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Spoils Handling from Coal Mines in the Waterberg Coalfield Area, South Africa

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Abstract The Waterberg Coalfield is estimated to host about 40% of South African coal resources. As the demand for energy in South Africa increases in the coming years, the coal produced from this area will prove essential as well as increasing the water demand as development continues. Acid rock drainage poses a big threat on water resources, for both ground and surface water. During mining operations the open pit will be backfilled with plant discards, overburden and intraburden spoils consisting of sandstone, mudstone and shale. The oxidation of iron sulphides (Pyrite (FeS_2)), present within the discard dumps and stockpiles can influence the hydrochemistry, by generating acid rock drainage, while siderite ($FeCO_3$) within the lithological units can have a basic effect to the immediate surroundings. Static and kinetic acid base accounting showed over 35% to 50% of the samples have an excess of acid potential, this classified the samples as having a higher risk for acid generation. About 30% to 40% of the samples have a higher neutralising potential, the rest of the samples have a medium risk to generate acid. The management plan for the acid generating spoils of the area has two possibilities. Firstly where acid producing potentials are higher, spoils should not be used where it will be exposed to oxygen and water for long periods of time, as the amount of acid generated cannot be controlled. A second option would entail the immediate compaction and flooding of the mined area so that the amount of acid produce will be controlled and limited. This may be a problem in the Waterberg due to the low rainfall with less water ingress, which implies that water will have to be channelled to the area.
Keywords waterberg coalfield, acid base accounting, spoils handling, backfill.

Introduction

The main aim of this study was to identify the appropriate handling of spoils from the overburden, intraburden and plant discard that will be removed and placed on the discard dumps and possibly used as backfill material based on acid base accounting. The findings of this study are discussed under the proposed handling of the spoils. Acid base accounting is used as a prediction tool to determine the acid potential of the lithological units.

The 11 coal-bearing zones in the Waterberg coalfield are mined in benches and handled according to their intended use (fig. 1). There are two main coal-bearing Formations in the Waterberg (Jeffrey 2005) these coal zones extend from the Volksrust formation into the Vryheid formation. Vermeulen et al. (2011) described three main categories identified by Bester (2009) based on the weathered geology from the area. Fig. 2 shows the three categories, green for full successions, yellow for Middle Ecca and pink where the area has been weathered in parts.

Acid-base accounting

In order to assess the various acid and neutralising potentials of the material sampled from various sections in the study area, acid-base accounting (ABA) tests were performed. ABA according to Usher et al. (2002) is a first-order classification procedure only, during which the acid-neutralising and acid-generating potential of rock samples are determined and the difference, also known as the net neutralising potential (NNP), can be calculated. The method only indicates the overall balance of acidification potential (AP) and neutralisation potential (NP) and is in its most basic form, merely a screening process. The static test provides a rough indication of the acid generation potentials of the various lithological units. Kinetic testing is done over a 20 week period and helps to establish which of the samples are prone to produce acid by exposing it to water and oxygen and to establish the rate of constituent leaching.

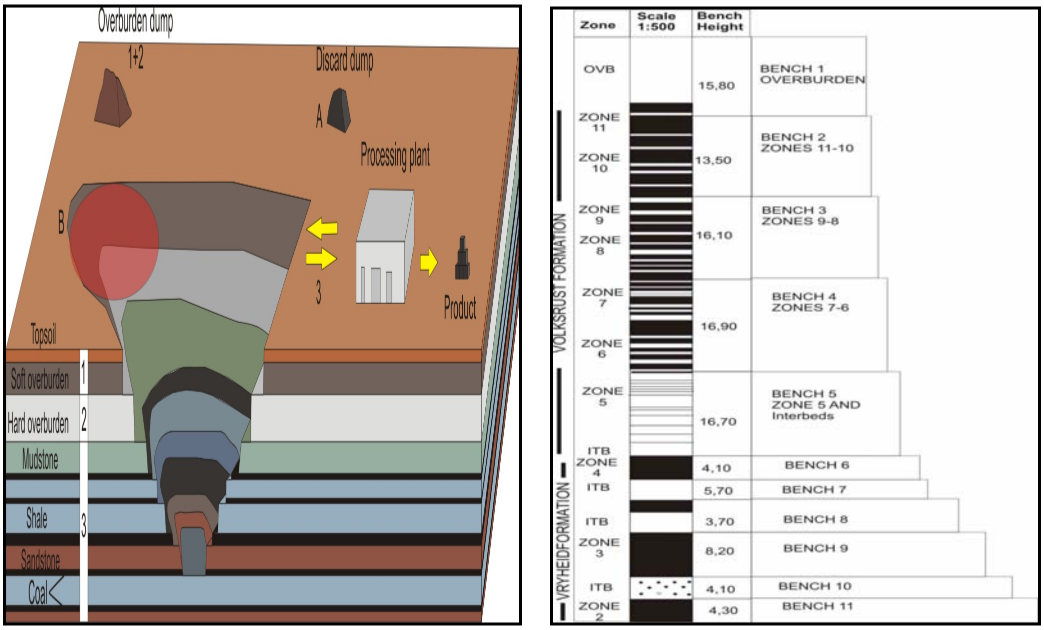

Fig. 1 *Open cast mining in the study area illustrating the waste generated at various phases during mining (Left);Stratigraphic column with the lithological units and benches mined in the Waterberg Coalfield (Right). OVB- overburden and ITB- interburden (Dreyer 1999).*

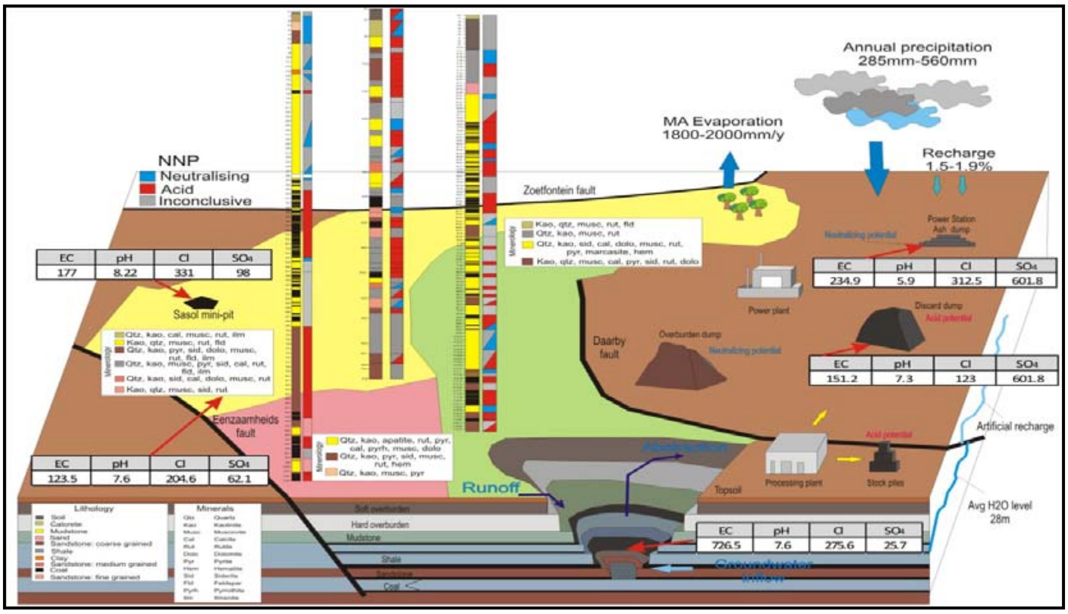

Fig. 2 *Summary of the acid and neutralising potential of the various contributing factors over the extent of the study area.*

The ABA and kinetic tests highlighted the lithological units that are prone to turn acidic or poses a neutralising potential. The geological units with a dominant base potential above the coal units included calcrete and sandstone. These units typically consist of quartz, kaolinite, muscovite, calcite, dolomite, rutile and feldspar. The minerals identified within the mudstone and shale units included quartz, kaolinite, muscovite, pyrite, hematite, marcasite and calcite. A summary of the geological logs, the minerals within the units as well as their acid and neutralising potential, are indicated in fig. 2.

Spoils Management

Spoils consist of mined overburden and noneconomic mineral deposits removed during mining operations. The composition of spoils vary greatly depending on the area, depth and lithology where mined. Backfilling methods must in general fit in with the mine design. The type of backfill that is going to be used is also usually identified during the design stages.

The plant spoils have a high propensity towards spontaneous combustion due to their high carbon content. The inter-burden material is very prone to combustion due to its carbonaceous nature. The major problem associated with such a large quantity of waste is the safe storage and disposal in a way that will prevent the occurrence of fires. Table 1 shows the waste production from the Grootegeluk Mine in the study area.

Table 1 *Waste material produced by Grootegeluk Mine (tons per annum) (Adamski, 2003).*

Material	Production (Mt/year)	Volume (Mm^3/year)	RD	Ash (%)	CV (MJ/kg)
Overburden	12.29	6.83	1.8		
Discards	17.32	9.12	1.9	71.88	5.88
Inter-burden (B7A & B8)	5.28	2.93	1.8	77.76	2.53
Inter-burden (B10)	1.72	0.91	1.9		
Total	36.61	19.79	1.85		

The spoils/discard that needs to be handled are mixtures of discards from various plants and waste from benches with unknown properties. The lack of detailed knowledge about material properties complicates the design of a "safe" heap. The chemical and physical properties of the different materials and mixtures were considered to be prerequisite for a safe waste dump/heap design. One of the main concerns at the mine is the reaction of coal when exposed to oxygen and the release of heat. The age of coal is an important factor, as the reactivity depletes with time. One of the most important factors contributing to spontaneous combustion is particle size.

Spoils are compartmentalised from different mined benches as seen in fig. 3, back into the mined out pit. It is important to cover the slopes within a 8 week period as well as the surface of any stacking level before 3 months to prevent the spontaneous combustion of the exposed material. Slope stability was determined at an angle no greater than 22º for both sides of the backfill.

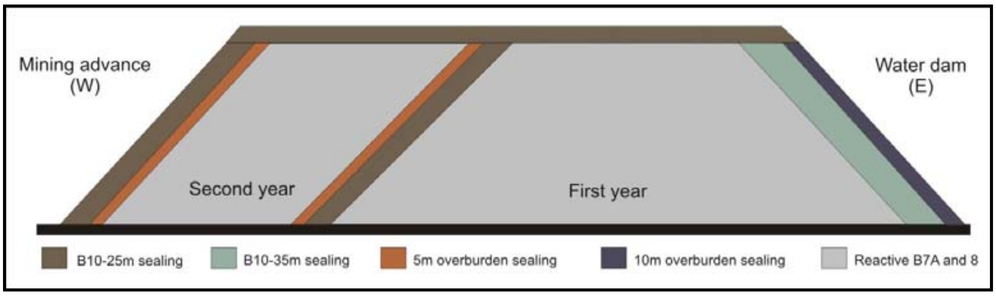

Fig. 3 *Second year compartment of inter-burden benches 7A and 8.(Redrawn from Adamski 2003.)*

There is a need to dispose large amounts of colliery waste or spoil in such a manner that the least amount of damage is done to the surrounding environment. About 80% of waste is dry or solid spoil and usually tipped on site close to the pit head. The other form of waste generated is a wet by-product during the washing of the coal. The main environmental effects of these processes include visual intrusion, loss of land, noise and dust from vehicle movement during tipping of dry waste, and potential water pollution. The various activities have an immediate visible effect on the local area but the effect can be much deeper. Placement of backfill is one of the tools used in managing voids, created during mining processes and reduces the cost and impact of a separate waste disposal site or process.

Proposed handling of spoils

The layered option proposed by Adamski (2003) which is the current means of backfilling at Grootegeluk Mine, has the lowest long-term environmental risk for water impact. It reduces ARD rates and leaches alkalinity into underlying acid generating discard material.

Backfilling with overburden directly into the opencast pit would not acidify, but rather neutralise the surrounding area. The groundwater system would not be influenced in a negative way. In the event of heavy rain and infiltration, no acid would be produced nor be introduced into the system. Backfilling with only interburden has a high possibility of acid production that would reach the groundwater system. In favourable conditions (exposed to oxygen and water), the interburden would generate acid over a longer period of time. The quantity and quality of the interburden material is not suitable to use as filler alone in the pit.

The management plan for the acid generating spoils, based on the static and kinetic ABA of the area, provided two handling possibilities. Firstly where acid producing potentials are higher, spoils should not be used where it will be exposed to oxygen and water for long periods of time, as the amount of acid generated cannot be controlled. The spoils also have the potential to spontaneously combust and thus need to be compartmentalised at a fixed width, sealed to reduce oxygen ingress and covered within eight weeks. A second option would entail the immediate compaction and flooding of the mined area so that the amount of acid produce will be controlled and limited. This may be a problem in the Waterberg due to the low rainfall with less water ingress, which implies that water will have to be channeled to the area. This would become rather costly and would also need to be controlled as the mining is a continuous process.

Conclusions

The following main conclusions were made:

Chemical and biological processes play an important role in the production, release, mobility, and attenuation of contaminants in ARD waters. The rate of oxidation can vary depending on the accessibility of air, moisture and microbes to the Pyrite surfaces. The type of mining and mineral processing plays a part in the initiation of the acid mine waters in the mining environment, and the methods that are employed have to be used in connection with the appropriate remediation and treatment to minimise the generation of ARD. Neglect to these factors can cause ARD problems that will be hard to control once it has begun.

The ABA results determined that the interburden and discards used as backfill material has a potential to generate acid. This includes the composite samples with various densities from the processing plant. While overburden material has a neutralising potential. The ABA illustrated that the shale and mudstone samples have both acid and neutralising potentials and the majority of sandstone samples beneath 60 m have a distinct acid generating potential.

The composite material can be used as backfill material within the pit. It only becomes a risk upon exposure to oxygen and water. The Waterberg area has a relatively low annual rainfall, high evaporation and deep groundwater levels, thus the risk to produce acid from infiltrating water is limited. The risk of exposure to oxygen leads to the spontaneous combustion of discard material.

The process of mining and beneficiation, stockpiling of coal, coal products and waste is an important factor in management practice, as it makes the environment and water more vulnerable to degradation. More care should be taken in understanding and managing exposed rock or waste piles, which creates paths for pollution migration. It is also important to understand the physical characteristics of the mine waste/stockpiles such as permeability and weathering, which play a role in accelerating the process of ARD. Prints of mismanagement, neglect and a lack of knowledge have left areas with abandoned mines with ARD issues.

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