'CLOSURE MINING' – Introducing a new concept for environmentally responsible development

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In this exclusive article, Prof Anthony Turton of the Centre for Environment, University of the Free State, introduces the concept of 'closure mining' as a solution to the environmental pollution legacy of the mining sector in South Africa.

South Africa is currently facing a challenge from three different drivers, all of which are strategically important. Firstly, we are transitioning into a water deficit situation in which all future economic growth and development will be constrained if we continue with the business as usual approach. Secondly, we are entering a period of our national development in which environmental risks are likely to increase exponentially, in response to various drivers (including the two mentioned here).

Thirdly, we are transitioning from a mining-based national economy to a future, as yet ill-defined beneficiation type of economy, in which the environmental externalities of the

past 120 years of resource extraction will increasingly present as constraints to job creation, social stability and global competitiveness. This opinion piece will unravel this complex bowl of spaghetti by offering a solution in the form of Closure Mining.

THE RISE AND FALL OF GOLD MINING

In all of recorded human history, a staggering 40% of the gold ever produced comes from the Witwatersrand Goldfields. The production cycle of gold is shown in Figure 1.

From this dataset a number of elements are evident. The most important is the steep rate of decline from the peak in 1970, interrupted by a brief respite in 1994/5 as we transitioned to a democracy. More important is the existence of three discreet sub-cycles, each representing different phases of technological development in the industry.

The first phase, peaking in the 1930s, was driven primarily by mechanical engineering as shallow underground operations (< 800 m below surface) were rolled out. The second phase, peaking in 1970, was driven primarily by geophysics capable of understanding the behaviour of rock under extreme pressure at depths of up to 3 000 m below surface. The third phase, peaking in 1995, was driven by improvements in metallurgical processes now capable of recovering residual gold from tailings dams. Working in unison, these three sub-curves generate the overall production cycle, which is now in a phase of dramatic decline, with catastrophic collapse in the near term future all things remaining equal.

STRATEGIC RISKS ARISING FROM THE LEGACY OF MINING

Why should we be concerned about this in the water sector?

The answer to this is complex, so let us try to unravel this bowl of spaghetti. What most non-mining people do not realise is that there are certain fundamentals on which the industry has been predicated. Arguably the most significant of these is that tailings (mine spoil or residue from the extractive process) have been deposited in vast quantities across the landscape.

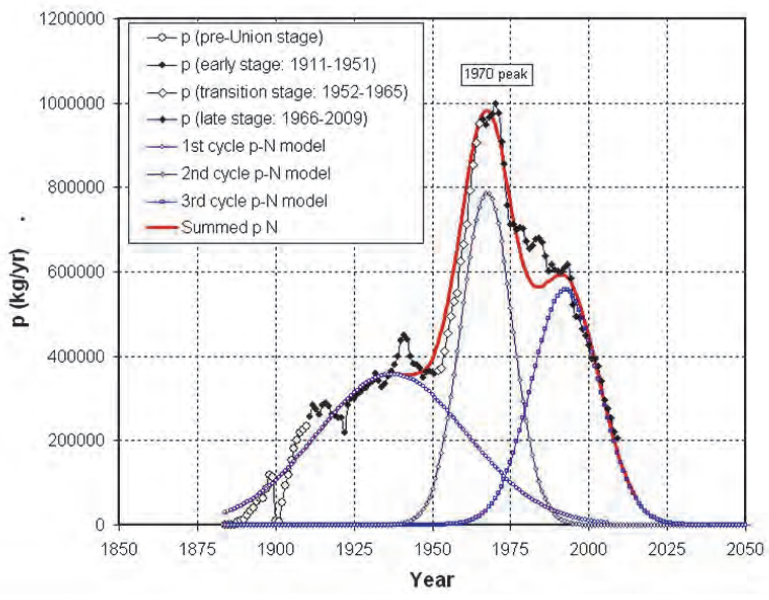

Figure 1
South African gold production life cycle. (Source: GDARD)

When initially deposited more than a century ago, most of these dumps were in the barren Highveld, far away from any human settlement. More importantly, these tailings piles consist of finely milled quartzite with the consistency of talcum powder. As such there is limited structural integrity to the dumps, which consist of a series of outer bunds created by pumping slurry into piles and then allowing that to dry. This creates a progressive ring around the base of the dump, much like a levee constructed to channel a river.

Once this outer levee is dry enough, the inner portion is filled with wet tailings, which slowly dry out as water is either evaporated off the surface or infiltrated into the ground. This process is repeated many times, resulting in the characteristic step-sided flat-topped structures we know today. However – and this is the big risk factor that will increasingly become relevant as the industry collapses – this shape is inherently unstable, so structural stability can only be assured if there is a continuous cash flow to pay for the constant maintenance needed to plug the gaps caused by erosion.

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This is the first strategic risk we need to understand. The structural integrity of mine tailings dams is 100% dependent on the continued existence of machinery to maintain the step-sided flat-topped profile. When the machinery goes the dumps simply collapse.

The second fundamental risk that needs to be understood is that these dumps are rich in uranium and a host of heavy metals, all of which are currently bound up in an increasingly unstable structure. For every ton of gold mined since 1886, between 10 and 100 t of uranium has also been brought to surface, depending on the reef band being mined at the time. In fact the combined mine tailings dams in the Witwatersrand Goldfields contain a staggering 430 000 t of uranium in various forms, all about to be released as the dumps start to

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Illegal miners or 'Zama Zamas' are becoming an increasing problem in South Africa.

collapse when the last remaining mining companies become insolvent, as they most certainly will in the next decade (unless they do things differently).

The third strategic risk we need to understand is the presence of uranium, about to be released into the environment in vast quantities, as dumps fall into disrepair and succumb to the erosion forces of wind and water. This is virtually a 100% certainty if we continue on the same trajectory and fail to implement a comprehensive mine closure strategy that simply does not yet exist in any coherent format.

The fourth fundamental risk is that all of the land from Randfontein in the west to Springs in the East that follows the Main Reef is structurally unstable. The reason for this is that a complex array of surface striking reef, roughly adjacent to the Main Reef Road, has all been undermined by historical mining activities, and now increasingly by artisanal miners known as Zama Zamas. We thus has a swathe of land, almost 100 km long and 2 km wide, passing south of the city centre, that is the only land left to develop, but is actually unfit for human habitation because of the absence of structural integrity.

The fifth fundamental risk is that this swathe of land is being settled both formally and informally. A study done in 2011 for Gauteng Department of Agriculture and Rural Development indicated that around 1.6 million people were already living on this land and that number is growing exponentially.

The same study made it clear that doing nothing was an extremely high risk strategy, proposing instead a formal policy that either moved the people from the hazard, or the hazard from the people. This policy has never been formally adopted by the Gauteng legislature, so people are settling on this land in an uncoordinated manner. This is a ticking time bomb.

"Outcome of closure mining is a rehabilitated landscape and functional ecosystem capable of supporting humans and other species."

The sixth risk is that of acid mine drainage (AMD), which we now know is generated mostly on the surface in these tailings dams, infiltrating into the void via multiple ingress points. Work in progress is showing that rain with a pH of 3 is failing on the flat topped tailings dams, triggering the acidification process as the hydroxide coating of the quartzite particle rich in pyrite is oxidised.

AMD is thus closely associated with tailings, but given that these tailings are uranium rich, also becomes a hazard for wind borne dust. The seventh risk is therefore the growing probability of dust-borne fallout of uranium over an as yet ill-defined footprint of land being drained by rivers and wetlands.

The eighth risk rapidly becoming a large blip on the radar screen is that of artisanal miners. As the gold industry collapses, so more Zama

Zamas are being encountered, and it is now probable that there are as many artisanal miners as there are legal miners. Closely associated with this activity is organised crime as explosives are used for ATM bombings and processed gold is swallowed up into sophisticated money laundering syndicates. A recent turf war between two rival Zama Zama gangs in the Florida area saw mass killings underground.

This is a taste of things to come. From an environmental perspective, these artisanal miners use mercury to concentrate their gold and this enters the atmosphere and aquatic ecosystems.

CLOSURE MINING AS A POTENTIAL SOLUTION

Closure mining can be defined as the deliberate long-term planning to optimise all mining-related processes and operations with a view to aligning the final outcome with the broader interests of society, in collaboration with all key stakeholders in a post-mining future, guided by the triple bottom line associated with sustainability reporting. The outcome of closure mining is a rehabilitated landscape and functional ecosystem capable of supporting humans and other species, while mitigating all legacy issues to the extent that they no longer act as constraints on future socio-economic development.

This is nothing more than an adaptive response by the mining industry and is actually in the best interest of society as well. The process is being tested in an experimental sense in the Western Basin and is shown schematically in Figure 2.

In simple terms, the low grade, high-volume tailings recovery is made economically viable by the high grade, low-volume ore from the extraction of surface striking reef. In the process, AMD is neutralised and the landscape is cleared of surface dumps. The void is closed out as are ingress points for water and entry points for artisanal miners. The land is ultimately rehabilitated to a standard that is fit for purpose, which has to be defined through a visioning process, also designed to build consensus about the overall benefit of the process.

As an experiment in progress three constraints have been identified to the successful implementation of this model. These are:

- Absence of a coherent body of technical knowledge to inform the rehabilitation of mine-impacted ecosystems.
- Absence of a post-closure vision capable of driving consensus around the need for rehabilitation and the standard to which rehabilitation needs to comply with.
- Absence of an institutional arrangement capable of engaging the many parties needed for a successful outcome.

CONCLUSION

If the business-as-usual model prevails, then the gold mining industry will collapse in the next decade, with a high level of certainty. This will have a devastating effect on the ecosystems of the Witwatersrand Goldfields, unleashing a deluge of uranium over the landscape, while triggering a wave of illegal mining activity that will be virtually impossible to police or regulate. Increasingly, angry people will turn on the government as their houses succumb to the geotechnical instability associated with construction on undermined land. Closure mining can prevent this, but it can only be done if consensus is built between all parties that the final outcome is indeed desirable for society as a whole.

If adopted as a strategy, then an environmental catastrophe of unprecedented magnitude can be averted. The recent events unfolding in the Western Basin do not bode well for this, however, so the prognosis for success seems tenuous at the time of writing. What we need is leadership of the calibre of the Gene Kranz, Mission Controller for Apollo 13, who said to his team that failure is not an option, when confronted by an unanticipated catastrophe. Should this type of leadership emerge, then Johannesburg need not be called the most uranium contaminated city in the world.

Watch Prof Anthony Turton talk at the TedX Table Mountain event earlier this year: http://youtu.be/VTr0QpOxyWY ❑

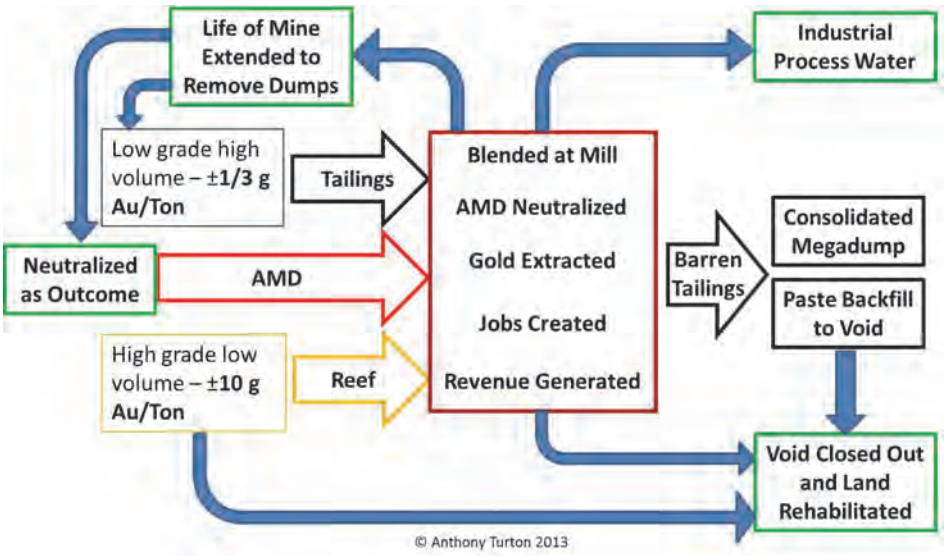

Figure 2
Schematic representation of the concept of closure mining as being refined in the Western Basin.