Presented at the Colloquium: Sustainable Development in the Life of Coal Mining, Boksburg, 13 July, 2005

POST-MINING REHABILITATION, LAND USE AND POLLUTION AT COLLIERIES IN SOUTH AFRICA

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ABSTRACT

Coal mining in South Africa is a mature industry and there are large numbers of closed collieries in the country's major coal fields. The state in which these collieries have been left varies greatly from best practice closure to abandonment, with most collieries in the latter category having closed some time ago. Today, the large multinational mining companies that dominate South Africa's coal sector apply scientific methods in surface rehabilitation and take steps to mitigate future pollution from closed mine sites. The socio-economic impacts of closing collieries are also recognised and companies participate in local economic development initiatives and integrated planning frameworks to reduce the dependency of local communities on mines before closure.

The challenges faced in closing coal mines should not be underestimated. The reactive nature of coal and its associated strata and the high level of surface disturbance result in potentially significant pollution problems which may persist for many years after mining has ceased. Methods exist to rehabilitate the surface and to ameliorate pollution, but the long-term success of these interventions depends on the nature of post mining land uses. There are instances where coal seams have been illegally re-accessed by artisanal miners after a mine has closed or where rehabilitated land has been inappropriately utilised by farmers. This may create water pollution, spontaneous combustion and severe safety and health hazards. In other cases, mines awaiting closure certification effectively sterilise surrounding coal measures as these cannot be accessed if such mining will potentially disturb the rehabilitated mine. This state may persist for years before a final closure certificate is issued.

Successful closure must consider medium to long term post mining land use and, critically, land capability. This paper reports on experience at selected South African collieries and draws conclusions regarding future optimisation of post-closure land use.

1. INTRODUCTION

Historically, when a coal measure was exhausted, production ceased and collieries were boarded up and abandoned. Today it is accepted that mine closure requires the return of land to a viable post-mining use, such as agriculture. It is not even sufficient to simply physically reclaim mined lands anymore as the socio-economic impacts of the closure must also be assessed and managed.

Challenges associated with mine closure are acute in mature mining countries: the number of operating coal mines in South Africa has declined by almost half, from 112 in 1986, to approximately 65 in 2004[1] (Mohring *et al.*, 2001; Phillips, pers. comm., 2005). The safety, environmental and social risks arising from badly conducted mine closure can result in significant liabilities for mining companies. For communities, closure can cause severe distress because of the threat of economic and social collapse. Abandoned mines may result in large clean-up costs and closure liabilities for governments (World Bank, 2002).

Diversity of species is a key characteristic of natural ecosystems. These ecosystems, in turn, form the basis of all ecosystem goods and services upon which sustainable livelihoods and food security depend. Historically, the mining sector has not recognised this, and mining activities have often resulted in destruction of, or radical alterations to, whole ecosystems. In such cases, full recovery of these ecosystems and their components may take many years, possibly even millennia (Cooke, 1999). Consequently, the impacts on the biophysical environment caused by the mining and minerals processing industry have frequently been accompanied by a significant loss of biodiversity. This may pertain even when a mine is rehabilitated after closure. Current best practice attempts to avoid negative impacts and, where necessary, to restore impacted environments. This is an essential step if the sector is to contribute significantly towards sustainable development in the region (Hoadley *et al.*, 2002).

South African legislation governing mine closure, particularly the Mineral and Petroleum Resources Development Act (28 of 2002), requires rigorous mitigation of both biophysical and socio-economic impacts. Before this Act, closure was governed by the Minerals Act (Act 50 of 1991). The Minerals Act provided a basis for environmental management for the first time, and prior to its passing into law, many mining companies "*used irresponsible mining methods with no regard towards protecting the environment and had often shirked their responsibility towards environmental rehabilitation by leaving an area unrehabilitated prior to them being liquidated or leaving the country*" (Swart, 2003). Mine closures before 1956 were not subject to legislative closure requirements and are now the responsibility of the State.

[1] Mine closure is an important reason for the reduction in numbers of operating mines, together with the ongoing consolidation of the domestic industry, in the form of mergers and acquisitions. Since the 2000, a number of new mines have been brought into production through Black Economic Empowerment initiatives.

Witbank: Spontaneous combustion, subsidence and acid mine drainage as the legacy of poor closure practice

At the old, abandoned Transvaal and Delagoa Bay colliery (T&DB), in Witbank, sink holes associated with *in situ* combustion of coal are evident. Bare patches are present around the sinkholes and gases are vented to atmosphere. The operation closed before rigorous closure practice was common and the former owners are no longer traceable. Rehabilitation of the site, now the responsibility of the state, may cost up to R100-million (Witcomb, pers. comm., 2001). The colliery began operating towards the end of the 19th century. Fires soon started, but were controlled while the mine was operating. Since closure in 1953, the fires have been out of control and in 1995, flames could be seen above ground. The 750 ha colliery site lies between the township of KwaGuqa and the industrial area of Ferrobank. Footpaths crisscross it, passing close to burning areas. Underground fires are not the only problem at the site. Acid water decants into the nearby Brugspruit. A R30-million treatment plant has been established treat this water but there are doubts about its effectiveness.

Figure 1. Water pollution arising from T&DB, an abandoned coal mine near Witbank.

Figure 2. Surface collapse due to abandoned burning workings at T&DB.

2. A Brief Overview of Colliery Closure Practice

Post-mining regeneration priorities for South Africa, in the light of the county's developmental context, include:

- restoration of land surface of sufficient quality to support pre-mining land use potential,
- restoration of the ecological function of mined land and in the case of previously degraded land, the ecological function must be improved,
- efficient alternative use of mine infrastructure should be encouraged where this can be economically justified; where no economic alternative uses exist, mine infrastructure must be removed and the site rehabilitated to pre-mining condition,
- Southern Africa in general, and South Africa in particular, experiences water shortages and therefore minimisation of current and potential future impacts on water quality and supply is imperative,
- job creation through education and stimulation of economic activity,
- development projects to enable equitable participation in post mining economies by all members of the community, especially marginalized groups,
- enhancement of leadership capacity within the community and local government may be required to ensure that development continues post closure,
- skills and literacy training for community members,

(Cooke & Limpitlaw, 2003).

3. RESTORING LAND CAPABILITY ON MINED LAND THROUGH REHABILITATION

3.1 Land Capability

Land use is a decision to be made by society. Land use can be changed – society can decide to change the land use on a rehabilitated colliery from crops to housing or industrial estates, but mines have an obligation to ensure that no net loss in land capability occurs. This must be the primary objective in rehabilitating mined land. Where land capability is not preserved, society is deprived of choice. Degraded lands can potentially support fewer land uses – no crops, for instance. Some argue that agreements with communities regarding land use can be made prior to rehabilitation whereby a lower quality of rehabilitation is acceptable. This may occur, for example, if the pre-mining land capability is arable, but the community are satisfied with grazing as a post-mining land capability. Such decisions, even when based on community preferences, do not promote sustainability. Soil formation takes thousands of years and, by only restoring a fraction of the original land capability, future generations are deprived of the choices that are available to this generation.

In many instances, the pre-mining environment consists of a biodiverse grassland of varying agricultural potential[2]. Through the rehabilitation process, land is returned to low levels of biodiversity as rehabilitation programmes preferentially use commercially available seed, with high nutrient and water requirements. Through over-fertilisation, grass monocultures are promoted, preventing the re-establishment of biodiverse pastures. For example, a commonly used rehabilitation grass, *Eragrostis sp*., secretes a hormone from its roots prohibiting the germination of other seeds. This problem has been detected by environmental audits in many rehabilitated colliery landscapes. Once the high input regime, established during the rehabilitation programme ceases, after five years or so, the grass cover often deteriorates.

Mono-specific grasslands and pastures are not able to sustain economic grazing systems because of their dependence on one grass species that has high input requirements. Current research is attempting to address this by monitoring grasslands established with greater species diversity. Such grasslands are expected to create better summer and winter grazing compared to the current situation where good grazing is only available in summer. The sustainability of grasslands is also largely dependant on the re-establishment of natural controls and a gradual removal of high-intensity interventions. It is practically very difficult to re-establish natural controls on grasslands, such as grazing, during mining and so the challenge unusally falls to the post-mining rehabilitation period. While this is the best way to get land back into natural mode, it is not often achieved as the transition is frequently too abrupt.

Preservation of land capability can only be achieved by carefully managing resources. In re-establishing land capability, topsoil is a key resource. Many old collieries have only

[2] Deep soils generally have high agricultural potential while shallow soils have low potential.

rocky surfaces available for revegetation. Such surfaces can never be used for intensive crop production.

Soil losses on rehabilitated lands are currently not fully appreciated as the effects may be latent for several years after rehabilitation is complete. Even where slopes are steeper than 1:5, soil loss only becomes evident after between 10 and 15 years. This loss is followed by the failure of rehabilitation and erosion. Salt migration upwards through rehabilitated surfaces is also a significant problem, especially in discard dumps. Where the soil cover is less than 200 mm, salts can migrate to the surface and impact on re-established vegetation. Where soils are thicker, clay accumulation layers may occur where salts precipitate between 300 and 500 mm from the surface.

Up until recently, mines have not been very successful in returning prime agricultural land to its pre-mining productivity, especially in rehabilitated areas associated with large open cast mines. This arises in part from a lack of understanding of the influence of soil depth on vegetation sustainability – replacement of thick layers of topsoil is not necessarily a recipe for crop success, as was previously thought. Compaction caused by machinery during the rehabilitation process is a factor, as is the possible hardsetting nature of soils when moved wet. Rehabilitation may be more prone to failure on compacted deep soils than on compacted shallow soils as, in the latter, plants are able to extract water from the underlying spoils which do not compact readily. Red soils, with a clay content of less than 28%, are common on the Highveld and are highly compactable when replaced during the rehabilitation process. This is especially true if the soils are moved when they have a soil moisture content in excess of 10%. The rehabilitation process often, unwisely, uses graders to smooth off rehabilitated surfaces to achieve a pleasing aesthetic landscape. The high bearing load on the wheels of this machinery promotes soil densification. Plant roots cannot penetrate such dense soils and water in underlying spoils cannot be extracted.

Although a compacted soil profile may contain soil water at field capacity, the inability of the roots to penetrate deeply into these soils means that the stored water is unavailable for plant growth. Under such conditions, one metre of soil is replaced, but only half a metre is available for growth. Even deep-ripping of re-emplaced soils has proved ineffective. Hard setting follows the first rains after deep ripping due to the lack of organic materials and microbes in the soils. This arises in soils stored too long, due to a lack of aeration, reducing the likelihood of crop re-establishment on previously mined land.

3.2 Post-Mining Land Use

A serious post-mining problem experienced at collieries in South Africa is the misuse of rehabilitated land by the new owner or lease holder. Farmers have, in some instances, heavily overgrazed land and then blamed the mine in an attempt to access government compensation. This type of misuse is commonly associated with rehabilitated land that is leased out. Farmers frequently see such mining land as inferior and attempt to extract benefit from it unsustainably – a typical case of the *tragedy of the commons*. To combat this, careful post closure land use guidelines need to be agreed with government departments, land users and mining rehabilitation practitioners.

Historically, mines have been poor record keepers of agricultural performance (e.g. mines seldom have records of nitrogen levels in rehabilitated soils). With heavy use, nitrogen levels drop off dramatically, reducing the carrying capacity of the land. At closure, agricultural records must be available. These will provide a detailed assessment of performance of the land. Such assessments can be used to create guidelines for land use, promoting certain uses and discouraging others. As mines should not be held responsible in perpetuity for post-mining land use, Government extension officers have an important role to play when transferring previously mined land to a new owner. Such extension officers should ensure, through an ongoing auditing and monitoring system, that conditions governing the use of rehabilitated land are followed by the new land user.

3.3 Latent Impacts

Sustainable rehabilitation of dumps is a huge challenge. These are not geologically stable landforms and in addition to the problems experienced by other rehabilitated surfaces, soil erosion is a critical factor on dumps. Even on flagship dumps, preliminary soil loss modelling suggests that on steep slopes (steeper than 1:5), the soil cladding will have been eroded and coal will be exposed at surface within 50 years. Field observations have shown that a dump in Mpumalanga lost between 30 and 40 mm of its 300 mm thick soil cladding in just four years while, in KwaZulu-Natal, dumps with slopes steeper than 1:4 have lost about 150-200 mm of soils in 12 years.

Erosion is also not uniform over the dump surface. Through rilling and gulleying, erosion proceeds at an exponential rate on some parts of the dump. Once coal discard is exposed, oxidation, acid burn and salt burn kill the vegetation cover, accelerating soil loss. This may lead to further acid generation, spontaneous combustion, increased permeability and groundwater pollution.

Subsidence is a problem that has not received adequate attention. The impacts of land subsidence have not been felt as originally predicted by models. Many board and pillar sections are between 50 and 60 years old and experience indicates that serious subsidence will only occur after between 100 and 120 years. As the old, closed sections age, mass subsidence may occur due to pillar runs and the collapse of whole areas.

A truism is that all underground excavations will collapse over time and pillars will spall. Where these excavations are near surface, ratholing and subsidence will follow. Even where such excavations are not very shallow, as in Springs on the East Rand, sinkholes have propagated 65 m up to surface (Stacey & Page, 1983).

Water impacts have also not been as severe as predicated at many closed sites. This may be due to the fact that many old mines are still not full of water. Experience indicates that mines that have ceased production less than 20 years ago have not yet reached a steady state where water starts to decant. The complexity of the mine’s hydrology and geochemistry may result in decant running acid at first and then becoming neutral. Other mines decant when only a portion of the mine remains flooded and the effluent runs acid or alkaline and can stay that way indefinitely. Geochemical reaction kinetics are very complex and serious water pollution problems may arise long after closure.

Coal left in pillars and dumps will stay a resource which may become viable depending on market conditions – rehabilitated sites that contain coal will potentially be re-accessed. Closure is thus only a certainty when all coal is depleted. This impacts on strategies for a catchment-wide water quality management. Great care is thus needed when specifying costly water management measures for defunct collieries.

4. PUBLIC-PRIVATE PARTNERSHIPS TO ADDRESS POLLUTION FORM OLD ABANDONED MINES

Many abandoned mines cause water pollution in the form of acid or saline drainage. In The Brugspruit catchment, where some of the earliest mining in the Witbank coal field took place, is particularly affected by acid mine drainage. It is estimated that up to 35% of the salt load to the Loskop Dam is from abandoned mines (Waygood *et al*., 2001). The legal situation of the abandoned mines is not always clear, with uncertainty about the ownership of the surface and/or mineral rights. Mining companies have therefore been hesitant to become involved in the rehabilitation of these mines, as there is concern that they may end up with a liability that was not of their making.

There exists a need for the formation of public/private partnerships to address these legacies of the past. The rationale for this is that operating mines are often in a far better position to address pollution issues from an abandoned mine than either the government or other private business interests. This is because operating mines have the required skills, infrastructure and equipment established and readily available. In addition, from the viewpoint of economic efficiency, it may often be more cost effective for a mine to mitigate pollution from an abandoned mine than to mitigate pollution originating at its own operations. This might be, for instance, because the operating mine causes diffuse pollution, which is expensive to mitigate, while the abandoned mine is an easily controlled point source. If this is the case, and provided that the salt load taken out of the system is equal to, or greater than, that the mine would have to address from its own diffuse source, then mitigating the impact of the abandoned mine would be more economically efficient. It makes little difference to downstream users where pollution is mitigated, as long as they experience the result of this mitigation. It would therefore be beneficial to the environment if pollution mitigation was freely transferable from one party to the next, as market forces would ensure that the party that can most cost effectively mitigate pollution will do so (at the highest profit). However, before this scenario can be realized, legislation needs to be put in place, which will allow industry to address pollution at abandoned mines without running the risk of being saddled with unrelated liabilities.

A similar and parallel argument can be made for the right to discharge polluted mine water, like the system established in the Hunter River Valley of New South Wales. Here, a number of mines and power stations have established a market for transferable discharge permits, which allows participants to sell or buy permits to discharge polluted mine water in the Hunter River, under certain conditions (EPA – NSW, 2001). In the Witbank and Middelburg Dam catchments the controlled release scheme has been in operation since 1996/97. The scheme, under the management of the Department of Water Affairs and Forestry, uses the assimilative capacity of the river system in times of high flow. Participating mines and power stations are allowed to discharge polluted mine water proportional to the assimilative capacity of the system and proportional to the mine's share in the scheme. Or by way of a simple example, if the assimilative capacity of the system, over a 24 hour, period is 100 tons of salt load and Mine "A" has a 10% share in the scheme, then Mine "A" will be allowed to discharge 10 tons of salt load over the 24 hours under consideration. This scheme could be converted relatively easily into a market system similar to the one operating in the Hunter Valley (Lodewijks, 2002).

One of the opportunities of such a scheme would be the inclusion of abandoned mines, which, by necessity, would be issued with discharge permits. If a party (a mine or a power station, or even a private person) mitigates the discharge of an abandoned site, then that party would take over the discharge permit issued to that site and could then use the permit for its own purposes, or sell it to the highest bidder. This will only work, of course, on the assumption that there is a cost difference in the mitigation of the abandoned site and some other site that is forced to apply mitigation. This cost difference would drive the market for transferable permits, while at the same time improve the environmental quality of the catchment.

The principle of transfer of mitigation liabilities can be extended to other spheres of sustainable development. It has been very successfully applied in the control of air pollution in the United States since the 1970s. Recently a mine, whose operations negatively affected a wetland, was given a mining license on the condition that a historically degraded wetland in the same catchment, of a similar or greater size was rehabilitated. Similar mechanisms are conceivable for such widely differing fields as biodiversity or community development.

5. INTEGRATED CLOSURE PLANNING

As part of a global review of good practice in mine closure, Cooke and Limpitlaw (2003) interviewed a range of stakeholders in the minerals sector to determine the current level of practice in South Africa. One of the key elements of good practice in current post mining site regeneration and closure that emerged from this exercise was the need for a holistic approach to closure planning. Such an approach should include the following elements:

- an assessment of the economic viability of the plan including the funding of post closure care and maintenance,
- inclusion of the closure plan as part of broader regional economic and development plan,
- relevance to the skills profile of area and local community buy-in to the plan,
- post-closure land capability targets and related land use option(s) identified from the outset (pre-mining) with review during the operational phase of the mine, and
- an avoidance of creating a culture of dependency in the local community.

Community consultation is of critical importance. During consultation expectations should not be raised to unrealistic levels and any excessive community focus on compensation must be carefully managed[3].

Biophysical aspects of closure that are emphasised in South Africa include:

- making the mine site safe,
- physical and chemical stability, and
- ensuring that there is no future pollution.

Potential risks relating to future water uses is a specific concern, especially when previously mined land is transferred to a new land owner(s).

6. CONCLUSION

Effective mitigation may require new approaches to mine design, for example, some old mines open pits have sufficient surface area to evaporate all water make and never decant. Consequently, they have a minimal impact on ground water quality. Opencast mines should be designed to achieve this objective.

The age of mine abandonment is thankfully past and rehabilitation of mined land is now the norm. Serious challenges remain, however, as rehabilitated land is not always returned to a land capability equivalent to its pre-mining state. This can only be achieved by careful management of soil resources, promotion of biodiversity and management of latent risks post-closure. Even where these actions are undertaken, poor post-closure land use practices can quickly degrade the rehabilitated surface.

To promote effective management of old collieries, Government extension officers must become more involved with the stewardship of rehabilitated lands. This effort may be bolstered by creating a system of tradable pollution permits whereby active mines could offset their pollution loads by participating in the rehabilitation of abandoned mines, without assuming liability for those sites.

Ultimately, an integrated approach to closure planning is required whereby joint action of stakeholders – mining companies, Government and communities – assume responsibility for the long term sustainability of closed collieries.

7. REFERENCES

Cooke, J.A. & D. Limpitlaw (2003) *Post-Mining Site Regeneration: Review of Good Practice in South Africa*, unpublished report for the Global Mining Consortium, Global Centre for Post-Mining Regeneration, Cornwall, UK.

[3] The ICMM community tools project is useful in this regard (www.icmm.com).

EPA – NSW (Environment Protection Authority of New South Wales) (2001) *Proposed Protection of the Environment Operations (Hunter River Salinity Trading Scheme) Regulation 2001*, Environment Protection Authority, Sydney, Australia.

Hoadley, E.M., D. Limpitlaw & A. Weaver (2002), *Mining, Minerals and Sustainable Development in southern Africa*, Vol. 1, MMSD southern Africa, Johannesburg, South Africa, 77 pp.

Lodewijks, H. M. (2002) *The application of transferable permits for the control of saline effluent from coal mines and power stations in the Loskop Dam catchment*, Unpublished mini-dissertation towards a Masters degree in Environmental Management, University of the Free State.

Mohring, R. P., H. R. Phillips, P. M. Morgan, C. J. Grobbelaar, J. M. Stewart & M. van der Riet (2001) South African coal related research and development, 2000/2001, *Country Report to the International Committee for Coal Research*, Prepared by the South African ICCR Delegation, *26th ICCR meeting, Strasbourg (France), 23-24 October 2001*.

Phillips, H.R. pers. comm., (2005) Head of School, Mining Engineering, University of the Witwatersrand, Johannesburg, Tel. +27-11-717-7403, e-mail: Phillips@egoli.min.wits.ac.za

Stacey, T.R. & C.H. Page (1983) Coal, Chapter 5 of *Engineering Geology of South Africa – Vol. 3: The Karoo Sequence*, ed. A.B.A. Brink, Building Publications, Cape Town, South Africa, pp 116-150.

Swart, E. (2003) The South African legislative framework for mine closure, *Proceedings of the Colloquium on Mine Closure for Sustainable Development*, South African Institute of Mining and Metallurgy, Johannesburg.

Waygood, C., K. van der Velde, K. Pigott & N. Naidoo (2001) *Assessment of Abandoned and Defunct Coal Mines within the Loskop Dam Catchment, Excluding Those in the White Paper*, Jones & Wagener Consulting Civil Engineers (Pty) Ltd, Sandton, Draft report commissioned by the Department of Water Affairs & Forestry, Pretoria.

Witcomb, A., pers. comm., (2001) Environmental Engineer, Golder Associates Africa, awitcomb@golder.co.za

World Bank (2002) *It's Note Over When It's Over: Mine Closure Around the World*, Mining and Development Series, World Bank and International Finance Corporation, 19 pp.