Tribute chromite mining and environmental management on the northern Great Dyke of Zimbabwe

Oliver Maponga and Benjamin Ruzive

Abstract

A combination of poor mining methods, waste storage and disposal systems, as well as the day-to-day activities associated with tribute and contract chromite mining are primarily responsible for environmental problems on the Zimbabwe Great Dyke. For instance, the unsystematic dumping of waste rocks in rivers blocks channels and results in flooding, which further sterilizes agricultural land and mineral resources. Erosion of these haphazardly located dumps causes siltation of water bodies and results in the dispersion of heavy metals in soils and watercourses. Vegetation growth on waste dumps is limited and constrained by the high pH levels from phytotoxic metals in soils, the lack of nutrients, poor moisture retention qualities of the mining waste and critical cation imbalances within dumps. This article attributes poor environmental management on the Dyke to poverty, a direct result of the nature of tribute agreements and output prices. Prices based on output targets are exploitative and undervalue labour and thus perpetuate poverty. By absolving claim holders from environmental liability, tribute agreements contribute directly to environmental problems. Thus, the incorporation of enforceable dual environmental responsibility requirements in contract mining agreements is needed to overcome this problem. This article recommends that, to break the poverty cycle, the primary cause of environmental mismanagement in the sector, miners need to be empowered through claim ownership and the enhancement of their capacity to negotiate prices with buyers of chrome.

Keywords: Chromite mining; Tribute mining; Environmental management; Zimbabwe; Revegetation; Environmental incentives; Social issues; Poverty

1. Introduction

Chromite mining on the Great Dyke of Zimbabwe is an integral part of the local and international metallurgical industry. Zimbabwe hosts 21% (930 Mt) of the world chromite reserve base and ranks fifth in both chromite production and world chromite ferro-alloy exports (South Africa’s Minerals Industry, 1999/2000).

Currently there are 131 chromite mines operating in Zimbabwe producing over 600,000 tonnes of ore and directly employing over 8,000 people. During 1999 officially registered chromite mines employed 13% of the total labour force in the local mining industry and contributed 3% to the total value of mineral output. Additionally, informal chromite mine operators employ a significant number of people. The export of ferro-alloys and ferro-silicon alloys by the sector generates direct foreign exchange earnings for the nation and provides important local linkages. Table 1 shows some salient features of the chromite mining industry in Zimbabwe between 1989 and 1999.

In addition to the direct benefits shown in Table 1, chromite mining has other important direct and indirect linkages with the rest of the Zimbabwean economy including the provision of raw materials to the ferro-chrome smelters, the generation of incomes in mining communities and the development of regional infrastructure in mining areas. The agricultural activities around mining areas are directly dependent of the prosperity of mining. Income flows from chromite sales have strengthened the linkages between agriculture and mining, as miners also engage in subsistence farming.
Numerous linear trenches and large conical and environmental scars from years of chromite mining include intrusions and dumping of toxic wastes still exist. Visible bodies, destruction of vegetation and animal habitats, visual including land degradation, erosion, siltation of water basic environmental problems associated with the sector and processing and the immense economic value generated, the northern Dyke. Mining town of Mutorashanga and other farming areas on economic multiplier effects on the Great Dyke, the nearby

The Great Dyke is a layered mafic-ultramafic igneous linear intrusion and hosts deposits of chromite, platinum group metals (PGMs) and base metals. It bisects the archaean granite-greenstone craton, trending NNE for more than 500 km. The width of the Great Dyke varies from 3 to 15 km (Figure 1) along its entire length. As noted by Worst (1960), the Great Dyke is not a true dyke in the strict sense but a series of linear boat-like structures, which are synclinal in transverse section with the igneous layering dipping towards the centre. Prendergast (1998) describes two major stratigraphic units of the Dyke to be the lower ultramafic rocks (ultramafic sequence) overlain by mafic rocks and the mafic sequence to constitute the major components of the Great Dyke. Dunites, pyroxenites, harzburgites and bronzitites dominate the ultramafic sequence, which is internally layered into cyclic units of repeated lithologies. The chromitite layers/seams occur at the base of each cyclic unit, with their thickness varying from a few centimeters to slightly over a metre. In the northern Great Dyke the chromitite layers hosted by the serpentinites range in thickness from 2 to 50 cm. The mafic sequence consists of gabbros, norites and olivine gabbros. Chromite layers do not occur in the mafic rocks. At and close to the surface, the dunites and pyroxenites are altered to serpentinites, with a hydrous assemblage of serpentine minerals and talc. Quartz, brucite, magnesite, calcite and various iron oxides constitute the rest of the alteration products of dunites. The lithologies change with depth from serpentinite, serpentinitized dunite to fresh dunite at depths of about 350 m, which varies with the degree of fracturing.

Geochemically, ultramafic rocks are enriched in heavy metal cations of nickel, manganese, chromium, cobalt and copper. Most of these heavy metals are present in the primary mineralogy of the chromite host rock and are later dumped on the surface and dispersed into the environment under appropriate conditions. Chromite is also economically concentrated in alluvial soils in the northern portion of the Great Dyke. Prendergast and Wilson (1989) observe that in Mutorashanga the deposits generally reach up to 60 cm in thickness with a chromite concentration between 3% and 40%. Beneath the alluvial soils the serpentinites are lateralized and contain economically recoverable amounts of nickel (Prendergast, 1998). The alluvial soils and nickelliferous laterites are derived from weathering of chromite-bearing serpentinites under tropical conditions. The laterites were once worked to recover chromite by gravity separation, and the stripped

<table>
<thead>
<tr>
<th>Year</th>
<th>Tonnes mined</th>
<th>Value Z$</th>
<th>% of total mineral prod.</th>
<th>Employment in sector</th>
<th>% of total mining employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>941,832</td>
<td>75,264,380</td>
<td>4.80</td>
<td>7828</td>
<td>13.0</td>
</tr>
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<td>6525</td>
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<tr>
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</tr>
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<td>75,264,380</td>
<td>2.31</td>
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</tr>
<tr>
<td>1994</td>
<td>516,801</td>
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<td>3.21</td>
<td>4978</td>
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<tr>
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<td>136,216,820</td>
<td>3.21</td>
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<tr>
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<td>516,801</td>
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<td>3.21</td>
<td>4978</td>
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</tr>
</tbody>
</table>


2. Chromite resources in Zimbabwe

The Great Dyke is a layered mafic-ultramafic igneous linear intrusion and hosts deposits of chromite, platinum group metals (PGMs) and base metals. It bisects the archaean granite-greenstone craton, trending NNE for more than 500 km. The width of the Great Dyke varies from 3 to 15 km (Figure 1) along its entire length. As noted by Worst (1960), the Great Dyke is not a true dyke in the strict sense but a series of linear boat-like structures, which are synclinal in transverse section with the igneous layering dipping towards the centre. Prendergast (1998) describes two major stratigraphic units of the Dyke to be the lower ultramafic rocks (ultramafic sequence) overlain by mafic rocks and the mafic sequence to constitute the major components of the Great Dyke. Dunites, pyroxenites, harzburgites and bronzitites dominate the ultramafic sequence, which is internally layered into cyclic units of repeated lithologies. The chromitite layers/seams occur at the base of each cyclic unit, with their thickness varying from a few centimeters to slightly over a metre. In the northern Great Dyke the chromitite layers hosted by the serpentinites range in thickness from 2 to 50 cm. The mafic sequence consists of gabbros, norites and olivine gabbros. Chromite layers do not occur in the mafic rocks. At and close to the surface, the dunites and pyroxenites are altered to serpentinites, with a hydrous assemblage of serpentine minerals and talc. Quartz, brucite, magnesite, calcite and various iron oxides constitute the rest of the alteration products of dunites. The lithologies change with depth from serpentinite, serpentinitized dunite to fresh dunite at depths of about 350 m, which varies with the degree of fracturing.

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soil has been accumulated into large waste dumps on the Dyke (Ruzive, 2000).

The Great Dyke’s economic potential for chromite, base and platinum group metals (PGMs) has been known since 1918 when the famous PGMs rich main sulphide zone (MSZ) was discovered (Prendergast, 1998). Today chromite is one of the major minerals mined on the Great Dyke in addition to PGMs. Precious metals (gold and silver) and base metals (copper, nickel and cobalt) are recovered as by-products.

3. Chromite mining: the tribute and contract system

Chromite mining currently covers the entire Great Dyke and is undertaken by large, medium, small-scale and artisanal miners. Two transnational corporations, ZIMASCO (formerly a subsidiary of Union Carbide) and Zimbabwe Alloys (a subsidiary of the Anglo American Corporation) operate the largest mines mainly on podiform deposits in the southern part of Zimbabwe. Tributors, cooperatives and individual
Contract chromite miners on the Great Dyke

The chromite production sector in Zimbabwe has three distinct layers of ownership, each with specific characteristics and responsibilities. Claim ownership represents the top stratum (‘rich layer’) and is dominated by the two large companies which own mineral-rights to a significant proportion of the mineral-rich Great Dyke. The second production layer in the chain is the tributors, made up of individuals, cooperatives and loosely defined groups and associations. The third layer, arguably the poorest of the three, is made up of contractors and sub-tributors and represents the ‘real’ producers. Tribute mining arrangements in Zimbabwe have to be understood within the context of events leading to the formation of chromite mining cooperatives in the mid-1980s. The decline in base metal prices in the mid-1980s occurred at a time when the Zimbabwean Government was enforcing minimum wage regulations and the elimination of the exploitative contract labour system within the mining sector. Chiwawa (1990) argues that these issues supposedly exerted pressure on company profits and they opted to retrench some full-time employees and terminate the contracts of part-time labour. Through negotiation, Government allowed the two companies, Zimalloys and ZIMASCO to retrench these workers. The retrenched workers were organized into cooperatives under the auspices of the Zimbabwe Mining Development Corporation (ZMDC). Cooperatives were to work on claims owned by the two companies and produce on contract. During its formative years, ZMDC operated an equipment hire and loan facility for cooperatives and also provided managerial advice.

Using a definition based on a combination of output levels, employment and mechanization, most chromite tributors in Zimbabwe can be described as small-to-medium scale (see Ghose, 1994 for various systems of classification of small-scale mining). These mines are generally characterized by low levels of mechanization and of labour-intensive mining and ore haulage methods. Basic tools such as shovels, picks and wheelbarrows are used for exploration, mining and mineral transportation. Thus, the lack of proper equipment is a major constraint in cooperative and contract mining operations and it reduces the distance that both ore and waste can be hauled, resulting in waste rock being deposited close to working areas. Also, mining is limited to shallow pits and trenches, where the host rock is soft and friable (Chiwawa, 1990). At greater depths, where the host rock is much harder, electric drilling machines and jackhammers are sometimes used by the better-equipped cooperatives, tributors and contractors. Analysts observe that poorly equipped tributors extract ore only up to depths of ten metres and abandon pits as ore becomes difficult to hoist, with manual means (Maponga, 1997). As a result ore located at greater depths is sterilized in these old trenches.

Although the smaller mines utilize lower levels of technology, tributors, cooperatives and individual contractors
exploitative in an environment where the stripping ratio is such an unfair pricing system. Basing prices on tonnage is economic environment characterized by high unemployment. Claim-owners and tributors received Z$590 (US$ 10.73) reportedly received Z$400 (US$ 7.27). Yet in both cases example, at one site on the Dyke, contract miners received to enhance living standards, producers accept any price. For who can easily collude, and because tributors are desperate for material of poor quality. Yet producers cannot sell the unwanted output to anyone else even where such a buyer exists. Thus, a rather restrictive supply contract typifies tribute mining agreements. The tribute agreements carry with them specific conditions and responsibilities for contractors, tributors and sub-tributors. For example, chrome tributors pay a 5% royalty to claim-holders and sell output exclusively to the grantors on the basis of prices set by claim-holders. These prices vary between the grantors and on the basis of: tonnage alone; tonnage and grade of ore; and set production targets. Since prices are set by the duopoly of claim-holders who can easily collude, and because tributors are desperate to enhance living standards, producers accept any price. For example, at one site on the Dyke, contract miners received ZS200 (US$ 3.64) per tonne of ore and at another they reportedly received ZS400 (US$ 7.27). Yet in both cases claim-owners and tributors received ZS90 (US$ 10.73) per tonne for ore sold to ZIMASCO and Zimalloys. An economic environment characterized by high unemployment (estimated at about 60%) provides fertile grounds for such an unfair pricing system. Basing prices on tonnage is exploitative in an environment where the stripping ratio is high, as this undervalues labour and intensifies exploitation. Time spent developing mining areas or sinking shafts is not paid for, as no ore is produced during this period. Yet if the same miners were company employees, they would be paid wages for similar work.

The tribute agreements bestow onto tributors or sub-tributors the legal responsibility to fill and compact mine openings; to conform with the Mines and Minerals Act and mining regulations; to dispose of tailings and residues; to obtain inspection certificates; and to fence off mined-out areas. Among other issues, the agreement describes what needs to be done to rehabilitate mined-out areas, yet it does not provide explicit details of monitoring methods to ensure compliance with the Mines and Minerals Act or other relevant regulations. The claim owner is absolved from any responsibility in the area of environmental management; his or her interest is limited to a certain minimum level of output.

As part of the agreement, some grantors provide technical assistance including equipment for hire to tributors, cooperatives and contractors. However, in the majority of cases, contract miners work on the basis of set production targets using equipment and methods at their disposal. The target output volumes set by claim holders determine minimum output which contractors, sub-tributors and tributors have to produce to maintain the contract. Otherwise they lose their contract to other miners.

In its current form, the tribute agreement entrusts the responsibility for environmental management to the tributor and limits the interest of the claim holder to output. The expectation is that tributors will conform to all regulations. This approach implicitly assumes that tributors have knowledge of their environmental responsibilities, of all the relevant acts and statutes governing mining and, that they are willing to comply. Although the system outlines responsibilities, it lacks incentives to miners to rehabilitate mining sites and does not have any specific penalties for non-compliance. Such loosely defined responsibilities are easily and knowingly violated by miners (Maponga, 2000). For example, the agreements expect tributors to take adequate steps to prevent any adverse effects to humans and animals from arsenic ores but provide no retribution for failure to do so.

The pricing system also has a bearing on the ability of miners to improve environmental performance and is at the centre of environmental problems in the sector. Because of the monopoly position of the buyers (ZIMASCO and Zimalloys), negotiated prices often disadvantage the producers, both contractors and tributors. For the so called contract miners (although most of them do not have any written contracts), prices paid for output are exploitative and take advantage of the high levels of unemployment in Zimbabwe. Contract miners are desperate for sources of livelihood and accept any prices offered by buyers.

Environmental problems in the sector can be directly attributed to tribute arrangements, the low prices offered

<table>
<thead>
<tr>
<th>Year</th>
<th>Total chrome output (t)</th>
<th>Production by large companies (t)</th>
<th>Production by tributors (t)</th>
<th>Proportion of tributor output (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>252,033</td>
<td>103,274</td>
<td>148,759</td>
<td>59</td>
</tr>
<tr>
<td>1994</td>
<td>516,801</td>
<td>237,047</td>
<td>279,754</td>
<td>54</td>
</tr>
<tr>
<td>1995</td>
<td>707,413</td>
<td>359,295</td>
<td>248,138</td>
<td>49</td>
</tr>
<tr>
<td>1996</td>
<td>743,434</td>
<td>261,636</td>
<td>441,798</td>
<td>59</td>
</tr>
<tr>
<td>1997</td>
<td>699,757</td>
<td>263,616</td>
<td>406,141</td>
<td>58</td>
</tr>
<tr>
<td>1998</td>
<td>653,479</td>
<td>248,422</td>
<td>395,057</td>
<td>59</td>
</tr>
<tr>
<td>1999</td>
<td>595,751</td>
<td>297,514</td>
<td>355,965</td>
<td>54</td>
</tr>
</tbody>
</table>

for output and the accompanying allocation of responsibili-
ties with regard to conformity to regulations. A system
enabling miners to receive reasonable or competitive prices
for output would allow accumulation of surplus income,
investment in better mining technology and conformity
with existing regulations. There is no mention of the legal
responsibility of claim-holders for environmental problems.
For instance, tributors are legally required to furnish produc-
tion details to the grantors on a monthly basis, yet no such
regulations exist on conformity to environmental responsibil-
dies, even after expiration of the tribute agreement.

In its current form, tribute mining is a way in which
the large resource-rich mining companies and individuals
minimize exploration and mining risks and costs by down-
loading these to tributors who further download them to
contractors. Miners bear the full risks and costs associated
with exploration and mining as producers pay only for
actual output. In a geological environment characterized by
a high stripping ratio and where payments are output-based,
labour employed for removing waste rock to expose ore is
not paid for. Also, while mining companies obtain tax credits
for exploration and other mine development costs, the tribute
system transfers these directly to underpaid producers. Thus,
the system results in an ever-deepening poverty cycle, as
tributors continue to ‘eat’ into their capital in order to remain
in production.

4. Mining methods and the environment

Mining activities, whether underground or surface, generate
more waste than product and thus environmental problems
from waste disposal are a permanent feature of the mineral
extraction processes. A high stripping ratio means a lot
more waste is generated from mining chromite than other
minerals.

Due to high costs and falling metal prices, the mining
systems on the Great Dyke have evolved over the years from
highly mechanized, deep underground operations to rela-
tively shallow workings. Deep mining by ZIMASCO and
Zimalloys extracted high-grade, thin and friable seams while
the shallow operations are confined to relatively low grade,
less friable but thicker seams (Prendergast, 1998). Mining
undertaken by tributors and cooperators is less mechanized
compared with deep mining, usually works at shallow depths
and thus moves smaller volumes of waste. The depth from
which the waste is extracted determines the physical and
chemical behaviour of the waste rock once on the surface.

Although when compared with small-scale gold producers
working the country’s rivers, chromite miners are relatively
environmentally friendly, their activities have an immense
adverse impact on the Dyke where they are concentrated.
The principal environmental problems from mining methods
used on the Dyke include surface disturbance, topsoil
removal, and removal of vegetation (deforestation) to clear
mining sites, for mine support, and for settlements. Stripping
of overburden is necessary to expose mineral bearing seams,
but at the same time it causes massive disturbance to the
land and hence the disturbance of lands is a major environ-
mental problem in both surface and underground mining
areas. Miners clear vegetation, the anchor of rock and soil,
to construct access roads and to open up mining areas. The
opened-up areas become easily erodible by both fluvial and
wind agents.

Figure 3. An abandoned trench overgrown with grass, Mutorashanga
Surface trenching, adit and winze are the common methods used by miners on the Dyke. Chromite outcrops are extracted using surface trenching up to depths of 10m using picks and shovels and at times explosives. It is thus not uncommon to encounter unfilled and ‘orphaned’ or abandoned trenches (some of them very deep) on the Great Dyke, as miners systematically abandon trenches and move to new mining sites in search of easier ore bodies to mine. These trenches, when overgrown with grass, are a serious hazard to other miners and to animals in the area. Figure 3 shows an abandoned trench overgrown with grass. Unfilled trenches disturb surface and underground water supplies through their effect on the water table.

The growth of villages around mining sites has exerted additional pressure on environmental resources in the area. Destruction of vegetation occurs continuously as miners harvest timber for mine support and for the construction of dwellings. Also, the nomadic nature of the mining activities results in a repetition of the environmental problems as miners shift from one location to another.

5. Waste disposal and the environment

The ways in which waste-rock is stored and disposed of during and after mining contributes to major environmental problems on the Dyke. Although rock waste in itself is not an environmental problem, its storage or disposal sterilizes agricultural and potentially mineral-rich areas. Indicators of poor environmental management on the Great Dyke due to waste disposal include: the inappropriate location of shafts that open into stream channels (see Figure 4); and the location of mine dumps on steep ground, as valley fills and along riverbeds. The dumping of municipal waste on unstable dumps in Mutorashanga is a new dimension to the problems of contamination of the biophysical environment. The haphazard external storage of rock waste destroys vegetation and retards any regeneration on the slopes of the Dyke.

Waste from both underground and open pit mining collects haphazardly into waste rock piles (dumps) located either close to the adits and shafts or farther away from ore draw points. These dumps are composed of material of varying sizes from fine silt-sized particles to boulders and range from small heaps with a few tonnes of waste to large conical or flat topped dumps covering up to 0.25 km² in aerial extent and hosting several thousand tonnes of waste rock.

The physical behaviour of the dumps through time and the subsequent environmental impacts can be extrapolated from types of dumps (Ruzive, 2000). Susceptibility of dumps to erosion, their interaction with groundwater and contribution to siltation also depends on morphology and location.

The material composition of a dump affects its density, cohesion, hydrological properties and its ability to support vegetation growth and hence stabilize erosion. Siltation of rivers is a common problem in Mutorashanga due to the washing of loose material from unvegetated dumps downslope. Figure 5 shows eroding dumps on the Dyke. Mining waste does not lie inert in the environment, but when exposed to elements, contaminants are leached out onto surface and underground water and this affects flora and fauna. The eroded sediment also disperses toxic heavy metals into river systems and these then endanger both wildlife and domestic animals in the area. Heavy metal contamination from chromium can also occur, and through bioaccumulation or buildup in tissue, can pass through the food chain to

Figure 4. Location of a mining shaft on the banks of a river channel
animals higher up the chain. Hexavalent chromium compounds have been reported to be carcinogenic to humans and animals and long exposure to chromium has been associated with gastro-intestinal disorders.

Sedimentation pollution due to erosion of dumps has caused severe flooding around the northern Dyke area. Studies in other areas have shown that sediments act as physical pollutants by changing the light, temperature and oxygen conditions in streams, conditions to which aquatic life has adapted over the years (Wild, 1965). Suspended sediments smother fish spawning grounds and reduce the oxygen storage capacity of streams and rivers. Thus, the pollution of water courses from mining activities devastates communities as it affects breeding areas of fish, a major part of the local diet. Acidic material deposited in the rivers also affects wild animals.

The haphazard dumping of rock waste causes aesthetic pollution and sterilizes agricultural land. It not uncommon to find dumps located on agricultural land, steep slopes and even in river channels (Figure 6). Unvegetated linear dumps
as remnants of chromite mining are a common occurrence on all sides of the Great Dyke (Figure 7).

6. Revegetation of waste dumps

Although it can be difficult to establish vegetation on metal-liferous dumps because of highly toxic metal content and sulphide weathering, vegetation cover represents the most economic and acceptable method of stabilizing mine dumps. Vegetation can form the basis for landscaping, stabilization and pollution control on mining sites after closure.

Vegetation grows naturally on waste dumps depending on their nature, especially the chemical composition of the waste rock constituting the dump which affects the acidity and alkalinity of soils. Both natural and artificial (assisted) growth of vegetation on dumps stabilizes these dumps and prevents erosion of loose material and subsequent siltation of nearby rivers.

However, not all dumps can be revegetated successfully whether naturally or artificially. For example, while some types of dumps on the Dyke are easily colonized by both grasses and woody species of plants (Figure 8), others do not naturally support vegetation growth due to the phytotoxic nature of serpentine soils characterized by high levels of chromium, nickel and cobalt (Wild, 1965, 1972; Brooks, 1987).

Revegetation of dumps is common on the Dyke, where miners cap dumps with a thick layer of soil and then plant easily vegetating grass. Trial dumps on the Dyke show a survival rate of about 70% of the planted grass (Ruzive, 2000). Natural succession usually enables perpetuation of grass on the dumps and pioneer plants create a pseudo-environment enabling other plants to colonize and stabilize the dumps. As can be seen in Figure 9, with time, new species of grass emerge on the dumps.

Vegetation growth is limited by the nature of soils on the dumps, and the costs involved (in money and time) are also a major constraint from the miners’ perspective. Also, miners are not under any serious obligation to provide resources for revegetation, as they are production oriented. For the miners, investing in environmental management programmes is an unaffordable ‘luxury’, as it has no immediate and tangible benefits to the small-scale subsistence miners.

The lack of prudent environmental management programmes on the Great Dyke is a function of many circumstances, including: the lack of financial resources; lack of willingness among miners; and a poor regulatory and monitoring system (Maponga, 1997). Poverty among producers stems from low prices paid to contractors and tributors (including cooperatives) by buyers of output (claim owners). This contributes to environmental problems on the Dyke and manifests itself as the never-ending cycle of environmental mismanagement. Because of low levels of mining and processing technology, output per unit of effort is low among miners and as such miners spend more time than is economically necessary to produce subsistence volumes of output for which they are paid uneconomic prices. The cycle of poor technology, low output, low prices and poorer technology is perpetual and self-reinforcing. Environmental planning is thus relegated to a peripheral position in the mining activities of tributors due to poverty.

The nature of agreements under the tribute system reinforces environmental irresponsibility on the Dyke due to
its exclusive emphasis on output as the basis of payment. Producers have no incentives to utilize time and resources on sustainable environmental management as this means reduced output and even lower revenue. Anecdotal evidence shows that miners are knowledgeable about ‘green’ mining, yet they choose not to do anything about causes of environmental problems. The lack of capacity in government agencies to monitor implementation of existing laws and regulations is a major contributing factor.

Day to day activities on the Great Dyke exacerbate the environmental problems emanating directly from chromite mining. For instance, the use of unvegetated dumps as municipal waste disposal sites by local authorities is another dimension to the environmental problems in Mutorashanga. Over time, the dumps could fail and municipal waste would find its way into the river systems and contaminate water, which is consumed by communities. Also, the emergence of mining villages without proper infrastructure has created...
environmental and social hazards on the northern Dyke. Although most mining areas on the northern Dyke have property controlled mining towns with schools, water and other infrastructure, numerous mining villages lacking such services have sprouted along some stretches of the Great Dyke. A host of social problems including prostitution and the breakdown of law and order are associated with such settlements, and these negative conditions impinge on the livelihood of miners, their health and the future of their families. Wood is the main source of fuel in these mining villages and this translates into accelerated harvesting of timber from naturally growing forests without replenishment. Also, trade in fuel wood with communities from nearby urban areas has increased on the Dyke, as enterprising miners attempt to supplement their meager mining income. Thus, many mining villages lack basic facilities such as clean drinking water, schools, and recreation, health and sanitary facilities. In some cases, mining communities draw drinking water from disused mine shafts, exposing communities to acidic minerals in the water. The lack of recreational facilities has resulted in the sprouting of an illicit (toxic) beer brewing trade within the villages. Miners are also exposed to serious occupational hazards due to the lack of proper protective clothing such as dust masks, hard hats and miners’ boots. Health and safety issues are peripheral and regulations are not adhered to despite the existence of the Mining (Management and Safety) Regulations of 1981, which stipulate these as mandatory requirements. Contract and tribute miners are not covered by any life insurance, despite working in an extremely unsafe environment where rock falls occur frequently. Worse still, there is no security, pension or medical coverage provided for miners.

The environmental issues highlighted in this article have to be understood within the context of the environmental management framework in Zimbabwe. Therefore to fully appreciate approaches available to deal with environmental problems in the sector it is instructive to review the Zimbabwean framework.

7. The mining and environment framework in Zimbabwe

The recent push by international organizations, including the United Nations and the World Bank, towards sustainable mineral resource extraction and utilization has put the environmental ‘imperative’ at the forefront of project development in Zimbabwe, but the country has historically had in place regulations, albeit fragmented, to deal with the effects of exploration, mining and mineral processing activities on the environment.

Maponga (2000) outlines the framework of seven acts and regulations, which govern mining and environmental issues in Zimbabwe. Besides its laws being fragmented, Zimbabwe lacks a central enforcing authority to monitor environmental interference associated with mineral exploration, mining and processing and ensure compliance with standards based on existing regulations. The drafting of the Environmental Management Bill (1998) represents a new thrust to consolidate these legislative pieces and align the country’s environmental regulations with the world best practice standards (Maponga, 2000).

Apart from the existing legal regulatory framework in Zimbabwe, the larger mining houses have also come up with their own ‘reasonably’ sound self-regulatory initiatives, which are in line with world trends (Maponga, 2000). These initiatives are formulated, implemented and monitored by the mining companies themselves in an effort to enhance their corporate image and credibility, and those of their parent companies, often transnational corporations of Australian or Canadian origin, where issues of environmental management are rather strictly enforced. Self-regulation complements legal and policy requirements such as completion of an EIA before development takes place. In most cases, self-regulation initiatives go beyond statutory requirements as they are driven by the company’s desire for a favourable international image. Yet these initiatives are no panacea for overcoming environmental problems.

As a signatory to conventions on sustainable development, Zimbabwe has moved ahead since the Rio Summit of 1992 to ensure that mining companies adhere to regulations and has even encouraged producers to adopt the best possible technology in their operations. Poor monitoring capacity remains the major limiting factor in these endeavours. Programmes such as empowering local authorities to monitor mining projects in their areas of jurisdiction testify to the Government’s commitment to greening the sector.

8. Improving environmental management on the northern Dyke — the way forward

After identifying the nature of environmental problems on the Dyke and the framework within which environmental issues are dealt with in Zimbabwe, it is instructive to outline possible methods to correct the sector’s environmental image and enhance long-term environmental and social sustainability. The approach suggested in this article encompasses legislative changes, the appropriate design and location of waste dumps, revegetation methods and empowering miners through a reform of the pricing and ownership system. The priority among the suggested recommendations should principally be to deal with poverty among miners, as it is the main underlying condition, engendering environmental problems on the Dyke.

8.1 Poverty reduction

Poverty is at the root of environmental problems in the mining sector in Zimbabwe. To enhance ecological sustainability, an approach is needed which improves prices...
paid for output, empowers miners financially and educates
them on the long-term benefits of ‘green’ mining.

The pricing system needs to be closely examined in order
to ensure competent environmental management. Enhancing
the capacity to negotiate for better prices among tributors
is one way to ensure high returns for output. Alternatively,
a revision of the claim ownership requirements enabling
small miners to own their claims would enable them to
negotiate for better prices. Alternatively, cooperative mar-
ket buying strategies (as adopted by the Lonmin group) could
empower miners to own their claims would enable them to
negotiate for better prices. Alternatively, cooperative mar-
tify as a unified force. Although this may be
difficult in the current economic environment where, ‘half
a loaf is better than nothing’, in the long run, miners would
be better off.

Another approach would be to push for an ‘environment-
ally’ sensitive price structure to include an environmental
rehabilitation cost element while maintaining the current
system. Local authorities would collect the levy and be
legally responsible for rehabilitation of mined areas. A sup-
portive legislative system empowering local authorities to
set and collect levies is needed, and this is currently limited.
The capacity within councils to rehabilitate mined-out areas
would need to be developed and supplied with all the neces-
sary material and manpower requirements. The levy would
enable authorities to monitor discharge into streams, dam
structures and slope stability well after mining operations
have ceased.

Community education programmes targeted towards
miners, and supported by grantors, could be developed.
Through such programmes, miners would be encouraged
to invest in self-regulation systems that would enhance
effective environmental sustainability, as miners would appreciate
the long-term benefits of good environmental stewardship.
Environmental capacity within local government institutions
has to be improved to prevent a situation where municipal
waste continues to be heaped on top of mining waste, which
seriously worsens the pollution problem by unstabilizing the
dumps.

8.2 Legal changes

Although not a panacea for success (in view of the Govern-
ment’s limited monitoring capacity), legal changes are re-
quired to improve environmental management of mine sites.
For example, mining dumps should be required by law
to be located away from streams, steep ground and ground-
water discharge areas. If locating a mine waste dump as
valley-fill is unavoidable, then appropriate drains should
be laid underneath and massive barriers constructed down-
stream to prevent the movement of waste rock. Drains
should be robust and sufficiently sized to handle storm flows,
and should go right through the base (from upstream to
downstream of a dump). Flat to gently sloping ground
should be preferred sites for dumps. The shape of dumps can
also help reduce erodibility and as noted by Ruzive (2000),
table and fan shapes are preferable for dumps as they are
easier to rehabilitate compared to other dump shapes. A
command and control approach with stringent requirements
for mine site rehabilitation reinforced by a penalty system
or a redeemable bond on successful performance would
enhance the sector’s environmental record. Site inspec-
tion by government officials should be mandatory for all
rehabilitated areas before a ‘release’ certificate could be
issued. For effectiveness, the system should include stringent
environmental standards and requirements from explora-
tion right through to mine production. Mine site rehabili-
tation agreements would be another environmental man-
agement approach to strengthen overall sustainability. In a
system with dual environmental responsibility, the granting
of new leases would be based on satisfying minimum envi-
ronmental performance standards with respect to previous
mining activities and, through this process, a culture of
responsibility would pass from generation to generation.

8.3 Diversion of streams

The diversion of streams to prevent rivers from undercutting
dumps should be a requirement in areas where topography
permits and where it is economically feasible for miners to dispose
of waste in old river channels. Alternatively, drains of similar
capacity, laid in the ground, could replace the blocked
streams and thus allow miners to use old river channels as
dumping areas. The surface of the former stream can then
be flattened to reduce slopes and ensure that the speed of
any run-off is reduced. Barriers can also be constructed on
the stream side of the dumps. Although costly, this would
certainly reduce the prospects of further erosion.

To reduce siltation from pumped water, special impound-
ments should be constructed to allow sediment to settle
before being discharged into the streams. This traps sediment
and also encourages seepage of contaminated water back
into the Great Dyke, rather than dispersing downstream. The
construction of sediment traps across the streams originat-
ing from the Great Dyke spaced strategically between the
dumps and the Dyke-granite contact would provide important
breaks. Such dams serve as ultimate sinks for the eroded
sediment from the dumps, and their size should be such
that the stream flow patterns are not significantly affected.
The sediment traps should be constructed in a manner that
allows periodic scooping of the accumulated sediment
back onto the dumps. A regular surface water-monitoring
programme, to respond to any disaster that might occur,
should support these measures. Modeling of water quality
emanating from sites, waste rock and tailings dams could assist in minimizing potential disasters.

Effective waste rock management techniques are needed, in order to minimize contamination. Those approaches that isolate rock piles from natural elements and allow for reclamation after mining are most effective. For example, location of waste rock piles away from watercourses is a simple but environmentally sound approach. The diversion techniques described earlier would reduce possible contact with water. Topsoil, subsoil or overburden could be used as dump cover. Another optimal approach involves the use of free-draining material to prevent the upward movement of toxic material during dry periods and allow vegetation to establish itself. Transplanting mature metal-tolerant-plants onto dumps also increases the survival rate (Maponga, 2000).

An optimal revegetation strategy for the dumps should create conditions supportive of the growth of appropriate plant species, usually those that can survive the harsh soil conditions on the dumps. Vetiver grass is known to have the potential to survive on the rehabilitated dumps and therefore should be the preferred grass type (Truog, 1999). Direct seeding has been observed to work on non-toxic waste. Topsoil, subsoil or overburden could be used as dump cover. Another optimal approach involves the use of free-draining material to prevent the upward movement of toxic material during dry periods and allow vegetation to establish itself. Transplanting mature metal-tolerant-plants onto dumps also increases the survival rate (Maponga, 2000).

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In order to enhance regeneration of vegetation on dumps, miners should be encouraged to strip and stockpile topsoil and then replace it onto stockpiles of waste at the end of the dumping cycle. Although a costly process and one for which miners receive no direct payment, its long-term benefits are immense as it supports vegetation growth. Covering dumps avoids (reduces) toxicity by providing suitable depth of covering material into which the chosen vegetation can root and develop satisfactorily before reaching the toxic waste. Topsoil, subsoil or overburden could be used as dump cover. Another optimal approach involves the use of free-draining material to prevent the upward movement of toxic material during dry periods and allow vegetation to establish itself. Transplanting mature metal-tolerant-plants onto dumps also increases the survival rate (Maponga, 2000).

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Also, miners should be encouraged to include local grasses and plant species in their revegetation programmes. Local plants may grow faster than exotic plants. Appropriately designed dumps can assist vegetation growth; for instance, shallow dump slopes create optimum conditions for infiltration and thus prevent erosion while enhancing plant growth.

The discussion in the preceding section on technical approaches to dealing with environmental issues on the Dyke requires financial resources to revegetate, divert streams and even conform to regulations. Thus, poverty reduction or eradication is at the core of challenging environmental problems on the Dyke. Economic empowerment of tributors through a competitive price structure would enhance environmental sustainability.

9. Concluding remarks

Many of the environmental problems on the Great Dyke are the result of poverty among miners. To overcome this, tribute agreements need to be revised to improve prices paid to producers and a system with dual responsibility for both tributors and grantors in environmental management has to be developed. Joint legal liability of tributors and grantors for rehabilitation of mined areas, revegetation of dumps and diversion of streams would enhance compliance.

Modification of the current tribute system to improve adherence with current regulations by compelling grantors to monitor tributors’ environmental management programmes and ensure compliance with all regulations including the filling of old workings, open surface workings and excavations and fencing off old trenches would strengthen the sector. The investment into best possible technology to minimize environmental damage should be encouraged through appropriate tax incentives. Tax credits could entice claim holders to rehabilitate mined-out claims, or at least encourage tributors to rehabilitate them, provided that such credits did not subsidise environmental degradation.

The move to an incentive-based environmental management system for both tributors and claim holders may help overcome weaknesses inherent in monitoring compliance. Grantors should be encouraged through appropriate incentives to provide technical assistance in the planning of mining operations and waste disposal systems. The levy approach suggested in this article would be another way to control environmental contamination from the sector.

A pro-active and progressive environmental management legislation to reward conforming grantors would be required to enhance the effectiveness of the proposed approach. Properly defined monitoring requirements and a system of penalties for punishable violations would support this. Alternatively, a licensing process which requires miners to submit rehabilitation plans with authorities would help reduce the number of ‘orphaned’ mines and trenches. The system of licenses should be based on environmental performance and should require organized small-scale miners to submit sound business plans that include prices paid to rehabilitate them, provided that such credits did not subsidise environmental degradation. The levy approach suggested in this article would be another way to control environmental contamination from the sector.

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