

# **The Effects of Spontaneous Combustion on Safety, Health and the Environment at New Vaal Colliery**

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## **SYNOPSIS**

Spontaneous combustion is a well-known but still poorly understood phenomenon in most coal mines. The fact that an increasing number of opencast mines are starting to mine coal on a large scale from seams previously mined by underground means has increased the risk of large scale coal fires as occurred at New Vaal Colliery. Stricter occupational health and safety regulations with greater enforcement and increased public awareness makes it essential to have practical solutions to the problems associated with spontaneous combustion. This paper provides simple, practical solutions and highlights the importance of a participative approach in identifying and solving safety, health and environmental problems associated with spontaneous combustion.

## **INTRODUCTION**

New Vaal Colliery is an Anglo Coal mine, a division of Anglo Operations Limited which is a wholly owned subsidiary of Anglo American plc. New Vaal Colliery is an opencast strip mine, which is situated on the banks of the Vaal River some 70 km south of Johannesburg. (Figure 1). The mine supplies 15,12 million tons per annum low-grade steam coal to the nearby 3600 MW Lethabo Power Station which is operated by the national electricity supply commission, (Eskom).



**Figure 1**  
**Location of New Vaal Colliery**

The lease area, known as Maccauvlei East, forms part of the Sasolburg coalfield and contains three economically viable coal seams of the Vryheid formation. All three seams have been previously mined by underground bord and pillar methods. In total 51 million tons or 7% of the reserves were mined but in surface area this covered over 70% (Figure 2). The underground colliery mined in this area from 1931 until closure in 1969 and was well known for its occurrences of spontaneous combustion. After closure the old mine workings were flooded and all access shafts sealed off. Opencast operations started in 1983 with the first coal produced in 1985 from the virgin coal area alongside the river on the eastern boundary.

New Vaal Colliery is different from other opencast operations in South Africa in that it is situated alongside a major strategic river and is surrounded by a major conurbation, which has greatly focused attention on environmental management.

## **FACTORS AFFECTING SPONTANEOUS COMBUSTION**

A number of factors affect the ability of coal to spontaneously combust.

### **Rank**

The lower the rank of the coal, the more susceptible it is to burning. New Vaal's coal is generally of a low rank. Oversusceptibility tests of the coal at the University of the Witwatersrand have shown, using the Differential Thermal Analysis Test, that New Vaal's coal results were high in terms of susceptibility to combust. These results are not absolute but relate to other South African Mines on an index called the WITS-EHAC liability index. The middle seam coal seam at New Vaal has the highest Wits-EHAC value of all coal seams tested in South Africa (Appendix 1).

### **Air flow**

To create an environment in which spontaneous combustion can occur there must be a supply of oxygen. This is provided by the numerous openings into the old workings such as: the old workings exposed by mining the strip, geological drill holes, blast holes



**Figure 2**  
**The areas where underground mining was carried out**

which penetrate the old workings and the blasted material voids. These openings provide airflow and thus supply the oxygen needed for spontaneous combustion.

### **Pressure differences**

The normal seasonal barometer pressure changes plus the pressure changes due to dewatering the underground workings ahead of mining provide a steady flow into and out of workings which encourages combustion.

### **Weathering**

Highly weathered coal tends to be more susceptible. The top seam has undergone a high degree of weathering where it occurs directly beneath the sand and is therefore more prone to combustion.

### **Water and surface moisture**

It is estimated that there was over 30 000 megalitres of water in the old workings. 23000 megalitres was pumped there by the Water Board. The remainder has flowed into the workings via fissures, faults and dykes. The extent of the water is illustrated in Figure 3. The presence of this water assisted in the prevention of spontaneous fires after the underground mine closed. Dewatering of the workings has created conditions conducive to spontaneous combustion since the coal became exposed to oxygen. Pressure differentials draw air into the workings. The coal was moist due to the high humidity within the air and heated due to the release of the latent heat of condensation and chemisorption effects.

### **Physical conditions within the old workings**

Poor roof conditions, which are due to the closeness of the present opencast operation, exist. The roof has collapsed leaving cavities in the roof and this has allowed carbonaceous interburden to fall into the voids which again supports combustion. The area was mined largely before the introduction of mechanical roofbolts with the roof only supported using removable timber sticks. Crushing of the ribsides has occurred due to the age of the old workings and the poor safety factors used (Figure 4). This has left large quantities of fine coal exposed to oxidation.



**Figure 3**  
**The extent of flooding of the underground workings**

## HISTORY OF SPONTANEOUS COMBUSTION

### Initial Fires

New Vaal started mining coal in September 1985, in the virgin unmined area along the eastern boundary. The first underground workings were mined in 1987 and initially no problems were encountered (Figure 5). In August 1988 the first spontaneous combustion occurred. It was a small outbreak in the middle seam in an opening into the old workings. A small backactor was used to drag the burning coal out from within the workings. The fire was thus extinguished in a matter of hours. During 1989 similar incidents occurred throughout the exposed old workings (Figure 6). These fires always occurred close enough to the mouth of the workings to be reached by backactor.

### Spreading of fires

The fires continued to be controlled using a backactor until February 1990 when the fires had spread to such a degree that the backactor was unable to reach the fires safely.

It was proposed that the mine should try to smother the fires using sand. Sand was tipped directly over the highwall above the old workings closing off the holings into the old workings (Figure 7). This did little to stop the spread of the fires and as the next cut was taken it was found that the fires had in fact advanced as far as 80 metres into the workings ahead of mining. It was realised that this option would never extinguish the fires and merely hid the fires from sight, which was a danger to personnel and equipment working on the benches above the fires.

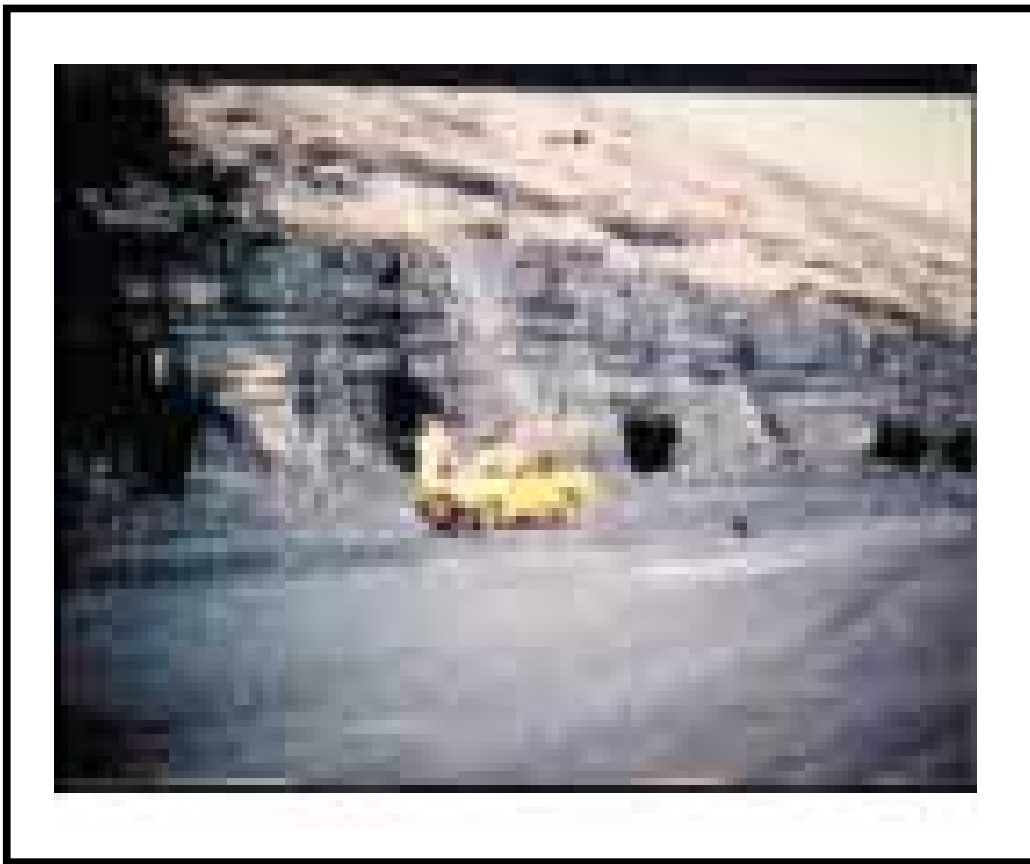
Figure 7 showing sand being dumped over the highwall to seal off the old workings

### Fires out of control

The fires became bigger and spread the entire length of the main pit some 4,5 km in length by October 1992. It became extremely dangerous to work in the pit with even the dragline operation having difficulty dealing with the fires (Figure 8). Drilling and blasting became extremely difficult with each hole measured for



**Figure 4**  
**The conditions of the underground board and pillar workings**



**Figure 5**  
**The exposed underground workings**



**Figure 6**  
**The first outbreaks of fires being treated by Track Dozer**



**Figure 7**  
**Sand being dumped over the highwall to seal off the old workings**

temperature before being blasted as the fires burnt up into the shales. This resulted in holes not being charged which in turn caused poor fragmentation and difficult digging conditions for the draglines and shovels.

### **Regaining control of the fires**

In May 1993 it was decided to stop all pre-splitting and to buffer blast the areas where the fires were raging in the underground workings. Buffer blasting is a technique where the coal pillars are totally destroyed by placing large charges in the pillars and the roof above the bords (Figure 9). This totally seals the entrance to the workings thus preventing air from entering the workings.

This had an immediate effect on the spread of the fires and slowly the fires were brought back under control (Figure 10). The extent of the buffer has increased from 20m initially up to 120m ahead of the current mining cut today.

The buffer blasting alone was not adequate to eliminate the fires and, in addition to the buffer blasting, sand dressing of the highwalls is common practice (Figure 11). This is currently our simple yet most effective treatment of spontaneous combustion fires at New Vaal.

## **EFFECTS ON SAFETY HEALTH AND ENVIRONMENT**

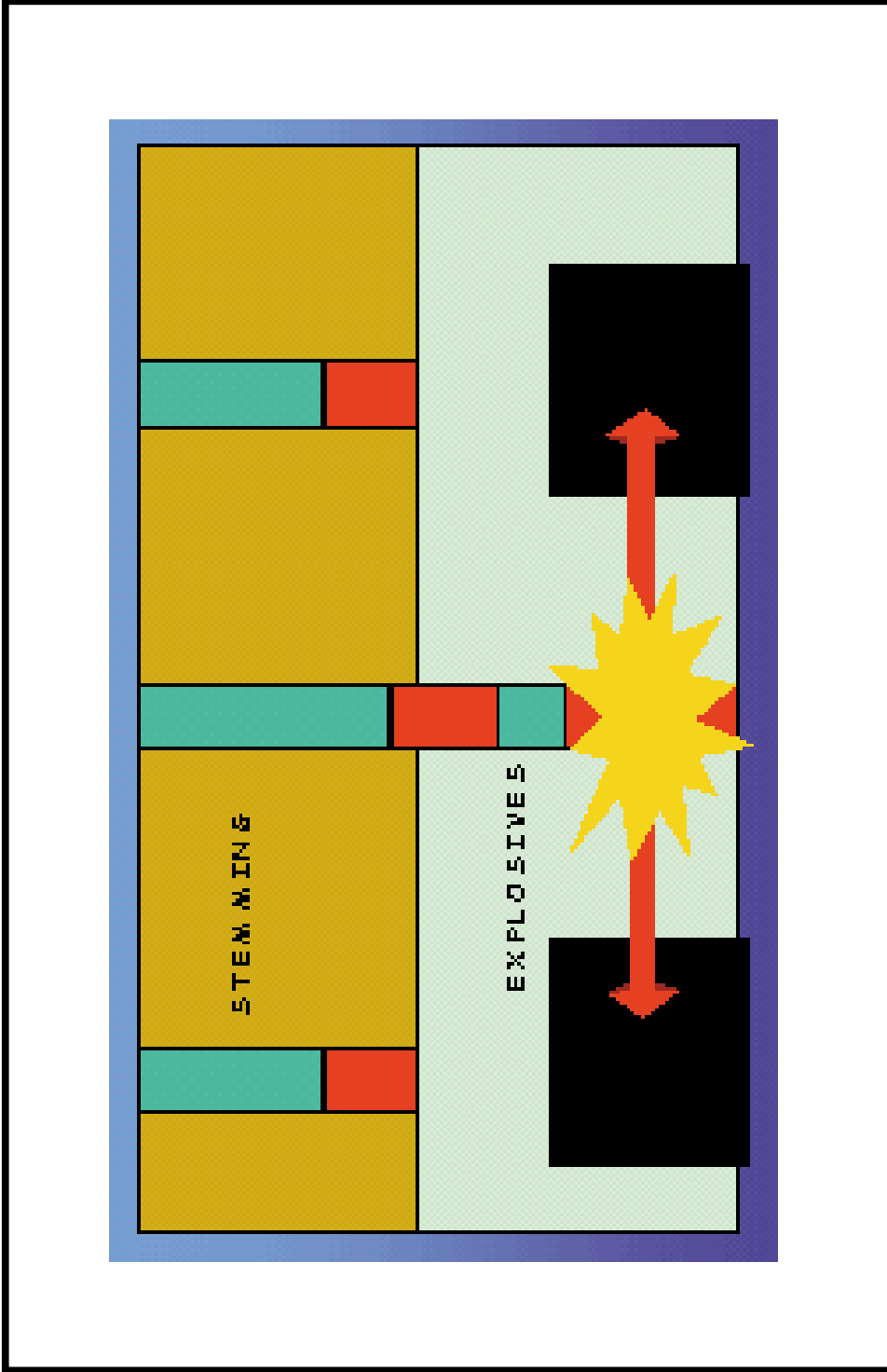
### **Effects on Safety**

#### *Drilling and blasting*

The first section to be adversely affected by the spontaneous combustion fires was the drilling section, which was required to drill the holes for the next cut. The holes burnt through within the bords and needed to be redrilled. The smoke and fumes cause discomfort for the drill operators but there is little danger to the rigs except if it should break down on a burning hole. All holes which have holed through into the workings are immediately sealed off and new holes are drilled 2,0 metres shorter.



**Figure 8**  
**Coal fire explosions in the dragline bucket while loading out burning coal**



**Figure 9 showing the schematic layout of a buffer blast in section**



**Figure 10**  
**The effect of sealing the bords using buffer blasting, thus eliminating the spread of the fires**



**Figure 11**  
**The effects of buffer blasting and sand dressing**

Blasting of areas, which contain fires, is a safety risk and therefore all holes are checked for temperature before being charged with explosives.(Figure 12). Standard procedures are in place that all holes are checked, temperatures measured and logged before charging up can take place. No blasts are held over and all blasts are blasted on the same day as soon as they are charged up.

### *Draglines*

The dragline operation is not at risk when it loads out the fires (Figure 13).

The operators and ground staff remain in the machine during this operation. Dust and fumes pose a health risk, which will be discussed later. When a dragline bucket has been working in fires then it is dangerous to work on the bucket before it has cooled off, eg changing of tips and adaptors.

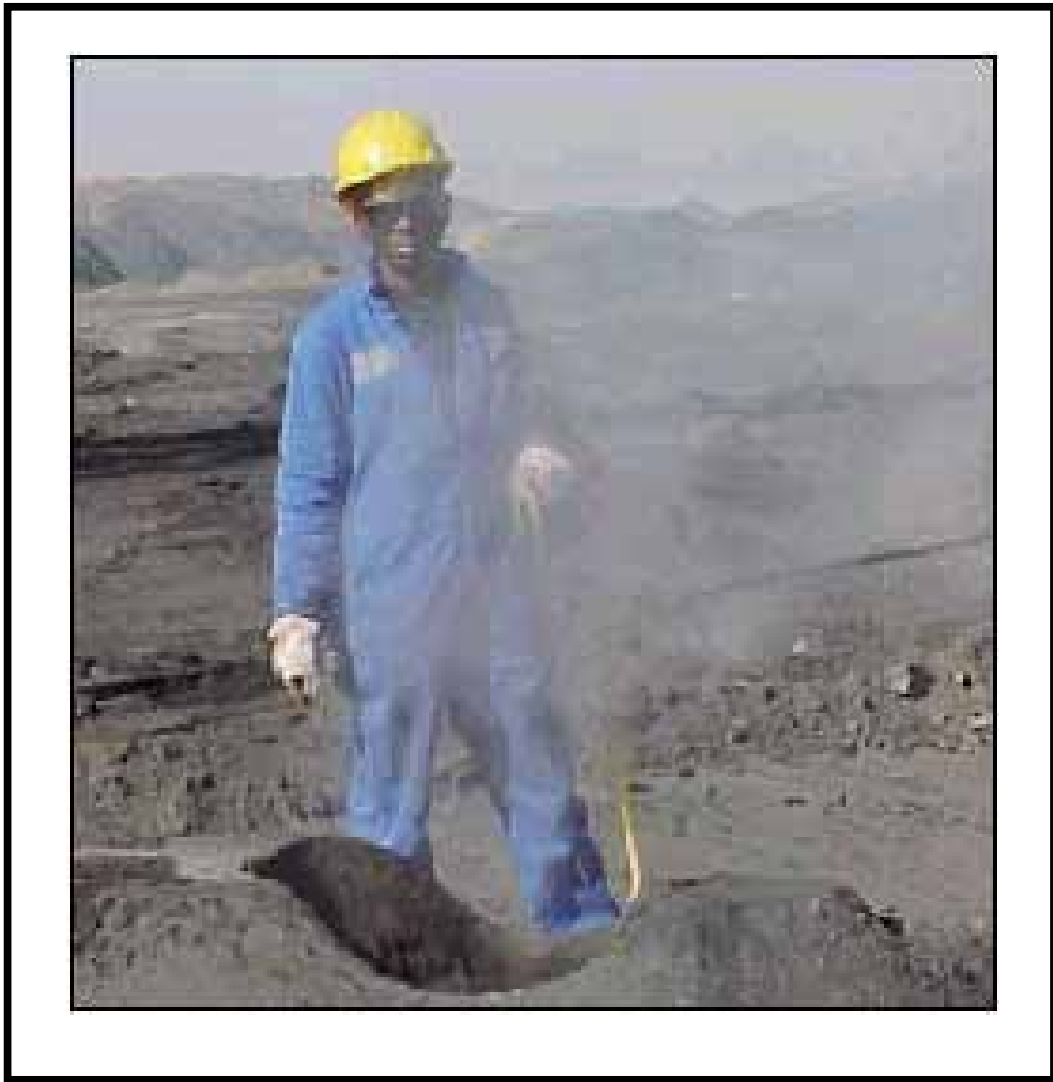
### *Truck and Shovel coal loading*

Loads the burning coal and ash to the tip. The greatest danger is to persons on the ground, who are not permitted within a 150m radius of the shovel when loading burning coal. Using the truck dispatch system has helped to rotate the trucks that load the burning coal as it prevents the tyres from overheating and catching fire. (Figure 14) Sand is also tipped in the face to cool down the floor. One instance of tyre damage has been recorded where a truck was assigned exclusively to a shovel loading burning coal and the tyres caught fire. Wheel loaders are not permitted to load from burning faces.

Figure 14 showing the tyre damage caused by continuous loading of burning coal

### *Ancillary equipment*

Only track dozers are used to push burning coal and ash. Wheel dozers are kept away from the faces except to push sand. Once a dragline has exposed coal track, dozers are not put onto the coal to clean as it is too dangerous and the roof of the bords can collapse (Figure 15).



**Figure 12**  
**Measuring temperature of fire in a drill hole.**



**Figure 13**  
**The dragline loading out burning material.**



**Figure 14**  
**The tyre damage caused by continuous loadng of burning coal**

## *People*

With the involvement of all stakeholders namely management, supervisors, safety officers, safety and health representatives, union officials and affected workers, a full risk assessment was conducted to highlight the dangers associated with spontaneous combustion fires. Standards were put in place and are strictly adhered to, to ensure the safety of operators and persons working near spontaneous combustion fires. To date no injury has been recorded which is related to spontaneous combustion fires or burning coal.

### **Effect of health**

#### *Fumes from spontaneous combustion*

From the risk assessment it emerged that the worst affected are the shovel operators followed by the truck drivers. The worst conditions occur in the winter months at night and early morning when the effect of the inversion of cold air layers aggravates the position. These operators complained of headaches and dizziness. During the period when the fires were most severe (1992 - 1996) CO monitors were put into the cabs of the shovels and draglines. The worst case measured was a CO reading of 27 ppm in May 1992. SO<sub>2</sub> readings of 3 ppm were also measured instantaneously. Generally the levels seldom exceeded 10 ppm for CO and 0,4 ppm for SO<sub>2</sub>. The CO monitors were set to alarm at 50 ppm and only on two occasions were alarms reported, and the operators withdrawn from their machines.

The threshold limit value time weighted average TLV-TWA, as laid down by the American ACGIH, is the accepted standard for surface works and are as follows:-

CO	TLV-TWA	-	50 ppm
	STEL	-	40 ppm for a maximum period of 15 minutes four times a day
	SO <sub>2</sub> TLV-TWA	-	2 ppm
	STEL	-	5 ppm
	TLV-TWA	-	Threshold limit value time weighted average over 8 hours
	STEL	-	Short term exposure limit



**Figure 15**  
**The collapse of burning bords after the dragline has exposed coal**

CO monitors are no longer required as the spontaneous combustion is under control. Spot checks are still carried out by the occupational hygiene officer for both CO and SO<sub>2</sub> when shovels load in areas where spontaneous combustion still occurs. Truck drivers are assigned by the truck dispatch system, which rotates the trucks randomly and prevents one operator from loading continuously at a shovel, which has burning coal. Shovel operators are rotated if they feel dizzy or start to experience headaches.

### *Dust*

Associated with spontaneous combustion is excessive dust from the coal and ash (Figure 16). New Vaal's coal is the poorest quality bituminous coal burnt in a thermal power station in South Africa with an average of 39,5% ash. The ash has a high silica content of some 50% which has the potential to cause long term damage to the health of the employees if it is not controlled. Respirable dust sampling is an ongoing process and a gradual improvement in the measurements has been seen as the incidence of spontaneous combustion was reduced and brought under control. Respirable dust sampling is done using a gravimetric dust sampling pump (Figure 17) carried by the employee for a full eight hour shift. Measurements are carried out in accordance with the Minerals Act and all exceptions (readings greater than 2,0 mg/m<sup>3</sup>) are investigated and reported.

When loading in very dusty areas only the newest equipment is used which has state of the art airtight cabs and working airconditioners. Initially all equipment supplied to New Vaal Colliery came without airconditioners and some smaller equipment was supplied without enclosed cabs. This has since all been modified and retrofitted to reduce the exposure and risk of the operators to dust and fumes. In all cases operators are issued with disposable dust masks which are worn when loading under severe conditions.

### **Effects on the Environment**

The most significant effect that spontaneous combustion has on the environment is the creation of dust and burning spoils.



**Figure 16**  
**The dust associated with the loading of burning coal.**

### *Dust Monitoring*

New Vaal Colliery is situated in an environmentally sensitive area and is constantly monitored by the public which has visual contact with the mine at all times, being as close as 800m from the opencast at the nearest point.

Dust monitoring began before the mine started operations in 1983 and has continued until today. The consultant used to do the pre-mining impact assessment, Professor H Annegarn, is still contracted to conduct the full spectrum of dust monitoring today.

To measure the impact of mining activity on coarse dust production and fall-out, dust monitors are located within the mine area and in Vereeniging and its residential suburbs (Figure 18).

Two types of dust collection buckets are used : open buckets, which lie in lines through areas of sensitivity, and wind direction buckets, which surround the colliery area. The latter determines the import and export of dust at the colliery. Wind directions and velocities are also recorded using cup anemometers. The twin-bucket wind directional system (Figure 19) was specifically designed for conditions at New Vaal Colliery. It has since been accepted by the Department of Environment and Tourism as a standard means of measuring dust fall-out. These monitors are now being utilised by government departments and other mining concerns.

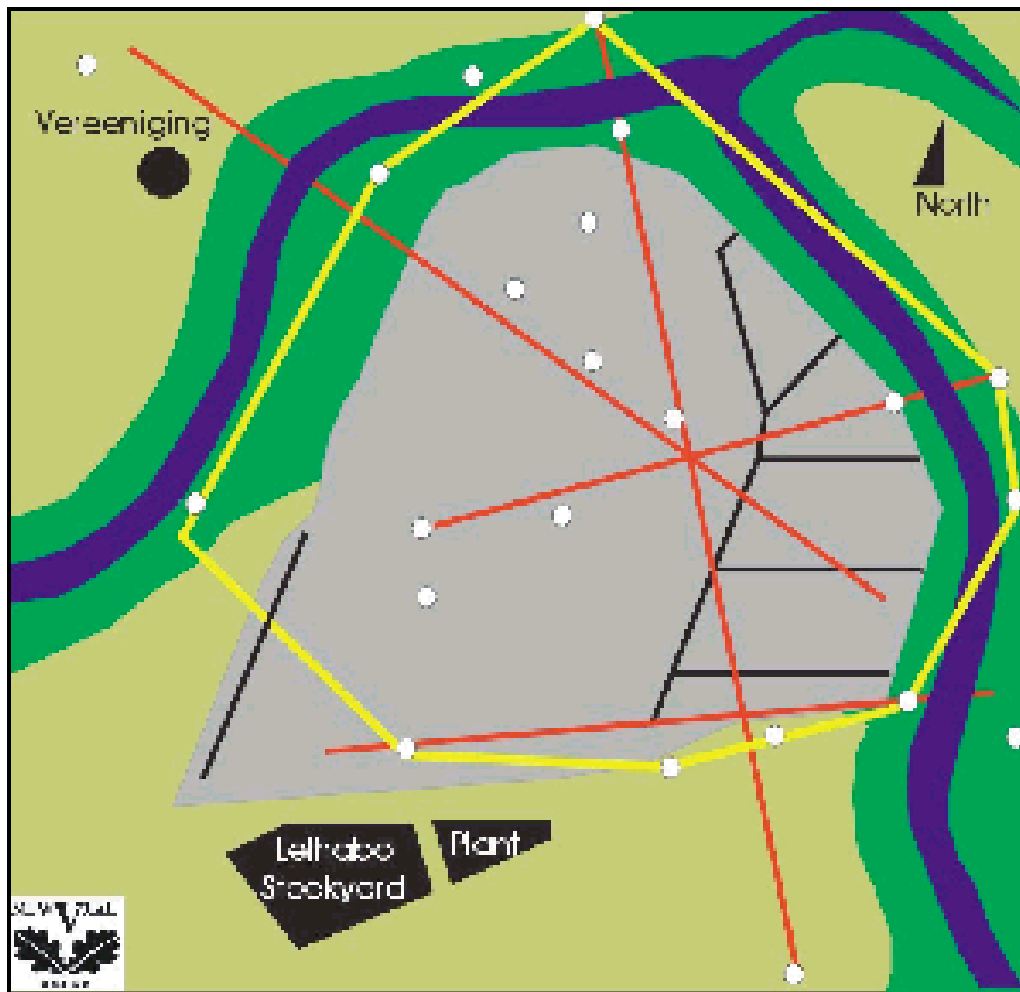
### *Dust monitoring results*

The dust buckets are collected on a weekly basis and analysed by AER (Annegarn Environmental Research (Pty) Ltd). The quantity of dust is measured in milligrams per day per square metre, and is reported, together with the wind directions and velocities. Dust levels are compared with the dust fall-out classification of "moderate" from the Department of Environment and Tourism (DEAT) guideline. The results are presented quarterly to the mine and all fall-out rates greater than 500mg/day/m<sup>2</sup> are discussed and action taken where necessary (Figure 20).

New Vaal has never exceeded the moderate range on the perimeter of the mine where it could affect the environment. Inside the



**Figure 17**  
**Gravimetric dust sampler being worn.**



**Figure 18**  
**The dust monitoring sites at New Vaal and predominant wind directions**



**Figure 19**  
**Dust monitoring site**

mine area there are two sites which exceed the heavy range. These sites are the run of mine (ROM) tip area and the plant ROM stockpile area. Dust readings in the very heavy range ( $>1200 \text{ mg/day/m}^2$ ) have often been encountered at these sites when the coal faces being loaded have sponcom fires. The effects have been reduced by installing a more effective dust suppression system at the tipping point and at the transfer points of the ROM belts. This is a low volume, high-pressure system which uses a surfactant (DT210-W) and humectant (BT 415) to control the dust.

### **New Vaal Atmospheric performance index**

The monthly dust index is derived from the average incremental export dustfall, by comparing it to the DEAT guideline for moderate dustfall. The New Vaal Atmospheric Performance Index (NVAPI) for dustfall is defined as follows:

NVAPI = AVERAGE (EXPORT (I) - IMPORT (I) / Moderate guideline) Value

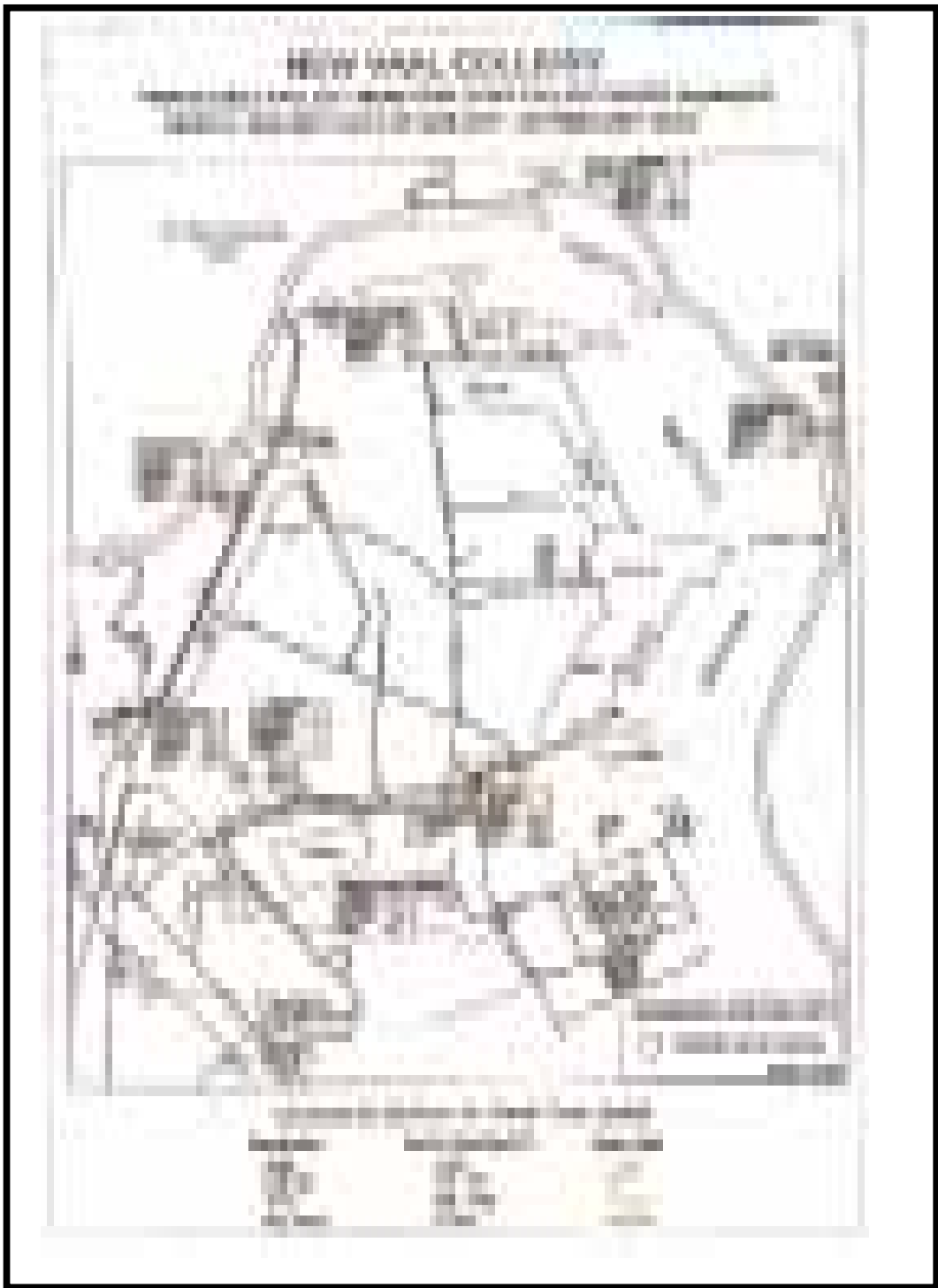
For I = 1 ton and MODERATE =  $500 \text{ mg/d/m}^2$

An index above 1 is regarded as excessive and an index value below 1 is regarded as acceptable.

New Vaal Colliery has not exceeded 1 during the last three year period with average values of 0,161 for 1998 - 0,253 for 1999 and 0,103 for 2000 to date.

### *Suspended Particles : Stack filter sampler*

The suspended (respirable) dust is collected in two size fractions. The top filter ( $8,0 \mu\text{m}$  pore size) collects mechanically produced type particles (coarse), with the size range ( $2,5 < d < 15 \mu\text{m}$ ). The smaller size particles (fine) originate from gas conversion and high temperature processes ( $d < 2,5 \mu\text{m}$ ) and are collected on a filter ( $0,4 \mu\text{m}$  pore size) beneath the top filter. The Department of Environment and Tourism guideline values - total suspended particulates (TSP)  $300 \mu\text{g/m}^3$ , 24 hour average. New Vaal Colliery has not exceeded these DEAT guidelines with the highest value recorded being  $57 \mu\text{g/m}^3$  thus far in 2000 and an average value of  $35 \mu\text{g/m}^3$ . These measurements are taken at the most densely



**Figure 20**  
**Results for January 2000**

populated area which is the mine village (formerly hostel) adjacent to the coal stockyard. These results are encouraging and indicate that the dust generated by the mining operation is under control.

### *Burning spoils*

A major environmental threat of spontaneous combustion is to have burning rows of spoils. In order to minimize this threat New Vaal Colliery has adopted a system of highwall access ramps as opposed to the usual low wall access ramps found in strip mines. Highwall ramps allow for the rehabilitation of the spoils to be completed right up to the edge of the mining window, without any ramp scars, thus preventing oxygen ingress. Once the spoils have been leveled, New Vaal places 1,25m of sand over the shaley spoil material which effectively seals off any voids through which oxygen could enter to propagate spoil fires. (Figure 21). This has been 100% effective and the rehabilitated area of some 481 ha shows no signs of any heating or combustion.

## **THE MINE HEALTH AND SAFETY ACT**

### **The Past and Present**

For many years the safety and health of persons working in mines in South Africa was controlled by the Minerals Act of 1991. In 1996 the Mine Health and Safety Act 29 of 1996 was promulgated with one of its key objectives being "to promote co-operation and consultation on health and safety between the state, employers, employees and their representatives". The management of New Vaal Colliery realised that spontaneous combustion needed a total onslaught from all sections as it posed a serious threat to the health and safety of the employees and the future of the mine. It required all sections to work towards a common goal which is to control spontaneous combustion to such a degree that mining can proceed safely without threat to man or machinery and at the same time protect the environment. Through a process of consultation and risk assessments, which involved all stakeholders, a simple cost-effective solution was found to deal with the spontaneous combustion fires. A lot of good work has been done, but due to its nature and the ideal conditions which still exist at New Vaal Colliery for spontaneous combustion to occur the battle for now



**Figure 21**  
**The leveled spoils with sand being placed.**

may be won but the war rages on.

### **The future beyond 2000**

New Vaal Colliery is currently involved in an industry wide sponsored research project "Coaltech 2020" to investigate further basic principles of spontaneous combustion as it occurs in the South African coal industry. By understanding the mechanisms it may be possible to treat new occurrences quickly and more effectively than in the past and save money while reducing the risks to safety and health. The main focus of this project is that prevention is better than cure. The Department of Minerals and Energy which administers the Mine Health and Safety Act and the Minerals Act and Regulations is a lot less tolerable to transgressions of the respirable dust counts and this has placed added emphasis on the control of spontaneous combustion fires which are a major source of dust. Environmental audits, which were conducted on a three yearly basis, are now being done annually and are open to scrutiny by the public. A nearby-proposed opencast colliery was refused a mining licence in 1999 due to pressure from the environmental lobbyists (Appendix 2).

### **CONCLUSION**

New Vaal Colliery has overcome a major threat by getting the spontaneous combustion fires under control. On reflection the number of ideal conditions that exist for the outbreak of spontaneous combustion should have been identified and provided for in the initial mine design. As this mine was unique in South Africa, being the first mine to mine coal from a field previously mined by underground bord and pillar methods on a large scale, there was no ready textbook to turn to. The problems associated with spontaneous combustion fires have been largely overcome and it is confidently anticipated that the current situation will improve further as mining progresses. With an increasing number of opencast mines in South Africa now mining coal from seams that have been previously mined the lessons learnt and the solutions found at New Vaal Colliery are being adapted and applied elsewhere to good effect.

## **ACKNOWLEDGEMENT**

The author wishes to thank New Vaal Colliery, a division of Anglo Operations Limited, for permission to prepare and present this paper.

## **APPENDICES**

Appendix 1 WITS-EHAC - Measurements for South African coal seams.

Appendix 2 SAVE Document

## **REFERENCES**

Annegarn, H, New Vaal Colliery dust fall-out monitoring quarterly reports 1998, 1999, 2000.

**IGNITION TEMPERATURE TEST TO DETERMINE THE  
WITSEHAC INDEX**

A sample of coal and a sample of inert material are placed in identical containers. The two containers are placed in an oil bath. The bath is then heated slowly and the temperature of both samples is monitored. Any discrepancy between the two sample temperatures must be due to physical or chemical properties. The results, when plotted, indicate.

1. Inert material stays at a constant temperature.
2. Coal drops in temperature initially and the temperature rises and crosses the temperature of the inert material.

The important points on the graph are:

1. The gradient as the coal temperature rises.
2. The crossover point of the coal's temperature and the inert material's temperature.

From these two factors it is possible to determine the WITSEHAC INDEX.

$$\text{WITSEHAC INDEX} = \frac{\text{Slope of coal's temperature}}{\text{Crossing-point temperature}}$$

Therefore the lower the crossing point temperature and the steeper the gradient, the higher the WITSEHAC INDEX.



CLC	Yoga	4.40
CHRYSLER	J.J. Kelly	4.40
CHRYSLER	C. Lopez	4.40
CHRISTIANITY	Yoga	4.37
CLC	Yoga	4.28
CHRYSLER	Yoga Story	4.28
CHRISTIAN	Yoga	4.25
CHRISTIANITY	ASANA-B	4.20
CHRISTIANITY	ASANA-M	4.20
CLC	Yoga	4.21
CHRISTIANITY	ASANA-T	4.18
CHRISTIANITY	ASANA-T	4.18
CHRYSLER	Y	4.18
CHRISTIAN	Yoga	4.17
CHRYSLER	Y	4.16
CHRISTIANITY	Yoga	4.15
CLC	Yoga	4.10
CHRISTIAN	Asana	4.11
CHRISTIAN	Yoga	4.10
CHRYSLER	C. Lopez	4.10
CHRISTIAN	Devotion II	4.10
CLC	Yoga	4.17
CLC	J. Thomas	4.17
CHRISTIAN	Complex	4.10
CLC	Yoga	4.11
CHRISTIANITY	Y	4.11
CLC	Meditation	4.10
CHRYSLER	Yoga	4.10
CHRISTIANITY	Yoga	4.10
CHRISTIANITY	Y	4.10
CHRYSLER	Yoga	4.10

**SAVE  
Save the Vaal environment**

MEDIA RELEASE

**DAVID SMITES GOLIATH**

LANDMARK MINING RULING

In a landmark judgement secured by the community/-based organisation Save the Vaal Environment (S.A.V.E.) on Friday, 12 March 1999 against the Gauteng Director of Mineral Development and Sasol Mining, a full bench of the Supreme Court of Appeal has placed the environment at the forefront of all future planned mining projects, bringing S.A. inline with international practice.

From now on, mining companies and the authorities have to listen to all interested and affected parties prior to deciding whether or not to issue a mining license in terms of sec 9 of the Minerals Act, Act 50 of 1991.

Up to now, Sasol and Gauteng's Director, Mineral Development, have maintained the position that the community has no say in such decisions, and need only be consulted on how to mitigate the effects that the planned new Sasol North West Strip mine on the banks of the Vaal River would have on the environment.

The court dismissed, with costs, the appeal by Sasol and Gauteng's director of Mineral Development against a High court decision in S.A.V.E's favour handed down in March 1999. The High Court had reviewed and set aside Sasol's authorisation to strip-mine the Rietspruit wetland on the Vaal River for coal.

In addition, Judge Pierre Oliver ruled that mining developments which meet present needs must take place without compromising the ability of future generations to meet their own needs. He said application of the audi rule - that the other side must be heard - when seeking a license was "Indicated by virtue of the enormous damage mining can do to the environment and ecological

systems."

The Court also confirmed that our constitution included environmental rights as a fundamental human right, which required that environmental considerations be given recognition and respect. "Together with the change in the Ideological climate must also come a change in our legal and administrative approach to environmental concerns. Said Judge Oliver.

This judgement is not only of value to S.A.V.E., but also to any other communities taking on big companies whilst trying to protect the environment.

The Judgement has had the effect of removing the mining licence for the existing Wonderwater opencast and Sigma underground mines, currently operating in the Sasolburg area. Both of these mines are also operating without approved Environmental Management Programs. This needs to be addressed by the authorities as a matter of urgency.

