold liberation. Because miners believe that gold is trapped in ball mill linings, stamp mills are the preferred milling option. Ball mills are also unpopular because the extra cost of transporting ore to a ball-milling center often outweighs any benefit from more efficient liberation. Because few custom milling centers in Zimbabwe have installed agitated leaching facilities, millers prefer stamp mills because the smaller particles from ball mills substantially reduce the percolation rate in passive cyanidation vats. In areas where stamp mills are not available, such as in Sanyati (90 km west of Kadoma), miners use ball mills out of necessity and are finding that the increased recovery from

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7 “Passive cyanidation” refers to non-aerated, non-agitated cyanide leaching of gold in which cyanide solution continually percolates through vats containing milled ore.
more efficient grinding outweighs the losses to the liners (Simba Sialumba, 2007—
Gold Procurement Administrator, Fidelity Printers and Refiners, pers. comm.).

3.4.8 Gravity concentration

By law, all milling centers are required to have two-stage gravity concentration
systems and miners must be allowed to collect gold from both stages (Zimbabwe
Mines and Minerals Act, Custom Milling Plant Regulations, 2002). Regulations
stipulate that the recovery system may be some combination of sluices, centrifuges or
copper plates. However, two-stage systems are not always offered, and miners are
only allowed to collect gold from a single concentrator, maximizing the gold passed to
the miller’s cyanidation circuits. The most common single concentrator is the copper
amalgamation plate, but more and more milling centers are offering single stage
systems composed of Knudsen Bowl centrifuges, which some miners believe to be
more efficient than copper plates. Unfortunately, because these centrifuges are in
reality not very efficient, the usual practice is to introduce one to three spoonfuls of
mercury (about 50 to 150 grams) into the centrifuge bowl.

After cleaning with nitric acid, copper amalgamation plates are freshly dressed
with about 150 grams of mercury before each batch. The mercury is kept active as the
pulp flows over the plate by rubbing a piece of cyanide briquette over the feed plenum.
Yellowish patches of oxidized copper on the plate are cleaned directly with the
briquette. Miners are not aware of the dangers of using cyanide in neutral pH pulp.
Once the feed and pulp flow are exhausted, the amalgam is scraped with a rubber
squeegee and the excess mercury is squeezed in a small piece of cloth. At some
mills, the copper plate is then scoured with coarse sand in an attempt to recover any gold remaining in the scratches and crevices on the plate. Scouring is an unusual practice (but not unique to Zimbabwe) that increases losses of mercury to the tailings and necessitates the use of nitric acid to remove the scoured copper from the amalgam (Swent, 2000). Fortunately, millers often do not permit scouring because it damages the copper plates. When scouring of plates occurs, about 20 g of the 150 g of mercury applied to the copper plate per tonne of ore are lost to tailings (Billaud et al., 2004). It must be emphasized that where copper plates are not used, mercury is invariably used in centrifuges. Miners estimate that the loss of Hg from centrifuges is about half that of copper plates.

3.4.9 Environmental consequences of custom milling

The growth of custom milling after independence has had significant environmental consequences. For example, Rhodesian-era stamp mill operations limited the loss of mercury from whole ore amalgamation by employing simple mercury traps at the foot of the copper plates. Most post-independence toll milling operators eliminated the traps to allow the gold and amalgam to pass to cyanidation. Leaving the traps in place invited miners to claim the trapped amalgam and gold. For the miller, the cost of any additional cyanide required to dissolve the lost mercury is outweighed by the value of the unrecovered gold that passes cyanidation.

8 Typical traps consisted of transverse troughs (5 to 10 cm deep by 10 to 20 cm wide) attached to the bottom end of the plate. Pulp was discharged from the trap over a baffle at the side of the trough, or into a pipe projecting up through the bottom of the trough. The heavy fraction (gold, mercury and amalgam) formed a bed at the bottom of the trough which was cleaned out daily (Peele, 1927; Imperial Chemical Industries, 1936).
3.4.10 Amalgamation of concentrates

Amalgamation barrels are required by law to amalgamate gravity concentrates, but most miners prefer to amalgamate their concentrates by hand stirring in bowls. Soap is used to keep the surface of the gold clean. Hand amalgamation is effective and does not tend to flour the mercury, as do amalgamation barrels when they are run too long or used with steel balls to promote mixing. It is reported that some miners use an unspecified small quantity of cyanide in amalgamation barrels to promote amalgamation. This practice has been reported to be effective, but no data exists specifying optimum cyanide concentration levels (Rubidge, 1973). When amalgamation barrels are used, mercury is added to concentrate at an efficient ratio of between 1:40 to 1:80 (Shoko and Veiga, 2004).

Retorts are required by law to be used at milling centers, but it appears that they are seldom used. Almost always, miners in Zimbabwe use nitric acid to remove mercury from amalgams before burning or retorting—removal of the mercury produces a porous texture which permits dissolution of accessory metals found in the interior of the amalgam as well as easier evaporation of any residual mercury during subsequent roasting and smelting. After pre-treating with nitric acid, the waste solution is discarded on the ground, and the residual mercury in the amalgam is roasted on the burning end of a 10-15 cm diameter log, blowing the embers with the mouth to maximize the heat\(^9\). The resulting gold doré is then mixed with a little borax and

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\(^9\) It is unknown how much of the mercury in the amalgam is dissolved and lost during pretreatment of the amalgam with nitric acid, and how much is evaporated during roasting and smelting. Nevertheless, reasonable guess is that the nitric acid dissolves about half of the mercury.
smelted with a torch by a mill employee. These processes expose the amalgam burners directly to inhalation of vaporized residual Hg.

3.5 Milling, cyanidation, elution and recovery practice at two milling centers

Environmental sampling by Billaud et al. (2004) yielded insufficient data to model the fate of the mercury lost at custom milling centers in Zimbabwe. Milling, cyanidation, elution, and smelting practices at two Kadoma area custom milling centers (Appendix 3) suggest however that most of the mercury losses at milling centers occur as a result of:

- Disposal of process solutions containing mercury
  - Nitric acid solutions from pretreatment of amalgams by the miners
  - Nitric acid solutions from digestion of cathode sludge by the millers
  - Waste cyanide solutions
- Evaporation
  - Roasting and smelting of miners’ amalgams
  - During elution, electrowinning and smelting by millers

3.5.1 Tireless Custom Milling Center

Tireless Milling center is located 20 km Southeast of Kadoma. Six 1450 lb stamp mills, each capable of milling 750 to 1000 kg/h (Singo, 2006), grind a range of ores, much of which has a relatively high sulfide content (Appendix 3). While most primary concentration at Tireless is accomplished with ABJ Knudsen bowl centrifuges (Figure
2) an amalgamation plate is available to miners who prefer this method. Because Knudsen bowl centrifuges are not very efficient, between 50-100 grams of mercury per tonne of ore are introduced to increase recovery, and centrifuge bowls are monitored to ensure that sufficient mercury is available to capture the gold. Centrifuges operate in locked rooms at Tireless, and miners collect their concentrate under the eye of the national “gold squad” police who are stationed at the mill to make sure that all gold produced at custom milling centers is sold to Fidelity Printers and Refiners. Miners amalgamate their concentrates by hand in plastic kitchen bowls, using a little soap to achieve good amalgamation. The amalgam is squeezed in a cloth, boiled in nitric acid to remove as much of the mercury and accessory metals as possible, and then

![Figure 2 — Milling and cyanidation at Tireless Milling Center](image)

Figure 2 — Milling and cyanidation at Tireless Milling Center
roasted on the end of a burning log. The miner then gives the gold doré to a mill employee who smelts it with borax at high temperatures under the miner’s supervision, burning off most of the remaining mercury and producing a doré which is assayed using a specific gravity method to calculate the payment.

Tailings from the centrifuges (or copper plates) become the property of Tireless Mill which uses a hydrocyclone to separate the sands (70%) from the slimes (30%). The sands are dewatered and put into 4 meter diameter x 2 meter deep concrete vats. At the bottom is a 0.5 meter deep filter consisting of cobbles, sand, and Hessian cloth protected by a layer of 10 cm diameter gum poles. New batches (24 tonnes of sand) are charged with 10 kg NaCN and 12 kg of caustic soda and soaked for 24 hours before circulation begins with recycled 0.1% cyanide solution\(^\text{10}\). (Methods for monitoring pH were not reported.) The pregnant solution passes through activated carbon adsorption cells before recirculation (Figure 3). Residence time is typically between 5-6 days, but varies according to ore type and grade. Gold values of the pregnant solution are monitored daily by a modified Purple of Cassius method (Appendix 4).

The slimes are dried, disaggregated in a trommel, and loaded into a 4.3 meter diameter by 3.2 meter deep concrete agitated tank (the bottom 1.2 meters is conical to facilitate discharge). The operator adds 18 kg of lime and 11 kg of NaCN to the batch, bringing cyanide concentration to about 0.1% (or 1 g/L). No air is injected into the

\(^{10}\) Cyanide concentration is controlled colorimetrically using potassium iodide as an indicator and titrating with silver nitrate.
After 18 hours of mechanical agitation, the pregnant solution is decanted to a clarifying tank. Spent slimes are agitated and washed in water for 90 minutes and discharged through the cone to unlined tailings ponds.

Figure 3 — Schematic diagram of cyanidation circuit at Tireless Milling Center

Tireless’ 6 passive and 2 agitated tanks feed a 2.75 meter diameter x 2 meter deep concrete clarification tank which filters the pregnant solution through a gum pole, Hessian cloth, river sand, and cobble filter similar to the filters at the bottom of the passive tanks. The hydraulic head pushes the solution through the filter into a holding chamber and then to the carbon adsorption cells. Five 25 kg activated coconut carbon cells are advanced in counter direction to solution flow along a 2.5 m x 0.4 m x 0.4 m
fiberglass trough. Barren solution is monitored with the Purple of Cassius method (Appendix 4).

At Tireless, the carbon elution and recovery circuit consists of 3 stainless steel tanks. As is common in Zimbabwe, the stripping solution contains only caustic soda (4% or 40 g NaOH /L H₂O). This solution is heated in a 400 Liter tank to 110° C by twelve 2 kW elements, and pumped to an 800 Liter elution tank which contains 400 kg of loaded carbon (Figures 4 and 5). The eluate circulates for 72 hours through a 40 Liter electrowinning cell containing 2 pairs of electrodes operating at 2.5 volts. Cathodes consist of 1 to 2 kg of steel wool wrapped on stainless steel bars (steel wool is used because it has a high surface area and permits high through-flow of eluate). No NaCN is added to the stripping solution. The high over-potential produces a polymetallic sludge. Adding 20% ethanol or methanol to the eluate could increase the rate of elution by a factor of 3 or 4, but because Tireless’ elution system can easily handle the mill’s output of loaded carbon, there is no need to add alcohol, a flammable solvent, to accelerate the process (Marsden and House, 2006).

Gold is recovered from the steel wool and sludge by digestion in 95% sulfuric acid for 45-60 minutes to dissolve iron and copper, and then in 95% nitric acid to remove sulfides and mercury. Washing the digested sludge 4 times with water yields a smeltalble gold-rich black residue. This product, which locals call the “calcine,” is then fluxed at a ratio of 1:2 with borax, silica, and saltpeter and smelted to an 80-85% pure gold doré.
3.5.2 Evermore Milling

Three stamp mills feed copper amalgamation plates at Evermore milling. Scouring the copper plate is not allowed at Evermore custom milling center. Copper plates are followed by a blanket or Hessian cloth-lined scavenger sluice. ABJ centrifuges are available on request, and when used, are placed in series in front of the copper plate and scavenger. Miners add mercury to the centrifuges as desired (Figure 6).
Natural sedimentation of pulp yields heterogeneous layers of sands and slimes, so Evermore uses a “drag classifier” which is a conveyor belt fitted with paddle blades that drag through the settled tailings, to classify sands (90%) and slimes (10%). As there are no agitated leaching facilities, slimes are dried and remixed with sands during loading of the vats to ensure even percolation during passive leaching. As at Tireless, 1 m wide x 1.5 long copper plates are dressed with 50-100 grams of mercury. Visual examination of amalgamation tailings in April, 2006 suggested that Evermore’s mercury scavenger was relatively efficient and confirms the importance of
not scouring the copper plate\textsuperscript{11}. Evermore reports that about 10 grams of mercury are lost per tonne of ore milled (roughly half of that lost at Tix Mill where scouring takes place. ABJ amalgamation barrels are available, but miners usually hand-amalgamate small batches in plastic kitchen bowls. At Evermore, the miners’ amalgams are pre-treated (but not boiled) in nitric acid. Evermore reports that it uses water-cooled retorts for amalgam burning.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{milling_and_cyanidation_diagram}
\caption{Milling and cyanidation at Evermore Milling Center}
\end{figure}

Passive cyanide leaching occurs in rectangular and circular concrete vats, about 2 meters deep, with gum pole, sand, Hessian cloth, and cobble filters constructed at the bottom. The average leaching time is 5 to 6 days. Pregnant solution

\textsuperscript{11} The single sample of amalgamation tailings containing 19.7 mg/kg Hg collected by Billaud et al. (2004) at Evermore suggests that the Hessian/blanket scavenger sluice is not an efficient mercury trap.
flows to a clarification tank and then through activated carbon cells inside a 3 m x 0.75 m x 0.75 m concrete tank (solution flows into the bottom of a cell and out the top into the next cell). Relatively coarse (-5 mm) coconut carbon is used.

Stripping and electrowinning occur simultaneously in a 325 Liter pressurized stainless steel tank \(^{12}\) (Figure 7). Temperatures of 100\(^\circ\) to 115\(^\circ\) C are achieved by five 2 kW elements in the bottom of the vessel, 3 of which are powered continuously during the 24 to 48 hour run-cycle. Convection from a water-cooled jacket drives the circulation of the eluate through an adjacent overflow vessel and downward through the carbon. Eluate contains 25 kg of caustic soda per 60 kg batch of carbon (about 6.25\% or 62.5 g NaOH/L H\(_2\)O, assuming 400 Liters of solution).

Electrowinning takes place in a pair of stainless steel baskets suspended at the top of the elution vessel. An interior perforated cathode basket holds about 2 meters of steel wool. Condensed mercury droplets are commonly observed on the lid inside the vessel, just above the electrodes. Unlike at Tireless, the elution vessel is outside at Evermore, covered a roof, minimizing worker exposure to mercury vapor.

The loaded steel wool cathode and sludge is first digested in hydrochloric acid and washed with water 4 times to remove the acid, then digested with nitric acid to

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\(^{12}\) Evermore reports that their elution system is a copy of a once-available commercial system. The manufacturer is unknown.
dissolve mercury and copper and iron sulfides, and finally water-washed another 3 times. Like at Tireless, the resultant black “calcine” residue is then smelted, producing an 80-85% pure gold doré (Figure 8). Final tailings at Evermore are not washed, but they are sampled and tested for grade to ensure efficient operations. Waste nitric acid solution is diluted and buried. Carbon is assayed for gold content and any residual gold in the spent carbon is recovered before disposal.
3.5.3 Interpreting the flowsheets

Zimbabwe’s milling centers grind with stamp mills that pass unliberated gold through a 1 mm screen to inefficient copper plates and Knudsen bowl centrifuges. Often ores contain significant quantities of sulfides, further reducing efficiency of copper plates, and quickly filling up the riffles in the centrifuges. Under these conditions, 50% to 70% of the gold in the ore passes to the millers’ cyanidation circuits (Shoko and Veiga, 2004).

These milling center flowsheets reveal mechanisms of mercury loss that have not previously been identified. Perhaps due to insufficient sampling density of tailings,
Billaud et al. (2004) did not recognize that cyanide might dissolve much of the mercury in the amalgamation tailings. Since Billaud et al. (2004) focused mostly on Tix Mill, which sends its loaded carbon off-site for elution, the authors may have also overlooked the mercury losses occurring during elution and smelting. In addition, Billaud et al. (2004) did not recognize the significance of scouring copper plates. Perhaps most importantly, however, Billaud et al. (2004) did not identify the practice of digesting miners’ amalgam and millers’ cathode sludge in nitric acid. Billaud et al.’s (2004) tailings sampling density was very low and is sufficient only to suggest the trend that cyanidation tailings consistently contain much less mercury than amalgamation tailings. Cyanidation at Tix, Glasgow and Evans Milling Centers removed 96.9%, 92.4% and 85.3% (respectively) of the mercury in the sampled amalgamation tailings (Table 1). These findings are consistent with Gunson (2004) who found that 87.2% of the mercury in amalgamation tailings at Gold Mountain, China dissolved during passive cyanidation.

Table 1 – Average concentration of mercury in tailings at custom milling centers in Kadoma-Chakari

Source: Billaud et al., 2007

<table>
<thead>
<tr>
<th>MILL</th>
<th>RECOVERY METHOD</th>
<th>NUMBER OF SAMPLES</th>
<th>AVERAGE MERCURY CONCENTRATION</th>
<th>% Hg LEACHED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Amalgamation</td>
<td>Cyanidation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tailings</td>
<td>tailings</td>
<td></td>
</tr>
<tr>
<td>Tix Mill</td>
<td>Amalgamation</td>
<td>11</td>
<td>22.5 mg/kg</td>
<td>0.7 mg/kg</td>
</tr>
<tr>
<td></td>
<td>plate/scouring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glasgow</td>
<td>Amalgamation</td>
<td>3</td>
<td>15.8 mg/kg</td>
<td>1.2 mg/kg</td>
</tr>
<tr>
<td>Mill</td>
<td>plate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Even Mill</td>
<td>ABJ centrifuge</td>
<td>4</td>
<td>6.1 mg/kg</td>
<td>0.9 mg/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evermore</td>
<td>Amalgamation</td>
<td>1</td>
<td>19.7</td>
<td>--</td>
</tr>
<tr>
<td>Mill</td>
<td>plate, centrifuge</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
Some millers have their own elution equipment, but others send their loaded activated carbon to custom elution centers for stripping. Operators of elution centers observe that loaded carbon contains varying amount of mercury, suggesting that mercury losses to tailings vary according to practices at milling centers. From Billaud et al.’s (2004) data, it can be inferred that when mills allow scouring of copper plates, a practice identified at Tix Milling Center, mercury losses to tailings can be as much a 22.5 g Hg/tonne of ore milled. At milling centers that do not use copper plates (Tireless Mill) or do not allow scouring (Evermore Mill), loss of mercury to amalgamation tailings may be half that at Tix (note that Evermore reported losses of 10 g Hg/tonne ore, but Billaud et al.’s (2004) single amalgamation tailings sample at Evermore contained 19.7 g Hg/tonne). Sampling of amalgamation tailings conducted by Billaud et al. (2004) at Glasgow and Evan milling centers was also extremely thin, but suggests losses of about 15 g Hg/tonne (Glasgow Mill) and about 5 g Hg/tonne (Evan Mill). From Billaud et al.’s (2004) data, it seems that about 90% of the mercury losses are due to cyanidation of these amalgamation tailings and subsequent evaporation during elution and smelting or dissolution during nitric acid digestion of cathode sludge.

Mercury losses can be minimized by not scouring copper plates, by using a mechanism to trap mercury lost from amalgamation plates and centrifuges, or by replacing whole ore amalgamation (either on copper amalgamation plates or in centrifuges) with vinyl loop carpets. In addition, retorting cathode sludge before nitric acid washing could reduce the losses associated with preparing the electrowon product for smelting during acid digestion. Finally, mercury in waste nitric acid
solutions can be recovered through cementation on aluminum wires or sheeting or electrolytically precipitated (Veiga, 1997).

An interesting feature of elution in Zimbabwe is the use of strip solutions containing only NaOH (NaCN is not necessary for elution because OH⁻ ions readily displace metal-cyanide complexes from carbon adsorption sites). Tireless’ and Evermore’s elution vessels are sized to accommodate the loaded carbon output from the mills’ adsorption cells, so the added cost of Zadra-type strip solutions or alcohol¹³ is not necessary (Zadra et al., 1952; Marsden and House, 2006; John Marsden, 2007—Freeport-McMoRan, pers. comm.).

3.6 Problems associated with the use of mercury and cyanide at milling centers

Small-scale cyanidation is being promoted as a significant improvement over mercury amalgamation for gold extraction in developing countries, but advocates of the practice overlook any possible harmful synergies between cyanide and the mercury contained in amalgamation tailings that are invariably subjected to cyanidation (e.g., Hollaway, 1999, UNECA, 2002, Maponga and Ngorima, 2003, Jaques et al., 2008). Dissolution of mercury in cyanide greatly increases the mobility of mercury in the aquatic environment, and likely enhances mercury’s ability to bioaccumulate in fish stocks. The holy grail of mercury-free artisanal gold extraction has not been found.¹⁴ Because cyanide remains the only practical lixiviant for gold

¹³ The use of 1-2% NaOH and 0.1% NaCN would increase the rate of elution by a factor of about 2. Adding 20% alcohol would increase the rate of elution by a factor of up to 4 (Marsden and House, 2006)

¹⁴ Mintek’s iGoli system, for example, is neither affordable nor as simple, direct and transparent as mercury amalgamation.
extraction (Spiegel et al., 2005; Hilson and Monhemius, 2006), the introduction of this technology to ASGMs without proactive safety training may well result in worsening environmental and human health, while benefiting only the few with the capital to build and operate the cyanidation systems.

Considerable quantities of cyanide are used in Zimbabwe. UNECA (2002) reported that about 6000 tonnes/annum of cyanide were exported to Zimbabwe during the early 1990s. Hinton et al. (2003) suggested that ASGM cyanide consumption levels were 5000 tonnes/annum. Sakuhuni (2007) documented the cyanide distribution chain in Zimbabwe (Table 2), establishing that three signatories to the International Cyanide Management Code\(^{15}\) (Tongsuh, Taekwang, and DuPont) sell about 3,000 tonnes/annum directly to suppliers for ASGM distribution.

From Billaud et al. (2004), it can be inferred that most of the mercury in amalgamation tailings (Table 1) is dissolved during cyanidation and subsequently reports to the carbon adsorption cells. This mercury either evaporates during elution and electrowinning or co-precipitates with gold at the cathode and is dissolved in nitric acid and discarded. In addition, because cyanidation tailings are rarely neutralized or washed in Zimbabwe, residual cyanide can mobilize any mercury remaining in the tailings.

\(^{15}\) The International Cyanide Management Code is a voluntary process in which cyanide manufacturers, transporters, and large-scale mining operations adhere to a code of best practices. At the code’s inception in 2000, stakeholders agreed that the code should eventually include small-scale mining operations, however the focus of the current code remains on large-scale mining only (UNEP, 2000).
3.6.1 Mercury solubility during cyanidation, elution and electrowinning

The kinetics of mercury in cyanidation and elution circuits and the low mercury content of the post-cyanidation tailings samples collected at milling centers in Kadoma-Chakari by Billaud et al. (2004) (Table 1) and at Gold Mountain by Gunson (2004) together support the hypothesis that cyanidation at Kadoma-Chakari’s small-scale milling centers removes most of the mercury from amalgamation tailings during vat leaching. During cyanidation, metal mercury dissolves at nearly the same rate as gold (Marsden and House, 2006; Basie Maree, 2007—Head of Metallurgy (Africa), AngloGold Ashanti, pers. comm.). Long residence times during passive vat leaching ensure that most of the mercury (which is more “liberated” than any partially occluded un-liberated gold particles) complexes with the cyanide.

Mercury forms the \( \text{Hg(CN)}_2^0 \), \( \text{Hg(CN)}_3^- \) and \( \text{Hg(CN)}_4^{2-} \) complexes with cyanide,
but Hg(CN)$_4^{2-}$ is the principal mercury species found under typical leaching conditions. Decreasing pH below 7 decomposes Hg(CN)$_4^{2-}$ to the more stable, soluble Hg(CN)$_2^o$ complex (Flynn and Haslem, 1995). Marsden and House (2006) report that:

1. Hg(CN)$_2^o$ adsorbs to carbon at almost the same rate as Au(CN)$_2^-$
2. Hg(CN)$_2^o$ competes for adsorption sites directly with Au(CN)$_2^-$
3. Hg(CN)$_2^o$ desorbs before Au(CN)$_2^-$ during elution.

During electrowinning, mercury, lead and silver reduce before gold, co-precipitating with gold on the cathode. Electrowinning is thought to proceed with the metal-cyanide species first adsorbing on the cathode, and then reducing to the metal species (Marsden and House, 2006).

Adams (1991) showed that Hg(CN)$_2^o$ has more affinity for carbon than the double negative charge of Hg(CN)$_4^{2-}$ which adsorbs to carbon only to a negligible degree. In addition, Adams (1991) noted that the reduction of mercury cyanide complexes by activated carbon to Hg$^o$ is not thermodynamically feasible. Some of Adam’s (1991) findings need to be verified, however. For example, he suggested that a cyanide-free eluant would not elute adsorbed Hg(CN)$_2^o$, but Hg$^o$ does in fact evolve during NaOH elution in Kadoma-Chakari. Furthermore, the mechanism of the shift from Hg(CN)$_4^{2-}$ (the predominant species during cyanide leaching of gold ores) to the adsorbed neutral species Hg(CN)$_2^o$ needs to be clarified.

3.6.2 Relationship between cyanide and methylmercury

Dissolved Hg (II) participates in a bacteria mediated process to produce methylmercury ($\text{CH}_3\text{Hg}^+$), usually in anaerobic conditions such as in subaqueous river
sediments. The literature suggests that cyanide may increase the bioavailability of mercury (Swain et al., 2007), but the nature of the links between cyanide and methylmercury are insufficiently studied. Sousa and Veiga (2008), for example, point out that mercury levels in fish tend to be high in regions where amalgamation tailings are subjected to cyanidation, but are not certain if the high levels are the result of methylmercury (or perhaps mercury cyanide) bioaccumulation. It remains unclear if cyanide is a bridge to methylation in a manner analogous to the oxidation of mercury by nitric acid, humic acids and dissolved organic matter (Meech et al., 1998; Melamed et al., 2000; Lu and Jaffe, 2001).

Hg(II) is bound with CN\(^-\) in complexes that are characterized by Flynn and Haslem (1995), as “partially weak-acid-dissociable”. While the fate of mercury-cyanide complexes in polymetallic tailings is largely unstudied, the acidic environments commonly found in tailings piles containing sulfidic ores favor the formation of the stable, soluble Hg(CN)\(_2\)\(^0\) complex whose mobility is influenced by pH, redox and other variations within heterogeneous tailings piles (Flynn and Haslem, 1995). Also unstudied is whether the degradation of cyanide provides an important nutrient source for methylmercury producing bacteria, or whether humic-rich soils used to cover tailings enhance methylation.
4 THE IMPACTS OF ARTISANAL AND SMALL-SCALE GOLD MINING IN KADOMA-CHAKARI

ASGM produces environmental and health risks, but it also makes significant contributions to low-income communities. It is axiomatic that throughout the world artisanal and small-scale mining (ASM) is driven by poverty (e.g., Hilson and Pardie, 2006). This is especially the case in Zimbabwe, where the per capita annual Gross National Income was only USD 340 in 2005 and 80% of the population is unemployed. The growth of contemporary small-scale mining in Zimbabwe mirrors the evolution of the nation’s drastic economic situation. Zimbabwe saw an upsurge in ASGM in the 1990s as a result of unemployment caused by the shutdown of large-scale mining activities, the collapse of the agricultural sector due to drought and the implementation of the land reform program, and the layoff of public sector workers caused by economic structural adjustments (Marquette, 1997; Tabajuka, 2005; Saunders, 2007).

4.1 Characteristics of the research area in Zimbabwe

4.1.1 Location and access

Kadoma-Chakari is located about 2 hours drive (140 km) southwest of Harare in the Hartley and Kadoma districts of Mashonaland West Province in Zimbabwe (figure 1). An active gold mining area for many centuries, first by indigenous Shona and later by European colonists, Kadoma-Chakari spans roughly 1,350 square kilometers (Zimbabwe map sheets 1982-B2 and 1982-B4). Gold mining is the most important economic activity in this region and accounts for about 10% of Zimbabwe’s ASM gold production (Shoko and Veiga, 2004).
The towns of Kadoma and Rimuka (Kadoma’s high-density suburb) are home to about 120,000 people, while another 120,000 people live in the region's rural areas. Access to Kadoma from Harare is by paved road, and most villages in the project area are accessible by good gravel roads. However, heavy rains in November, December and January can limit access to some mining communities. Local transportation consists of mini buses, but fares are often beyond peoples’ means.

4.1.2 Miners and their communities

The average income in the region is approximately USD 15 per month (Mtetwa and Shava, 2003). Because many miners have families in distant rural homelands or in urban centers, gold mining often disrupts basic family structure and contributes to prostitution and the high prevalence of sexually transmitted diseases including HIV/AIDS. In 2006, the prevalence of HIV/AIDS in Zimbabwe was 15.6%, down from 26.5% in 2001 due to mortality and behavior change (UNGASS, 2007). In Kadoma-Chakari, the HIV/AIDS prevalence is thought to be considerably higher than the national average, but concrete data supporting this is lacking.

Literacy amongst the mining communities is remarkably high with 50% of the population having attended high school—fewer than 10% are illiterate. Shona is the dominant language for day-to-day life for most people, but many Zimbabweans are multi-lingual and most people in the project area can readily converse in English (Mtetwa and Shava, 2003).

Sadza, a thick porridge made from ground corn or “mealy-meal”, is the staple food in Zimbabwe and is usually served with stewed vegetables and meat (if
Fish is imported from other regions because local stocks have been depleted. Maize production, both at the commercial and family level, has been severely limited due to droughts during the past 7 years—many children in mining communities are reported to be undernourished. The drought during the 2006-2007 rainy season was particularly severe and contributed to food shortages during late 2007.

Rural sanitation and water quality are now often substandard, having declined from the 1980s when Zimbabwe was a world leader in water and sanitation programs. At that time, borehole wells and “ventilated improved pit latrines” (or “Blaire toilets” as they are named after Zimbabwe’s Blaire Research Institute) were installed throughout the rural countryside, but currently there are insufficient government funds available for water and sanitation programs.

Healthcare is limited to the services of visiting rural nurses and a few regional clinics. Acute cases are referred to the under-equipped and short-staffed Kadoma District Hospital, or to Harare. Private vehicles or public minivans serve as emergency vehicles, although the district hospital has recently acquired an ambulance.

Elementary schools are within 7 kilometers from most mining villages, but increasing uniform and tuition costs are making basic education prohibitive for many mining families. Schools are generally poorly supplied and physically decaying. For example, the concrete floors of the Mayflower School (located one kilometer from Tix custom milling center, about 10 km south of Kadoma) are cratered with 20 cm diameter holes, and blackboards are cracked and crumbled. Boys’ participation in
mining activities leads to significant absenteeism from schools during the active mining season.

4.2 The GMP’s preliminary assessments of mining community needs

In 2003 and 2004, the GMP reviewed the socio-economic, health and environmental status of ASGMs in Kadoma-Chakari. The aim was to inform the field interventions that would follow, and to contribute to a global database that would justify future ASGM interventions. A team of Harare-based sociologists conducted structured interviews with miners and millers, environmental scientists from the Bureau de Recherches Géologiques et Minières (BRGM, France) collected and analyzed soil, sediment and water samples (Billaud et al., 2004), and medical toxicologists from the Ludwig-Maximilians University (Germany) collected biological samples and evaluated miners’ psychomotoric behavior (Boese-O’Reilly et al., 2004). With the exception of the Health Assessment, the researchers generated their reports with little dialogue with the beneficiary communities. Mining communities’ voices are not well represented in the reports, and research findings were ultimately not well communicated to the study participants.

4.2.1 Socio-economic assessment

The socio-economic assessment established that about 90% of the miners in 2003 were males who were mostly between 20 and 40 years old (Mtetwa and Shava, 2003). About 17% of the miners were illiterate, and many late primary and secondary school aged children were engaging in mining, rather than pursuing their studies. Interestingly, the authors noted that the use of nitric acid with mercury was potentially
problematic, but the subsequent environmental and health assessments missed this crucial finding. This socio-economic assessment was based on structured interviews with 115 miners and millers, but did not disclose how the participants were selected. The interviews did not invite participants to establish any development priorities for their communities. The findings give the impression that the voices of miners was unnecessarily filtered by the researchers, as the data is primarily factual (e.g., age, sex, income, number of years mining, etc.) and does not describe the perceptions and aspirations of the miners (Mtetwa and Shava, 2003).

4.2.2 Environmental Assessment

The Environmental Assessment conducted by the BRGM (France) on behalf of the GMP (Billaud et al., 2004), found that mercury contamination is largely due to point-source discharges at milling centers. Fish in the project area are bioaccumulating mercury (even small carnivorous fish have 2 to 4 times the WHO limit for consumption of 0.5 ppm Hg). This is not surprising, however, given that ASGM mining and milling operations in Zimbabwe have subjected amalgamation tailings to cyanidation (which dissolves and mobilizes mercury) for about 100 years (Phimister, 1975). In some instances, drinking water mercury levels are elevated (but remain within WHO guidelines of 0.1 ppb Hg), presumably due to contamination with Hg bearing silt or dissolved mercury from the cyanidation of amalgamation tailings. At face-height above freshly dressed copper plates, air can contain over 100 µg/m³, but the time weighted exposure was about 20 µg/m³, below the WHO’s 8-hour worker exposure limit for mercury of 25 µg/m³ (Billaud et al, 2004).
4.2.3 Health Assessment

A team of toxicologists from the Institute of Forensic Medicine (IFM) at Munich’s Ludwig-Maximilians University evaluated the health status of about 220 miners and their families in 2003 and 2004. Combining the results of various psychomotoric tests with bio-monitoring analyses, the IFM team concluded that 70% of amalgam burners, 63% of mercury users, and 23% former mercury users were chronically intoxicated with mercury. The findings showed that children who handle mercury have a high incidence of mercury intoxication (69%) (Boese-O'Reilly et al., 2004). To its credit, the health assessment emphasized that mercury intoxication is only one of many health challenges Zimbabwe’s miners face, and argued that poverty, HIV/AIDS, malaria and water borne diseases are likely more significant contributors to the poor health of Zimbabwe’s mining communities than mercury exposure.

4.2.4 Financing and Microcredit Assessment

The development of financing schemes with microfinance banks is currently impossible for artisanal and small-scale mining operations in Zimbabwe because of the country’s extreme inflation rate. The GMP’s financing study (Dube, 2004) identified the programs that offer, or have offered, micro-credit for ASGMs in Zimbabwe. In essence, the study recommended that the Zimbabwe government should develop special loan guarantee and flexible payment schemes for miners similar to the financing programs already available to the nation’s small farmers who face similar unpredictable outcomes. The GMP recommended that Fidelity Printers and Refiners, the gold buying arm of the Zimbabwe Reserve Bank and the only authorized gold
buyer in the country, provide seed capital for a revolving loan fund (Dube, 2005). Another option would be to fix loans in gold, thus insuring that the lending institutions receive the real value of their loans on repayment.

4.2.5 Mercury Trade Assessment

In 2004, it was estimated that between 1.7 and 3.4 tonnes Hg/a were lost at milling centers in the Kadoma-Chakari area (Shoko and Veiga, 2004). In a subsequent study, the GMP surveyed mercury imports into Zimbabwe and concluded that national losses were between 20 and 25 tonnes per annum (Handelsman, 2006). Handlesman’s estimates square reasonably well with Shoko and Veiga’s (2004) figures, since it is believed that Kadoma-Chakari produces about 10% of the country’s ASM gold. In September 2007, the price of mercury from commercial suppliers in Kadoma was USD 62.50 per kg, down from about USD 110.00 per kg in early 2006 (at the same time, Fidelity Printers, the government gold buying institution, sold mercury at a reduced price of USD 75.00 per kg). In 2006, the average international price of mercury was USD 15.94 /kg (USGS, 2008).

4.3 ASGM in Zimbabwe—an update

Since the publication of the above GMP assessments, Zimbabwe has seen further collapse of the agricultural sector and extreme growth in inflation. ASGMs have been forced to sell their gold on the black market because they have received only a fraction of the value of their gold from the official gold buyer, Fidelity Printers. In 2007, Operation Chikorokoza Chapera (a government operation to control the black market and stop ASGM environmental degradation) led to the arrest of thousands of miners,
halted almost all ASGM activities for over 6 months and stopped the GMP TDU training program. In addition, the imploding national economic system restricted the scope of the intended training, awareness and policy interventions of the GMP detailed in Chapter 6.

4.3.1 Collapse of commercial farming

Harts-Broekhuis and Huisman (2001) and Deininger et al. (2004) have outlined the economic and social history of the land reforms that led to the mass exodus of white commercial farmers from Zimbabwe beginning in the 1990s. Once considered the “breadbasket of Africa,” the loss of farming equipment and expertise, combined with years of successive drought and lack of fuel and fertilizer, has devastated Zimbabwe’s agricultural sector. Severe shortages of foreign exchange caused by the failure of the agricultural sector has led to insufficient imports of critical supplies such as fuel, medicine and many other necessities. Even with its programs of land redistribution, “socialist” Zimbabwe has become a class society with 20% of the population holding 80% of the national wealth (Tibaijuka, 2005).

With farming on the ropes, the country’s dependence on gold production for foreign exchange has dramatically increased. Gold mining contributed about 30% of the nation’s foreign currency earnings in 2001, but deliveries to the Fidelity Printers and Refiners (Zimbabwe’s only legal gold buyer) have since declined drastically, reflecting the low official price of gold which fuels trade on the black market (Saunders, 2007). In 2006, gold mining provided 16% of foreign currency earnings when producers declared 10.96 tonnes of gold, down from 13.45 tonnes in 2005
It is unknown how much of the reported gold was produced by ASGMs, but observers believe that about half of the national gold production is sold annually on the black market.

4.3.2 Hyperinflation

In early 2008, inflation in Zimbabwe was easily the highest in the world (official rates were over 100,000% per annum, but unofficial rates exceeded 250,000%). The price of chicken in supermarkets during 2007, for example, rose 236,000% in local currency. In September 2007, supermarkets were stripped bare of almost all stock and rumors of deliveries of staple foods such as cooking oil, corn meal and wheat flour would precipitate long lineups at stores. Fuel shortages, regular power blackouts, and an extremely oversubscribed communications infrastructure make day-to-day business operations in Zimbabwe almost impossible. For example, in September 2007, the Institute of Mining Research’s (IMR) offices and laboratories at the University of Harare had water and power service only two days a week, and the University’s internet server was often out of service. Hyperinflation makes delivery of ASGM training programs extremely difficult, and poses major challenges for economic, environmental and human security (Szamel, 2007).

4.3.3 The black market: official vs. unofficial rates for gold and currencies

The existence of the illegal gold market is a result of the low price that Fidelity Printers and Refiners pays miners for their gold. In March 2007, for example, the “support” or official price for gold was $Z 16,000/g while the black market rate was $Z 400,000/g. If based on the official (and only legal) currency exchange rate of
$Z 250/USD, Fidelity’s price valued the gold at USD 64/g [$Z 16,000/g Au ÷ $Z 250/USD = USD 64/g Au]. However, because the official exchange rate does not reflect the real cost of goods which follow black market currency rates (at the time about $Z 8,000/USD), the effective price the government paid the miners was only about USD 2/g Au[^16] [$Z 16,000/g Au ÷ $Z 8,000/USD = USD 2/g Au].

The black market in foreign currencies provides Zimbabweans with foreign exchange to purchase needed supplies from abroad and a hedge against inflation. Exchange rates on the black market are extremely variable, and can be especially high at the end of every quarter when it is rumored that the government purchases the foreign currencies on the black market to meet its international obligations.

4.3.4 Lack of government capacity to solve socio-economic problems

The government consistently fails to solve the economic crisis. In 2005, for example, Operation Murambatsvina, ostensibly an urban renewal and resettlement project, evicted 700,000 slum dwellers, disrupting health care and antiretroviral programs for 80,000 HIV/AIDS patients (Lancet Editorial, 2005, Tabajjuka, 2005; Government of Zimbabwe, 2005). In early 2007, Operation Chikorokoza Chapera’s enforcement of new environmental legislation put up to 80% of the nation’s gold miners out of work. In mid 2007, a government initiative to control inflation required that all shop owners cut retail prices by 50%, forcing liquidation of stock and causing most stores to close their doors. Supermarket shelves were stripped of all staple

[^16]: In March, 2007, 1 g of gold was worth USD 20 on the international market (kitco.com, 2008)
goods in September 2007, and wheat and bread were only available at extremely inflated prices on the black or “parallel” market. Bread was to be as scarce as gold (BBC, 2007b).

4.3.5 Chikorokoza Chapera and Zimbabwe’s new environmental legislation

In 2003, the GMP socio-economic study estimated that as many as 300,000 to 400,000 people were actively gold mining in Zimbabwe, and that as many as 2 million of the country’s 13 million population relied on mining (directly or indirectly) for their livelihoods (Mtetwa and Shava, 2003). Beginning in November, 2006, however, police supporting “Operation Chikorokoza Chapera” began to enforce the country’s new environmental legislation in an attempt to manage the environmental effects of mining activities, control the diamond rush in the Eastern Highlands, and put an end to the illegal activities associated with gold mining, especially the trading of gold and foreign currency on the black market. This stopped virtually all ASGM operations in the country and led to the arrest of at least 31,500 miners (BBC, 2007a). At the end of 2007, some observers estimated that as few as 100,000 miners were active in Zimbabwe (most of these were working clandestinely) even though the precipitous decline of the national economy suggested the number of people seeking a living in the sector should be growing. Chikorokoza Chapera has made it impossible to test any estimates of the number of active miners.

The legislation supporting Chikorokoza Chapera was the new Environmental Management Act (EMA), which began requiring miners and millers to have approved Environmental Impact Assessments (EIA) and Environmental Management Plans
(EMP) in late 2006, effectively making ASGM illegal because most small-scale operations had not applied for certification. Miners reported that the lack of an EIA and EMP was often used to confiscate gold ore and equipment during Chikorokoza Chapera, and that police bulldozed what were arbitrarily deemed “substandard” workers’ housing, destroying or confiscating their meager household possessions (BBC, 2007a, Herald, 2007).

In late 2007, about 25% of the Kadoma-Chakari’s miners were back in operation, but most these were forced to work clandestinely because they continued to lack EIA/EMPs. Most miners were producing only high grade ore which they could process themselves by hand in mortars and pestles, providing little low-grade feed for custom milling centers.

4.3.6 Influence of Chikorokoza Chapera on milling operations

In early 2007, most custom milling centers in the Kadoma area were also shut down by Operation Chikorokoza Chapera due to lack of valid EIAs and EMPs, but by September, about 50 to 70% of these mills had obtained the required permits. Currently there is a high degree of police surveillance of gold recovery processes at custom milling centers due to government’s belief that both miners and mill owners have been diverting gold to the black market, rather than selling to Fidelity Printers and Refiners. Some mills now have 24-hour police presence, while others must bring police officers from Kadoma whenever they wish to access loaded carbon cells and operate the gold recovery circuits. It is reported that these police officers threaten fines or suspension of operations if their demands for favors are not met.
5 ADDRESSING THE IMPACTS OF ASGM IN KADOMA-CHAKARI, ZIMBABWE

5.1 The Global Mercury Project

In 2001, the World Bank’s Global Environmental Facility contracted the United Nations Industrial Development Organization (UNIDO) through the United Nations Development Program (UNDP) to implement the Global Mercury Project (GMP), a pilot program in six countries designed to eliminate the barriers to the adoption of cleaner artisanal and small-scale mining technologies, with primary focus on the loss of mercury during the extraction of gold (UNDP, 2001). Zimbabwe was included in the GMP because it hosted a large number of artisanal miners who used mercury in watersheds that drain into an international water body (the Zambezi River). From 2002 until the end of 2007, UNIDO subcontracted research activities focusing on the economic, environmental and health status of mining communities, on improving the awareness of mercury hazards, and on the introduction of mineral processing alternatives. Unfortunately, slow implementation of training programs alienated many of the project’s partners and dampened local enthusiasm for the GMP’s programs. The extremely difficult socio-economic and political environment in Zimbabwe added to these challenges, further restricting the ability of the GMP to carry out its programs.

5.2 GMP activities in Zimbabwe

As indicated in Chapter 4, the Global Mercury Project established socio-economic, health and environmental baselines in 2003 and 2004. In 2006, an awareness and training program was initiated to convince miners and millers that mercury can and should be used more safely. Awareness and training focused on the
key finding of the Health Assessment that the worst exposure pathway (breathing mercury vapor when burning amalgam) can be avoided by using retorts (Boese-O’Reilly et al., 2004). Simple vinyl loop carpeted sluices were introduced in 2006 which, pending further testing, are now considered to be a viable replacement for whole ore amalgamation with copper amalgamation plates and mercury-containing Knudsen bowl centrifuges.

Other GMP activities included mercury importation and micro-credit studies, policy initiatives to regulate mercury use and to streamline environmental permitting of mining and milling sites, an awareness campaign based on the locally developed drama “Nakai,” training of trainers, creation of a Transportable Demonstration Unit (TDU), tests to support efficient cyanidation practice, a national retort campaign coupled with capacity building of the Zimbabwe Panners Association (ZPA), and the development of a strategy to sustain further miner awareness and training programs.

5.2.1 Assessments of miner’s needs

The scope of the GMP program in Zimbabwe was established through negotiations with government, in consultation with the University of Harare’s Institute of Mining Research (UNDP, 2001). In addition to the suite of formal assessments completed between 2003 and 2005, participants of the ASGM training of trainers workshop held in Kadoma in April 2006 further identified the needs of Zimbabwe’s mining populations (Appendix 1). In November 2006, workshops held in Harare, Chinhoyi, Kadoma, Gweru/Shurugwi, Bulawayo, Masvingo, Mutare and Bindura with local governments, traditional leaders, miners’ representative associations and miners
themselves, provided a means for stakeholders to inform national mining policy development.

During the April 2006 training workshop in Kadoma, it was recognized that “stakeholders” did not feel that they had any control over the direction of the GMP’s field program. For this reason, an entire day of the training was devoted to a brainstorming session in which participants identified a number of the health, social, legal, financial, and technical challenges facing mining communities. Trainees were randomly divided into 5 groups that focused on various ASM problem areas, identifying possible solutions and perceptions as to who might be responsible (the miners themselves, miners’ organizations, government, or the GMP) to help the miners meet their needs. Keywords summarizing group discussions were written on 20 x 35 cm cards and taped to the wall by rapporteurs and discussed during plenary sessions. It should be noted, however, that the trainees were drawn mostly from the Zimbabwe government and the ZPA (who were themselves operators of small-scale mines), none of whom were truly representative of artisanal mining communities.

Participants identified the following obstacles: permitting and environmental impact assessments, finding and financing of mining operations, dewatering mines, hauling ore to mill sites, high real-cost of milling, and poor understanding of modern mineral processing methods. Trainees also voiced concern about child labor and disruption of family units as family members seek mining opportunities far from home, sexually transmitted infections, alcoholism, drug use, and the widespread lack of water, sanitation, and antenatal care (Appendix 1).
5.2.2 GMP Training programs

A four-day training of trainers workshop was conducted in Kadoma in April 2006. Thirty-two trainers were introduced to the objectives of the GMP and the findings of the health, environmental, and socio-economic assessments. Trainers learned methods for communicating simple messages about the impacts of mercury on family health, methods for minimizing exposure, how to use and reuse mercury safely, how to build and use retorts, and how to achieve more efficient gravity concentration. In addition, the training presented an exhaustive review of mining practices and equipment used by artisanal and small-scale miners around the world, and an overview of underground mine safety. Participants included representatives from the Ministries of Health, Environment and Mines, local medical staff, the Institute for Mining Research (Harare), the Zimbabwe School of Mines (Bulawayo), Amakhosi Theater (Bulawayo), the Zimbabwe Panners Association, the Women in Mining Association, and independent miners.

A 1 x 2 meter sluice lined with 3M Nomad carpet (“medium traffic with backing, Type 6050”) was demonstrated at the Tix Milling Center. Participants of the workshop received copies of the Global Mercury Project’s “Manual for Training Artisanal and Small-Scale Gold Miners” (Veiga et al., 2006), as well as “Good Practices in Gold Processing for Small-scale Mining,” a locally published ASGM manual (Singo, 2006).

The Zimbabwe School of Mines (ZSM) was the favored subcontractor to assemble and operate the TDU, having had previous experience delivering training programs to ASGMs. Unfortunately at the 11th hour, the ZSM declined to submit a bid,
and the contract was awarded to the IMR, an institution with insufficient administrative and training capacity.

The IMR was subcontracted to run the awareness campaign, and to assemble and operate the GMP’s Transportable Demonstration Unit (TDU) containing a jaw crusher and ball mill, a hammer mill, a centrifuge, a generator and a steel sluice equipped with vinyl loop carpets. The IMR reported that they trained 569 miners in 2006, but this training was lecture-style because the TDU equipment had not yet been assembled, and probably not very effective.

Operation Chikorokoza Chapera shut down virtually all mining and milling operations in the project area from January through May 2007 when a few operations had managed to obtain the requisite environmental permits. In early June, the IMR reported that its foreign currency assets that were earmarked for TDU equipment and training expenses had been frozen by the Zimbabwe government in an investigation of illegal currency trading by an officer of the IMR’s bank. About half of the IMR’s assets were released in early July, enabling testing of the Chinese vinyl loop carpets in late July and August, and the training of 154 additional miners (as in 2006, these trainings were lecture-style).

In June and July of 2007, members of the ZPA who had attended the Kadoma training of trainers workshop in 2006 carried out a national outreach program to raise awareness about the dangers of mercury. These miners demonstrated how retorts make mercury use safer and introduced vinyl loop carpets\(^\text{17}\) as a substitute for copper plate amalgamation. The ZPA showed these technologies to over 1000 people at 27

\(^{17}\) The vinyl loops act as mini-riffles, trapping the heavy minerals and gold. Carpets are easily washed by immersing in water tubs made from 200 L steel fuel drums which are cut lengthwise.
mill sites and one school. During this campaign, the ZPA reported that the signs and symptoms of mercury poisoning were common amongst miners in many communities throughout Zimbabwe. At one site, the ZPA observed that “children were engaged in gold mining activities. The situation was bad, most of these children are aged between 8 to 12 years. However, they seemed very bright as it was easy for them to catch up on the use of retorts.” The ZPA reported that most miners were unaware that mercury is a poisonous substance and that they were surprised to see so much mercury recovered in retorts. In another workshop the following October, the ZPA trained 23 of its regional members to teach mercury awareness and improved gold recovery methods throughout the country’s gold mining districts (Evans Ruzvidzo, 2007—President, Zimbabwe Panners Association, pers. comm.).

The ZPA’s national outreach and training initiatives, costing only USD 20,000, were perhaps the most effective of all of the GMP activities in Zimbabwe. Not only were a large number of miners introduced to new mineral processing options, but the ZPA was able to strengthen itself as an institution by conducting these workshops throughout the country.

5.2.3 GMP Awareness Campaign

Mercury has been used in ASM in Zimbabwe for over 100 years (Phimister, 1975), and most miners do not believe its use leads to negative health or environmental consequences. Awareness building and offering acceptable solutions are therefore are the first steps toward safer practices. The GMP awareness program in Zimbabwe was based on the community play “Nakai” or “Precious Little Thing”, the story of a farmer’s daughter exposed to mercury by her artisanal miner boyfriend.
A cartoon book following the story line of “Nakai” was designed, and selected cartoons were to be used by the IMR for handbills, posters and billboards. Unfortunately, the IMR did not meet its obligation to print cartoons and posters, or place billboards along the main mining roads leading to Kadoma. Communication of mercury hazards was limited to “Nakai” which reached about 8,800 people, and which played in 15 mining communities in the project area.

5.2.4 Policy initiatives to promote safer use of mercury

Resistance to the adoption of more efficient gold recovery technologies in Zimbabwe is strong. Government metallurgists believe that mercury contamination is relatively unimportant and are focusing their limited resources on maximizing government revenue streams from the diamond and platinum industries. Nevertheless, the GMP worked with the Zimbabwe Ministry of Mines to develop appropriate policies for mercury use in ASM gold mining at milling centers and other processing sites near towns and villages. Following national stakeholder consultations in November 2006, mercury management recommendations were drafted and submitted to government, advocating a ban of whole ore amalgamation, responsibility for mercury use at milling centers, use of retorts, and regulation of mercury trade. These recommendations were promoted in meetings with the Ministry of Mines and mining associations such as the ZPA and the Zimbabwe Mining Federation (Spiegel, 2006, Metcalf and Spiegel, 2007). To date, the government has adopted none of the GMP recommendations.
Due to the current economic crisis in Zimbabwe, gold mining has grown in importance as a means of survival. As the mining sector has grown, so too has gold smuggling and illegal mining, as well as mercury use and other environmentally destructive practices. The GMP found that these problems were mainly due to the inappropriately low official gold prices paid to the miners. Responding to advocacies advanced by the GMP and other stakeholders, the Reserve Bank of Zimbabwe established a review committee to ensure that gold prices are regularly evaluated and adjusted to reflect inflation. On October 1, 2007, for example, the official purchase rate was increased from Z$ 3,000,000 to Z$ 5,000,000/g of gold, which was equivalent to about USD 520 an ounce at the parallel exchange rate of $Z 300,000/USD\(^{18}\). This has significantly reduced the illegal trade of gold, and provided a more viable economic basis for gold mining.

5.2.5 Mineral processing tests

The Zimbabwean government has been hesitant to support a ban of whole ore amalgamation. In an effort to address this reluctance, the GMP partnered with the Ministry of Mines, providing special funding to the Institute for Mining Research (IMR) to determine if low-cost vinyl loop carpets are more efficient than copper plates, and to establish the optimum amount of cyanide necessary to recover as much gold as possible while minimizing the dissolution of mercury in amalgamation tailings. While these tests were never fully completed by the IMR, preliminary results confirmed the relative efficiency of the vinyl loop carpets. According the Ministry of Mines, a statutory

\(^{18}\) The international price on October 1, 2007 was USD 755 per ounce (Kitco.com, 2008)
instrument banning whole ore amalgamation will eventually be promulgated, following further testing of the carpets by the Ministry of Mines' metallurgists (Valentine Vera, 2007—Chief Metallurgist, Zimbabwe Ministry of Mines, pers. comm.).

Low-cost Chinese manufactured vinyl loop carpets were tested on 8 batches of ore (7 batches at Imperani Milling Center, and 1 at Chimukute Milling Center). Batch sizes ranged from 0.6 tonnes to 21 tonnes. Ore types included rubble/gravel, quartz and schist. Tests were conducted on a 1 x 2 meter sluice using a vinyl loop carpet trapping mechanism with an effective length of 1.8 meters, followed by a Knudsen bowl centrifuge scavenger. The slope of the sluice was approximately 1:10. The results showed that between 5.1% and 68.7% of the gold in the ore accumulated in the stamp mill's mortar box, which acts like a jig concentrator. The mortar box recovered about 30% of the gold in the ore. The carpet sluice was not optimized, but it nevertheless captured between 9.8% and 40.9% of the gold (average recovery from the carpet was about 25% of the gold in the ore, or about 9 times the gold recovered in the centrifuge). About 40% of the gold passed to tailings. Of the gold that was lost to tailings, over half was in the >250µm size fraction, most likely unliberated gold (Masiya and Chigwida, 2007). The authors did not run any tests of copper amalgamation plates in place of vinyl loop carpeted sluices, but since it is believed that the combined recovery of copper plates and mortar box ranges between 30% and 50%, Masiya and Chigwida’s (2007) 55% average combined recovery of vinyl loop carpets and mortar box suggests that the carpets are indeed more efficient than copper amalgamation plates. Factors influencing the relative efficiency of vinyl loop carpets and copper
amalgamation plates in Kadoma-Chakari include the length of the sluice, the 
coarseness of the gold, and sulfide fouling of mercury coatings on the copper plates.

Fidelity Printers and Refiners is conducting additional tests of the vinyl loop 
carpets at its Odzi milling center in Mutare where it has found that miners prefer the 
carpets to centrifuges. Once recovery results are compiled, Fidelity promises to 
advocate that government purchase large quantities of these carpets for distribution to 
the nation’s milling centers. While acceptance of the carpets by the miners is likely, 
millers will resist any changes that reduce the gold in their cyanidation circuits, and it 
is likely that carpeted sluices longer than 1.5 to 2 meters will be more efficient than 
copper plates or centrifuges.

In a review of the behavior of mercury in carbon in leach and carbon in pulp 
processing, Menne (1998) suggested that concentrations of cyanide from 0.1% to 
0.2% (1 to 2 g/L) maximize gold recovery while minimizing mercury (HgS not Hg⁰) 
dissolution. Testing the hypothesis that there may be an optimum concentration of 
cyanide that minimizes Hg⁰ dissolution, Dhliwayo (2007) determined that after 5 days 
of leaching with high Hg⁰ concentrations (48 mg/kg, 0.15% CN), gold recovery in 
amalgamation tailings was almost 20% less than when tailings contain no mercury 
Dhliwayo (2007) did not report the gold grade of the ores tested. While Dhliwayo 
(2007) was able to show that dissolution of gold proceeds optimally when CN 
concentration is between 0.1 to 0.15%, he was not able to determine the effect of 
cyanide concentration on mercury dissolution rates due to a lack of capacity to 
analyze mercury. Dhliwayo’s (2007) findings suggest that the typical cyanide 
concentration at custom milling centers of between 0.2 to 0.5 % unnecessarily
increases costs and possibly mercury dissolution (Givemore Sakuhuni, 2007—Zimbabwe National University of Science and Technology, pers. comm.).

5.3 Results of the GMP interventions

Even though the GMP faced significant challenges in Zimbabwe, some of the barriers miners face to the adoption of cleaner technologies were lowered. Wherever they were introduced, vinyl loop carpets were accepted as a viable substitute for whole ore amalgamation. It is hoped that the availability of the carpets will be addressed soon by Fidelity Printers and Refiners, an arm of the Zimbabwean government which has the ability to facilitate importation. Awareness of mercury hazards and more productive gold concentrating methods increased in Kadoma-Chakari, largely due to the message-focused theatrical play “Nakai” which was seen by about 8,800 miners and community members.

On the other hand, the IMR (subcontracted by the GMP) never fully assembled the TDU, and the training program did not take place as hoped in mining communities. TDU trainings took a lecture approach rather than a hands-on teaching. No posters, brochures or billboards were produced and distributed. The testing of carpets and optimum cyanide concentrations was never completed. All of this was very discouraging, indeed.

Perhaps the greatest legacy of the GMP is the strengthened Zimbabwe Panners Association. The ZPA now has a network of over 30 ASM trainers who live throughout the country’s gold mining districts. These individuals are committed to improving the health and livelihood of small-scale miners. If this new capacity is to
ever bear fruit, however, continued commitment and support on the part of the
Zimbabwe government and donors is essential.
6 THE USE OF THEATRE TO PROMOTE ASGM DEVELOPMENT IN AFRICA

6.1 Introduction

Theater has been used as an informal learning tool in Africa since the beginning of the colonial era when mission schools mounted plays to inculcate European values amongst indigenous students. Since about 1930, didactic plays have been used in Africa to promote a range of development objectives. Didactic theatre’s ability to stimulate participation and sustainability of programs has evolved considerably over the past 80 years. The potential of “theatre for development” or “TfD,” as didactic theatre is now often called, lies in its ability to give communities a chance to voice concerns that normally remain unspoken, concerns that come to the surface only after trust is established (when properly facilitated, theatre is a trust building process). Unfortunately many development programs still do not allow project beneficiaries identify what they consider their most pressing needs, and projects are weakened by not building upon local knowledge and singing, dancing, and story telling skills (Boeren, 1989, and Kidd, 1994).

Awareness of Zimbabwe’s “Pungwe,” (popular all-night singing, dancing and theatre parties that took place during Zimbabwe’s war of liberation in the 1970s, in which guerilla cadres would teach communities about the objectives of the independence struggle) would have helped GMP planners to better use local theatre and community development strengths to support its communication and awareness efforts (Kidd, 1984b; Chifunyise, 1990; Mlama, 1991).
Not surprisingly, agencies funding development programs seek measurable indicators that their messages have been delivered to their target audiences. In the hope of capturing large audiences, donors tend to support relatively ineffective theatre-based awareness programs in which the message, like a hard to swallow pill, is made palatable with a sugar coating of entertainment. Donors believe their activities should be politically neutral in order to engage the support of host governments and powerful local stakeholders, and are leery of opening up community discussions because doing so can easily lead to challenges of the political status quo (Ross Kidd, 2008—University of Botswana, per comm.; David Kerr, 2008—University of Botswana, pers. comm.). Experience has shown, however, that pre-determination of message content by funding agencies can lead to the suppression of community level discussions that can reveal the key structures that impede change (Okoth et al., 1998).

This chapter reviews the evolution of TfD in Africa in the context of indigenous and colonial theatre practice. The continued widespread practice of traditional dramas for ritual and community entertainment purposes has given Africans a sense that storytelling, singing and dancing are part of everyday life. Traditional indigenous drama contained normative messages much like those found in didactic “development” plays. Traditional indigenous theatre responded to colonial presence with a satirical voice that expressed objections to European oppression and led to a diversity of popular neo-traditional theatrical forms that delivered social and political messages, typically performed by low-budget traveling theatres and presented in local languages.
In the 1970s and 1980s, African and expatriate adult educators and theatre experts explored the potential of neo-traditional drama to generate community ownership and enthusiasm for a range of development goals such as improved water and sanitation, and literacy. During the 1990s, TfD programs began shifting from a focus on class struggle to awareness of health issues, especially of HIV/AIDS prevention as health workers realized that participatory drama engaged at-risk populations more effectively than dissemination of “expert knowledge” (Okoth et al., 1998, Settergren et al., 1999, Johannson, 2006).

This chapter also summarizes the process of production of the GMP play, “Nakai”, and discusses its accomplishments and limitations. Concluding remarks examine the future of TfD as a tool for development programs which are funded to accomplish pre-determined sets of objectives, and suggests ways to use TfD most effectively.

6.2 History of theatre in Africa

6.2.1 Theatre in pre-colonial Africa

During the pre-colonial era (which ended during the 19th Century), mimetic representations of hunting, epic re-enactments of historical events, and short satiric sketches were performed by special groups or societies who represented various aspects of tribal social organization. Performances often focused on negotiating life’s important passages—birth, puberty, marriage and death. Traditional “theatre” contained both ritual and entertainment features, and was either performed at fixed locations or moved through the village. Spectators would join in the songs, offer on-
going comments, or enter the theatrical space to reward favored performers. Tragedy, which implies a sorrowful sense of human destiny and which was perceived as having the ability to bring ruin to the actors, was not a subject of traditional drama (Graham-White, 1970 and 1974; Brink, 1982).

Many African rituals expressed the need of hunters and farmers to repeat past successes in order to survive. Dramatic enactments of seasonal and human cycles gave traditional peoples a sense that they had some measure of control over the outcome of their daily efforts. Few traditional African societies made a distinction between ritual (which tends to be functional and promise future results) and drama (which infers no expectation beyond the performance itself), because both forms used dramatic elements such as impersonation, dialogue, conflict and plot, and carried participants into worlds that operated on logic quite apart from daily experience (Graham-White, 1970).

Some researchers believe that traditional theatre evolved from ritual when aesthetic interest began to dominate function. Changing circumstances, such as the diminishing risk of contracting smallpox after the early epidemics, allowed spectators to focus attention on the way that a ritual was performed rather than on its original purpose. This aesthetic distance allowed the incorporation of entertainment in the evolving rituals, while retaining ritualistic elements such as masks, singing and dancing (Graham-White, 1970 and 1974).
6.2.2 Theatre in Colonial Africa

Early colonists understood that indigenous power and values were embodied in traditional theatre which supported communal economic structures that impeded “progress” toward modern economic structures (such as the creation of a large labor force to develop the land appropriated by European farmers and miners). Suppression of traditional culture was seen as key to controlling the new African colonies, while the notion of African cultural inferiority served as a justification for the slave trade and for exploitative commodity exchange. For example, Christian missionaries abhorred what they believed were indecent and provocative traditional dances which they condemned as “sexual” in order to mask their underlying colonial intentions. Such suppression sometimes met with clever resistance, as for example when the highly sensual Mbende dance was banned in Zimbabwe in 1910, chiefs gave it superficial Christian connotations, renaming it the “Jerusarema” and petitioning for permission to keep practicing the dance (Graham-White, 1974; Welsh-Asante, 1985; Kerr, 1995).

Indigenous theatre reacted to colonialism by developing forms of satirical theatre in the early 20th century that expressed their outrage with the Europeans and fueled nationalist independence movements. During wars of liberation, freedom fighters used traditional song and dance to lift their spirits and explain their governance agendas to illiterate rural populations. Post-colonial governments used traditional theatre as way to reverse the effects of decades of white supremacist culture (Chifunyise, 1990; Kaarsholm, 1990; Kerr, 1995).
6.2.3 Colonial literary theatre

For colonial settlers, European literary (i.e., written or scripted) theatre was an entertaining diversion from the hardships of settler life and a link to cultural and economic home bases in Europe. Theatre attendance supported the colonists’ self-image of superiority and entitlement, and was a means by which the diverse classes of settlers (from middle class administrators to peasant farmers) could collectively define themselves in distinction to their African neighbors. This emergent sense of colonial identity provided the ideological basis for programs of racial exclusion (Kerr, 1995).

Productions of European plays ranged from trivial contemporary comedies to the classical canon (e.g., Shakespeare and Molière) and were extremely popular among white populations. For example, there were some 15 professional theatre companies touring Southern Rhodesia in 1910 (Kerr, 1995). Where colonial populations were large, only whites were allowed to attend or act in theater clubs. Under these circumstances, neo-traditional African genres emerged, such as Concert Party in Ghana and Yoruba Opera in Nigeria. On the other hand, elite Africans were encouraged to participate in European theatre activities in regions where there were relatively few colonists, such as in French West Africa. After independence (most African states achieved independence during the late 1950s and early 1960s), many African governments began to support companies of traditional dancers and literary actors, while continuing to support colonial-style white theatre (Etherton, 1975; Chifunyize, 1990; Kerr, 1995).
6.2.4 Colonial film and radio

As early as the 1930s in British colonial Africa, educational films were shown from projection vans that traveled the countryside, introducing agricultural, health and political messages to illiterate populations. Live “interpreters” animated the screenings of these silent development films in local languages, sometimes satirically twisting the intended meaning of the messages. Early extension workers found that films were significantly more popular than one-dimensional didactic plays. During World War II, Britain increased the use of mobile projection vans to ensure that war propaganda messages reached its colonial subjects. In mid-century, Western movie producers found Africa to be an inspiration for films that depicted the white man bringing civilization to the “savages,” justifying the colonial presence to European and American audiences. As in the world’s other colonial regions, Africa became a marketplace for trivial, B-grade Hollywood and European films (not surprisingly, censors filtered out films that showed white men and women behaving immorally) (Kerr, 1995).

Radio broadcasting systems modeled after the British Broadcasting Corporation and the Société Radiophonique de la France were established in the 1930s as colonial administration instruments aimed at native populations. Like colonial literary theatre and film, radio also served to unify settler communities and link them to their homelands by providing entertainment and news. When television broadcasts began in post-colonial Africa (the 1960’s and 1970s), most programming consisted of trivial European and American shows that had little to do with African life (Eyoh, 1987; Kerr, 1995). Post independence programming in Zimbabwe demonstrates how
television is an excellent medium for the transmission of top down information (Epskamp and Swart, 1991).

6.2.5 Colonial neo-traditional theatre

In the early 20th Century, a diversity of theatrical forms emerged that combined pre-colonial traditional indigenous dramatic practice with parodies of European culture (such as coronation festivals and military parades) and the missionary dramas used to make Christian stories appealing to potential converts. The antagonistic ethnic alien roles that personified a sick person’s suffering during traditional spirit possession dances expanded to include a number of European stereotypes such as white shopkeepers, farmers and priests. Satirical representation of colonists became a core element in many local festivals. Christian missionaries with their unique clothing and religious language and paraphernalia were commonly satirized, as were white explorers, soldiers, and extension officers. A favorite dramatic character in Rhodesia was a whip-cracking police sergeant whose exaggerated height (on stilts) and whip represented the cruelty of white colonialism—fortunately his exaggerated height prevented him from beating audiences who simply sat down and ridiculed him. Such satirical mimesis became a powerful form of resistance to colonial rule. In the 1920s, for example, a colonial administrator facing resistance to the establishment of mission schools in Nyasaland (now called Malawi) tried to stop satirical impersonations of

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Satire is a strategy used all over the world to indirectly denounce abusive behavior by making a person look ridiculous. To many indigenous Africans, the introduction of colonial capitalism was a direct threat to traditional communal values and structures. Mounting dramas that mocked religious dress and iconography empowered Africans by giving voice to their understanding of the underlying exploitive nature of colonial culture.
white people by banning all impersonations in traditional performances--only animal figures were allowed to perform (Kerr, 1995).

Satirical protest songs such as “Paiva,” a call-and-response work song about the brutal managers of a cotton plantation in southern Mozambique, expressed indignation and rage at the work conditions on the Zambezi River delta (Vail and White, 1978a; Kerr, 1995). Portugal, like other European colonial powers in the mid 20th Century, was attempting to achieve self-sufficiency in agricultural commodities such as cotton, but climatic conditions on the Zambezi delta were too wet for cotton production, so the Paiva plantation could only make a profit by relying on forced labor. One version of “Paiva” mocks the Paiva overseer, Makwiri who was famous for locking children in boxes in order to force their mothers to work harder, and for his brutal sexual assaults: “Makwiri !! Makwiri !! Makwiri !! Can I pick my child up? Can I pull my knickers down!” (Vail and White, 1978b).

6.2.6 West African travelling theatre

In traditional Ghana, stories of the trickster spider “Ananse” were told by a narrator and a group of drummers and mime artists. By the 1920s, this story-telling form had merged with the festivities associated with the British Empire Day celebrations and end-of-school-year concerts. These “Concert Party” performances were entrepreneurial events, designed at first to appeal to the new conservative African elites who were enjoying the urban “highlife scene.” Snobbish Concert Party programs at cinemas and dancehalls combined silent films, vaudeville and comedy

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20 Portugal’s Salazar government permitted forced labor in Mozambique but this was eventually deemed illegal by the ILO in 1961.
routines with orchestral dance music such as foxtrot, ragtime, rumba and highlife (Collins, 1976b; Collins, 1977). Concert party plays contained a set of stock stereotypes: faithful wives, gullible husbands, gold-digging younger women, poor farmers, corrupt police, prostitutes, fast-talking conmen and so on. These cliché characters gave the actors freedom to improvise the storyline while focusing on maximizing their rapport with the audience. Realistic theatrical illusion was less important than connecting with audiences who were encouraged to engage the actors during the performances (Kerr, 1995).

The content of early Concert Party was relatively conservative (celebrating, for example in 1930, the coronation of British King George VI). Lacking sufficient audiences in the urban centers, Concert Party ensembles toured rural towns in vans, attracting audiences with bell ringers, clowns and drums. Growing audiences led to a popularization of content. As the snob appeal of concert party waned, new themes focused on social and class conflict due to urban migration, emancipation of women, and conflict over land inheritance arising from cash cropping. By 1950, plays included topics like the imprisonment of Kwame Nkrumah by the British (“Nkrumah is a Mighty Man” and “Nkrumah is Greater than Before”). Concert Party performances were very popular, and in the 1970s, some fifty concert party groups were performing throughout Ghana (Collins, 1976a; Kerr, 1995).

Like Concert Party, Nigerian Yoruba Opera evolved from regional pre-colonial theatre and traveled the hinterlands in search of paying audiences. Yoruba Opera blended traditional “egungun” (Yoruba masked funerary dances) with the cantatas introduced by European missionaries. Responding to the racism that increased with
the introduction of formal colonial rule in Nigeria in the 1890s, secessionist millenialist churches staged “Native Air Operas” replacing the traditional theatre-in-the-round format with a shallow picture frame (proscenium) stage in which a singing cast swayed continuously from side to side. By the 1940s, religious themes were animated by more movement on stage and more realistic dialogue. After World War II, stories began to reflect the conflicts between Christian ideology and the growing nationalistic sentiments amongst the elite. Audiences included the urban elite and working classes who were at the center of resistance to colonial rule. Simple religious stories (e.g. “Garden of Eden,” “Israel in Egypt”) were replaced with anti-colonial plays (e.g., “Human Parasites” and “Strike and Hunger”). Up to 100 Yoruba theatre companies adopted Concert Party’s improvisational scripting and Vaudeville approach, traveling the country during the relatively wealthy oil boom era from 1960 to 1985 (Kerr, 1995; Cole 1997; Barber, 2000).

Neo-traditional Yoruba theatre continues today, albeit with significantly reduced audiences. Contemporary neo-traditional Yoruba theatre consists mostly of epic portrayals of the deeds of Òrishà gods, metaphorically addressing the tensions between Nigeria’s classes and religions. In the current Nigerian economic crisis, low budget video production has eclipsed live theatre--story lines of English language videos feature glamorous elites involved in marital scandals and born-again Christians fighting a corrupt world. Yoruba language videos feature middle class professionals facing marital problems, the urban criminal underworld, and popular music and dancing (Barber, 2000; Müller, 2005).
6.2.7 East African Military Mimes

In early 20th Century East Africa, elaborate militaristic mimes parodied the precision marching and brass bands of colonial parades. Like West African traveling theatre, militaristic mimes functioned as a link between the traditional and modern worlds, and provided (especially for rural people) an opportunity to integrate and process experience of the modern world gained during labor migrations and school attendance. Militaristic mimes gave participants the opportunity to demonstrate their modernity, status and power by demonstrating familiarity and comfort with aspects of colonial rule, while their independence from colonial bureaucratic structures fostered proto-nationalist consciousness. Indeed, many missionaries and colonial authorities viewed militaristic mimes as a threat. To them, indigenous dance should take the traditional “ngoma” form (dancing in circles, dressed in animal skins and bark), not militaristic parades (precision military formations with loud horns and marching drums). Like other pre-independence theatre forms, military mimes became increasingly political after World War II. In the 1960s for example, precision military mime performances in Zambia included songs supporting Kenneth Kaunda’s United National Independence Party (Kerr, 1995).

6.3 Theatre for Development

6.3.1 The “Development Era”

In the mid 20th Century, the production of cash crops for export (tea, cocoa, cotton and tobacco) in developing countries promised immense economic opportunities for the world’s colonial powers. Because the shift from subsistence
farming to cash crop production for export implied increased dependence on the colonial system, the new farming methods were not welcomed by many indigenous farmers (Vail and White 1978b; Nogueira, 2002). Beginning in the 1930s, extension workers attempted to make new agricultural techniques attractive and understandable to illiterate native populations. The effectiveness of lectures, written materials and demonstration classes was limited in these early awareness campaigns, so colonial agricultural agencies experimented with improvised dramas in local languages, emphasizing the benefits of changing to the new practices. The incorporation of traditional song and dance in these early didactic dramas reflected the didactic sensibility of pre-colonial drama, and masked the social changes implied in the embedded messages. Development workers now condemn this kind of appropriation of indigenous culture to convince audiences to accept technical, economic, or social changes that are not in their best interest (Kerr, 1995).

After World War II, newly independent former colonies were designated as “underdeveloped countries” in need of improvements in standard of living that could best be achieved by adopting a range of “first world” practices. The “green revolution” in agriculture, for example, required industrial inputs (technology, mechanization and chemicals) to support cash crop production for export. Many now contend however that “development” has disproportionately benefited Westerners while contributing to the third world’s economic, social and environmental demise (Nogueira, 2002). In the post war milieu, the practice of using didactic dramas in the service of development came to be called “Theatre for Development” (Epskamp and Swart, 1991). Since then a large number of terms have been used to reflect various ideological and functional

6.3.2 Evolution of modern TfD

TfD is no longer the crude propaganda tool of the 1930s. During the 1960s, university drama programs began to make literary theatre available to the working and peasant classes through traveling extension programs. At the same time, extension workers began realizing that awareness programs that were designed in participation with the project beneficiaries were much more successful than those formulated by technocrats far removed from the affected communities (Mda, 1993; Boeren, 1992; Nogueira 2002).

After independence, many African governments continued to use the colonial theatre-as-propaganda model, and did not include “beneficiaries” in goal setting or ongoing management of development programs. These didactic theatre programs supported health, agricultural and birth control programs, especially in remote areas beyond the reach of mass media. Extension media such as posters, instruction booklets, chalkboard lectures and demonstrations focused on the already educated, not the whole community. Some development workers concluded that this kind of awareness approach led to apathy on the part of project beneficiaries, so they began
looking for bottom-up alternatives that might foster the development of critical awareness (Kidd and Byram, 1982; Kerr, 1995)

In 1973, Ross Kidd (an expatriate Canadian educator in Botswana) was inspired by the use of theatre to examine the relocation of the Newfoundland town of Sally’s Cove by Parks Canada, and began experimenting with community theatre in Botswana (Filewood, 1989). In 1974, Kidd conducted a community theatre workshop in Northern Botswana, refining the approach through subsequent workshops in the late 1970s (Kidd and Byram, 1982). By the 1980s, it became evident that the most effective TfD programs are those that sustain relationships with communities over longer periods, and which encourage spectator participation and analysis (Kidd 1984; Mda, 1990).

The Botswana experiments drew on theoretical work of Paulo Freire in annual activist “Laedza Batanani” workshops (“the sun is up, let us go and work together”): dialogue between extension agents and project beneficiaries should be two-way rather than top down. Theatre activities were designed to be “popular” in as much as they would target the entire community, not just the educated, and would be presented in the local language. The entertainment aspect of theatre, it was hoped, would stimulate community cooperation (Kidd and Byram, 1982). At roughly the same time, two Kenyan theatre and adult education academics facilitated a community theatre process in Kamiriithu near Nairobi that led to the production of the celebrated play, “I will marry when I want,” that was quickly banned by the Kenyan Government which was threatened by the level of empowerment the villagers had achieved in the story generating process (Kidd, 1983). A series of international workshops in Zambia,
Malawi, Zimbabwe and Cameroon refined the Laedza Batanani approach (Kidd and Byram, 1982; Mlama, 1991; Kerr, 1995).

6.3.3 Botswana: Laedza Batanani workshops

The Laedza Batanani workshops began with a community process of listing the knowledge, misbeliefs and attitudes that limit development, determining which constraints could be successfully reduced or eliminated, and establishing which current community practices should be strengthened. This “constraint analysis” was then formulated into a drama (Eyoh, 1984; Mda, 1990). Early Laedza Batanani campaigns (in 1974, 1975 and 1976) focused on sanitation, vegetable growing, contraceptives and sexually transmitted diseases, youth unemployment, tuberculosis, domestic conflict and cattle theft. The didactic plots and the use of stereotypical characters reflected local traditional and neo-traditional theatre practice. Unfortunately, the communities’ most powerful stakeholders dominated the constraint analysis discussions, so not surprisingly, their interests were reflected in the annual choice of themes (Kidd and Byram, 1982).

The Laedza Batanani model was summarized at a workshop in Molepolone, Botswana in 1978:

- Participants are extension workers and professional actors
- Workshops run for about 2 weeks in total, and only about 1 week is spent with a given beneficiary community
- The workshop leaders first give an introduction to popular theater to participating extension workers and actors
• After working intensively to develop their dramatic skills (acting, dance, song or puppetry), participants gather information and perform a “constraint analysis” in the villages where they prepare and rehearse the performance for several days.

• After the performance, the animators evaluate the process and develop a follow up program. Typically, however, little follow up occurs (Kerr, 1995).

6.3.4 Zambia: Chalimbana workshop

In 1979, Zambian TfD practitioners opened the International Theatre Institute (ITI) in Lusaka, and subsequently coordinated a two-week workshop based on the Laedza Batanani model at Chalimbana, Zambia, bringing in experts from Botswana, Tanzania, Lesotho, Canada and the USA. Because the international workshop participants could not speak the local language, a dance-play without dialogue was produced. The play told the story of a man who, having drunk contaminated water, fell sick but was not helped by a traditional healer. He therefore decided to go to the district hospital where he was cured. In the end, the villagers dug a clean well and celebrated. The play incorporated popular traditional music with African Highlife and Afro-rock. Chalimbana participants (most of whom were performing artists) felt that professional quality performances were necessary to hold the attention of audiences who were accustomed to the skilled performers of traditional and neo-traditional theatre (Kerr, 1995).

6.3.5 Swaziland, Malawi, Lesotho and Sierra Leone workshops

In 1981, some of the Chalimbana workshop’s international experts organized a TfD workshop for community health workers in Swaziland, and the Traveling Theatre
of the University of Malawi held a two-week workshop at Mbalachanda, Malawi. In 1982, the Ford Foundation funded a TfD program at the University of Lesotho, and Sierra Leone experimented with the Laedza Batanani model in 1983, producing plays that ran in conjunction with local dances, film and sport events (Malamah-Thomas, 1987a and 1987b).

6.3.6 Nigerian workshops

The “ABU Collective,” a TfD group based at the Ahmadu Bello University in Northern Nigeria, held workshops in 1977 (Soba) and 1979 (Maska), following the two-week Laedza Batanani approach. ABU members included a number of young Africans and two expatriate lecturers (Irish play-write Michael Etherton, and Brian Crow who is currently head of the Theatre Department at the University of Birmingham). In 1980, the ABU group held a workshop at Boma, Nigeria, that applied a “theatre as discourse” approach in which the public rehearsals essentially became the “performance” itself. At Boma, farmers developed scenes in which they played the roles of themselves responding to expropriation of their lands. In 1982, ABU organized a national workshop at Makurdi, Nigeria for actors and extension workers which followed the Laedza Batanani methodology, but which also experimented with presenting various unfinished scenarios to communities for discussion and revision. At the end of the workshop, these “unfinished plays” were presented as part of a large local neo-traditional theatre event, the Kwagh-hir performances.
6.4 TFD workshop approach critiqued

By the 1980s, development workers had began to object that the two-week long Laedza Batanani workshop model was far too short to generate any meaningful relationship with communities, that follow up was minimal, and that communities were being used as guinea pigs to test TFD ideas. Kidd and Byram (1982) critiqued their own Laedza Batanani work, suggesting that even limited community participation can cover up underlying processes and ensure that communities accept the status quo by subordinating their interests to those of government and powerful stakeholders. Laedza Batanani type TFD, they argued, is not popular theatre because it is controlled by privileged stakeholders and community members whose position is strengthened by participation of NGOs and government officials who commonly attend the openings of workshops. For Kidd and Byram (1982), jargon such as “participatory” “bottom-up” and “liberation” belies the paternalistic control implicit in government involvement, which inhibits mobilization for social and economic change (Kerr, 1995; Michener, 1998).

Others argued that the length of time that workshops were involved with communities was far too short to transfer the acting and organizational skills needed to ensure the viability of community based theatre programs (Etherton, 1982). The Oxfam funded “Theatre for Social Development” program based in Malya, Tanzania (southeast of Mwanza) extended over 18 months during 1982 and 1983, and achieved more sustained community participation due to five relatively long visits by the animator team from the University of Dar es Salaam (Mlama, 1991; Kerr 1995).
While the complexity of traditional and neo-traditional dramatic characters allowed for ambiguity and depth, Laedza Batanani’s stereotypical characters (e.g., the drunk miner, the superstitious patient, etc.) were often one-dimensional and unconvincing. This lack of depth oversimplified the distinction between “good” and “bad,” and tended to scapegoat the poor. Furthermore, because issue-oriented problem-solving campaigns concern themselves with achieving quantifiable results, they tend not look at the underlying social and economic structures that maintain the status quo (Kerr, 1995).

6.4.1 Refining the Laedza Batanani Model

In 1983, the ITI and UNESCO organized a month-long workshop for 100 international participants to explore the ABU approach in Murewa, Zimbabwe (Mlama, 1991). Having recently experienced activist Pungwe theatre during the anti-colonial war of the 1970s, communities energetically participated in developing the workshop’s scripts and performing in the plays. Experience in Murewa confirmed the effectiveness of drawing communities into the development of scripts and acting in the plays. In 1984, the ITI and UNESCO sponsored a second international workshop in Cameroon, which experimented with the ABU Collective’s open-rehearsal and unfinished scenario techniques (Eyoh, 1985; Kerr, 1995).

In 1985 in Malawi, the University Theatre Department and a local rural primary health care unit developed a form of “community diagnosis” which involved repeated performances, follow up visits and evaluations. The frequent visits led to a relationship of trust with the audience, strengthening the dialogue and analysis. Influenced by the
ABU Collective’s open-rehearsal and unfinished scenario approach, audiences were incorporated into the plays through placing dilemmas at “cut off points” in the script where the actors opened up discussion with the audience (Kerr, 1989 and 2002).

Kerr (1995) emphasized that analysis of needs must occur within and by the beneficiary community by citing Freire (1973 in Kerr, 1995): “I cannot think for others… Even if people’s thinking is superstitious or naive, it is only as they rethink their assumptions in actions that they can change.” Kerr further argues that theatre programs linked to government or official institutions, especially when these institutions are connected to international aid organizations, are necessarily limited in their ability to promote awareness of any underlying economic (class) constraints.

6.4.2 Performance bartering

A strategy of “bartering” songs, dance and plays from the developed world in exchange for local cultural expressions was explored by Eugenio Barba’s *Odin Teatret* (Denmark) in communities in Europe, South America and Asia, beginning in 1974. Barba’s approach recognized that people are typically more open when watching theatrical performances, especially when the performers “act naturally” and do not try to assimilate with the audience. In 1982, Mette Bovin took one of Odin’s performers to Niger in an attempt to strengthen her anthropological research by provoking the sharing of local cultural practices (Bovin, 1988).

Performance bartering resembles traditions of performance exchange in Africa and Asia, and is currently used as means of promoting horizontal rather than top-down development communication and of stimulating community discussion in South Africa
and Bangladesh. In performance bartering, both development workers and “project beneficiaries” open the door to communication by entertaining and teaching each other. Because the power differential between donors and beneficiaries cannot easily be leveled, great care must be taken to ensure that “beneficiaries” are not simply seduced by the entertainment into compliance with the donor’s objectives (David Kerr, 2008—University of Botswana, pers. comm.).

6.5 Global Mercury Project theatre program in Kadoma-Chakari

As discussed above, “theatre for development” (TfD) has been used in Africa to communicate development information since the 1930s. Today, TfD is commonly used to create awareness about health issues, especially about HIV/AIDS and malaria (e.g., Settergren et al, 1999; Panford et al., 2001; Bagamoyo College et al, 2002; Ghosh et al 2006; Johansson, 2006).

In 2006, The GMP contracted the Amakhosi Theater group to generate a script containing the GMP’s core messages in order to build awareness that mercury makes people sick. Amakhosi has produced TfD in Zimbabwe for almost 30 years, focusing on safe use of agro-chemicals, HIV/AIDS, and on the need for post abortion care. Importantly, Amakhosi has credibility with ASGM communities because it produces the popular, award-winning weekly television drama, “Amakorokosa,” (or “gold panner”) which contrasts the lives of poor gold panners with the lives of wealthy small-scale mine owners. During 2005 and 2006, Amakhosi held a series of workshops with the ZPA and the Kadoma-based Tamuka Theater Company to generate an entertaining script carrying the messages that mercury slowly and progressively
makes people sick, women and children are especially vulnerable, retorts should be used, and better concentrating methods are possible.

From these discussions, the play “Nakai” emerged whose plot follows the blossoming love of two young people, Nakai and her miner boyfriend Aringo. Much like in Shakespeare’s “Romeo and Juliet,” the two lovers come from families with a history of animosity: Nakai’s father is a farmer whose land has been invaded by gold panners, and Aringo’s father is a successful artisanal gold miner. In the course of the story, Aringo develops symptoms of mercury intoxication (irrational behavior and impotence) and Nakai has complications with her pregnancy. In the end, the feuding families find common ground in their love of their children, and resolve to support safer mercury use and better management of mining waste. The play’s Shona title, “Nakai,” means “precious little thing” and refers equally to the gold amalgam that artisanal miners recover and burn, and to the wife and unborn child of the artisanal miner who are intoxicated by exposure to mercury vapor (Appendix 5).

Eventually in 2007, fifteen performances of “Nakai” took place throughout the Kadoma-Chakari region, reaching 8,800 people. Before the performances, Tamuka’s drummers moved through the villages announcing the beginning of the show. Once an audience gathered, performances were proceeded by 45 minutes of the Tamuka’s energetic traditional singing and dancing, projecting a feeling of vitality and contextualizing the story of “Nakai” in a positive milieu of health and power.
6.5.1 Creating the TfD play “Nakai”

During the early planning stages for the Transportable Demonstration Units (TDU), GMP managers considered creating an awareness “circus” that would arrive at training sites with great fanfare on a truck carrying demonstration mining and safety equipment. A small 2 or 3 person troupe of performer/technicians would juggle, sing, play music, and present little dramas on the hazards of mercury, similar to the street theatre documented by the BBC in Santarém, Brazil (BBC, 1993). With the help of a mining technician, the performers would double as technical educators, showing the miners how to use sluice boxes, retorts, and other pieces of equipment to improve gold recovery and reduce mercury emissions. The trainers would sleep in the “circus”/classroom tent and move on to the next community after a few days. It was believed that adding entertainment elements to the TDU would draw crowds to receive the GMP messages. The play “Nakai” grew from this original circus idea.

6.5.2 Selection of the TfD subcontractor in Zimbabwe

In May 2005, the Kadoma District Hospital Administrator, Steven Banda, mentioned the popular television series, “Amakorokoza,” a ½ hour long, prime time program broadcast weekly on Zimbabwe Television (ZTV). “Amakorokoza: A man’s lonely fight against the forces of greed and corruption” focuses on the lives of Zimbabwe’s small-scale and artisanal gold miners, and is very popular in mining communities. The story line of Amakorokoza contrasts the lives of poor artisanal miners with the lives of the family of a well-connected, rich politician whose daughter is involved with a retired general with interests in the mining sector.
Hoping to embed mercury safety messages in Amakorokoza’s story line, this author contacted the producer of the program, Bulawayo-based Amakhosi Theatre Company, to investigate possible synergies. Initial discussions with Amakhosi centered around the purchase of blocks of sponsorship time of Amakorokoza on national TV, but based on its experience delivering awareness programs for Ciba Geigy, Research Triangle Institute and the Kellogg Foundation, Amakhosi immediately proposed managing all of the GMP’s awareness activities in Zimbabwe. Amakhosi would bring the Ministries of Health, Mines and the Environment together with miners associations and unions for discussions that would eventually lead to the development of an awareness campaign that would include a theatre performance.

Much like the GMP’s early “circus” idea, Amakhosi suggested using a play to introduce the TDU to the communities where training would take place. The Kadoma project area would be divided into 5 km “walking radius” zones in order to ensure that everyone could easily attend the performance and TDU trainings. Politically neutral individuals living near the center of these zones would be designated as GMP “point persons” and be hired to distribute information and conduct a survey of local needs, hopefully becoming health and safety leaders in the mining villages at the end of the GMP. Any printed material, Amakhosi advised, should be functional and locally focused, such as calendars featuring photographs of children in a local school choir.

In July 2005, Amakhosi proposed sponsorship of Amakorokoza broadcasts at USD 3,000 per episode. Each episode would carry two minutes of GMP commercials that would demonstrate retorts and high efficiency gravity concentration equipment. In addition, if the GMP sponsored 13 episodes, two of these episodes would feature the
TDU nurse\textsuperscript{21} interacting with panners. Amakhosi also proposed a 50-minute traveling play using local actors, at a cost of USD 10,000 for script writing and actor training, plus an additional USD 850 per performance.

Believing that the TDU subcontractor would manage the entire awareness campaign from its operating budget, the GMP declined Amakhosi’s offer, but decided to commit USD 12,000 to an Amakhosi-managed traveling theatre program. For this reduced funding, Amakhosi agreed to coordinate the development a script and hire local actors to present the play at fifteen villages in the Kadoma-Chakari area. While Amakhosi preferred to have local miners and villagers act the parts of the various characters in the play (supported by a few professional actors in some of the roles, if necessary) the limited funding precluded this level of engagement with the villagers. The logistics of casting individuals from remote villages was simply too costly. Even though its scope was thus limited, Amakhosi’s theatre program became the core of the GMP’s awareness program because the TDU subcontractor did not produce any brochures, posters, or billboards.

6.5.3 Selection of the local theatre group

In 2006, the Zimbabwe Women in Mining Association and the Zimbabwe Panners Association proposed that Amakhosi hire the Tamuka Theatre Company, a young semi-professional dance troupe with relatively limited acting experience. Tamuka would function as a subcontractor to Amakhosi, managing all scheduling and transportation to the villages, coordinating performances with the movements of the

\textsuperscript{21} In 2006, the GMP intended to hire a nurse as a full time TDU trainer, however this did not happen due to subsequent funding short falls.
TDU. After Amakhosi provided a number of workshops to build Tamuka’s acting capacity, it was agreed that Tamuka would perform all of the acting roles.

Amakhosi, Tamuka and the ZPA were the primary participants in the script development workshops. The first workshop was held in March 2006 to establish the general story line and prioritize the script’s messages:

1. Health effects of mercury
2. Mercury use behavior change and gender
3. Environment
4. Legislation and policy
5. Micro credit and capacity building.

It was agreed that of these core messages, only two could be effectively emphasized in any given play. Health and behavior change thus became the focus of an emerging story where two families with a history of mistrust would be reconciled by a person disinterested in the historic conflicts, perhaps by one of their children. It evolved that the son of an environmentally careless family would fall in love with the daughter of a more established and environmentally responsible family, exacerbating an old interfamily conflict, but also leading to an eventual resolution.

Following conventional script writing structures, the first two scenes introduced the issues and characters, the next 4 scenes established the conflicts in the plot, and the final 2 scenes resolved these conflicts. The first two scenes of “Nakai” established the health issues, while environment, policy and capacity building became subtexts of the conflict development, middle section of the play. Gender would be woven into the strength of the women characters. The ZPA motto, “Proud to be a Panner” would be
reflected in the dignity and strength of the miners’ characters. All the issues would be molded into a clear message in the resolution of the conflicts: people would use mercury more safely, make more profit, and the health of the community and two families would improve.

Subsequent collaboration between Amakhozi, Tamuka and the ZPA fleshed out the story of “Nakai.” Styx Mhlanga, a director and playwright with Amakhozi, wrote the script’s dialogue which was adjusted iteratively through discussions with the ZPA and Tamuka. At one point, contention arose as to whether Aringo could become impotent and whether Nakai’s pregnancy might be threatened due to mercury exposure. This researcher argued that impotence and miscarriage were unlikely outcomes of mercury exposure, and that focusing on the extreme cases might weaken the credibility of the GMP’s core messages. It would be better, perhaps, to represent the more realistic outcomes of “mad hatters disease” and developmental disorders in children. The ZPA, on the other hand, was committed to focusing on the impotency and miscarriage tropes, even if they represented the extreme case. The “community” wanted this storyline, so it was accepted on the advise of Amakhosi. The final script was approved by the Ministry of Mines in December 2006 and distributed to the actors.

6.5.4 Creating awareness through theatre in Kadoma-Chakari

At the opening performance of Nakai in Kadoma in March 2007, Amakhosi’s Styx Mhlanga invited the stakeholders in the audience to discuss the play in order to probe whether the content was appropriate, or whether there should be any changes. The tone of this post-performance discussion was polite and formal, and no critical
feedback was offered. The various institutions and stakeholders only praised the efforts of the local theatre group, perhaps perceiving that the play was already a finished piece. A week later, the play debuted to miners and their families in an open-air performance at Golden Valley, a mining community 20 km north of Kadoma. While this audience clearly enjoyed the show, Tamuka and the ZPA were unable to hold the audience for any post-performance discussions. Post-performance discussions were similarly lacking after a performance in Kadoma’s central plaza in September 2007.

While the play “Nakai” was seen by over 8,800 people (about 5% of the residents in the Kadoma-Chakari area) during 15 performances (Appendix 5), it is unclear whether the play will lead to any significant improvement in mercury safety practice. No systematic evaluation of the impacts of “Nakai” was conducted. The final performance and sub-contractor’s self evaluation was cancelled because of threats of police interventions. The ZPA, however, reported that the performances effectively conveyed the GMP’s core messages: “…the issues portrayed are echoed by listeners as being real. A lot of mining communities want the drama group at their mining places, as they believe it’s very educative. I went to Patchway, New Plus, Brompton, Chakari and other areas and they praised the drama group” (Evans Ruzvidzo, 2008—President, Zimbabwe Panners Association, pers. comm.).

It was not possible to run “Nakai” as an introduction to any safety or equipment demonstrations because financial and management difficulties prevented the TDU training subcontractor from assembling the equipment and conducting trainings in 2007. Tamuka was forced to present the play as a stand-alone awareness event in locations chosen to attract large crowds. This disassociation from training activities
may explain why Tamuka and the ZPA had difficulty holding audiences for post-
performance discussions. The full suite of TDU training equipment would have
commanded the audiences’ attention and discussion much more than a few retorts.

In the end, Nakai was not a play that dialogued with mining communities. The
script was developed by Amakhosi (based in Bulawayo), Tamuka and the ZPA (both
based in Kadoma), and while some of these collaborators were familiar with mining
communities and their needs, none actually lived in mining villages. Miners
themselves had no input, and were not given an opportunity to show their strengths as
dancers and actors, or to define the obstacles they faced and wanted to address. The
story contained messages determined by outsiders that did not reflect local priorities
(such as clean water and sanitation) which had already been voiced by mining
communities (Boese-O’Reilly et al., 2004; Steven Banda, 2005—Chief Administrator,
Kadoma District Hospital, pers. comm.). Although they were very accomplished
dancers, Tamuka’s enthusiastic actors may have been too young and inexperienced
to convincingly portray the complexities of gold panners’ lives.

Repressive one-party political environments limit the extent to which
communities can determine the direction of their own development (Kidd 1983, and
Kerr, 2002). Zimbabwe’s national secret police constantly watched GMP training
sessions and carefully monitored all training materials. High-ranking government
officials attempted to co-opt GMP activities to benefit the ruling party. Even though the
script had been reviewed by the Ministry of Mines to ensure that it contained no
challenges to the government, the final performances of “Nakai” had to be cancelled because police began viewing performances as a potential political rallies 22.

The GMP theatre program was fraught with delays. Amakhosi and Tamuka were extremely frustrated and discouraged by the pace of the theatre project, which took nearly 2 years to mount 15 performances. In addition, Amakhosi was forced to cut all pre-performance interactions with mining communities because it received less than one third of the value of its contract because bureaucratic constraints prevented the transfer of funds either directly in US dollars or at preferred UN rates through the UNDP in Harare. Funding shortages were exacerbated by increased operating costs in the hyper-inflationary economy, and by attrition of trained actors seeking more reliable employment.

In retrospect, Amakhosi’s July 2006 proposal would have clearly been a better course, putting the responsibility for the entire awareness campaign in the hands of awareness professionals with experience in delivering health messages to rural communities in Zimbabwe. Sponsoring episodes of Amakorokoza would have communicated the GMP’s messages to a vast national television audience. Amakhosi’s proposal would not have increased the GMP’s awareness expenditures in Zimbabwe costs as funds could have been diverted from the TDU subcontractor, who in the end did not conduct any awareness activities.

Successful as it was in terms of numbers of people reached, the GMP’s theatre project in Zimbabwe did not address any the underlying limiting economic structures

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22 Amakhosi’s director had been arrested the previous year for producing the play, “Pregnant with Emotion,” a satire about a woman who is 13 months pregnant with a baby that refused to be born until President Mugabe leaves office.
(i.e., the oppressive custom milling operations that require ASGMs to pay millers to poorly process their ores, and leave little option to whole ore amalgamation).

Unfortunately, the money allocated to theatre activities in Zimbabwe was not sufficient to fund interactive community dialogue. Had sufficient funding been available to give Kadoma-Chakari’s communities the chance to develop and tell the story themselves, the GMP could have more easily addressed the structural impediments to changing amalgamation practice.

6.6 Effective use of TfD

6.6.1 Community-focused, message-focused, or both?

As described above, theatre can be used either as a means to promote community driven development by helping communities create sustainable solutions to self-identified problems, or simply as a tool to communicate development messages that are pre-determined by donors. The use of theatre as a top-down message communication tool has been widely criticized in Africa (e.g., Kidd, 1984a and 1994). Use of theatre in the service of community development yields more sustainable results (e.g., Kidd, 1994; Kerr, 1995; Osofisan, 1998; Settergren et al., 1999; Andrews, 2004; Moriarty, 2004; Plastow, 2004; Boon and Plastow, 2004; Mhlanga, 2008). Donors take a message-focused approach because they require quantifiable success indicators such as the number of beneficiaries contacted, because they find the open-endedness of participatory community dialogue potentially politically troublesome, and because the cost of long-term commitment to communities invariably exceeds program resources.
Knowledge of the “drama-discussion” (“start-stop”) interactive theatre method (see section 6.3.6, Nigerian workshops) leads to an understanding that theatre can be a problem solving activity. TfD, when practiced by skilled animators, can be much more than a little entertainment followed audience discussions that are dominated by a few individuals or interest groups (Kidd, 1984 and 1994).

The effectiveness of theatre for communication of development messages (such as health and safety) has not been well studied (Ross Kidd, 2008—University of Botswana, pers. comm.). Where results have been evaluated, short-term behavior change is limited even though awareness of risks may have increased (Ghosh et al, 2006). Those arguing in favor of community-focused TfD make it clear that communication of donor-determined messages rarely leads to behavior change because outside solutions leave communities out of the process, causing people to feel they have no investment in the results. Being told what to do, and how to do it undermines beneficiaries' sense that they can assume responsibility for solving their problems (Kidd, 1994; Séguin and Rancourt, 1996; Okoth et al., 1998).

The GMP’s theatre program would have been more effective if it had followed a more holistic community-focused approach. If communities are unaware of specific problems (such as the hazards of mercury), awareness can grow during drama development activities. Research is required to determine the effectiveness of message-focused traveling theatre programs such as “Nakai”, and whether it is possible to make these kinds of dramas more effective by using the strategies of effective community-focused theatre. In either case, communities must be free to prioritize their needs.
In typical message-focused TfD, beneficiaries are disempowered because problems and solutions are identified by people outside the target community. These solutions are often inappropriate because they do not reflect the complex realities that communities face. Extension workers and actors do the thinking and work, while beneficiaries are merely passive spectators. Interventions are short term with no follow up.

On the other hand, beneficiaries are the drivers of community-focused theatre where communities develop and act in plays that express their perceptions of the challenges they face. Community discussion leads to solutions that are implemented with ongoing support from project facilitators. Extension workers are non-directive facilitators skilled at ensuring that the less powerful participate and grow in confidence (Kidd, 1994).

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23 For example, acceptance and use of retorts (one of the GMP’s top solutions to limit mercury exposure in Kadoma-Chakari), was limited because miners were hesitant to burn their amalgams where they could be watched by the gold squad police.
7 RECOMMENDATIONS FOR CHANGE IN KADOMA-CHAKARI

7.1 Community organization and project administration

7.1.1 National level partnerships

International organizations that fund ASGM interventions need to develop programming that reaches the people at the bottom of the socioeconomic spectrum. Transparent consultation with miners (not simply with so-called miners' associations) when programs are designed, would lead to more focus on the needs of miners, promote “buy-in” and ownership of the project at the local level. Such an approach would nourish organizational structures within mining communities that would promote sustainability of project activities after funding is exhausted and help ensure fair and efficient project administration.

ASGM communities in Zimbabwe are in a desperate situation. The lack of government resources requires continued donor support for ASGM interventions. The choice of national level partners is paramount. Zimbabwe’s Ministries of Environment and Health and Fidelity Printers and Refiners would be more effective partners than the Ministry of Mines (which was unable to effectively administer the GMP). At the practical level, implementation partners should include NGOs such as the LEAD Trust or Practical Action\(^{24}\), both of which have extensive grass-roots networks.

The experience of the GMP in Kadoma-Chakari suggests that in addition to quarterly oversight by donor agencies, new mechanisms for accountability need to be

\(^{24}\) LEAD Trust is a Zimbabwe-based development NGO started by US AID in 2004. Practical Action (formerly the “Intermediate Technology Development Group” or ITDG) is a UK-based development NGO with offices in Zimbabwe. The focus of both institutions in Zimbabwe is presently on food security, a critical need of ASGM communities. Practical Action managed the Shamva Mining Center in Zimbabwe, but it is currently not involved in any ASM interventions, either in Zimbabwe or globally.
These mechanisms might include the creation of community-based trusts directed by local individuals committed to improving the lives of miners, and who because of their professional standing (e.g., priest, hospital administrator, etc.) are unlikely to find themselves in a conflict of interest situation. The GMP also found that low-budget interventions (USD 10-20,000) such as its theatre and national retort campaigns produced more results than more-costly initiatives such as the transportable demonstration unit.

7.2 Financing and micro-credit

Mining is only legal in Zimbabwe when operations have approved environmental impact assessments and management plans. Under current conditions, the cost of hiring a consultant to complete the applications required to obtain an EIA and EMP and paying for government inspectors to make site visits is prohibitively high for most miners. The GMP and the ZPA argued unsuccessfully in 2007 that the government should permit miners to operate provisionally while they paid for their impact assessments and management plans.

7.2.1 Government guaranteed micro-finance programs

As suggested by Dube (2005), the current inflationary environment (now more than 1,000,000 % per annum) precludes most options for micro-finance in Zimbabwe, except for government guaranteed loans similar to those offered to Zimbabwe’s emerging small-scale farming sector. Access to mining equipment in Zimbabwe needs to be actively supported by government initiatives such as currently under
consideration by Fidelity Printers and Refiners to import vinyl loop carpets, pending finalizing carpet efficiency tests at its mill in Odzi near Mutare.

7.2.2 Short term loans by millers to select miners

Another form of microcredit are short-term loans by milling centers wishing to optimize the grade of ore that miners deliver for stamp milling. Because more gold passes to the millers’ cyanidation circuits when miners find and extract higher grade ore, some millers are willing to finance exploration support services and mining equipment such as dewatering pumps, drills and compressors for their most competent miners. This form of microcredit, however, is not suitable for purchases of more efficient gravity recovery equipment by miners (such as vinyl loop carpets) because millers benefit directly from the current inefficient practices.

7.3 Technology transfer

Technological improvements need to be gradual and reflect the limitations of Zimbabwe’s stressed economic situation. Expectation for change needs to be realistic and achievable. Interim measures that are capable of achieving significant immediate mercury reductions (such as mercury traps which might be seen as environmental compromises, should be favored over more idealistic, long-term measures such as an outright ban of whole ore amalgamation). Technology transfer requires the follow up (Jonsson et al., 2008) of local mining engineers hired to conduct trainings reflecting the needs expressed by the miners themselves (Appendix 1).
7.3.1 Keeping mercury out of the cyanidation circuit

Custom milling operators need to become aware of the benefits of keeping mercury out of the cyanidation circuit and be shown how to accomplish this without radically changing the current gold sharing arrangements with the miners. Training programs for millers should include instruction on alternate recovery methods (including mercury scavengers and traps), agitated leaching, efficient and safe cyanidation, waste management and nitric acid disposal, and retorts and mercury vapor scrubbers.

7.3.2 Pros and cons of milling centers

Zimbabwe’s custom milling centers have the advantage of restricting most of the adverse environmental effects of mineral processing (improper tailings disposal and mercury losses) to relatively few discrete locations. In theory, the roughly 240 milling centers currently producing gold in Zimbabwe could be efficiently monitored by government inspectors (if fuel and qualified personnel are available). On the other hand, the high hidden cost of milling (the miller assumes ownership of the miners’ inefficiently milled ore for cyanidation) holds ASGMs in a cycle of poverty and dependence on the custom milling system while enriching the miller. In addition, lack of knowledge on the part of milling center workers often leads to dangerous exposures to process chemicals (Shoko and Veiga, 2004).

7.3.3 Whole ore amalgamation

Whole ore amalgamation brings disproportionate benefits to the mill owners who are certain to resist the introduction of more efficient concentration systems. That
said, any attempt to ban whole ore amalgamation will not succeed in Zimbabwe until new concentration methods are fully introduced and accepted by both miners and miller. In the meantime, short lengths of vinyl loop carpets (about 1-1.5 m long) can be substituted for amalgamation plates by retrofitting existing copper plate stands. Such small changes may be acceptable to millers because short carpets would not significantly exceed the efficiency of current recovery methods.

7.3.4 Use of mercury traps

Mercury traps (transverse collection troughs placed after the primary concentrator) were used for many years in Zimbabwe until the advent of custom milling operations in the 1990s. Because millers are familiar with their operation, re-introduction of mercury traps would be a more acceptable solution to whole ore amalgamation than an outright ban.

A study of the effectiveness of mercury trap designs should be undertaken, perhaps in partnership with the Ministry of Mines’ metallurgists. Short of accomplishing a ban of whole ore amalgamation, mercury traps would decrease the amount of mercury in sands and slimes destined for cyanidation.

7.3.5 Stripping mercury with silver amalgamation plates

Silver amalgamation plates have been used to clean mercury from amalgamation tailings in Venezuela (Veiga and Gunson, 2004), but promoting this practice in Zimbabwe could slow the acceptance of alternatives to whole ore amalgamation by introducing a new form of whole ore amalgamation. Vinyl loop carpeted scavenger sluices or mercury traps at outflow of amalgamation plates may be as efficient as a
zigzag silver amalgamation plate system, and less expensive. A test program to establish the relative recovery efficiencies of these methods to reduce mercury loss is long overdue.

7.3.6 Re-evaluation of GMP technology recommendations for Zimbabwe

The GMP attempted to introduce ball mills as a means of improving recovery in Zimbabwe (Veiga, 2004). While no trainings took place on the TDU ball mill, it is now appears that ball mills would not be accepted as a replacement for stamp mills in Kadoma-Chakari because miners believe they loose gold in the mill linings, and because millers would resist any changes that could decrease the amount of gold sent to cyanidation. Testing of recovery efficiency should precede ball mill introduction in order to determine the length of carpet that would produce recoveries acceptable to both miners and millers.

Another important barrier to the acceptance of ball mills in Zimbabwe is the retarding effect of finer grinding on solution flow through sands in passive cyanidation vats. Ball mills would necessitate the introduction of agitated tank leaching to accommodate the slimes. Even if a suitable design for construction of agitated tanks were provided free of charge, mills would still require significant new capitalization, training and improved tailings and waste management systems.

There is little political will for changing the socio-economic structure that supports the custom milling center system. For example, the government has not allocated funding to support ownership of milling centers by cooperative associations, and an initiative to collectivize the ownership of custom milling center tailings in order
to more fairly distribute the profits from cyanidation to the miners failed in 2005 (Titus Nyatsanga, 2005--Director of Mining Promotion, Zimbabwe Ministry of Mines, pers. comm.). The introduction of low cost hammer mills, however, might provide a means whereby miners can end their dependency on custom milling centers.

Miners’ incomes would increase if they had the option of processing their own ores. Miners would recover more gold by using hammer mills and sluices with a few meters of vinyl loop carpet than they currently recover at custom milling centers. In addition, they would be able sell their tailings to millers for cyanidation. The cost of a high quality Brazilian hammer mill in 2007 was USD 2,368 (FOB Harare)\textsuperscript{25}, so a locally made copy, powered by a small motor such as used to drive corn grinding mills, could cost well under USD 2,000.

While the low cost of the hammer mills would make ownership and control of milling equipment possible for small syndicates of miners, Fidelity Printers and Refiners and the “Gold Squad” police would likely object to the introduction of difficult to monitor mobile mills. Hammer mill operations would have to be permitted under Zimbabwe’s Environmental Management Act, requiring an environmental assessment and management plan. Millers would also oppose the introduction of hammer mills, as this would reduce their access to low cost cyanidation feed.

Retorts have not been accepted in Kadoma-Chakari, despite the GMP’s training and awareness program. In reality, millers only have retorts on site to show to inspectors, and most burning and smelting of amalgam is still done on the ends of burning logs or with an open torch due to the shortage of fuel and transparency of the

\textsuperscript{25} 2007 Pro-forma invoice from Damboz S.A., (Brazil): mill, (USD 1,180), 20 spare pairs of hammers (USD 500), and shipping (USD 600); motor not supplied.
open burning methods. Retorts might be a solution at the village level, but at milling centers, small-scale mercury vapor collectors such as those introduced in Laos and Indonesia that permit open burning with torches might be more easily accepted.

A primitive bellows called a “mvuto” was tested at the Coetzee Milling Center in Kadoma-Chakari in 2006. The “mvuto” employs an empty plastic 20 kg flour sac which pumps air through a steel pipe to the fire, greatly increasing temperatures and speeding the retorting process. But while the “mvuto” eliminates the need for a gas torch, it requires time to prepare the small bonfire. Closed retorts reduce process transparency, and while the more transparent kitchen bowl retort might be acceptable to miners in villages, promotion of this method would require intensive follow up for a significant period of time (Jonsson et al., 2008).

Since millers in Kadoma-Chakari are unlikely to change their milling and gravity recovery methods, two types of training and awareness programs should be offered: one focusing on the needs of the millers, and one on the needs of the artisanal miners. Millers, for example, could be trained to keep mercury out of their cyanidation feed (saving money on cyanide costs) and to use safer, cleaner elution and smelting practices. Artisanal miners, on the other hand could be trained in the use of small, efficient carpeted sluices and retorts, as well as in safer underground mining practice, and water and sanitation.
7.4 Address mercury losses due to cyanidation and elution

7.4.1 Quantify mercury losses

More comprehensive sampling of amalgamation and cyanidation tailings in Kadoma-Chakari is required to support (or deny) the suggestion that about 90% of the mercury in amalgamation tailings in Kadoma-Chakari mercury is dissolved during cyanide leaching. It is believed that most, if not all of the cyanide-complexed mercury is adsorbed to the carbon and dissolved during elution. Depending on the temperature of the eluate, perhaps one third of this mercury evaporates during elution and electrowinning, while two thirds of the mercury co-precipitates with the gold and is subsequently dissolved and discarded during nitric acid digestion of the cathode sludge. Mercury analysis of loaded carbon, eluate, cathode sludge and waste nitric solutions would clarify how much mercury is lost during the various stages of gold recovery.

7.4.2 Prevent exposure to mercury vapour during elution and electrowinning

It is believed that mill workers are exposed to significant levels of mercury in the atmosphere while working inside buildings where precipitated mercury vaporizes during elution. The US EPA’s prototype aerosol condenser (recently tested in Brazil) removes between 40% and 80% of the mercury aerosols that result from rapid evaporation during burning of amalgams, but recovers relatively little mercury vapor26.

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26 Because the saturation concentration of mercury vapor at operating temperatures in exhaust hoods is less than 100 mg/m$^3$ (15 mg/m$^3$ at room temperature) and because the total mercury concentrations in the exhaust stream often exceed 1000 mg/m$^3$, Argonne (2008) believes that about 90% of the mercury in the exhaust stream exists in aerosol form. As these mercury aerosols pass through the ducting, they coagulate, growing in about 6 seconds from about 0.3 µm to about 30µm-diameter particles which are removed from the airstream as they impact on the collector’s steel baffle plates.
Carbon filters are used by large-scale mines to collect mercury emitted in tank houses, but these filter systems would need to be scaled down for custom milling center applications. Locating elution systems in the open air with only a roof covering and some sort of security fence would be an affordable way to reduce worker exposure to mercury vapor.

7.4.3 Recycle mercury contained in waste nitric acid solutions

Chapter 3 identified the loss of mercury in waste nitric acid solutions produced by miners pre-treating their amalgams before roasting on the end of a log, and by washing of cathode sludge by millers in preparation for smelting. Simple methods of recycling the dissolved mercury this waste nitric acid solution such as precipitation of mercury on aluminum foil sheets should be tested and introduced.
8 CONCLUSIONS

8.1 Strategies for more effective ASGM interventions in Zimbabwe

The need for further ASGM interventions in Zimbabwe is clear: Miners lack knowledge and access to better mining and gold recovery methods. Increased income from better gold recoveries can mitigate the impacts of inadequate nutrition, health care, contaminated water and inadequate sanitation in mining communities. Increased awareness can reduce the number of miners and their families who are exposed to mercury vapor (currently 33% of children in Kadoma-Chakari’s mining communities are chronically intoxicated with mercury).

While the need for intervention is easy to identify, design and implementation of ASGM programs in Zimbabwe is very difficult because the country's repressive government creates an atmosphere that stifles problem-solving discussions and frightens miners from participating in training programs. Zimbabwe's collapsed economy restricts importation of alternative mining and mineral processing equipment. Low official currency exchange rates and hyperinflation lead to constant budget adjustments and compromises in project strategies. All of these challenges are amplified by a poorly functioning domestic and international communications infrastructure. Maintaining a strong in-country management presence\(^{27}\) is essential to effectively meet the challenges that arise in such difficult political and economic environments.

\(^{27}\) In some situations, expatriate managers may be less subject to government and special interest pressure, and better able to insure that project goals are achieved.
Improvements in the economic, health and environmental status of ASGMs in Zimbabwe are achievable if programs allow beneficiaries to be the ones who decide what problems (within the scope of a given program) should be solved. Community participation in program design, implementation, and evaluation would better ensure funding is translated into action in the field. Technical solutions, of course, must fit local geology, ore mineralogy and customary practice at milling centers.

Programs must identify implementation partners who are true champions of the poor, who understand their responsibility for communication and engagement, and who are skilled facilitators of community growth. Government is a necessary participant, but NGOs and local community organizations would be better managers of ASGM programs than government ministries and university institutions that are socio-economically distinct and geographically removed from mining communities. Program facilitators should be locally based and funded for the long term. It should be recognized that change will be slow, and that new practices that bring no immediate financial benefit to the miners will not be easily accepted.

8.1.1 Theatre as a tool for communication and stakeholder consultation

Theatre can communicate development messages to large numbers of people, but can also be an effective consultation tool that enhances “buy-in” and sustainability of programs, especially when horizontal communication between donors and beneficiaries leads to community control of the development process. Community control ensures that problems are not seen in isolation and that solutions are realistic.
When sensitively facilitated, theatre is also a means of guaranteeing that the voices of less powerful “stakeholders” are heard.

8.2 Improvements in mineral processing technology

8.2.1 Increasing gold recovery

Better gravity recovery is possible and affordable in Kadoma-Chakari. Even though not yet completed, the preliminary results of tests conducted by the IMR and the Ministry of Mines suggest that vinyl loop carpets can recover more gold than copper amalgamation plates and centrifuges. Indeed, when miners have been given a choice, they have preferred these carpets to copper amalgamation plates and ABJ centrifuges, a strong indication that the carpets are more efficient.

Acceptance of vinyl loop carpets by owners of milling centers is an outstanding problem that must eventually be addressed. The government of Zimbabwe might eventually introduce a ban of whole ore amalgamation. In the meantime, however, retrofitting existing amalgamation plate frames would facilitate introduction of short carpet lined sluices (less than 1.5 meters long) which would not significantly exceed the recovery efficiency of current methods or reduce the gold in the millers’ cyanidation feed. Once miners see how well the carpets work, they can negotiate for longer carpets.

Unfortunately the unavailability of foreign currency in Zimbabwe has blocked importation of vinyl loop carpets. The government gold buyer, Fidelity Printers and Refiners, indicates they will facilitate importation and distribution of the carpets, once they have completed testing of carpet efficiency.
8.2.2 Reducing mercury losses

Cyanide and nitric acid have been identified as the main pathways for mercury loss at milling centers. Indirect evidence suggests that as much as 90% of the mercury contained in amalgamation tailings in Kadoma-Chakari is dissolved during cyanidation. It is believed that the dissolved mercury is adsorbed to carbon and subsequently evaporated during elution and electrowinning or is re-dissolved during nitric acid washing of cathode sludge and improperly discarded. Miners also pre-treat their amalgams with nitric acid before burning and smelting at custom milling centers. Perhaps half of the mercury in miners’ amalgams is improperly discarded with these nitric waste solutions.

The best way to reduce mercury losses at milling centers is to keep mercury out of the cyanidation circuits altogether. This could be accomplished by switching to better gravity recovery methods such as vinyl loop carpets. A good interim measure might be to reintroduce the mercury traps commonly used by millers before the advent of custom milling system. Where mercury cannot be kept out of the cyanidation circuit, methods to recover and recycle the mercury in the cathode sludge or dissolved in waste nitric acid solutions should be developed, tested and promoted\(^\text{28}\).

The optimum cyanide concentration for passive vat leaching is between 0.1 to 0.15%, considerably less than the typical cyanide concentrations at custom milling centers (between 0.2 to 0.5 %). Better understanding of effective cyanidation practice by the millers would lower their operating costs, and reduce the dissolution of residual mercury in un-rinsed cyanidation tailings.

\(^{28}\) Hg (II) in acid solutions can be easily bio-methylated.
Finally, retorts have not been widely accepted by miners at milling centers. The current system whereby custom milling centers smelt miners’ amalgams (pre-treated with nitric acid and roasted) is transparent, relatively quick and fuel efficient, and an effective way to ensure sale of doré to the government. While the primitive local bellows called a “mvuto” is an effective means of obtaining the high temperatures needed for retorting on bonfires, high temperature retorting with a “mvuto” yields a solid button that is more difficult to smelt than roasted amalgams. Follow up research and training are needed.

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29 Miners must ensure that their doré contains more than 70% gold, the cutoff purity for purchases by milling centers.
9 OPPORTUNITIES FOR FURTHER RESEARCH

9.1 Theatre for development

As discussed in Chapter 6, theatre has the potential to give mining communities a chance to direct their own development. Experience gained in Zimbabwe suggests that it would be productive to hold a regional workshop to explore the potential of community-focused theatre to support ASGMs in Africa.

9.2 Product stewardship for ASGM cyanide use

During the past 3 years, numerous attempts have been made to secure research and training funding from the manufacturers of cyanide, either from producers directly or through the International Cyanide Management Institute. Further discussion with the cyanide industry is needed to ensure that producers extend their product stewardship commitments to ASGM cyanide operations.

9.3 Improving gold recovery

Gum poles lining the surface of sand filters in cyanidation and clarification tanks may adsorb significant quantities of gold, and therefore should be tested for gold content.

9.4 Keeping Hg out of the cyanidation circuit

9.4.1 Vinyl loop carpets

The efficiency of vinyl loop carpets relative to copper plates and Knudsen bowl centrifuges has not yet been conclusively demonstrated. Masiya and Chigwida (2007) tested the efficiency of vinyl loop carpets, but did not establish a comparison with
copper plates or centrifuges. Tests comparing amalgamation plates and centrifuges with vinyl loop carpets need to be completed.

9.4.2 Mercury traps

The ability of various mercury trap designs to capture the mercury lost from copper plates and centrifuges should be studied. Quantifying the amounts of gold and mercury captured by various scavengers and traps would inform discussions with millers about how much gold they would lose from their cyanidation feed by reintroducing these old methods.

9.5 Prevention of mercury loss during gold recovery and refining

Mercury losses during elution, electrowinning and smelting need to be quantified at custom milling centers.

9.5.1 Two-stage electrowinning

According to Marsden and House (2006), it is theoretically possible to precipitate mercury from eluate before precipitating gold. To do this, elution plants would need sufficient control of electrowinning voltage and current to prevent coprecipitation of other metals in the mercury removal cell (Sheya et al. 1998). Research is necessary to determine optimum electrical potentials, temperatures and eluate chemistry. An other option follows Adams’ (1991) suggestion that mercury can be eluted by a cold caustic cyanide solution—if true, it could be possible to remove mercury from loaded carbon before stripping gold with hot eluate solutions.
9.5.2 Retorting cathode sludge

Retorting loaded carbon is not an option because adsorbed Au(CN)$_2^-$ disassociates to metallic gold at temperatures above 180° C, making elution more difficult (Marsden and House, 2006). It may be feasible, however, to retort the cathode sludge before nitric acid digestion and smelting.

9.5.3 Vapor collection

Even though mercury levels in the atmosphere of elution tank houses at milling centers were not evaluated by Billaud et al. (2004), it is very likely that elution workers are exposed to high atmospheric concentrations of mercury.

Vapor collection methods suitable for custom milling centers’ tank houses could be scaled down from industry practice. Hg vapor evolved from carbon regeneration kilns at Barrick’s Cortez mine, for example, passes through a water-cooled condenser bed and then through a 4 tonne carbon filter (Natalie Deringer, 2007—Barrick Gold Corporation, pers. comm.). The use of carbon filters would necessitate development of ways to recycle or safely dispose of the mercury collected in the carbon filters.

9.5.4 Nitric Acid

Mercury precipitation at the cathode leads to the formation of a gold rich sludge that is digested in nitric acid to prepare for smelting. Nitric acid is also used by miners to pre-treat their amalgams before roasting. If suitable methods can be developed (e.g., aluminum foil precipitation), mercury could be recycled from this waste nitric acid solution. If cementation and other methods of precipitating dissolved mercury such as
the addition of calcium sulfide (Bolland, 1985; Sandburg, 1986) are not feasible, then safer disposal options such as subsidized transport of nitric acid waste to a central reprocessing/disposal facility should be evaluated.

Eliminating the practice of dissolving mercury in nitric acid in Zimbabwe will be difficult. Retorting of cathode sludge before acid digestion could reduce amount of mercury dissolved in nitric acid, but miners will be hesitant to stop pre-treating amalgams with nitric acid because millers agree to purchase (on behalf of Fidelity Printers and Refiners) doré containing less than 70% gold.
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### LEGAL ISSUES

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<td>Poor law enforcement on the hazardous substance act</td>
<td>The act should be lawfully enforced and individuals should be educated on the use and control of the hazardous substances</td>
<td>Once the Environmental Protection Act is operational, the GMP should support the Zimbabwe Panners Association (ZPA) to teach miners how to comply</td>
</tr>
<tr>
<td>Abuse of gold panning legislation</td>
<td>Government should implement legislation in a friendly but effective way. Enforcement of gold panning laws is necessary</td>
<td>The GMP should recommend legislation concerning mercury use in mining, maybe following models implemented in other countries such as those in Latin America.</td>
</tr>
<tr>
<td>Easy availability and accessibility of mercury</td>
<td>There should be law to control the buying and selling of mercury from the manufacturer to the end user.</td>
<td>The GMP should promote awareness about the hazards of mercury -- e.g., prepare labels with skull and cross bone/diamond warning label)</td>
</tr>
<tr>
<td>Unlicensed panners, buyers and miners</td>
<td>Government should monitor the industry seriously so that only licensed individuals are allowed to operate. Government should educate people about how to acquire licenses and should relax the license requirements</td>
<td></td>
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<tr>
<td>The issue of protective clothing is not being emphasized</td>
<td>Government mining inspectors should make regular inspection of mining and milling sites.</td>
<td>The GMP Transportable Demonstration Unit should educate miners about protective clothing, produce posters and calendars for awareness; TDU trainers should model safe practice</td>
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<tr>
<td>Mine inspectors are immobile due to the lack of fuel</td>
<td></td>
<td>The GMP should draft voluntary codes that are simple enough for miners to follow with minimum regulator surveillance</td>
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<tr>
<td>Environmental impact assessments and management plans not done</td>
<td>The Government should consider alternatives such as self-assessed environmental management plans as the “environmental impact declarations” miners complete in Bolivia and Peru</td>
<td>The TDU should introduce “SSM Env. 1 Form” to miners. Once the environmental protection act develops its new policy, this can be taught to miners by ZPA</td>
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### GEOLOGY

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</tr>
</thead>
<tbody>
<tr>
<td>Lack of expertise in geological survey procedures</td>
<td>Government should expand the Ministry of Mines (MoM) geological survey dept to include extension services</td>
<td>Consider supporting pegging with differential GPS</td>
</tr>
<tr>
<td>Ore reserve estimation</td>
<td>Government could periodically provide district geologist from Kwekwe to participate in TDU and other trainings</td>
<td>TDU can create awareness that miners would benefit from geological professionals</td>
</tr>
<tr>
<td>Prospecting</td>
<td>MoM could provide peggers to control costs</td>
<td></td>
</tr>
<tr>
<td>Suitable Exploration Tools</td>
<td>MoM should resuscitate Mining Investment Loan Fund (MILF)</td>
<td></td>
</tr>
</tbody>
</table>

### MINING

<table>
<thead>
<tr>
<th>PROBLEMS</th>
<th>SOLUTIONS</th>
<th>GMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools and equipment</td>
<td>TDU should demonstrate low cost heavy duty Bosch electrical drills (Bosch GBH 11) with 2kW generator</td>
<td></td>
</tr>
<tr>
<td>Finance</td>
<td>Recapitalization of Mining Industry Loan Fund is not enough</td>
<td>TDU should provide training in:</td>
</tr>
<tr>
<td></td>
<td>--how to get investors</td>
<td>--how to make a good contract</td>
</tr>
<tr>
<td></td>
<td>--business planning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The GMP should suggest benefits of partnerships between millers and miners</td>
<td></td>
</tr>
<tr>
<td>Lack of experienced mining personnel</td>
<td>Training: The Zimbabwe Panners Association can sponsor ZSM classes in Kadoma --e.g., mine safety</td>
<td></td>
</tr>
<tr>
<td>Access roads are bad or non-existent.</td>
<td>Miners need to take responsibility (miners need to solve their own problems themselves)</td>
<td></td>
</tr>
<tr>
<td>Occupational hazards</td>
<td>Government (MoM) should provide training and extension services</td>
<td>The TDU should focus on safety awareness</td>
</tr>
<tr>
<td>--Roof collapse/support</td>
<td></td>
<td>The TDU should demonstrate ventilation equipment</td>
</tr>
<tr>
<td>--Personal Protective Equipment</td>
<td></td>
<td>The GMP should prepare a miners handbook</td>
</tr>
<tr>
<td>--Ventilation and lighting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Blasting hazards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental degradation</td>
<td>Training, awareness, supervision</td>
<td>TDU should raise awareness of miners about the responsibilities to future generations of extracting mineral wealth today</td>
</tr>
<tr>
<td>Dewatering pits</td>
<td></td>
<td>TDU should include a demonstration dewatering pump</td>
</tr>
<tr>
<td>Lack of business planning</td>
<td></td>
<td>Teach business planning</td>
</tr>
<tr>
<td>MINERAL PROCESSING</td>
<td>PROBLEMS</td>
<td>SOLUTIONS</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td>Miners don't understand mineralogy: -e.g., is the ore oxide ore or sulfide ore? -e.g., what is gold particle size range? -e.g., how does one achieve maximum recovery?</td>
<td>Training and site demonstrations --analyze rock samples --teach basic mineralogy</td>
</tr>
<tr>
<td>Lack of knowledge: --milling --liberation --gravity concentration</td>
<td>Training of alternatives such as ball mills, hammer mills, shaking tables, sluices, strakes</td>
<td>TDU should provide training in geology and mineralogy: --distinguish between ores and know how fine to grind --train how to collect a representative sample --train to use simple methods to test grade (e.g., the Plattner Blowpipe method for assaying gold which was a 19th Century method where the weight of a tiny bead of gold was determined by measuring it between two sub-parallel lines.</td>
</tr>
<tr>
<td>Low Recovery --Copper plates --Screen sizes of stamp mills are too coarse leading to poor liberation --Use of stamp mills is not efficient --Clay James tables</td>
<td>Use better methods --centrifugal concentrators --use smaller screen sizes --use of other mill types --use proper sluices and mats</td>
<td>TDU should demonstrate testing the efficiency of grinding to different sizes</td>
</tr>
<tr>
<td>Very high milling costs</td>
<td>Government should establish own mills at low rates --Government will buy the gold!</td>
<td>Government should establish own mills at low rates --Government will buy the gold!</td>
</tr>
<tr>
<td>Transport --high charges --must pay in gold but the government price is too low</td>
<td>Micro-credit finance --groups could buy tractors, transport</td>
<td>TDU should educate about proper grinding vs. over-grinding --demonstrate liberation analysis to determine proper screen size</td>
</tr>
<tr>
<td>Existing legislation, SI 329, Custom milling regulations --Metallurgical requirements necessitate copper plates</td>
<td>Government must amend regulations</td>
<td>Educate how copper plates release Hg to environment Educate miners on advantages and disadvantages of copper plates Support ban of copper plates and mercury in centrifuges as in Latin America</td>
</tr>
<tr>
<td>SOCIAL ISSUES</td>
<td>PROBLEMS</td>
<td>SOLUTIONS</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Improper Accommodation</td>
<td>Overcrowding</td>
<td>Distribution of condoms</td>
</tr>
<tr>
<td></td>
<td>Prostitution leading to spread of STI and HIV/AIDS</td>
<td></td>
</tr>
<tr>
<td>School dropouts</td>
<td>Petty and violent crime</td>
<td>Law enforcement, statutory instruments (SI), awareness of children’s rights</td>
</tr>
<tr>
<td></td>
<td>Poor water and sanitation</td>
<td>Enforce UN convention on child labor and right to education</td>
</tr>
<tr>
<td></td>
<td>Child labor and sexual abuse</td>
<td>Enforcement of SI 275</td>
</tr>
<tr>
<td>Disruption of family units and normal social fabric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corruptuion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>--enforcing SI of alluvial mining</td>
<td>ZPA could:</td>
</tr>
<tr>
<td></td>
<td>--improve conditions of service of regulatory agents</td>
<td>--Establish a national association/council of mining/panners associations to lobby government (trustees could monitor this national association to prevent in-fighting and greed to ensure stability, --ZPA could function as an intermediate between MoM and panners --Panners should define the needs for training</td>
</tr>
<tr>
<td></td>
<td>--awareness and training</td>
<td></td>
</tr>
<tr>
<td></td>
<td>--introduction of technologies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>--mobile clinics/awareness</td>
<td></td>
</tr>
</tbody>
</table>
## HEALTH ISSUES

<table>
<thead>
<tr>
<th>PROBLEMS</th>
<th>SOLUTIONS</th>
<th>GMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumoconiosis Injuries</td>
<td>-- Enforcement of SI 271</td>
<td>TDU should educate miners on</td>
</tr>
<tr>
<td>Respiratory diseases and suffocation</td>
<td>-- Awareness and education of communicable diseases</td>
<td>-- how to refill pits and replant</td>
</tr>
<tr>
<td>High manifestation of communicable diseases</td>
<td>-- Awareness and prophylactic treatment</td>
<td>-- how to prevent mosquito habitat</td>
</tr>
<tr>
<td>High incidence of malaria and water borne diseases</td>
<td>-- Rehabilitate mined areas; spraying insecticides</td>
<td>--BioSand filters</td>
</tr>
<tr>
<td></td>
<td>-- Low cost water treatment units -- boreholes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-- Larvicide funding needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-- Blair Research Institute of (Ministry of Health) has a plant whose leaves have toxic effects on mosquitoes—It's up to miners to implement</td>
<td></td>
</tr>
<tr>
<td>No antenatal care for expecting mothers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No immunization for children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide poisoning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane—explosive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury intoxication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcoholism</td>
<td></td>
<td>The GMP should consider if it could address this complex problem through drama</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TDU should support awareness that drinking and marijuana leads to accidents</td>
</tr>
<tr>
<td>Panners Association needs support</td>
<td>-- Vehicle</td>
<td>GMP should consider loan of project vehicle to ZPA at end of project</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROBLEMS</td>
<td>SOLUTIONS</td>
<td>GMP</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Inability to access finance</td>
<td>Set up micro finance scheme for ASMs</td>
<td>Lobby Minister for free services</td>
</tr>
<tr>
<td></td>
<td>Introduce flexible lending conditions that can be achieved by ASMs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>--Low interest rate is 60% per year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>--No collateral except for mine claim</td>
<td></td>
</tr>
<tr>
<td></td>
<td>--Grace period of 4 months or more</td>
<td></td>
</tr>
<tr>
<td>No finance for geological services</td>
<td>Facilitate free geological services</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>See above</td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>See above</td>
<td></td>
</tr>
<tr>
<td>Mining Equipment</td>
<td>Establish sustainable plant and equipment hire schemes</td>
<td>Zimbabwe Panners Association acquire</td>
</tr>
<tr>
<td></td>
<td>--hire to buy or direct hiring</td>
<td>equipment for hire</td>
</tr>
<tr>
<td>Safety considerations</td>
<td>See above</td>
<td>Partnership with Government/RBZ and share</td>
</tr>
<tr>
<td>Milling charges</td>
<td>See above</td>
<td>50/50</td>
</tr>
<tr>
<td>Lack of skills</td>
<td>Training facilities for ASMs</td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td>Finance management</td>
<td></td>
</tr>
<tr>
<td>Water sanitation and electricity</td>
<td>Introduce heavily subsidized electricity and water scheme for the period of 5 years</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix 2: Ore grades, gold recovery and mercury loss at custom milling centers

<table>
<thead>
<tr>
<th>Source</th>
<th>Head Grade</th>
<th>Gold recovery</th>
<th>Mercury Input/loss</th>
<th>Ore characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kevin Woods&lt;sup&gt;30&lt;/sup&gt;</td>
<td>Range: 5-10 g Au/t; Average: 7 g Au/t (very little ore &gt;20 g Au/t)</td>
<td>40-50% 3-3.5 g/t</td>
<td></td>
<td>Most refractory ores are located near Kwekwe (100 km from Kadoma)</td>
</tr>
<tr>
<td>Shoko and Veiga (2004)</td>
<td>30% (of gold produced at mill) 70% (of gold produced at mill)</td>
<td>Loss: 2 g Hg/g Au produced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masiya and Chigwida (2007)</td>
<td>Calculated head grade from 8 tests: Range: 0.6 to 13.7 g/t Average: 6.5 g/t</td>
<td>Input: 100-150 g Hg in centrifuges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simba Sialumba&lt;sup&gt;31&lt;/sup&gt;</td>
<td>5 g Au/t (inferred) (Vinyl carpets and centrifuges in series)</td>
<td>2.5 g Au/t Input: 50-100 g Hg in centrifuge bowl; additional Hg added during concentration</td>
<td>&gt;33% ores contain sulfides 50% ores are &quot;quartz/rubble&quot;</td>
<td></td>
</tr>
<tr>
<td>Tireless Milling Center</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evermore Milling</td>
<td></td>
<td></td>
<td>Loss: 10-20 g Hg/t</td>
<td></td>
</tr>
<tr>
<td>Billaud et al., 2004</td>
<td>30%</td>
<td>Input: &gt;135 g Hg/t on copper plates</td>
<td>Loss: About 20 g Hg/t at Tix Mill (from copper plate) Loss: 25-30 g Hg/t at Amber Rose Mill (from centrifuge)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>30</sup> Kevin Woods, 2008—Small Mining Supplies, Harare, pers. comm.

<sup>31</sup> Simba Sialumba, 2008—Gold Procurement Administrator, Fidelity Printers and Refiners, pers. comm.
<table>
<thead>
<tr>
<th>Source</th>
<th>Head Grade</th>
<th>Gold recovery</th>
<th>Mercury Input/loss</th>
<th>Ore characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Miner</td>
<td>Miller</td>
</tr>
<tr>
<td>Singo, 2006</td>
<td></td>
<td>11.7 g Au/t at 3 milling centers</td>
<td></td>
<td>Refractory ores at depths &gt;30 m</td>
</tr>
<tr>
<td>Patience Singo³²</td>
<td>Gravity recoverable gold: 4 to 15 g Au/t</td>
<td></td>
<td>Alabama and Chakari mines: 4-5 g/t average recovery. Gold is associated with chalcopyrite in grey-white quartz veins 20-100 cm wide (thinner veins can yield recoveries of 10-15 g Au/t). Little oxidization. Golden Valley, Brompton, Venice mines: Gold is associated with arsenopyrite in grey-white quartz veins with 8-10 g Au/t average gravity recovery. Glasgow and Alabama mines: Oxidized ore yielding up to 330 g Au/tonne (secondary enrichment?). Little oxidation below 30 m.</td>
<td></td>
</tr>
</tbody>
</table>

³² Patience Singo, 2008—Mining Engineer, Global Mercury Project, Bulawayo, pers. comm.
### Appendix 3: Mineral processing at Tireless and Evermore custom milling centers

<table>
<thead>
<tr>
<th>OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAME OF MILL</strong></td>
</tr>
<tr>
<td><strong>MILLING</strong></td>
</tr>
<tr>
<td>Number of stamp mills</td>
</tr>
<tr>
<td>Screen size</td>
</tr>
<tr>
<td>Number of ball mills</td>
</tr>
</tbody>
</table>
| Ore characteristics | -Sulfide ore: +35%  
-Quartz or Rubble ore: 40-45% | |
| Average grade | Not disclosed | Not disclosed |
| Recovery | Not disclosed | 50-85% recovery |
| Cost of milling/hour | Z$400,000/hr (about 1 USD on black market) in September 2007 | 1 million Z$/hr in December 2007 |
| **TAILINGS MANAGEMENT** | | |
| **Classification** | Cyclone | Drag classifier |
| Slimes | -Slimes always 30% of tailings  
-Dried and disaggregated in trommel before leaching in agitated vats | -Slimes constitute 5-10% of tailings  
-Remixed with sands for passive leaching |
| Sands | Passive vat leaching | Passive vat leaching of sands blended with slimes |
| Process water | | |
| Final tailings storage | -Sands are washed with water and contain less than 0.02% NaCN when discharged.  
-Slimes are not washed  
-Storage not lined | Tailings are not washed, but are checked for grade |
| Nitric acid disposal | Discarded on ground by miners | Diluted and buried |
| Mercury losses are significant with nitric acid disposal, and can occur with discharge of silty process water or with waste cyanide tailings and solution when not properly impounded. | | |
| **GRAVITY RECOVERY** | | |
| Copper plate | One on site, but rarely used | One per mill |
| Centrifuge | One ABJ centrifuge per mill per customer preference | ABJ centrifuges optional |
| Copper plate used in series with centrifuge | Only when customers request | Yes—when customers request |
| Copper plate + carpet in series | No | Yes—blanket or Hessian cloth to catch mercury/amalgam |
| Mercury used in centrifuges | Yes; 1-2 tsp Hg per batch; check during operation | Yes |
| Mercury trap | No | Yes (carpet) |
| The mercury trap at Evermore milling was a Hessian cloth-lined scavenger sluice—the efficiency of this method needs testing. | | |
| **AMALAMATION** | | |
| Amalgamation barrels or hand panning | No amalgamation barrel  
-Hand panning of concentrates | No amalgamation barrel  
-Hand panning of concentrates |
| Mercury use | - mercury use depends on grade of ore  
-use 2 teaspoons (100 g) to | -2 teaspoons per square meter of copper plate  
-Mercury loss is 10% per |
### OBSERVATIONS

<table>
<thead>
<tr>
<th>NAME OF MILL</th>
<th>Tireless Milling</th>
<th>Evermore Milling</th>
</tr>
</thead>
<tbody>
<tr>
<td>dress a new plate</td>
<td>- Amalgams weigh between 0.7g and 12 g</td>
<td>tonne of ore (i.e., 10 g Hg/tonne if 2 tsp (100 grams) are used)</td>
</tr>
<tr>
<td>Scouring of plates with sand</td>
<td>Scouring not allowed as it is thought to lower efficiency of copper plates</td>
<td>Not allowed</td>
</tr>
<tr>
<td>How much Hg lost per tonne of ore?</td>
<td>Not reported</td>
<td>-10 g per tonne from whole ore amalgamation (reported)</td>
</tr>
<tr>
<td>Mercury losses are associated with amalgam pretreatment with Nitric acid, roasting on logs, and burning with torches without retorts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### RETORTS

<table>
<thead>
<tr>
<th>Pretreatment with Nitric acid and roasting of amalgam</th>
<th>- Boil Amalgam in Nitric acid</th>
<th>-20 ml nitric per 10 gm of amalgam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- use 20 ml of Nitric for 10 gm amalgam</td>
<td>- not boiled in Nitric acid</td>
</tr>
<tr>
<td></td>
<td>- toast sponge on end of log</td>
<td>- customer does not pre-roast on logs at mill.</td>
</tr>
<tr>
<td></td>
<td>- smell with torch +(borax, salt peter and salt; sometimes add silica)</td>
<td>- Water cooled retort available.</td>
</tr>
<tr>
<td>Description of retort used by miller</td>
<td>No retort used</td>
<td>Water cooled</td>
</tr>
<tr>
<td>Ventilation system provided</td>
<td>Amalgam smelted inside small hood with exhaust fan</td>
<td>Exhaust hood for torch smelting of sponge</td>
</tr>
<tr>
<td>While Evermore claims to have a water cooled retort available, this may simply be on site to show inspector</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CYANIDATION

<table>
<thead>
<tr>
<th>Treatment of slimes</th>
<th>Agitated tanks</th>
<th>Slimes dried and blended with sands for passive leaching</th>
</tr>
</thead>
</table>

#### Agitated tanks

<table>
<thead>
<tr>
<th>Number of agitated tanks</th>
<th>2</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>27 tonnes ore/vat</td>
<td></td>
</tr>
<tr>
<td>diameter</td>
<td>4.3 m</td>
<td></td>
</tr>
<tr>
<td>depth</td>
<td>2 m + 1.2 m discharge cone</td>
<td></td>
</tr>
<tr>
<td>reagents</td>
<td>-18 kg lime</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-11 kg Na CN (= 0.1% CN)</td>
<td></td>
</tr>
<tr>
<td>Time of agitation</td>
<td>18 hours</td>
<td></td>
</tr>
<tr>
<td>Decantation rate</td>
<td>Decantation takes 24 hours</td>
<td></td>
</tr>
<tr>
<td>Impeller</td>
<td>3 rubberized blades</td>
<td></td>
</tr>
<tr>
<td>Motor</td>
<td>7.5 kW/ 525 / 550 volts 1450 RPM Direct drive</td>
<td></td>
</tr>
<tr>
<td>Process notes</td>
<td>-45% solids</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Final rinsing with water decanted for 90 minutes; remainder flushed to tailings dam</td>
<td></td>
</tr>
</tbody>
</table>

#### Passive vats

<table>
<thead>
<tr>
<th>Number of vats</th>
<th>6</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>Estimated 4 meters</td>
<td>- Rectangular with shared walls</td>
</tr>
<tr>
<td>Depth</td>
<td>2 meters: 1.5 meter for sand 0.5 m for filter</td>
<td>Estimated 1.5 to 2 meters</td>
</tr>
<tr>
<td>Construction</td>
<td>Concrete Top edge at ground level 9&quot; thick walls</td>
<td>Concrete Top edge at ground level Wall thickness unknown</td>
</tr>
</tbody>
</table>
### OBSERVATIONS

<table>
<thead>
<tr>
<th>NAME OF MILL</th>
<th>Tireless Milling</th>
<th>Evermore Milling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter</td>
<td>(0.5 m filter at bottom)10 cm poles - 30 cm river sand - Hessian cloth - 10 cm cobbles</td>
<td>Gravel and stone covered with Hessian cloth</td>
</tr>
<tr>
<td>Capacity</td>
<td>24 tonnes of ore</td>
<td>Variable sizes</td>
</tr>
<tr>
<td>Reagents</td>
<td>- New batches are charged with 10 kg NaCN and 12 kg Caustic Soda (NaOH) - Soaked for 24 hours, then circulated with recycled 0.1% CN barren solution</td>
<td>Not reported</td>
</tr>
<tr>
<td>Process time</td>
<td>5-6 days</td>
<td>5-6 days</td>
</tr>
</tbody>
</table>

### CLARIFICATION OF PREGNANT SOLUTION

<table>
<thead>
<tr>
<th></th>
<th>Separate clarification tank</th>
<th>Separate clarification tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>(About 2.75 m)</td>
<td>no data</td>
</tr>
<tr>
<td>Depth</td>
<td>2 meters deep including filter (same as passive vats)</td>
<td>no data</td>
</tr>
<tr>
<td>Filter construction</td>
<td>• 10 cm poles • 30 cm river sand • Hessian cloth • 10 cm cobbles • Drain</td>
<td>no data</td>
</tr>
<tr>
<td>Process notes</td>
<td>Periodic raking of top of filter is necessary</td>
<td>no data</td>
</tr>
</tbody>
</table>

### CARBON ADSORPTION

| Type and dimensions of column or carbon cell system | Horizontal About 2.5m x .40m x .40 m Cells are about 40 cm cubed | Horizontal About 3m x .75m x .75 m |
| Construction                                                      | Appears to be fiberglass on steel frame | Concrete construction Flow through the bottom and overflows into the tank |
| Type of carbon                                                   | coconut                                    | coconut                                    |
| Size of carbon grains                                           | 2mm                                        | 5 mm                                      |
| Cost per kg                                                     | Not reported                               | Not reported                               |
| Manufacturer                                                    | Not reported                               | Imported in 120 kg containers             |
| Flow rate of pregnant solution through the carbon cells         | 25 Liters/minute                           | 25 Liters/minute                           |
| Loading of gold in carbon                                       | Avg. loading is 1000 g Au/400kg carbon (or 2.5 g Au/kg carbon) range 2-4 g Au/kg carbon (note: Literature says that the typical loading is 5-10 g Au/kg carbon) | Not disclosed |
| Loading rate (calculated)                                       | 2,500 g Au/tonne carbon /72 hours elution cycle at this mill suggests rate of 34 g Au/hr/tonne (Note literature says that typical loading rates are between 10-
<table>
<thead>
<tr>
<th><strong>OBSERVATIONS</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NAME OF MILL</strong></td>
<td>Tireless Milling</td>
<td>Evermore Milling</td>
</tr>
<tr>
<td><strong>ELUTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressurized</td>
<td>Yes (due to heating over 100 degrees)</td>
<td>Yes</td>
</tr>
<tr>
<td>Run time</td>
<td>72 hours</td>
<td>Needs 24 hrs minimum, but usually run for 48 hours</td>
</tr>
<tr>
<td>Size of vessels</td>
<td>Heating vessel: -1.3 m x 1 m—400 l Eluting vessel: -2 m x .75—600 l</td>
<td>Combined heating, eluting and electrowinning vessel ID 0.46 meters Height ~1.8 meters Volume 324 Liters 5 cm insulation Filled ¾ full Volume in overflow tank Not reported but may be 75 Liters (the tank itself appears much larger) 400 Liters solution including overflow</td>
</tr>
<tr>
<td>Materials</td>
<td>Stainless steel</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Size of batch</td>
<td>400 kg carbon per batch (400 kg is 800 l at bulk density of .5 kg/l)</td>
<td>60 kg carbon per batch</td>
</tr>
<tr>
<td>Recovery per batch</td>
<td>900-1200 g/batch (can be as high as 1500 g/batch)</td>
<td>Not reported</td>
</tr>
<tr>
<td>Reagents</td>
<td>40 kg Caustic Soda/batch = 40 g caustic/Liter 40 kg in reported 200 Liters of solution .2 kg/l No NaCN used in elution</td>
<td>25 kg Caustic soda/batch = 62.5 g caustic/Liter (if 400 Liters solution) [need to calculate volume and pore space of carbon] No NaCN used in elution</td>
</tr>
<tr>
<td>Evidence of mercury condensing during elution</td>
<td>None reported</td>
<td>Beads of mercury reported to condense on lid of elution vessel</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>Preheat to 110 degrees for 1 hour before circulation</td>
<td>115 degrees optimum --actual T ranges between 100-115 deg</td>
</tr>
<tr>
<td>Twelve 2 kW elements accessed from bottom of separate heating tank</td>
<td>Five 2 kW elements --only use 3 elements during run</td>
<td></td>
</tr>
<tr>
<td><strong>ELECTROWINNING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separate box: Reported 40 Liter capacity box Estimated dimensions 35 cm x 35 cm x 35 cm</td>
<td>Anode and cathode suspended in to of elution vessel</td>
<td></td>
</tr>
<tr>
<td>Pre-wash new carbon</td>
<td>yes</td>
<td>Not reported</td>
</tr>
<tr>
<td>Electrodes</td>
<td>2.5 V 150 amps (Note the US EPA (1994) states that the electrowinning potential was 2.5 volts at 250 A at Montana’s Golden Sunlight Mine.)</td>
<td>Not reported</td>
</tr>
</tbody>
</table>
### OBSERVATIONS

<table>
<thead>
<tr>
<th>NAME OF MILL</th>
<th>Tireless Milling</th>
<th>Evermore Milling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathodes</td>
<td>2 (top of box)</td>
<td>Perforated basket suspended within anode at top of elution vessel</td>
</tr>
<tr>
<td></td>
<td>1-2 kg steel wool wrapped on each cathode</td>
<td>About 2 meters of wool</td>
</tr>
<tr>
<td>Anodes</td>
<td>2 (bottom of box)</td>
<td>Tray surrounding basket at top of elution vessel</td>
</tr>
<tr>
<td>Form of recovered gold</td>
<td>sludge</td>
<td>sludge</td>
</tr>
<tr>
<td>Observations</td>
<td>Current process uses 40 kg Caustic Soda USD 25.20 (Sept 2007 at Rocke (Kadoma): Caustic costs about USD 0.63/kg NaCN costs USD 3.75/kg)</td>
<td>Mercury beads observed at seal of lid</td>
</tr>
<tr>
<td></td>
<td>Note: Using an alternative process like Zadra (2 g/l NaCN and 10 g/l Caustic) would cost 13.80/batch (10 kg caustic = $6.30 2 kg CN = $7.50)—this contradicts statements that Caustic Soda elution is cheaper than NaCN elution—further evaluation of alternatives is recommended.</td>
<td>Carbon is tested for gold content before stripping to enable operators to predict the amount of reagents and length of time to operate</td>
</tr>
<tr>
<td>Flow rate (bed volumes or volumes of carbon?)</td>
<td>(Note: Literature says that the flow rate is typically 2 to 4 bed volumes per hour)</td>
<td></td>
</tr>
<tr>
<td>RECOVERY OF GOLD FROM CATHODE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid and water washes yield a black residue called locally, &quot;calcine&quot;</td>
<td>Sulfuric Acid 95% dissolves wire wool (operators say this removes copper and silver) for 45-60 minutes</td>
<td>HCl used to dissolve wire wool; Wash 4x to remove HCL</td>
</tr>
<tr>
<td>Nitric Acid 95% (Operators say this removes one third of sulfides) for 45-60 minutes</td>
<td>Wash in Nitric to dissolve Copper and pyrites</td>
<td></td>
</tr>
<tr>
<td>-Wash with water 4 times, each time letting sludge settle to bottom, decanting water; repeat until the water is clean. -The settled black residue is called &quot;calcine&quot;</td>
<td>-Wash 3 times with water -The settled black residue is called &quot;calcine&quot;</td>
<td></td>
</tr>
<tr>
<td>RECYCLING OF CARBON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soak water for 24 hours in 400 l barrel</td>
<td>Wash with water after each use to remove lime</td>
<td></td>
</tr>
<tr>
<td>After 3 or 4 uses, soak in 10% HCl for 24 hours.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambiguously reported that carbon is washed in acid &quot;once a month&quot; and discarded after the 3rd acid wash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removal of organic foulants (grease,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No heating used; can be sent off site if necessary, however</td>
<td>Not an issue</td>
<td></td>
</tr>
<tr>
<td>OBSERVATIONS</td>
<td>Tireless Milling</td>
<td>Evermore Milling</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>NAME OF MILL</td>
<td>Tireless Milling</td>
<td>Evermore Milling</td>
</tr>
<tr>
<td>organic material etc)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removal of inorganic foulants</td>
<td>HCl reported as used to remove lime, and then later as not used.</td>
<td>Nitric acid is used to wash out residual Hg in Carbon</td>
</tr>
<tr>
<td>Residual gold in carbon after eluting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Literature says that the “Zadra” system (using 0.1 % NaCN and 0.5 % NaOH) leaves 40-45% of the gold in the carbon</td>
<td></td>
<td>Carbon is tested for gold content before disposal</td>
</tr>
<tr>
<td>SMELTING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>location</td>
<td>outside</td>
<td>outside</td>
</tr>
<tr>
<td>Doré</td>
<td>85-90% Au</td>
<td>85-90% Au</td>
</tr>
<tr>
<td>Fluxes</td>
<td>Borax, silica, salt peter</td>
<td></td>
</tr>
</tbody>
</table>
Appendix  4: Process control at Tireless milling Center

1. Collect a 750 ml sample of CN solution from the tanks
2. Add 1 teaspoon of Zn dust
3. Shake (solution turns grey)
4. Leave for 1 hour
5. The precipitate settles
6. Decant liquid
7. Dissolve the precipitate in 5 ml aqua regia
8. Put precipitate/aqua regia in crucible and heat on a fire until dry
9. Put 5 ml of HCl (95-100%) and boil for 1 minute
10. Cool and pour in test tube
11. Add 1 drop of Stannous Chloride--If the yellow solution turns black, then there is still gold in the tank
12. Continue to run tank for 1 more day and test again

Test solution color gets progressively lighter as gold concentration in the pregnant solution decreases. When the test is eventually colorless, the leach tank no longer contains leachable gold.
Appendix 5: Theatre for Development in Kadoma-Chakari

“NAKAI” - Play Synopsis
(by Styx Mhlanga)

Appendix 5 has been removed due to copyright restrictions. The information removed contains an unpublished play synopsis and scene outline of the play “Nakai” by Styx Mhlanga and emailed to the author of this thesis by Cont Mhlanga on May 15, 2006. The play synopsis identifies two families, the Tabengwas and the Ndebvudzewayas, in a fictional gold mining area in Zimbabwe. The Tabengwas are farmers whose land is overrun by artisanal gold miners, led by the gold dealer Ndebvudzewaya. The conflict between the two men dominates the story, but the love affair between their two children Nakai (Tabengwa) and Aringo (Ndebvudzewaya) eventually leads to a resolution of the families’ long-standing animosity. At the beginning of the play, Tabwenga unsuccessfully tries to drive the artisanal miners from his farm. Soon, Nakai realizes that she is pregnant, but an attempt to get her father’s blessing for her marriage with Aringo fails. Nakai leaves her father’s home and moves in with Aringo, who later becomes ill from exposure to mercury vapors during amalgam burning. Nakai also becomes sick and nearly loses their baby during delivery. Tabengwa regrets his harsh treatment of his daughter and after Ndebvudzewaya begins to improve the environmental practices at his mines, he blesses the marriage between their two children.
The scene outline summarizes Nakai’s 11 scenes:

1. A nightclub -- The two lovers dance a Jersulamea but are discovered by Nakai’s brother who threatens Aringo in an attempt to stop him from seeing his sister.

2. Tabengwa’s farm -- Tabengwa tries to make Ndebvudzewaya (Aringo’s uncle) and the gold miners leave his farm because of the environmental and human health problems they are causing, but he fails because Ndebvudzewaya has a legal mining permit. Importantly, Ndebvudzewaya argues that miners should be given a chance to make some decent money. The scene ends with Tabengwa threatening to call the police.

3. Nakai and Aringo alone together -- Nakai discovers she is pregnant, but Aringo reassures her, saying he can take care of everything, believing that their relationship will help resolve the families’ differences.

4. Tabengwa’s farmhouse – the Ndebvudzewayas offer to pay for damages due to mining degradation as well as the bridal purchase fee, or “lobola,” if Tabengwa blesses the marriage between his daughter and Aringo. Tabengwa however, angrily rejects the deal.

5. Aringo’s hut -- Aringo is burning a mercury-gold amalgam inside the hut with Nakai sitting nearby, knitting a sweater for the baby. After Ndebvudzewaya suggests that Aringo should look for another wife if Tabengwa continues causing trouble, Nakai is distraught. The cast sings a song that describes how painful it is to be in love when parents treat their children this way.
6. A short scene -- Aringo is talking and laughing with a friend who gives him a bottle of Vuka Vuka medicine, telling Aringo about how it can improve his performance in the bedroom.

7. Aringo’s hut – Nakai complains that Aringo’s sexual abilities have declined and she is frustrated with his excuses. When Ndebvudzewaya arrives to intervene, Aringo says his impotence might be due to mercury poisoning. Ndebvudzewaya, however, denies it is possible to become impotent from mercury exposure.

8. A short scene -- Aringo reveals that Nakai is in hospital, due to complications with the birth. The baby, however, is okay.

9. Hospital ward -- The doctor tells Aringo and his relatives that he suspects mercury poisoning led to complications with Nakai’s pregnancy because there were high levels of mercury in her hair, blood and urine. The doctor says there are no known cures for mercury poisoning. Tabengwa apologizes to Nakai for having sent her away, but holds Ndebvudzewaya responsible for not teaching the miners to take precautions with mercury vapors.

10. Tabengwa’s farm -- The cast sings a work song while Ndebvudzewaya while the miners reclaim old mining workings on Tabengwa’s farm by planting trees. Tabengwa and Ndebvudzewaya agree they are now relatives who need to live together peacefully.

11. Finale -- The cast sings a traditional wedding song to celebrate Nakai’s and Aringo’s marriage.
Appendix 6: Educational Cartoon by Levi Phiri – Scene From The Play “NAKAI”

Appendix 6 has been removed due to copyright restrictions. The information removed is a one-page cartoon containing 4 color panels illustrating the first scene in the play “Nakai” in which the protagonists, Aringo and Nakai, are confronted by Nakai’s brother who tells Aringo to stop dating his sister. The cartoon was designed by a Zimbabwean artist, Levi Phiri, for the Global Mercury Project in Zimbabwe in 2006, but never published.
Appendix 7: Schedule of Theatre Performances

<table>
<thead>
<tr>
<th>Date (2007)</th>
<th>Location</th>
<th>Size of Audience</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 21</td>
<td>Kadoma Playhouse, Grand Opening</td>
<td>200</td>
</tr>
<tr>
<td>March 31</td>
<td>Kadoma Sports Club, Women in Mining</td>
<td>200</td>
</tr>
<tr>
<td>April 1</td>
<td>Patchway Field</td>
<td>400</td>
</tr>
<tr>
<td>August 15</td>
<td>Botha Mine 1</td>
<td>500</td>
</tr>
<tr>
<td>August 16</td>
<td>Botha Mine 2</td>
<td>400</td>
</tr>
<tr>
<td>September 11</td>
<td>Cotton Research Beer Hall</td>
<td>600</td>
</tr>
<tr>
<td>September 12</td>
<td>Hoffmarie Farm</td>
<td>350</td>
</tr>
<tr>
<td>September 18</td>
<td>Riyon Mine</td>
<td>300</td>
</tr>
<tr>
<td>September 19</td>
<td>Patchway Mine</td>
<td>400</td>
</tr>
<tr>
<td>September 20</td>
<td>Alabama Farm</td>
<td>450</td>
</tr>
<tr>
<td>November 3</td>
<td>Mperani Mine</td>
<td>500</td>
</tr>
<tr>
<td>November 4</td>
<td>Rimuka Bus Terminus</td>
<td>2000</td>
</tr>
<tr>
<td>November 5</td>
<td>Rio Tinto Mine</td>
<td>1500</td>
</tr>
<tr>
<td>November 6</td>
<td>Waverly primary and secondary schools (mostly students)</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Final Show and Evaluation</td>
<td>Cancelled due to political and police pressure</td>
</tr>
</tbody>
</table>

**TOTAL AUDIENCE** | 8800