

## Investigation of The Relationships Between Cerchar Hardness Index and Some Index Properties of Coal

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**ABSTRACT:** Within the scope of this paper, firstly index tests used for defining cuttability of rock are applied to specimens which are prepared from block samples taken underground. Secondly, Cerchar hardness index tests are performed by means of bits which have peak angles of 99° and 125°. Then, the relationships between index tests and Cerchar hardness test are investigated. Finally, interpretations of these relationships are discussed and the results are given

### 1 INTRODUCTION

Coal, which has high potential of reserve among in all other fuel resources, is mostly used in both iron-steel industries and other industrial fields. As it is an inevitable raw material used in our country, it should be produced efficiently, fast and economically. Therefore, the mechanized excavation, which is more advantageous in comparison to drilling and blasting methods, should be investigated in all details. In this respect; many successful applications of mechanized systems are present in Turkey. For instance, in the last decade, some of them such as Ansch, high pressure air blasting technology (HPABT) and Cardox (blasting by using liquid CO<sub>2</sub>) have been tried in Turkey Hardcoal Enterprises (TTK). Among these systems Cardox and HPABT are still being used for coal production at high efficiency rates.

Since cutting machines used in underground mines for mechanized excavation are the systems which require high investments, it is necessary to predict the machine performance before selecting a suitable machine to buy. That's why some rock properties such as pétrographie, physical and mechanical have great significance in predicting the performance and advance rate of mechanized excavation systems. In addition, rock quality designation (RQD) properties and in-situ strength tests should also be performed.

All these tests have been used to predict the cuttability of coal. In order to determine cuttability

with high accuracy, some parameters like dry sampling, stronger parts of rock, high loading rates, cubic specimens (H/Dsl) and small specimens should be considered (Natau et al. 1991). What makes this proves so important is that not only the pick consumption, but also the energy consumed by cutting machine should be considered during the cuttability studies. Thus, the properties which depend on rock should be determined accurately and the results should be interpreted carefully. An error made in experimental studies causes an increase in the costs and a loss in time.

The aim of this study is to investigate the relationships between some index properties of coal seams in Zonguldak Hardcoal Basin. For this purpose; block and channel samples are taken. Block samples are prepared for uniaxial compressive strength (UCS), Shore hardness index (SH), cone indenter value (CI), and Cerchar hardness index (CHI) tests. Moreover, impact strength index (ISI) tests are applied to channel samples. Then, all these tests are carried out and finally the relationships between these parameters are determined.

### 2 MATERIALS

To determine index properties of coal, laboratory and in-situ tests are carried out. For this reason, block and channel coal samples were taken from 10 unoxidated distinct seams located in the basin where production works were in progress. The seams had

different thickness varying between 1.5 to 4 m and had inclination between 20° to 40°

Because of the difficulties in preparing block specimens, the hardest coal seams are selected. In addition, channel samples are taken from the seams that are dirt band free

### 3 LABORATORY STUDIES

During laboratory studies, the tests given below are carried out. Different kinds of samples are prepared for each test. At the time of sample preparation or performing the tests, many problems like breakage or dispersing of coal samples are encountered due to elasticity of coal

#### 3.1 Strength and index tests

Strength and index tests are very essential in selecting a cutting machine. To define strength properties of coal, uniaxial compressive, uniaxial tensile (or Brazilian) strength tests are carried out. Besides, some index tests are applied to estimate the strength values indirectly

##### 3.1.1 Uniaxial compressive strength test

Uniaxial compressive strength test is defined as the maximum compressive stress which a rock sample can resist in one direction (Gerçek 1999). It is the most common and widely in use one because of its reliable results

In this study, cubic specimens are trimmed in 70 x 70 x 70 mm dimensions. The discontinuity planes which are parallel to the loading direction are covered with plaster. Then, tests are applied at 0.1 kN/sec loading rate. Finally, the load values (F) are recorded and uniaxial values are calculated

##### 3.1.2 Cone indenter test

This test is used for measuring the resistance of a rock sample against penetration with a conically shaped indenter (Stimpson & Acott 1983). It is usually used to determine cuttability, drillability and for the estimation of uniaxial compressive strength of intact rock

In one of the Ghose & Chakraborti's (1986) studies, they got very excellent correlation coefficient with uniaxial compressive strength versus cone indenter value (Fig. 1)

For cone indenter test, prismatic samples which are 12 x 12 x 6 mm in dimensions are prepared. In order to minimize the roughness, the sample

surfaces are grinded with abrasive (in number 0). Then, the test is carried out and results are recorded

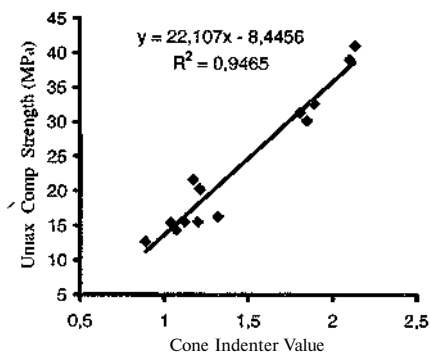


Figure 1 The relationship between cone indenter value and uniaxial compressive strength (Ghose & Chakraborti 1986)

#### 3.1.3 Impact strength test

Impact strength index test is first discovered by Protodyakonov to put forward an idea about the rock's strength properties, cuttability and brittleness, then is improved by Evans & Pomeroy (1966)

This test is performed by a vertical cylinder apparatus which is 30.48 cm in height and has a steel plunger 1816 gr in weight. Channel samples are screened within -9.5/+3.17 mm fractions and are weighted in 100 gr. Then, sample is poured down into the apparatus and steel plunger is dropped on it for 20 times. Finally, the samples which are taken out the cylinder are screened from 3.17 mm sieve and the oversize is accepted as impact strength index of coal

The test procedure is repeated 6 times and means are accepted

#### 3.2 Hardness tests

Hardness is one of the properties of rock that is a measure of resistance to indentation or scratch

While hardness is affected by moisture in soft rocks and quartz content in hard rocks. To determine hardness values, three kinds of methods which are scratch hardness tests (Mohs), rebound hardness tests (Shore, Schmidt) and indentation hardness tests (Vickers, Knoop, Cerchar) are used

##### 3.2.1 Cerchar hardness index test

The test is generally used for defining the strength and cuttability characteristics of coal or rock

samples (Bilgin 1992, Coder 1973, Valantin 1973). According to this test, indentation time of bits (in seconds) into the prepared sample (for 1 cm) is measured.

In Turkey, there are not many studies about Cerchar hardness index test. However, there is one that was carried out by Bilgin et al. (1992) by using 5 x 5 x 5 cm coal samples. In their study, they figured out a linear relationship between uniaxial compressive strength and Cerchar hardness index as given in Figure 2.

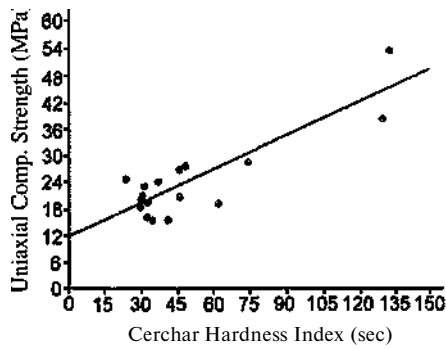


Figure 2. The relationship between uniaxial compressive strength and Cerchar hardness index (Bilgin et al. 1992).

In addition, for coal samples, they formed a cuttability classification by using CHI values that is given in Table 1 (Bilgin et al. 1992).

Table 1. A cuttability classification for Cerchar hardness index (Bilgin et al. 1992).

| CHI (sec) | Cuttability    |
|-----------|----------------|
| <15       | Easy           |
| 15-21     | Normal         |
| 21-54     | Difficult      |
| >54       | Very difficult |

In this study, modified Cerchar hardness test machine is used so as to determine the Cerchar hardness index values. Test machine is made up of four basic parts (Fig. 3). These are a bit, a chronometer, a vertical weight (to provide compressive force) of 20 kg and a horizontal belt which can be changed for three different positions such as 190, 500, 700 rev/min to adjust the drilling rates.

The test is performed at 190 rev/min drilling rate, by using cubic samples in 70 x 70 x 70 mm dimensions. In addition, two bits with different peak

angles (99° and 125°), which are produced particularly in 8 mm length based on DIN 8039 standards, are used.

Initially, the test is applied by means of the bit with peak angle of 99°. The specimen is placed in the clamp, the vertical scale is adjusted for 1 cm and the penetration time is recorded. Second, the bit with peak angle of 125° is affixed and the test is repeated on the cross surface of the cubic specimen. Finally, the penetration times are accepted as CHI values.

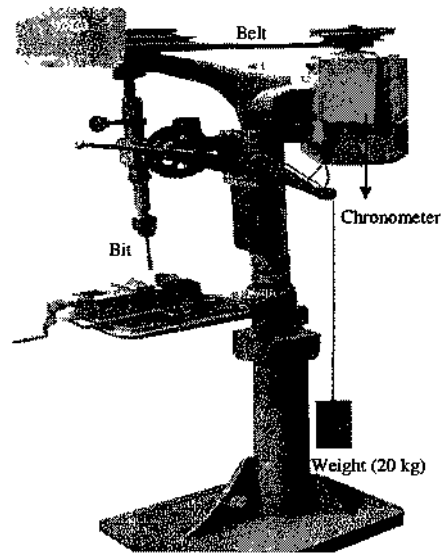


Figure 3. Modified Cerchar hardness test machine.

### 3.2.2 Shore hardness test

The Shore hardness index test is used in empirical equations concerning drillability and wearing of drill tools, which is also influenced by rock mineralogy, elasticity and cementation (Altindag 2002, Rabia & Brook 1978).

The Shore scleroscope measures hardness in terms of the elasticity of the material. A diamond-tipped hammer is allowed to fall from a known height on the surface of specimen to be tested and the hardness number depends on the height to which the hammer rebounds is determined (Material hardness 2001).

In order to perform the tests, samples are prepared to have 15 cm<sup>2</sup> surfaces and 1 cm thickness. Then, surfaces are polished with abrasive. D model scleroscope which exists in Zonguldak Industrial Support Centre's Laboratory is used to perform the tests. Shore hardness values are

recorded for 20 times in 3 mm spacing on the surface and mean value is accepted SH value

#### 4. RESULTS AND DISCUSSIONS

The main objective of this paper is to investigate the relationships between Cerchar hardness index test (for two different peak angles of 99° and 125°) and some index tests which are applied after sample preparation and laboratory studies. In this frame, test results are mentioned in Table 2 and it has been found that even the hardest coal seam having 17 MPa compressive strength in the basin has approximately 37 sec/cm CHI value. The relationships obtained from these results are given in Figure 4-7.

Table 2. The results of the laboratory studies (Su, 2003)

| Coal Seam Name | UCS (MPa) | SH    | ISI  | CI   | CHI (sec) |       |
|----------------|-----------|-------|------|------|-----------|-------|
|                |           |       |      |      | 99°       | 125°  |
| Batı Acılık    | 2.82      | 31.35 | -    | -    | -         | -     |
| Doğu Acılık    | 4.23      | 34.40 | 41.2 | -    | 12.40     | 60.1  |
| Domuzcu        | -         | 39.70 | 43.7 | 10.6 | 8.24      | 11.60 |
| Acenta         | -         | 34.20 | 52.7 | 0.65 | 12.27     | 24.31 |
| Unudulmuş      | 4.09      | 31.90 | 56.0 | -    | -         | -     |
| Nasıfoğlu      | 5.08      | 37.70 | 42.1 | 10.3 | -         | -     |
| Sulu           | 3.41      | 34.05 | 42.6 | 0.82 | 4.11      | 3.73  |
| Çay            | 4.39      | 28.80 | 40.1 | 0.46 | 6.12      | 8.80  |
| Kalın          | 12.19     | 56.35 | 68.8 | 1.46 | 28.77     | 25.11 |
| Taşlı          | 17.34     | 60.40 | 71.4 | 1.30 | 31.13     | 36.90 |

According to Figure 4, there are excellent linear relationships between uniaxial compressive strength and Cerchar hardness index. Two graphs conflict at 9.5 MPa. The author thinks that because of the cracks and discontinuity planes in coal structure, the relations obtained for the values above 9.5 MPa may be more realistic.

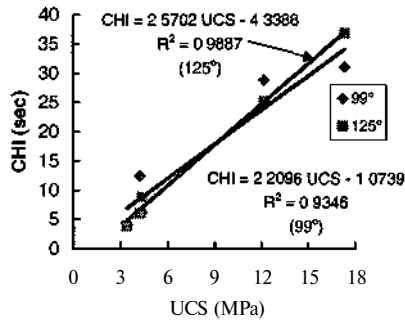


Figure 4. The relationship between Cerchar hardness index and uniaxial compressive strength

As given in Figure 5, linear relationships are found out between Shore hardness index and CHI values. The correlation coefficient obtained from the test during which the bit with peak angle of 99° is higher than that of the one with 125° due to the elasticity of coal. In this case, block samples should be selected as hard as possible.

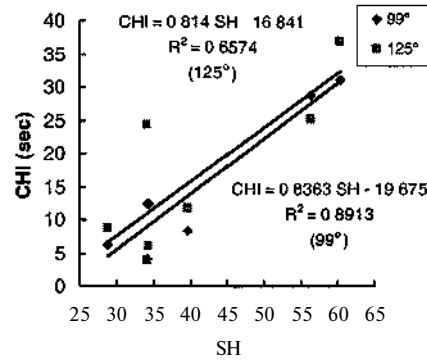


Figure 5. The relationship between Cerchar hardness index and Shore hardness index

Moreover, there are linear relationships and higher correlations between impact strength index and Cerchar hardness index values (Fig. 6). The coefficient with the peak angle of 99° is also higher than the other.

Although the specimens are taken in two different ways, the obtained high correlation coefficients indicate that both the channel and block samples reflect the same characteristic.

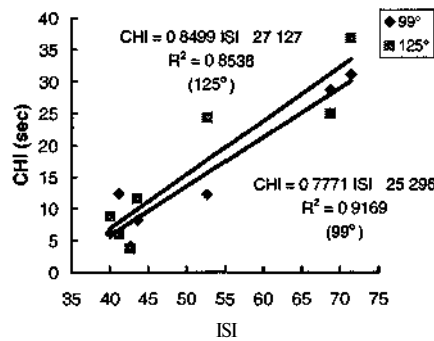


Figure 6. The relationship between Cerchar hardness index and impact strength index

There is no meaningful relationship between cone indenter value and Cerchar hardness index test carried out by means of the bit with the peak angle

of 125°. However, a linear relationship is figured out the one applied with a peak angle of 99°. Either cone indenter value or indentation time of bit increases as seen in Figure 7. It is difficult to prepare specimen due to low strength properties of coal, cone indenter tests should be carried on with more specimens.

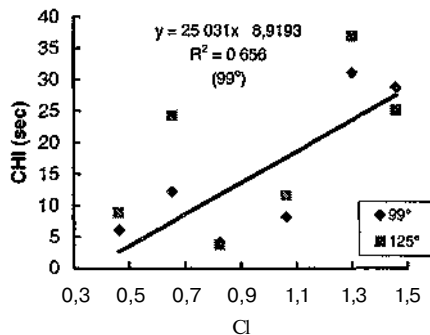


Figure 7 The relationship between Cerchar hardness index and cone indenter value

## 5 CONCLUSIONS

This paper concerns with some index tests affecting the Cerchar hardness of coal samples.

For this purpose two kinds of samples are taken from Zonguldak Hardcoal Basin and samples are prepared in different dimensions. Then, index tests are carried out and the relationships related to CHI are investigated.

During Cerchar hardness index tests, two kinds of peak angles (of 99° and 125°) are used. The best fit for CHI values is figured out with UCS values that are limited at 9.5 MPa. Values higher than 9.5 MPa provide more accurate results due to elasticity and brittleness of coal.

Besides strength tests, index tests have linear relations versus CHI values. In the light of the higher correlations obtained from test results, it is highly recommended that the Cerchar index test for coal samples should be carried on by using a bit with a peak angle of 99°.

Moreover, probably because of the deficiencies in performing the test or the insufficient number of the specimens, no relation between cone indenter value and CHI test applied by means of a bit with the peak angle of 125°, is found.

The results and relations can be considered while the drillability and cuttability studies.

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## Wireless Lan System For Leg Pressure Monitoring

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**ABSTRACT:** The harsh and unpredictable environmental conditions present in an underground coal mine place special demands on equipment and a communication systems. Therefore, the system must be robust, remotely configurable and have the capacity to re-establish itself on power-up without user intervention. The communication link must also support the increasing bandwidth requirements of a modern control system, including data from intelligent sensors and video equipment, which is beyond the capacity of existing serial communication system.

Authors successfully developed the innovative wireless local area network system. It successfully installed at experimental longwall mine. The WLAN was successfully transmitted the underground sensors data. The better data quality and continuity was achieved with this innovative system. Therefore, the powered supports performance was evaluated efficiently in real time. As a result, the management achieved productive mining operations. Besides, this innovative system has many advantages over the conventional systems. In this paper, the discussions mainly focus on wireless data transmissions.

### i INTRODUCTION

The longwall mining is potentially dangerous with human operators exposed to significant risk of injury or death. As longwall equipment has become larger, and safety hazards have increased. Automation of the longwall mining process is therefore seen as highly desirable in order to improve the safety and productivity of longwall mines (Mathur, 2004).

The successful longwall operations are mainly depend on chock shields performance. The continuous monitoring and forecasting of chock shields behaviour is imperative for effective mining operations. The data transmission from underground multiple sensors to surface monitoring system is expensive and need huge maintenance by conventional data cable. Moreover, the signal attenuation and noise influence will be more in long distance cable transmissions. Furthermore, the data quality and continuity will be poor due to signal attenuation and noise. As a result, the conclusions during adverse behaviour will not be reliable and leads to false decisions because of poor data quality. Therefore, the Wireless Local Area Network (WLAN) was successfully implemented for avoiding aforesaid limitations. Thus, this paper will discuss the successful case study of development and application of the WLAN system for achieving data quality and continuity to effective forecasting of the

chock shields performance for efficient longwall operations.

### 2 WIRELESS LOCAL AREA NETWORK (WLAN)

Wireless networks have been around for many years. In fact, early forms of wireless communications include Native Americans waving buffalo skins over a fire to send smoke signals to others over great distances. Also, the use of pulsing lights carrying information through Morse code between ships has been and still is an important form of communications. Of course, cell phones are also a type of wireless communication and are popular today for people talking to each other world wide. The wireless networks use either radio waves or infrared light as a medium for communication between users, servers, and databases. Wireless network fall into several categories, depending on the size of the physical area that they are capable of covering.

The wireless LAN supplies high performance within the specified range. Users in these areas typically have laptops, PCs, and PDAs with large screens and processors that support higher-end applications. The wireless LAN satisfies connectivity requirements for these types of computer devices. The wireless LAN easily provides high level of performance that

enables the higher-end applications to run smoothly. The wireless LAN is similar to traditional wired Ethernet LANs in their performance, components, costs, and operation. Because of the widespread implementation of wireless LAN adapters in laptops, most public wireless providers deploy wireless LANs to provide mobile, broadband access to the Internet. The network can be implemented using commercial, off-the-shelf Ethernet components and standard hardware such as optical connectors. IEEE 802.11 is the most prevalent standard for wireless LANs, with versions operating in the 902 MHz, 2.4 GHz and 5 GHz frequency bands. In this development, the wireless operations were successfully implemented in 902 to 928 MHz range. More details are in the following sections (Hargrave et al. 2003).

### 3 LEG PRESSURE MONITORING

#### 3.1 Pressure sensor

Pressure sensor (Figure 1) of strain gage type has a maximum range of 1000 bars. The accuracy was 1% of FSD (Full Scale Division). The pressure sensors were installed at test port of the chock shield rear leg circuit as shown in Figure 1. The sensors have in-built signal conditioning facilities. All the underground sensors were interfaced to the wireless data acquisition system through the borehole. The sensors were intrinsically safe. Therefore, the sensors were compatible to underground mining environment.

#### 3.2 Wireless data transmissions

The distance between the underground sensors to surface monitoring system was around 10 km. The eight powered supports were selected for continuous monitoring based on preliminary field investigations. They were four from centre of the panel and two each from main and tail gate. The total number of pressure sensors interfaced to chock shields was 8. The data cable required for transmitting 8 sensors data to 10 km was of around 100 km length or more for implementing conventional method. Moreover, the data continuity and quality will be poor in conventional long distance cable data transmissions because of signal attenuation, frequent cable cuts and so on. Therefore, wireless data transmissions were successfully implemented. The abounded borehole was located on surface over the longwall workings (Figure 1(b)). All the sensors data cable was taken out from the borehole and interfaced to the data acquisition system. The radio modem was received data from data acquisition system as shown in Figure

1. The radio modem was interfaced to the wireless antenna. The wireless antenna was commissioned on top of the tower to maintain the line of sight with the receiver (Srinivasulu tadisetty et al. 2003).

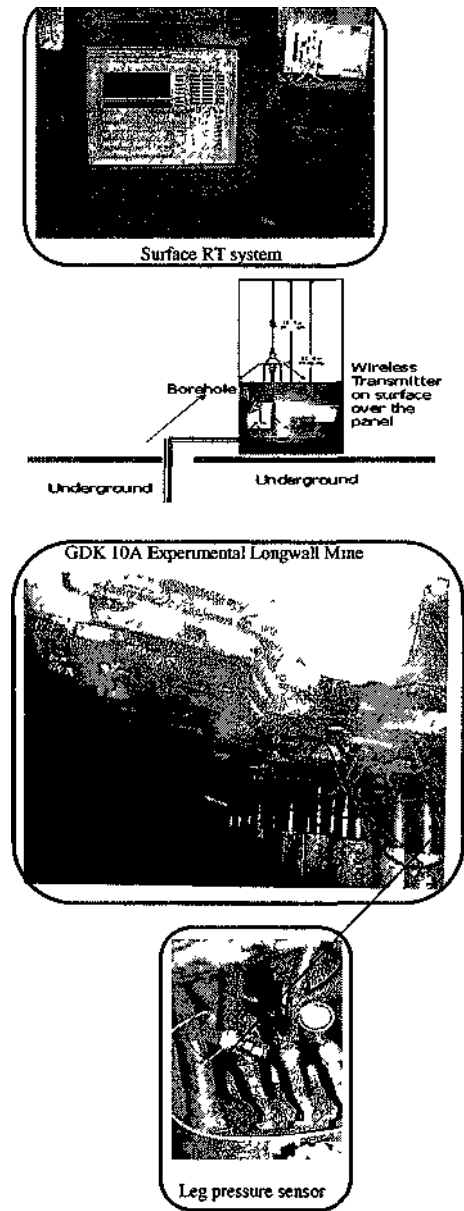


Figure 1(a) Leg pressure sensor interfaced to surface RT system via WLAN



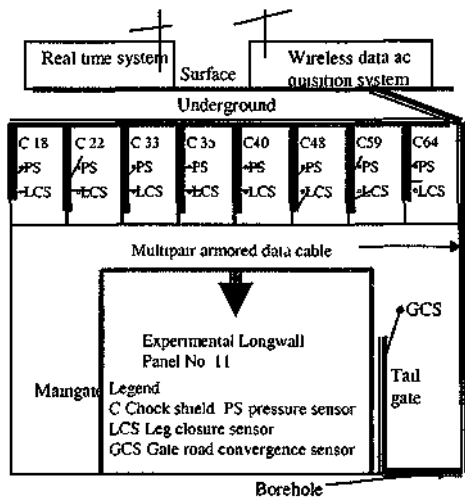


Figure 1(b) Instrumentation Layout at experimental panel

Consequently the wireless operations were successfully implemented for transmitting the underground multiple sensors data in real time. However, the wireless operations can be implemented in underground rather than routing through borehole. Furthermore, the transmission range will reduce due to many problems like signal attenuation, absorption, obstacles, line of sight and so on.

The main important task was to maintain line of sight in underground. Therefore, it needs more wireless modules, complex operations and expensive. Thus, the simple and economical solution was to locate the old or abandoned borehole for implementing wireless data transmissions as discussed above.

### 3.3 Real Time System

The intelligent dump terminal was interfaced to RT system. The RT system interfaced to radio modem and wireless receiving antenna as shown in Figure 1. The display of intelligent dump terminal can be called as real time display. The real time system has 40 channels. Furthermore, the number of channels can be increased as and when required. The acquisition time was selected one minute. All the operations were menu driven and user friendly. The RT system was automatically analysed acquired data of underground sensors and displayed the chock shields performance as shown in Figure 1. The chock shield behavior was displayed in graphical form on real time display. The rate of change in chock shield pressure was displayed in numerals. In addition, comprehensive information of various sensors like

type of sensor, units, location, excitation, and calibration status was displayed. The complete data was stored in standard format to retrieve quickly and easily.

The real time system was successfully recorded periodic falls, hydraulic leakages, periodic weights, goaf falls, face falls and gate roads convergence. The display was updated with latest information for every minute. Therefore, the continuous information of the chock shield performance was available for quick decisions to implementing precautionary measures during adverse behaviour for achieving effective and efficient longwall operations.

## 4 DATA ANALYSIS AND INTERPRETATION

The RT system was generated a very big data base because of the data continuity. The setting and yield pressure of powered support was 345 and 434 bars respectively. The powered supports performance was grouped into six categories as per the support resistance. They are type 'A', 'B', 'C', 'D', 'E', and 'F' (Peng & Chiang, 1984). The type of support behaviour was successfully forecasted in real time. The data analysis and interpretation of the RT system records are as follows.

The support setting pressure of C35 chock was 380 bars at 8:23 hrs on 20<sup>th</sup> March 2003 (Figure 2). It was advanced at 12:24, 16:25, 19:25 and 20:25 hrs. The support resistance was always less than the rated setting pressure. The support pressure was reduced to 150 bars at 14:24 hrs due to hydraulic leakages. The support was in the centre of the panel.

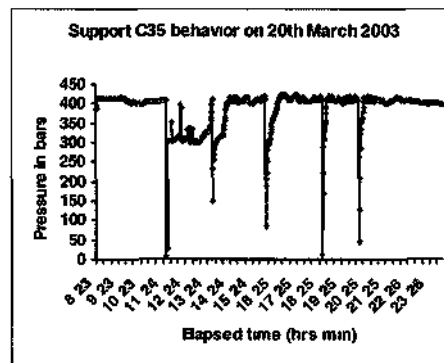


Figure 2 Chock Shield C35 behavior on 20<sup>th</sup> March 2003

The support was not offered adequate resistance due to deteriorated roof conditions. The roof condition was deteriorated due to severe face cavities. The face operations were disturbed frequently with the continuous face spalling. Therefore, the powered

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support C35 behaviour was a 'type E' (Peng & Chiang, 1984) as per the discussions. Furthermore, the management was successfully implemented various preventive/precautionary measures for avoiding major disaster. Subsequently, the management was alerted the maintenance staff for preventing further deterioration of hydraulic leakages. As a result, the productivity and safety of mining operations maintained. The RT system was successfully recorded and forecasted hydraulic leakages and periodic weightings. Eventually, The RT system was successfully forecasted the powered supports performance in real time.

## 5 CONCLUSIONS

The WLAN system was successfully developed and installed at experimental longwall mine. The geo mechanical data from underground leg pressure sensors was successfully transmitted. The innovative WLAN system was avoided the requirement of expensive data cable and its huge maintenance. The better data quality and continuity was maintained for reliable analysis of strata and supports performance. It was an economically viable system due to indigenous development. Besides, it was fully compatible to underground environment.

At present, the WLAN is in application for transmitting data from underground leg pressure sensors. The system can be used for transmitting to any type of geomechanical parameters. This new WLAN system was helped the Indian mining industry for achieving better productivity.

## Acknowledgement

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## Short and Long Terms Strength Performances of Cemented Paste Backfill

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**ABSTRACT:** This paper presents the short (up to 28 days) and long (up to 180 days) terms strength gain performances of paste backfill samples prepared with two types of Portland composite cement (types PKC/A and PKC/B) and two mill tailings with different sulphur content (tailing samples T1 and T2). For the selection of an optimum paste backfill mixes at 28 days of curing, four binder contents ranging between 4 and 7 wt% were used. The end results showed that paste cylinders with a binder content of 6 and 7 wt% produced maximum unconfined compressive strength values of 0.8 and 0.9 MPa, respectively. Moreover, 7 wt% of binder content was used to evaluate the effects of binder and tailing types on the long term strength performance of cemented paste backfill. As a result, the strength development of paste cylinders with PKC/A binder has shown a 13% higher compressive strength than that of the PKC/B binder. For a given binder type, the hydration process seems to be directly related to the tailings composition and the binder content.

### 1 INTRODUCTION

Mine backfilling is of great importance to provide a safe working environment in underground mine openings and to prevent and/or minimize subsidence occurring on surface (Thomas *et al.* 1979; Stone, 1993; Brackebusch, 1995; Hassani and Archibald, 1998; Grice, 1998). The underground mine openings created by the ore stopping are backfilled using a cemented tailing paste in order to provide ground support for the surrounding mine structures and/or a disposal site for sulphide tailings. The paste backfill becomes increasingly widespread world-wide. The possibility of placing underground up to 60% of the produced tailings and reducing significantly the tailings disposal and rehabilitation costs are important advantages of the paste backfill. As a matter of fact, the tailings containing sulphide are unstable in the presence of air and water by generating acid mine drainage.

Paste backfill can be defined as a high density material that consists of mixing humid fine tailings, hydraulic binder composed of one and/or more cement reagents with a proportion ranging between 3 and 7wt%, and mixing water to set a solid content ranging from 70 to 80 wt% depending on the desired consistency. The main role of binders used in paste backfill is to produce the needed mechanical

resistance. Each of paste backfill components plays greatly an important role during its transportation, placement and strength gain at short and long terms (Brackebusch, 1995; Beleme/*al.*, 2001; Benzaazoua *et al.* 2002; Kesimal *et al.* 2002a, b; Yilmaz, 2003; Yilmaz *et al.* 2004a, b; Fall *et al.* 2005).

Some problems in the short and long terms performances of paste backfill are encountered in some cases of sulphide rich mill tailings. It is also well known that deterioration of construction works occurs when they are subjected to the waters containing sulphate or acid. In the case of paste backfill the oxidation of existing sulphide minerals, such as pyrite and pyrrhotite, in the presence of oxygen and water may lead to the formation of acid and sulphate and to the undesired chemical reactions (called sulphate attack) with the components of the backfill. The sulphate attack could result in the loss of the fill stability and eventually the collapse of the backfill with the concomitant losses in workforce and halt in ore production (Benzaazoua *et al.* 1999; Berniere/*al.* 1999).

Many researches have shown that the strength acquisition of the paste backfill depends on the characteristics of binder, tailing and mixing water, and their proportion used in mixture (Lamos and Clark, 1989; Quellet *et al.* 1998; Bernier *et al.* 1999;

Belem et al 2000, Ereikdi et al 2003, Yılmaz et al 2003, Kesimal et al 2003, Benzaazoua et al 2004) The purpose of this paper is to investigate the short and long terms strength gaming of paste cylinders prepared from various binder types and proportion To reach this aim, mill tailings from a Turkish hard-rock mine were sampled (tailing samples T1 and T2) for the preparation of various paste mixtures The short term strength gain was investigated through the analysis of the effects of binder types and their proportion used with the mill tailings T1 and T2 at 3, 7 and 28 days of curing periods The long term strength gam was studied through the analysis of the effects of binder types used with tailing samples T1 and T2 after curing times of 3, 7, 28, 90 and 180-day using a binder content of 7% by dry weight

## 2 MATERIAL AND METHOD

### 2.1 Material

#### 2.1.1 Sampling

Two types of sulphide mine tailings (samples T1 and T2) from a high grade copper-zmc underground mine in northeast of Turkey are sampled for the preparation of various paste backfill mixtures These samples are taken as representative of the tailings streams after having been filtered at the paste backfill plant The solid concentration of the tailings is ranged between 74 and 84% Tailing samples T1 and T2 have a sulphur content of 47% and 34%, respectively Mam physical properties of the both mine tailings are presented in Table 1

Table 1 Physical properties of mill tailings T1 and T2

| Property  | T1    | T2    |
|---|-------|-------|
| Specific gravity (g/cm <sup>3</sup> )           | 4.67  | 4.40  |
| Specific surface area (m <sup>2</sup> /g)       | 175   | 2.65  |
| D <sub>10</sub> (pm) grain size at 10% passing  | 0.80  | 0.81  |
| D <sub>20</sub> (fun) gram size at 20% passing  | 2.50  | 3.00  |
| D <sub>30</sub> (um) grain size at 30% passing  | 7.00  | 6.00  |
| D <sub>50</sub> (urn), gram size at 50% passing | 18.50 | 17.00 |
| D <sub>60</sub> (jim), gram size at 60% passing | 26.50 | 25.00 |
| DM (Jim), gram size at 90% passing              | 66.00 | 75.00 |
| C <sub>u</sub> "', coefficient of uniformity    | 33.13 | 31.25 |
| C <sub>c</sub> "', coefficient of curvature     | 2.31  | 1.80  |
| U**', uniformity                                | 2.98  | 4.36  |

$$* < D_{60}/D_{10} > " KD_{30}^2 / (D_{80} D_{10}), ** [(D_{90}-D_{10}) / (D_{60})]$$

The gram size distribution of the tailing material was obtained by using a Malvern Mastersizer® particle size analyser under humid conditions Tailing sample T1 was found to have approximately 52 wt% of 20

µm particles and tailing sample T2 have approximately 54 wt% of 20 /µm particles, which indicates that both mill tailings can be classified as a medium size tailings according to Kesimal et al (2002b) These types of tailing material usually good paste backfill, but typically have lower strength than the coarse tailings because of a higher water-to-cement ratio needed for reaching the target consistency (Landnault, 2001)

### 2.1.2 Binders

In this study, the Turkish Portland composite cements (PKC), namely, PKC/A 32.5-R (type A) and PKC/B 32.5-R (type B) were used The PKC/A binder is got from milling 94-80 parts of Portland cement clinker together with a corresponding amount of two kinds of additives (6-20 parts) and a quantity of gypsum The PKC/B binder is got from milling 79-65 parts of Portland cement clinker and a corresponding amount of two kinds of additives (21-35 parts) as well as a quantity of gypsum Each of these cements was manufactured in compliance with the TS 12143 standard The chemical properties and compressive strengths of the binders are listed in Table 2

Table 2 Properties of binder types used (Ünye Çimento Sanayi A.Ş.)

| Elements                              | PKC/A 32.5-R (%) | PKC/B 32.5-R (%) |
|---------------------------------------|------------------|------------------|
| SiO <sub>2</sub>                      | 19.12            | 28.03            |
| Al <sub>2</sub> O <sub>3</sub>        | 7.01             | 8.21             |
| Fe <sub>2</sub> O <sub>3</sub>        | 2.68             | 3.42             |
| CaO                                   | 42.50            | 32.60            |
| MgO                                   | 1.08             | 1.48             |
| SO <sub>3</sub>                       | 1.96             | 1.53             |
| Free CaO                              | 0.55             | 0.23             |
| Insoluble residue                     | 11.60            | 15.06            |
| Soluble SiO <sub>2</sub>              | 9.72             | 5.83             |
| Loss on ignition                      | 2.08             | 2.65             |
| Undetermined                          | 1.70             | 0.96             |
| Total                                 | 100.00           | 100.00           |
| Unconfined compressive strength (MPa) |                  |                  |
| 1 day                                 | 9.2              | 6.3              |
| 2 day                                 | 16               | 12.2             |
| 7 day                                 | 33.8             | 23.9             |
| 28 day                                | 44.1             | 35.3             |

### 2.1.3 Preparation of mixtures

In this study, two different mixture recipes were prepared to better understand the strength gain of the paste backfill after short and long terms curing times Table 3 presents the laboratory tests program for the

relevant mill tailings at short and long terms curing times. The best slump for these tailings was established to 7" (Kesimal *et al* 2004). In the present study, however, the effect of the slump on the paste backfill performance was not investigated.

Tap water was used as mixing water during the preparation of the paste backfill samples. Water-to-cement ratios for the mix with solid concentration of 82% and using binder proportions of 4, 5, 6 and 7 wt% are 5.7, 4.6, 3.9 and 3.4, respectively. Water-to-cement for the mix with solid concentration of 77% and using binder proportions of 4, 5, 6 and 7 wt% are 7.8, 6.3, 5.3 and 4.6, respectively.

The prepared paste samples were cast into plastic cylinders (having 10 cm diameter and 20 cm height) and a ratio of height to diameter of 2. A total of 204 paste backfill samples were then cured in humidity chamber at approximately 75% for short and long terms curing in order to simulate the underground mine conditions.

## 2.2 Mechanical testing

In the present study, the short and long terms strength acquisition of paste backfill samples were investigated through the unconfined compression tests on a total of 204 paste cylinders to determine their unconfined compressive strength (UCS).

The UCS values were used to select an optimum mixture recipe for each of tailing types. The compression tests were performed by using an ELE Multiplex 5.0 digital mechanical testing equipment

having a normal load capacity of 50 kN and a displacement speed of 1 mm per minute.

## 3 RESULTS AND DISCUSSION

### 3.1 Effect of the binder type and proportion at short term

In the mine backfilling operations, a slight reduction in the binder content leads to a substantial cost saving. Therefore, it is important to perform a series of tests using different paste backfill mix, to study the effect of binder content on the strength gain of the paste backfill. In this study, the UCS values were obtained from averaging the UCS of three test samples for each binder content and curing time.

Figs 1 and 2 show the relationship between the UCS and curing time for paste backfill samples. As expected, binder type and content play a direct role on the strength gain of the paste backfill samples. As shown in Fig 1a, the strength acquisition of the paste backfill with PKC/A binder is always proportional to the binder contents. The strength gain of the paste backfill samples increases with curing time. At curing time of 3 and 7-day, the strength development of the paste cylinders is similar for 4, 5 and 6 wt% binder contents. After 28 day of curing time, paste backfill mixtures with PKC/A binder having binder content of 7 wt% reached the maximum UCS value of 1.1 MPa. Fig 1b shows that the UCS values of the paste backfill samples prepared using PKC/B binder with 4 and 5 wt% are 0.4 and 0.5 MPa, respectively. However, these values for paste backfill produced with a binder content of 6 and 7wt% are 0.8 and 0.9 MPa (these values are almost twice than previous ones), respectively.

Table 3 Laboratory paste backfill testing program for the studied mill tailings

| Paste backfill samples<br>(Total of 144 samples) | Short term unconfined compressive strength tests |      |                |               |             |                    |    |    |
|--|--|------|----------------|---------------|-------------|--------------------|----|----|
|  | Slump  |      | Binder content | Solid content | Water/solid | Curing time (days) |    |    |
|  | (inch)   | (cm) | (wt %)         | Cw (%)        | ratio       | 3                  | 7  | 28 |
| Tailing T1 with PKC/A binder                     | 7  | 178  | 4, 5, 6, 7     | 82            | 0.22        | 12                 | 12 | 12 |
| Tailing T1 with PKC/B binder                     | 7  | 178  | 4, 5, 6, 7     | 82            | 0.22        | 12                 | 12 | 12 |
| Tailing T2 with PKC/A binder                     | 7  | 178  | 4, 5, 6, 7     | 77            | 0.30        | 12                 | 12 | 12 |
| Tailing T2 with PKC/B binder                     | 7  | 178  | 4, 5, 6, 7     | 77            | 0.30        | 12                 | 12 | 12 |

| Paste backfill samples<br>(Total of 60 samples) | Long term unconfined compressive strength tests |      |                |               |             |                    |   |    |    |     |
|---|---|------|----------------|---------------|-------------|--------------------|---|----|----|-----|
|   | Slump   |      | Binder content | Solid content | Water/solid | Curing time (days) |   |    |    |     |
|   | (inch)  | (cm) | (wt %)         | Cw (%)        | ratio       | 3                  | 7 | 28 | 90 | 180 |
| Tailing T1 with PKC/A binder                    | 7   | 178  | 7              | 82            | 0.22        | 3                  | 3 | 3  | 3  | 3   |
| Tailing T1 with PKC/B binder                    | 7   | 178  | 7              | 82            | 0.22        | 3                  | 3 | 3  | 3  | 3   |
| Tailing T2 with PKC/A binder                    | 7   | 178  | 7              | 77            | 0.30        | 3                  | 3 | 3  | 3  | 3   |
| Tailing T2 with PKC/B binder                    | 7   | 178  | 7              | 77            | 0.30        | 3                  | 3 | 3  | 3  | 3   |

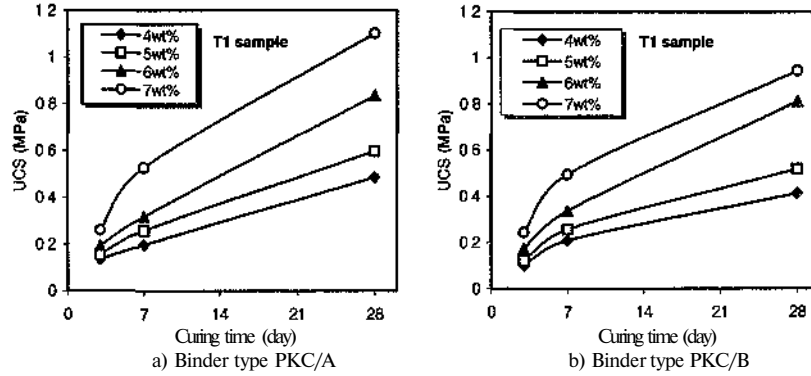


Figure 1 Unconfined compressive strength versus curing time for the cemented paste backfill samples produced from the tailing T1 using (a) PKC/A binder and (b) PKC/B binder

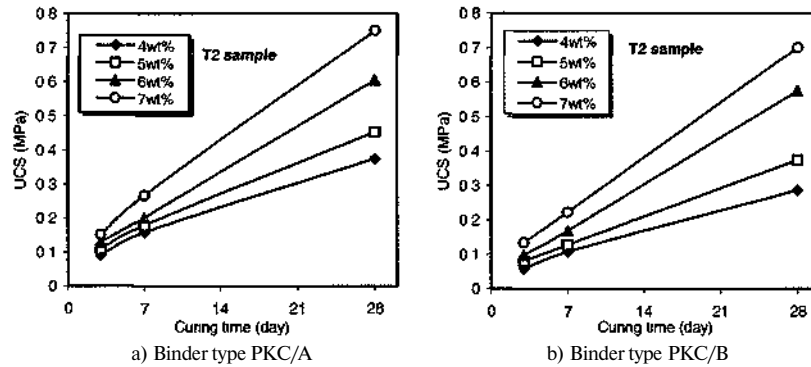


Figure 2 Unconfined compressive strength versus curing time for the cemented paste backfill samples produced from the tailing T2 using (a) PKC/A binder and (b) PKC/B binder

As a result, for a given binder type and proportion, these differences concern both the strength value of paste backfill samples and the effect of the binder percentage. Moreover, from the short term UCS values, paste backfill samples with PKC/A binder were found to have a better performance in comparison to paste backfill samples with PKC/B binder. This may be attributed to the composition of PKC/A binder that contains much more natural and/or artificial additives compared to PKC/B binder. This observation must be supported by more investigation to verify for the short term lower strength value using binder type PKC/B.

Fig. 2 also showed that the strength increase of paste backfill cylinders for each binder type is proportional with binder content within mixture after 28-day of curing. However, the strength gain in the case of binder types used for tailing T1 is slower compared with tailing T2. At 3- and 7-day of curing time, the average strength values of the paste backfill

with tailings T1 and T2 is approximately 0.25 and 0.13 MPa, respectively. It should be noted that the hydration process is influenced by both the material composition for each tailing type and the binder percentage used in the paste backfill mixtures.

Finally, these curves clearly show differences on the strength of each backfill samples. For a given binder, these differences in terms of the unconfined compressive strength are attributed to the chemical and mineralogical composition of each tailing.

### 3.2 Effect of the type of mill tailings at long term

The effect of binder type and proportion on the strength gain of paste backfill made by using mill tailings having different sulphide content was examined for the long term. Only a binder content of 7 wt% was tested. Fig. 3 shows the variation of UCS of the paste backfill made of two different tailings samples in the course of curing time.

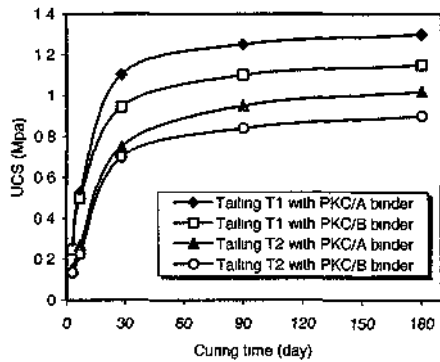


Figure 3 Variation of the UCS of the paste cylinders T1 and T2 using 7 wt% binder in the course of curing time

From Fig. 3, it can also be seen that the UCS values of paste backfill samples with tailing sample T1 is always relatively higher than the ones of paste backfill with tailing sample T2. The UCS of paste backfill samples made of tailing sample T1 and binder type PKC/B obtained between 28- and 180-day of curing time provided a better strength gain varying between 20 and 36%, respectively. All the paste cylinders with PKC/A binder have a positive effect on the strength acquisition of the samples in comparison with PKC/B binder. From the long term tests results, tailing sample T1 produced the higher strength acquisition of around 28% higher than tailing T2 for the same binder percentage.

It is well known that sulphide rich mill tailings produce acid in the presence of oxygen and water. Sulphide minerals within the cemented composites can oxidize and produce soluble sulphates which can have a negative effect on the paste backfill strength acquisition. In most cases, the mechanism of sulphate interaction within the paste backfill acts as three main stages:

- The first stage (stage I) corresponds to a low sulphates (<1000 ppm of  $SO_4^{2-}$ ) concentration that can lead to an inhibition of hardening process. This creates a negative effect on the paste backfill strength gain.

- The second stage (stage II) corresponds to a relatively high sulphate concentration (>1000 ppm and <10000 ppm of  $SO_4^{2-}$ ). Precipitation of sulphate can occur and help to the hardening process in parallel with the appearance of hydrated phases such as C-S-H. This helps cohesion and positively influence strength of the paste backfill.
- The third stage (stage III) happens within already hardened material. Sulphate continues to precipitate until no place is available for the precipitation and then expansion occurs (phenomenon called sulphate attack).

In the case studied here, tailings T1 and T2 may involve mechanism of stage II and I, respectively.

### 3.3 Selection of optimum mix

When paste backfill is used as an underground backfill material for ground support, this material should be investigated in detail from every aspect to ensure strength gain respecting ground support constraints. If this is neglected, an unexpected event such as backfill failure in underground mine may take place. That event is avoided by mine operators because of the costs and mine safety.

Stone (1993) reported that the binder type and content must confer strength of 0.7 MPa after 28-day of curing time (short term) and strength of 1 MPa at 90-day curing time (long term). According to the UCS values obtained in this study, an optimum mixture for tailing samples T1 and T2 after curing time of 28-day were obtained from paste backfills made with binder proportions of 6 and 7 wt%, respectively. Moreover, the target strength values for each tailing sample after 90- and 180-day of curing time (long term) were reached with paste cylinders having a binder content of 7 wt%.

### 3.4 Stress-strain behaviour of the paste cylinders

The deformation behaviour of the paste backfill were determined and presented in terms of axial strain ( $\epsilon_0$ ) and major principal stress ( $\sigma_1$ ) curves.

Table 4 Young's modulus and UCS values for 180-day cured samples of the different paste backfill (7 wt% of binder)

|                              | UCS, a.<br>MPa | Young's modulus, MPa |                |               |               |
|------------------------------|----------------|----------------------|----------------|---------------|---------------|
|                              |                | Initial $E_b$        | Tangent, $E_t$ | Secant, $E_s$ | Average $E_m$ |
| Tailing T1 with PKC/A binder | 1.28           | 120                  | 200            | 167           | 194           |
| Tailing T1 with PKC/B binder | 1.12           | 100                  | 169            | 127           | 167           |
| Tailing T2 with PKC/A binder | 0.98           | 67                   | 147            | 114           | 141           |
| Tailing T2 with PKC/B binder | 0.83           | 40                   | 111            | 67            | 104           |

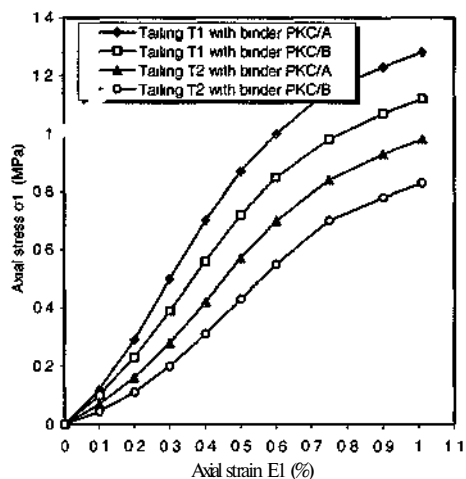


Figure 4 Stress-strain curves of paste backfill with tailing samples T1 and T2 tested after 180-day of curing time

Fig 4 shows the axial stress and strain curves for each of paste cylinders with PKC/A and PKC/B binder types tested after 180 day of curing time. Moreover, all of the unconfined compressive strength values ( $\sigma_1$ ) and Young's modulus ( $E$ ) of the paste backfill samples derived from the curves of Fig 4 are presented in Table 4. Young's modulus of paste material varies depending on binder type and tailing composition.

From Fig 4, it can be seen that the stress-strain behaviour of the samples is elastic-plastic. The failure type of the paste backfill samples is a ductile deformation. That means paste cylinders never burst under excessive deformation stress such as brittle material. Conversely, they may be broken in sample mass, not showing by outside.

#### 4 CONCLUSIONS

In this study, a total of 204 of paste backfill cylinders prepared with two different mill tailings (tailing samples T1 and T2) and two binder types (namely, PKC/A and PKC/B) were tested to investigate their short and long terms performances. The last results confirm that the strength gain of paste cylinders, for each of tailing samples, is proportional to the binder content. The results also showed that the tailing composition depending upon sulphide content and binder types and content has a significant influence

on the strength acquisition and hydration process of the paste backfill.

From the UCS values, the strength gain of paste cylinders with tailing sample T1 is greater than the one of paste cylinders with tailing sample T2. As a result, the physical, chemical and mineralogical characteristics of tailing, mixing water and binder to be used in the paste mixture should be investigated in detail. To increase the strength of paste backfill samples in the long term rather than in the short term, the tailing composition should be suitable with binder used in the mixture. Moreover, the effect of sulphate attack on strength gain at long term should be examined precisely when the paste backfill was produced from sulphide rich tailings. To minimize this negative effect, alternative methods (e.g. the addition of sand and/or lime to the mixture, the use of both sulphate resistant cement and natural and/or artificial additives) should be tried on the samples.

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## **An Integrated Approach at Reducing The Risks Associated with Underground Coal Pillar Extraction of Bord and Pillar Development Areas in South Africa**

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**ABSTRACT:** The Analysis for Pillar Extraction Potential (A-PEP) tool is an expert system which can be used as a preliminary output indicator when considering the secondary extraction of regional support pillars in the Witbank and Highveld coalfields of South Africa based on certain physical, risk and economic factors which combine to be indicative of operational success in terms of these attributes. A-PEP has been successfully tested and validated against an underground coal pillar operation and it has shown that its predictive nature is consistent to the workings at the operation and as such it can be successfully used as a mine planning tool. The A-PEP mine planning tool represents a positive step as a risk management tool in its integrated approach to underground coal pillar extraction when considering legal and operational aspects which could form the basis for legislative guidelines when considering the future of pillar extraction in South Africa.

### **1 INTRODUCTION**

A research initiative (part of the Coaltech 2020 collaborative research programme) investigated the status of underground coal pillar extraction in an attempt to provide the industry with a framework from which an attempt could be made to safely and economically extract the reserves remaining in the form of regional stability pillars in the Witbank and Highveld coalfields. Various pillar extraction operations in South Africa were visited to gain recent experiences with this mining method. The results of these visits, together with an extensive literature review of local pillar extraction planning and design considerations (Beukes, 1989, Livingstone-Blevins & Watson, 1982, Plaistowe *et al*, 1989) showed that little in the way of new technologies, ideas or mining methods have been developed in South Africa in recent years (except for the NEVED method). As this research attempts to develop a design methodology for pillar extraction to increase the utilisation of coal resources, looking at the history of pillar extraction in South Africa provided a good platform of general practices but did not provide any solutions as to how to take this mining technique (considered an art more than a science) successfully into the future. A solution to this problem was to look at other pillar extraction techniques outside of South Africa to identify what elements of these operations could be adopted or

adapted for use in the Witbank and Highveld coalfields. A study tour to New South Wales in Australia was undertaken (where seven underground pillar extraction operations were visited) to assess what mining methods and design criteria are used to ensure the success of this mining practice there. Although the predominant extraction there is based on rib-pillar techniques (which is an unlikely method in South Africa going forward) which differs vastly from the traditional removal of previously developed pillars, it was believed that their success factors could be emulated. This visit highlighted some pertinent success factors associated with pillar extraction and these formed the basis for the development of a design methodology and planning tool called A-PEP (an acronym of Analysis of Pillar Extraction Potential) which is a user-friendly, intelligent tool enabling the potential for pillar extraction of an operation to be assessed by inputting certain physical, risk and economic factors. This paper highlights some of the major findings of the research investigating means of safely and economically extracting underground pillars in the Witbank and Highveld coalfields.

### 1.1 Review of pillar extraction experiences in New South Wales, Austral»

The visit to pillar extraction operations in New South Wales in Australia in the first half of 2001 was aimed primarily at ascertaining whether any new pillar extraction technologies exist which may be of benefit to future pillar extraction operations in South Africa. Australia has a long history of pillar extraction dating back some 60 years (Shepherd & Chaturverdula, 1992); most notably having developed the rib pillar extraction technique (more commonly known as the Wongawilli method). Another innovation developed in Australia and which has found application in the USA is the single- or double-sided Outside Lift and Christmas Tree methods (Mark & Chase, 1999). The operations in New South Wales are however moving away from the pillar extraction techniques in favour of the safer and more productive longwall method of mining. Nonetheless some important design considerations were obtained from pillar extraction experiences in New South Wales (McKensy, 1992); the most notable of which included the specific legislative guidelines for pillar extraction, the use of Mobile Breaker Line Supports (MBLS's), geotechnical mapping and the intensive training undergone by all underground personer (Lind, 2002(a); Lind, 2002(b)). All of these initiatives have their birth in the risk-based approach taken, which is the focus of the design methodology for pillar extraction developed for South Africa situations.

The operations visited in New South Wales were a combination of partial and full pillar extraction methods. All of the mining methods were designed around specific health and safety, economic and environmental requirements of the individual operations. The choice of a partial versus a full extraction system appeared to be based on the following factors:

- Surface subsidence;
- Nature of the immediate 20 m roof; and
- Geological nature of the potential goaf zone.

Where the roof is massive and problems with goafing anticipated, partial pillar extraction was conducted. Also, if surface subsidence was expected that would negatively affect the usage thereof, partial pillar extraction was conducted. The nature of the immediate roof strata, ranging from the seam roof to 20 m above the seam, plays a critical role when the goaf is formed and how cantilevering of the goaf strata leads to collapses which is one of the most im-

portant design factors in deciding whether to conduct full or partial pillar extraction (Anderson, 1993). Generally for New South Wales conditions, when the W:D ratio (width of the panel to the depth below surface) is greater than 1.4, full caving can be expected and when the ratio is greater than or equal to 2 one can expect surface disturbances and this was used as a guide for designing an extraction method. Where favourable conditions existed, full pillar extraction was conducted whenever possible.

Of the full pillar extraction operations, two utilised modified Wongawilli methods designed to suit their individual conditions and where the fender geomechanics and their behaviour with this extraction method are well understood (Shepherd & Lewandowski, 1998). Also, all of the full pillar extraction operations visited had no restriction on the amount of surface subsidence that they created. There was also no sterilisation of overlying economic reserves resulting from the full pillar extraction operations.

All the pillar extraction operations conducted lifting of pillars on retreat and at an angle of 60° and generally in open ended lifts (except in one case where small ribs at times were left between lifts as a result of high stresses in places). Double sided lifting was practiced at all the collieries visited, made possible by the introduction of remote controlled continuous miners and remote controlled MBLS's. A study in the USA found that MBLS's influence the overlying strata up to 18 m (Maleki & Owens, 2001). In terms of the inference that the immediate 20 m roof dictates the goafing behaviour (Anderson, 1993), this indicates that MBLS's are a successful means of controlling the immediate overlying strata during pillar extraction and ensuring that goafing occurs in a controlled manner.

Generally, the trend in New South Wales is to move away from the pillar extraction method of mining in favour of longwall mining. This move is primarily for safety reasons although the successes obtained from the use of MBLS's in reducing goaf overrun and enabling increased productivity and safety ensures that in certain instances pillar extraction can be used<sup>12</sup>.

## 2 A DESIGN METHODOLOGY FOR PILLAR EXTRACTION IN SOUTH AFRICA

Following the successful study tour to pillar extraction operations in New South Wales it was identified that South Africa has no up-to-date design

methodology from which decisions can be made as to whether an operation would be able to conduct pillar extraction safely and economically. It became clear after the visits in Australia that the Mine Health and Safety Act (Act 29 of 1996) in South Africa provided inadequate guidelines to assist an operator with regard to underground pillar extraction. These guidelines in the Mine Health and Safety Act (MHSA) are currently limited to specific subsections which may be considered out dated or no longer applicable. Rather, the MHSA requires that employers (mine owners) as far as reasonably practicable provide a safe operation and healthy environment irrespective of the type of mining method to ensure that all risks associated with the operation are identified and remedial action planned for and implemented before such permission is granted (Chapter 2.1 of the MHSA). Again this legislation is in no way prescriptive as to the nature or the content of what constitutes a reasonably practicable argument to remove or mitigate risks and their associated hazards of pillar extraction. This implies that the application to conduct pillar extraction can and do change from operator to operator. This is not unusual as circumstances will be different from one operation to another. However, inconsistencies will exist in the content and quality of the various applications made to the Department of Minerals and Energy (DME). It is thus at the discretion of the Principal Inspector of Mines to grant approval for pillar extraction based on the content of the application. Further, the Principal Inspector of Mines does not grant approval for mining methods and extraction layouts for pillar extraction in particular, but rather ensures compliance of such a mining practice on a case by case basis in terms of the MHSA. The MHSA however requires that mandatory Codes of Practice exist in coal mines to:

- Combat roof fall accidents on collieries;
- « Prevent coal dust explosions in underground mines; and
- Ventilate mechanical miner sections in coal mines.

Apart from these Codes of Practice, additional portions of the MHSA pertaining to the proposed mining method need to gain approval from the Principal Inspector. In particular Chapter 5 of the Regulations of the Act pertaining to the protection of the surface is given special consideration. Aspects under this chapter include protecting the workings from flooding (through boreholes and any other potential

ingress of water), protecting surface structures (such as road, power lines, buildings, etc.) and monitoring any surface subsidence of the workings if these are less than 240 metres below the surface.

The MHSA merely requires that an experienced geotechnical engineer conducts an investigation into, and participates in the design of, any area that is considered for pillar extraction (specifically focusing on the direction of extraction, the method of extraction and the method of temporary support during extraction). The MHSA further requires that risk analyses be undertaken to aid an operator in providing a safe and healthy work environment (especially where the mining method involves letting down the roof) and thus mitigate any risks through the implementation of Codes of Practice and specific mine standards to enforce these Codes of Practice. Thus a suitable risk analysis process for pillar extraction which identifies high risk factors associated with this mining method and suggests some mitigating controls that will aid an operator in complying with the conditions of the MHSA when considering pillar extraction is required.

## 2.1 A risk analysis for underground pillar extraction in South Africa

A risk analysis is based on the concept that hazards have consequences and the product of these define the risk in a quantifiable manner. Although this risk analysis process has been detailed before<sup>13</sup> it is worth highlighting some of the pertinent issues again.

The risk assessment and control used to develop the framework for the design methodology has been adapted from generic risk models (Tweedale & Joy, 1997). Such a "Broad Brush Risk Assessment" should cover a high proportion of the total mine activity and by its very nature cannot be expected to go into a high degree of detail. One of the pertinent circumstances for which this type of assessment can be conducted includes a need by management to feel confident that they have an understanding of not only the risks involved in the operations of the mine (which an experienced mine manager already has) but also of their relative magnitude and the range and adequacy of the safeguards of all types (Tweedale, 1997). The context (be it strategic or organisational in nature) needs to be established so that the risk assessment has "buy-in" from the necessary stakeholders. A case in point here is the need from an environmental, legislative and profitability point of view to conduct pillar extraction on such a broad-based platform so as to ensure the long-term supply

of coal to the South African and international markets from areas which have been lying dormant for many years since primary development.

There are many different methods available for undertaking a risk study and that the selection of the appropriate method depends on the circumstances of the study<sup>14</sup>. Further, any of the several methods which can be used will give comparable results. It is for these reasons that the risk analysis process presented here was chosen as appropriate in utilising the Workplace Risk Assessment and Control (WRAC) process to identify the pertinent risks associated with pillar extraction. The WRAC method of identifying risks is discussed in great detail by more experienced references (Joy, 1994; Tweedale & Joy, 1997) than this author and should be consulted for greater insight.

The results of the risk analysis conducted for pillar extraction in the Witbank and Highveld coalfields are summarised in Figure 1 (Lind, 2002(c)). In total there were 369 consequences to the 98 hazards identified. The majority of the consequences are related to the pre-production (planning) phase while the operational (production) issues feature high in the risk rating. There are also a high number of issues ranked at the median which indicates that those issues have limited available information pertaining to them in relation to their potential significance. The high risk range is considered to be those with a rating up to and including 6 and in this range the planning and production issues are represented equally. This merely indicates what we intuitively know: should the planning process not be adequate and the necessary operational restrictions be put in place the potential for a serious mishap increases.

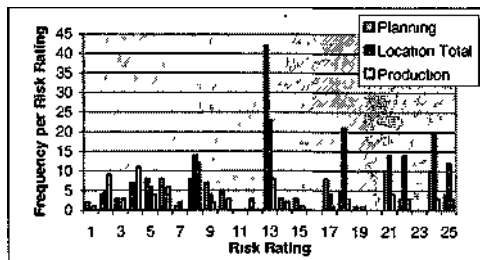


Figure 1 : Risk rating versus frequency per risk rating for the hazards and consequences associated with underground coal pillar extraction

This risk analysis process identified the major risks that need to be considered prior to pillar extraction (Table 1) in South Africa.

Table 1 : High risk hazards for which mitigation is required for pillar extraction

|  |
|--|
| <u>START OF A PANEL</u>                          |
| <u>Original design parameters and conditions</u> |
| <u>Presence of water</u>                         |
| <u>Presence of gases</u>                         |
| Massive roof conditions                          |
| <u>LOCATION WITHIN A PANEL BEING EXTRACTED</u>   |
| <u>Goaf behaviour</u>                            |
| <u>Pillar behaviour</u>                          |
| <u>GENERAL OPERATIONAL ISSUES</u>                |
| <u>Creation of large unsupported spans</u>       |
| <u>The role of remote controlled em's</u>        |
| <u>Cutting parameters</u>                        |
| <u>Interruptions in production activity</u>      |
| <u>The role of temporary supports</u>            |
| <u>The role of intersections</u>                 |
| <u>Ventunng into the goaf</u>                    |
| <u>Pre-sptting of pillars</u>                    |

Apart from the successful mitigation of the consequences associated with the risks in Table 1, the choice of extraction (full, partial or no extraction) needs to be decided for the design methodology to be appropriate. An important geotechnical point is to ensure that either an exclusive system of full or partial extraction be conducted, but never a combination of the two for various reasons<sup>18</sup>. The design methodology should therefore be able to distinguish between these two extraction approaches. Figure 2 represents the aspects stemming from the risk analysis process which acts as a simplified aid in deciding on whether full or partial or no extraction should take place. One of the important conclusions drawn from the flow chart in Figure 2 is that partial pillar extraction could be employed under most conditions.

Deciding on the type of extraction will require that Codes of Practice be drawn up and the necessary mining standards set in place to achieve the objectives of these Codes of Practice. Figure 3 shows a process stemming from Figure 2 to achieve the necessary structures before which to submit an application to the DME to conduct underground pillar extraction. The factors could either be categorised collectively or in combination from which to draw up Codes of Practice and the standards to satisfy the regulations of the MHSAs as well as the high risk issues identified through the risk analysis. These issues are of course not exhaustive but can be considered as

being likely for any pillar extraction operation to consider in South Africa.

### 3 THE ANALYSIS FOR PILLAR EXTRACTION POTENTIAL (A-PEP) PLANNING TOOL

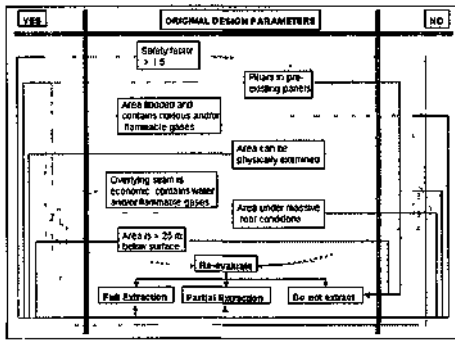


Figure 2: Risk based decisions to decide on full or partial or no extraction

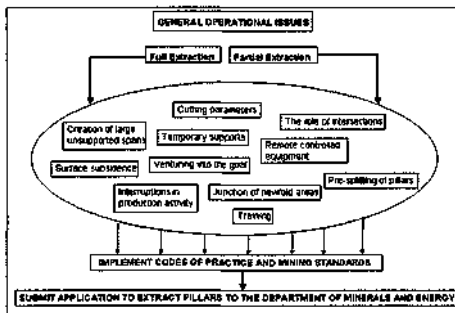


Figure 3: Risk areas needing Code of Practice coverage

The risk issues discussed here begins to highlight the most important issues which will need consideration and action before pillar extraction can be considered. The approach detailed here in deriving this design methodology stems from the requirements of the Mine Health and Safety Act and high risk factors identified through a risk analysis (which produced a number of high risk elements from both a planning and operating perspective) from recent experiences in both South Africa and New South Wales in Australia. All of these elements are now drawn together into a planning tool (A-PEP) which can be used to create an initial assessment of the potential pillar extraction area.

The research up to this point consists of a risk based design methodology prioritizing pertinent risks associated with pillar extraction. The research was taken a step further to attempt to predict the suitability of pre-developed bord and pillar workings for secondary pillar extraction. An attempt to estimate secondary mining potential (SMP) of inactive and abandoned palachian highwalls was conducted in 1990 (Lineberry *et al*, 1990). That approach consisted of 16 parameters grouped into four major categories (geologic conditions, existing infrastructure, site conditions and environmental conditions) to make this judgment. The objectives of that research were to review available literature for current and future methods for safe and economical secondary mining of the abandoned and inactive mining sites and to categorize the conditions for the application of each method<sup>20</sup>. That research attempted to understand the surface conditions and although not extensively tested against real cases it provided a risk-based framework from which to draw conclusions as to the SMP. The Analysis of Pillar Extraction Potential (A-PEP) was designed to draw together the risk based framework and pertinent legislative features to assess the secondary mining potential of underground coal pillars.

It is for this reason that the A-PEP tool is considered of value to the estimation of underground pillar extraction potential as it forms an adequate basis from which future adjustments can be made. The following valuable statement which should be borne in mind when designing such an assessment tool (Lineberry *et al*, 1990):

*"... and at least an engineering 'feel' for ranges and limits influencing choice. Some subjectivity and judgment unavoidably remain...but should still provide a valuable checklist in selecting or evaluating a secondary mining method."*

The A-PEP design tool calculates various output parameters based on inputs which would enable an operator to make certain preliminary decisions in terms of:

- Whether or not the potential for pillar extraction exists based on physical and risk ratings;

- What type of pillar extraction (full or partial) can be conducted based on the physical and risk ratings;
- What type of mining methods can be employed based on the full extraction or partial extraction recommendation; and
- If pillar extraction is recommended, the economic benefit that can be achieved is calculated from additional inputs.

The use of A-PEP is demonstrated with the aid of a case study (in the Witbank coalfield) in South Africa later in this paper while the mechanics of the tool are briefly discussed here.

A-PEP takes relevant physical parameters (see Figure 5) and assesses original geological and primary extraction characteristics to profile the area under consideration. Criteria such as the original design parameters, time since primary extraction as well as the characteristics of the coal seam are evaluated. A-PEP considers depth below surface, the age of the pillars as well as the overall width of the panel as the most critical of these physical factors and these contribute to the overall risk rating (see Figure 6).

The operational risks considered by A-PEP constitute the bulk of the overall risk rating and highlight what was confirmed in the risk analysis process that operational issues could ultimately impact a pillar extraction operation if not considered. The issues are assigned a risk rating of between 1 - 10 for each of the ten most critical issues identified by the research as factors which could lead to potential hazardous situation. The way in which the questions are answered will ascertain the relevant risk. Of these ten issues the presence of overlying coal seams, the presence of surface structures and the presence of an overlying massive strata (such as the strong dolerite sill which overlies much of the Highveld coalfield) are considered the dominant factors which need to be planned for when considering pillar extraction (although all ten issues have a risk rating attached to them). The overall risk score is a combination of the physical factors mentioned and the ten operational risk factors which give a preliminary indication as to whether pillar extraction can take place and the potential method that can be employed.

The use of the A-PEP planning tool is demonstrated here against a real life pillar extraction operation. This case study serves as the validation that the A-PEP tool is able to predict the extraction method when data from the operations were inputted.

### 3.1 Case study: colliery A in the Witbank coalfield

The pillars being extracted at Colliery A were created in the mid-1980\*s (the exact date is unknown) and are situated approximately 80 m below the surface. The surface land is unrestricted (in that there are no surface structures or features of significance) and belongs to the mine ensuring that pillar extraction can occur without any further permission from the Department of Minerals and Energy. The extraction sequence is shown in Figure 4.

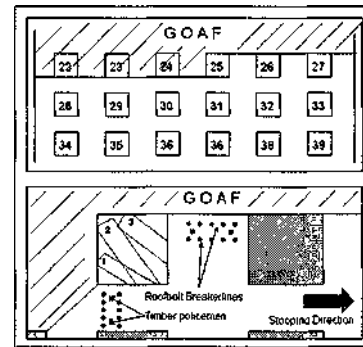


Figure 4: Pillar extraction sequence as used at Colliery A

The seam height is 6 m and the section originally mined the bottom 4 m leaving a 2 m coal roof. The original pillar centre distances were 17 m square with 6.5 m bords with 7 bords in the panel which were created using drill and blast methods. As a consequence pillar slabbing of 0.5 m has been measured when the pillars start to take load, which is slightly more than the expected 0,25 - 0,3 m (Madden 2003). This has resulted in a number of injuries with the pillar corners slabbing off when the load on the pillars increase as the pillar extraction progresses. These slabs are too large to bar down by hand and are made into "no-go" areas (indicated by stonedust markings on the pillar corners) to prevent the potential of persons being injured or killed in these areas. The factor of safety permissible for pillar extraction at Colliery A is 1.8 (although 1.6 is permissible dependant on the goafing angle). It appears as if the goaf angle has a correlation with the safety factor in that the steeper the goafing angle the lower the safety factor needed to conduct safe pillar extraction (Madden, 2003). For example at Colliery A a goaf angle of 60° requires a safety factor of 1,8 while a goaf angle of 85° requires a lower safety of 1,6. The pillar extraction section has a monthly production target of 44,500 tons al-



though 96,000 tons per month have been achieved. The section utilises a HM31 continuous miner with three 20-ton shuttle cars. Use is made of roofbolt breakerlines which are spaced 1 m from one another. The immediate roof consists of interbedded shales and sandstones which is considered ideal for goaf formation in this area as it breaks readily (Madden, 2003) which is attributed to the roofbolt breakerlines being successful in this area. As a rule of thumb at Colliery A, the roof needs to consist of a minimum of 5 m of this sandstone roof irrespective of the depth below surface to be considered for pillar extraction. Timber policemen props are used to give an indication of roof movement (see Figure 4). The mining direction is left to right (as is the ventilation) with holing of the barrier pillar taking place on the left-hand side of the section on every split during extraction. This is done to allow the mine overseer immediate access to the adjacent panel (which will be extracted after this panel has been extracted) to inspect any faults or slips which may run through the panel, to allow controlled ventilation to the new panel as well as to facilitate against any intrushes of water and/or gas from this panel. This allows a measure of continuous risk analysis to be done on the extraction operation and helps facilitate planning on a shift by shift basis.

The extraction planning process followed at Colliery A includes Geological Mapping (GM) which was introduced as part of the planning process in June 2002. It is based on the work done in New South Wales and which is now common practice in the pillar extraction operations there (Sheppard, 2001). The Geological Mapping is conducted in the adjacent new panel while the current panel is being extracted. Of importance at Colliery A is the marking any slips or faults and other geological features and/or anomalies (such as floor rolls) on the plan which is considered to be part of the risk process employed at the mine. The Geological Mapping results are put onto the section plan so that the section miner and supervisors are always aware of the potential hazards in the section. The mine also has a comprehensive Code of Practice for pillar extraction in which all the section personnel are trained to be competent in. A copy of this Code of Practice is available at the section waiting place as well as from all line management. From this it is decided whether the three cut extraction sequence shown in Figure 4 is permissible for the individual pillars which is drawn on each pillar in the section before extraction commences. Dependant mainly on the presence of faults or slips instruction is given to extract cuts 1

and 2, 2 and 3 or 1, 2 and 3 (see Figure 4). In all cases the lift through the pillar centre is taken.

As a result of the time lapsed since the pillars were first created there is a rehabilitation programme associated with the pillar extraction process. The most significant part of the rehabilitation programme is resupporting the roof as systematic roof support was absent during the primary extraction phase since the original roofbolts were 0.7 m long point-anchor installed with wooden headboards. The panel rehabilitation requires that 2.1 m full column resin bolts are installed to secure the coal roof into the overlying strata. This onerous task has resulted in 540 bolts being installed (1 m apart with 4 bolts in a row) around each pillar (including the roofbolt breakerlines). In addition to the resupporting cost, the panel requires new belt infrastructure, ventilation construction and the area to be swept clean.

There have been a total of 8 continuous miner burials, all of which have occurred in the final cut (3<sup>rd</sup> pillar lift) since pillar extraction was started at Colliery A in 1997. In an attempt to minimise this occurrence the final lift (no. 3 in Figure 4) is now only cut to half its planned distance. This has ensured that a stronger snook (higher width to height ratio) than was previously left remains. This was done by trial and error and was found that cutting shorter than halfway leaves too strong a snook which does not break while cutting further than halfway increases the potential of the snook failing prematurely and burying the continuous miner. Since the introduction of this measure in mid-2002 there has not been a continuous miner burial nor have there been any adverse problems associated with the goaf formation. Using this background information A-PEP was populated and the results shown in Figures 5, 6 and 7.

| Physical Factors   |         |
|--|---------|
| What is the average depth below surface of the panel considered for extraction (in metres)?                  | 100     |
| What is the pillar centre to centre width (in metres)?   | 12      |
| What is the pillar centre to centre length (in metres) (if values differ between the three values of above)? | 18      |
| What is the average pillar height (in metres)?   | 6.5     |
| What is the average pillar height (in metres)?   | 4       |
| How many bolts are there in the panel?   | 7       |
| What is the average height (in metres)?  | 700     |
| What is the average density of the coal?   | 1.2     |
| What is the average age of the pillar that are considered for extraction (in months)?                        | 10      |
| Panel width from rehabilitation group  | 103     |
| Width of the immediate roof below of the pillar (in metres)?   | 103     |
| Width of the immediate roof below of the pillar (in metres)?   | 103     |
| Pillar width in metres   | 12      |
| Pillar strength from information group (kPa)   | 8.51    |
| Pillar load from information group (kPa)   | 5.26    |
| Current cut day factor (Time and temperature group)  | 1.52    |
| Current overall panel and pillar (in metres)   | 82      |
| Estimated average available load from information group  | 1157180 |
| Estimated average remaining in panel from information group  | 82298   |

Figure 5: A-PEP physical factors output for Colliery A

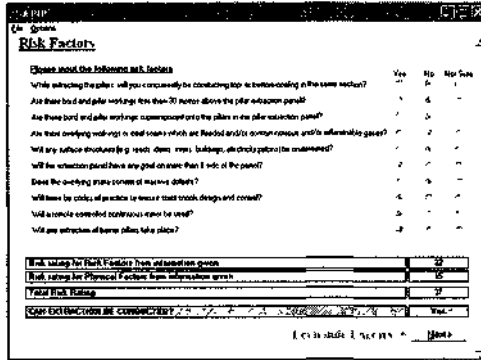


Figure 6: A-PEP risk factors output for Colliery A

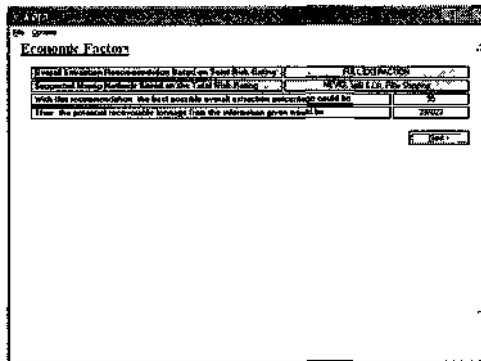


Figure 7: A-PEP economic factors output for Colliery A

From Figures 5, 6 and 7 it is seen that the A-PEP planning tool is able to predict the extraction method employed at Colliery A when all the relevant physical and risk factors are evaluated. From Figure 6 we see that the age of pillars is flagged because it has been 5 or more years since they were originally developed (the pillars were formed 10 - 15 years ago). The safety factor is 1.62 which is within the range required by Colliery A to consider conducting pillar extraction which indicates that the goaf angle for this panel is greater than 80°. This analysis has not taken into account the effects of pillar slabbing as a result of them being formed by drill and blast methods however (the assumption being that the pillars will remain intact until additional load is placed on them as the goaf line progresses with the pillar extraction operation). From the summary in Figure 6 it is seen that the operational risks are low and that these, when combined with the physical risks, have a total risk ranking of 37. This value is considered low enough by A-PEP to recommend that pillar extraction be conducted. Figure 7 shows that A-PEP in fact suggests that full pillar extraction be conducted when

considering that above physical parameters and operational risk parameters.

Because there are a myriad of full pillar extraction methods, A-PEP only makes some suggestions of mining methods that would be appropriate for the given set of circumstances. The pillar extraction method employed at Colliery A can be described as being a full pillar extraction operation. The definition assumed here of full pillar extraction comprises the letting down of the roof against the goaf line in a controlled manner whereas partial pillar extraction utilises the yield pillar technique of letting down the roof in a controlled manner over time.

#### 4 CONCLUSION

This paper has highlighted that the process followed in implementing pillar extraction techniques and processes remains one which is unstructured in its general approach in South Africa. This paper attempts to provide a basis from which consideration can be given to the general and most likely risks that will be encountered by an operator when faced with a pre-developed bord and pillar area for which he wants assess its pillar extraction potential (based on the success of this mining method in Australia). The A-PEP tool (which is based on a risk analysis of the pillar extraction mining method) has been introduced and has shown that it is able to correctly predict an appropriate secondary extraction method based on information pertaining to the unique geological and initial mining conditions of an operating pillar extraction operation in the Witbank coalfield.

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## Platinum Market - Position Paper

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**ABSTRACT:** This paper considers the fundamentals affecting platinum prices. It offers a brief overview of supply and demand patterns and highlights the volatility in market prices over the last decade. This situation has left South African producers of platinum with the difficult challenge of planning future capacity. Although no solution is offered for the problem of estimating future platinum prices at reasonable confidence level, this article nevertheless offers the reader an understanding of price variables currently at issue in South Africa.

### 1 INTRODUCTION

South Africa is one of the wealthiest countries in terms of mineral resources and it is the world's number one gold and platinum producer. South Africa alone produced seventy-seven percent (4.98 million oz) of annual global platinum output during 2004. Anglo Platinum (Angloplat) the world's number one platinum miner, produced 2.45 million oz of platinum in 2004 making up almost fifty percent of the South African annual platinum production.

To be able to predict future platinum prices, we need to have a look at the fundamentals affecting the platinum market. This paper attempts to identify those fundamentals.

### 2 USE OF PLATINUM

The platinum group metals (PGMs) play a vital role at the heart of everyday living. From fountain pens to aircraft turbines, from anti-cancer drugs to mobile phones, from catalytic converters for automobiles to ceramic glazes all rely on platinum and other PGMs. The International Platinum Association (2005) estimates that about one in four goods in daily use owes its existence to PGMs (platinum, palladium, rhodium, iridium, ruthenium and osmium).

As an industrial metal, platinum is enormously useful and valuable. It is the hardest of the precious

metals, and has many unique properties that make it essential and irreplaceable to many vital industries. One of the most common industrial uses for platinum is based on its attributes as a catalyst. Automobile catalytic converters rely heavily on platinum (and palladium) to reduce polluting emissions from cars. Platinum is most efficient as a catalytic converter in automobiles burning diesel fuel, the fossil fuel that sustains most of the world. Platinum is also used as a catalyst in cracking crude oil into various other petroleum distillates.

Platinum has a very high melting point of 1700 degrees Celsius (70% higher than gold) and is useful in industrial applications exposed to high heat, including industrial thermocouples and laboratory vessels. Other civilian uses include electrical wiring in harsh and demanding environments, corrosion resistant applications, and providing cathodic protection systems for large ships, pipelines, and steel piers exposed to ocean water.

Platinum is extremely important for defense and aerospace applications, and is used in environments exposed to tremendous heat for long periods of time, including coating ballistic missile warheads to protect from atmospheric re-entry heat to constructing high performance jet engine components. The US government declared platinum a strategic metal while working on the Manhattan Project in the 1940s, as it is tremendously important in nuclear fission and fusion physics and applications. Many other uses will probably be

discovered for platinum's unique and unequalled physical properties (Hamilton, 2000).

The outlook for future industrial use for the metal is very bullish, as it will most likely be a critical ingredient in the much hyped hydrogen fuel cells. The fuel cells will be an alternate form of power, employing platinum to help separate common water into its component hydrogen (high yield fuel) and oxygen (oxidizer). Honda Japan recently started delivering fuel cell powered cars to the USA (Platinumtoday, 2005)

### 3 PLATINUM PRICES

Like any other commodity, the platinum spot price is mostly driven by the supply and demand figures which require comprehensive analysis in terms of predicting future platinum prices. The main factors that influence the platinum prices are:

- Supply and demand
- Speculative activities
- The ratio between US dollar - South African rand rates
- Market cyclically

In addition to these factors, political uncertainty and research and development had some impact on platinum pricing. Those impacts are somehow visible in supply and demand figures. The market leaders in these fields like Johnson Matthey, Barclays Capital, UBS Investment Bank, JP Morgan Investment Bank, etc. are the organisations that usually predict the future platinum price trading range through a comprehensive analysis of these factors.

#### 3.1 Supply

Mauve (2000) defined supply as "the provision of a commodity". An analyst must recognize the effect the following factors have on availability. Tilton (1985) lists the following factors which drive supply for most mineral commodities:

- The price of the commodity
- The status of the commodity
- Input costs
- Socio-political disruptions
- The structure of the market
- Technological change
- Governmental activities

Total world supply for a commodity is estimated by calculating the total amount of that commodity made available to the market. Mineral commodities are made available from primary production (which generates individual products, main products, co-products and by-products) and secondary production, i.e. new and old scrap. Figures for both primary and secondary production can be acquired from annual reports of producers.

Such data should be audited and must be verified to ensure the accuracy of supply estimation. Supply can be measured at each stage of the production process of a commodity (e.g. comminution, concentration, refining and scrap metal recovery).

#### 3.2 Demand

Mauve (2000) defined demand as "the desire that a consumer has for a commodity". Tilton (1985) lists the following factors which drive demand for most mineral commodities:

- The price of the commodity
- Income (growth in GDP)
- The availability of substitutes for a commodity
- The availability of complimentary substances which can be used in combination with a commodity
- Consumer preferences
- Technological change
- Governmental Activities

An understanding of these factors is critical to an analysis and prediction of demand for a commodity. Demand can be measured and analysed at different stages of use. Platinum demand, for example can be measured during the following stages of beneficiation:

- Fabrication of refined platinum and platinum products
- Manufacturing of platinum products (i.e. mints, autocatalyst producers, jewellery manufacturers etc.)
- « Consumption of final platinum products

Radetzki and Tilton (1988), suggest four techniques for estimating the demand for a mineral commodity. These are:

- The Intensity of Use (IU) technique which calculates the demand for a commodity based on its use in all final products.

- Demand for a commodity in relation to its determinants. This technique suggests that demand for a commodity is a function of its price, the price of its close substitutes and GDP.
- Demand based on one specific application of a commodity. An example of this is the estimation of total world copper demand based on its use in the manufacture of insulated cable.
- The use of input-output tables. This technique requires that input-output tables are sufficiently disaggregated to allow an analyst to identify the individual commodity and determine its intermediate and final uses.

Two factors are critical when estimating annual world demand for a commodity, viz:

- Data used must be validated. The higher the quality of the data used the more accurate the estimation of demand
- Changes in inventory must be accounted for. This is a difficult task due to the general lack of reporting on inventories. It is important to remember that quantities demanded by inventories must be negative in order to compensate for shortfalls in supply

| Platinum Supply and Demand   |              |              |              |              |              |              |              |              |              |              |
|------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| '000 oz.                     | 1995         | 1996         | 1997         | 1998         | 1999         | 2000         | 2001         | 2002         | 2003         | 2004         |
| <b>Supply</b>                |              |              |              |              |              |              |              |              |              |              |
| South Africa                 | 3 270        | 4 390        | 3 793        | 3 630        | 3 400        | 3 873        | 4 100        | 4 450        | 4 100        | 4 900        |
| Russia                       | 1 280        | 1 220        | 900          | 1 300        | 540          | 1 100        | 1 300        | 900          | 1 050        | 800          |
| North America                | 240          | 240          | 240          | 230          | 270          | 280          | 300          | 300          | 290          | 360          |
| Others                       | 100          | 100          | 120          | 130          | 160          | 105          | 100          | 150          | 175          | 240          |
| <b>Total Supply</b>          | <b>4 990</b> | <b>6 950</b> | <b>4 960</b> | <b>5 430</b> | <b>4 870</b> | <b>6 258</b> | <b>6 800</b> | <b>5 970</b> | <b>6 290</b> | <b>6 430</b> |
| <b>Demand by Application</b> |              |              |              |              |              |              |              |              |              |              |
| Autocatalytic gross          | 1 850        | 1 890        | 1 830        | 1 300        | 1 010        | 1 890        | 2 570        | 2 990        | 3 210        | 3 430        |
| recovery                     | (320)        | (350)        | (570)        | (400)        | (400)        | (470)        | (500)        | (560)        | (640)        | (695)        |
| Chemical                     | 275          | 290          | 295          | 230          | 320          | 295          | 290          | 275          | 315          | 360          |
| Electrical                   | 250          | 275          | 305          | 300          | 370          | 455          | 305          | 315          | 260          | 280          |
| Glass                        | 245          | 185          | 265          | 220          | 200          | 255          | 290          | 245          | 160          | 240          |
| Investment: small            | 75           | 110          | 180          | 210          | 20           | 40           | 50           | 45           | 30           | 25           |
| large                        | 270          | 130          | 60           | 105          | 90           | (100)        | 40           | 35           | (15)         | (20)         |
| Jewellery                    | 1 880        | 1 990        | 2 150        | 2 430        | 2 830        | 2 830        | 2 590        | 2 820        | 2 440        | 2 200        |
| Petroleum                    | 135          | 185          | 170          | 125          | 115          | 110          | 130          | 130          | 150          | 160          |
| Other                        | 230          | 255          | 245          | 305          | 385          | 375          | 425          | 540          | 570          | 570          |
| <b>Total Demand</b>          | <b>4 840</b> | <b>4 960</b> | <b>5 130</b> | <b>5 370</b> | <b>5 800</b> | <b>6 050</b> | <b>6 270</b> | <b>6 470</b> | <b>6 420</b> | <b>6 470</b> |
| <b>Movements in Stocks</b>   | <b>150</b>   | <b>20</b>    | <b>(170)</b> | <b>30</b>    | <b>(720)</b> | <b>(300)</b> | <b>(270)</b> | <b>(600)</b> | <b>(220)</b> | <b>(40)</b>  |

Figure 1. Platinum Supply and Demand (Johnson Matthey, 2004)

Information pertaining to annual estimates of supply and demand for commodities is available from a number of sources. Actual observation, internet web sites, news reports and annual reports of producers and consumers are the most current and relevant sources for such data. Once data has been sourced it must be verified and validated before it can be used with any degree of confidence. The higher the degree of accuracy of all data which constitutes total world supply or demand for a commodity, the greater the confidence in a prediction of the state of the market.

Once the underlying factors that affect supply and demand of a commodity have been well researched (sourced and validated), a supply and demand

balance can be worked out. This balance can be calculated for historic, current and future commodity markets. A derived excess or shortfall in future supply (within the "balance") will assist analysts in their predictions of commodity prices (Mauve, 2000). Figure 1 shows platinum supply and demand over the last ten years while Figure 2 shows the graphical representation of similar data between 2000 and 2004.

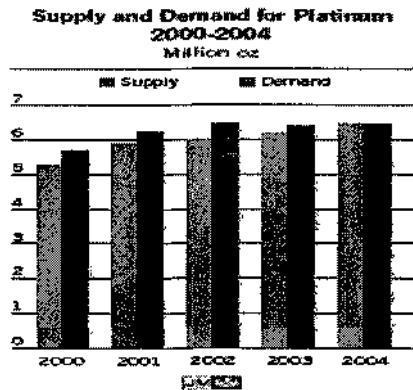


Figure 2. Platinum Supply and Demand (Johnson Matthey, 2004)

Figure 3 shows platinum prices over the last five years. Over the last five years, platinum demand was always greater than the supply but Johnson Matthey (2004) as well as UBS Investment Bank (Brown, 2004) forecast that in 2005, supplies of platinum would expand faster than demand, so that the market would move into surplus for the first time in six years. If surplus take places, it will have a negative impact on platinum prices. However, the platinum price rose from \$815/oz at the beginning of January 2004 to a twenty-four year peak of \$937/oz on the 19<sup>th</sup> of April, 2004. Johnson Matthey claims that speculative activities such as platinum features by funds as well as investors were primarily responsible for driving the platinum price high. According to Johnson Matthey, speculative activity is likely to continue to have a substantial influence on daily movements on the platinum price.

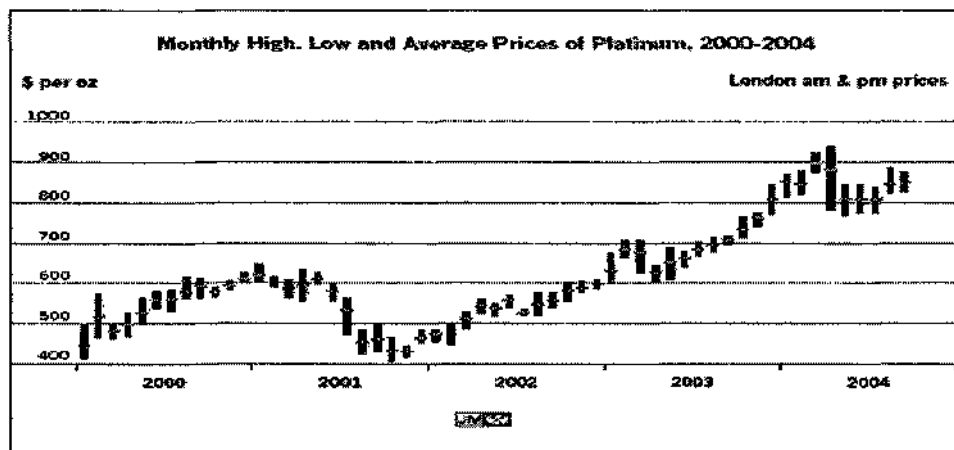


Figure 3. Platinum Prices 2000-2004 (Johnson Matthey, 2004)

When platinum demand by application is considered, the autocatalyst sector is the biggest user (40%) of the metal while jewellery follows with 38%.

Johnson Matthey reported that in 2004 purchases of platinum for use in autocatalysts increased by 7 per cent to a record 3.43 million oz, propelled by higher diesel car sales in Europe and tighter emissions limits. Higher European demand resulted from the ongoing growth of diesel car sales, and an increase in average catalyst loadings in response to Euro IV emissions limits, which came into effect for new car models in January 2005. The result of this

regulation necessitated the use of higher platinum loading in diesel oxidation catalysts. Currently, the European Commission is evaluating plans to introduce more stringent emission legislation on diesel particulate emissions. Under the term of the proposal, emissions would be reduced to 5 milligrams per kilometre from 2010 - a major drop from the current Euro IV emission standard of 25 milligrams per kilometre (Platinumtoday, 2005). Johnson Matthey (2004) forecasts that Japanese autocatalyst demand for platinum will also rise as truck manufacturers launch models that meet new emissions regulations.



Platinum demand by application 2004  
Total: 6.47 million oz

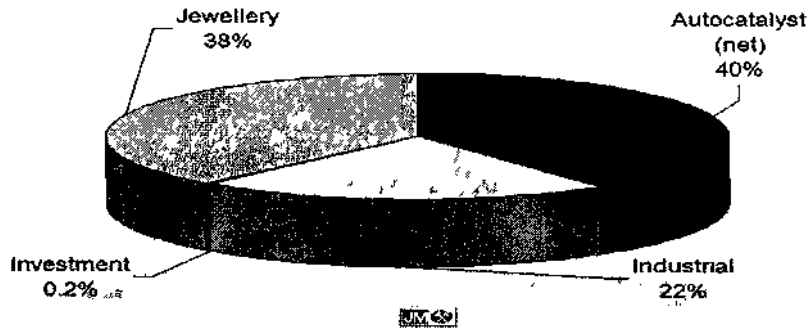


Figure 4 Platinum demand by application 2004 (Johnson Matthey, 2004)

However, demand for platinum from the jewellery industry is forecast to drop by 240,000 oz to 2.20 million oz, the lowest total since 1997, because of the high platinum price. This led to an increase in palladium demand, one of the PGM metals, in the jewellery sector which is considerably cheaper in comparison to platinum jewellery (figures 1 and 4).

Industrial demand for platinum continues to increase. This increase is supported by not only the

expansion of LCD glass manufacturing capacity in Asia but also more and more industrial applications requiring platinum, such as nerve gas detection technology and treatment of cancer (Platnumtoday, 2005). Demand for platinum in fuel cells continues to grow as fuel cell powered cars have already started taking market shares in the USA. The Japanese industry ministry has announced plans to fund research into extending the lifespan of fuel cells (Platnumtoday, 2005).

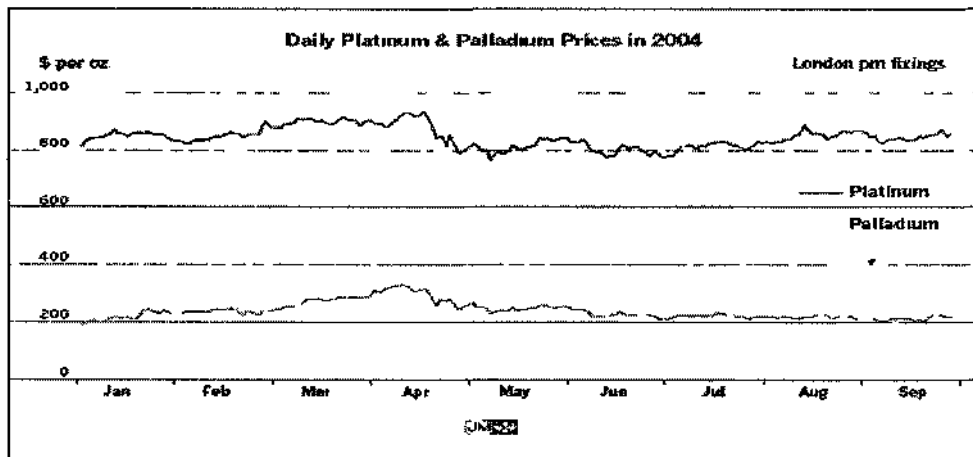


Figure 5 Daily platinum and palladium prices in 2004 (Johnson Matthey, 2004)

Palladium has platinum features and is also used as a catalyst, in jewellery as well as in electronics and dental applications. In the US, auto companies continue to move towards greater use of palladium-

based catalyst systems for gasoline vehicles. Platinum is the main component of diesel catalyst systems. In April 2004, Urmcore, a Belgian catalyst manufacturer announced that it had developed

technology (Steward & Tredway, 2004) that will allow palladium to replace some of the more expensive platinum in diesel autocatalysts, which will use 25 percent of palladium (Tredway, 2004). This news helped to push palladium price up to \$333 in April 2004 but the rally was short-lived. In November 2004 at the World Platinum Congress in Johannesburg, Johnson Matthey reported that a big US jewellery seller had stopped selling its palladium products because of all the returns. All these factors, in addition to a surplus supply of palladium, pushed the price difference between platinum and palladium to up to \$690 in February 2005, which indicated a 4.6 to 1 price ratio between platinum and palladium. (Figure 5) (Candy, 2005).

### 3.3 The ratio between US dollar - South African rand rates

The platinum prices for South African producers are highly sensitive to the ratio between the US dollar (USD) and the South African rand (ZAR). Platinum is traded predominantly in dollars and since 2001, the US trade and current account deficit have continued to widen the main reason behind US dollar weakness against all major currencies. The US current-account deficit stands over \$600 billion annually for 2004. The weak US dollar pushed the commodity prices higher (Sergeant, 2005).



Figure 6 US dollar versus South African rand 2001 - 2004

The strong rand had a major impact in mining operations in South Africa. In December 2004, the South African rand touched 5.61 to the US dollar, its best level since November 1998. The continuing strength of the rand against dollar over the last two years forced South African platinum mines to reconsider their future expansion plans. Angloplat, which supplies about 38 percent of the world's platinum output, announced in 1999 that it would expand platinum production from 2 to 3.5 million ounces per annum by 2006, but was forced in December 2003 to scale that back to 2.9 million ounces because of rand strength (Steward & Tredway, 2004). According to Angloplat results for the year ended 31 December 2004 which was published on 14 February 2005, the production

target for 2006 was cut furthermore to between 2.7 and 2.8 million oz. The fact that most of the SA platinum miners cost are mainly in rand while their revenues are wholly in US dollars makes USD versus ZAR ratio extremely important to the platinum mining industry. The strong rand has had huge implications over the last two years in particular where new projects became less viable; as a consequence the possibility of new job creation was stalled. Figure 6 shows ZAR and USD values between 2001 and 2004.

One of the most important implications of the strong rand is its impact on the amount of platinum supply to the market. South Africa's major producers, Angloplat and Impala Platinum, confirmed that platinum supply from South Africa

would be tempered by the strength of the rand (Candy, 2005) Candy (2005) also reported that Virtual Metals, the London-based precious metal consultancy believes that the strong rand will see a continued supply shortfall It seems as though the market is heading to a new era where the rand sets the platinum price Table 1 shows platinum price forecast for 2005 by the market leaders

Table 1 Platinum price forecast in USD for 2005

| Institutions                  | Low | High | Average |
|-------------------------------|-----|------|---------|
| Impala Platinum*              | 825 | 875  | 850     |
| Johnson Matthey <sup>b</sup>  | 760 | 880  | 820     |
| JP Morgan <sup>c</sup>        | 807 | 891  | 849     |
| Barclays Capital <sup>d</sup> | 750 | 950  | 850     |

Source a Candy, 2004, b Brown, 2004

### 3.4 Market cyclicalities

Davutyan and Roberts (1994), proved that most metal commodities "can be described as having some degree of cyclicalities, in the sense that there is a duration dependence on the length of phases" These phases or cycles are contractions or expansions in market prices and are clearly seen in platinum spot prices over a period of time Phases are defined as a period of prices occurring between a price peak and a price trough The former comprises a price which is higher than at least two years of preceding prices and the latter a price that is lower than at least two years of preceding prices The work by Davutyan and Roberts (1994) established that there is an increasing likelihood of a drop in the price of a commodity as a phase of relatively high prices for that commodity persists The cycles of commodities can be assessed over varying periods of time Davutyan and Roberts (1994) suggests long-term, moderate term and short term cycles usually exist for any one commodity

## 4 CONCLUSION

The future price of platinum will heavily depend on supply and demand patterns South Africa supplies almost 78 percent of the world's platinum output making it an important factor to consider when estimating the future price of platinum The continued strength in the South African rand will probably force the platinum price above the current rates in the short to medium term The challenge is to quantify all the supply and demand variables impacting on platinum prices and to derive a model for estimating future prices within reasonable confidence limits Such a model will be of great

benefit to platinum producers who firstly, must negotiate price agreements and secondly, plan optimal production capacity for the short, medium and long term

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## Sustainable Development Concept in Mining Sector

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**ABSTRACT:** In this study, first of all the definition of sustainable development is made and the awareness of environmental, social and economic issues in the public for diverse sectors and mining have been reported. Then, the literature examining the applicable sustainable development in the corporate mining context at national and international scales are studied and the sustainable development agendas for mines have been investigated. Finally, the steps that a mine must take in order to improve the sustainability of the operations are emphasized improving the social and economic satisfaction in association with the necessary environmental conservation and several recommendations have been proposed for this purpose.

### 1. INTRODUCTION

It has become a prominent concern among the public in the recent years to focus more on the environmental impacts of several industries and for this purpose, many conferences were held in different parts of the world in the last decade to argue and find immediate solutions to environmental and socioeconomic issues. A major outcome of these meetings, The Brundtland Report, which was published in 1987, compelled the governments and the industries pay more attention to environmental problems and socioeconomic responsibility. This report has brought into agenda a brand new concern - sustainable development for the first time. Sustainable development can be defined as meeting the needs of the present time without risking the requirements and sources of the future generation (WCED, 1987). The term "sustainable development" functions to integrate the needs of economy, environment and society by finding solutions in the common ground for all parties. Sustainable development is generally the combination of improved socioeconomic growth, advanced

environmental protection and pollution prevention. Other definitions presented up to date are given in Table 1 (Barrow, 1999).

After the realization of sustainable development by a wide range of companies and governments, they began to make commitments more to these issues and consult the spirit of sustainable development as a guide in policy-making activities. One of the controversial industries that interfere with economic, social and environmental benefits is the mining sector. According to the sustainability policy that will be put into practice, the role and objectives of the government and also the strategies to keep sustainable development operational and fresh in the mining industry, certain initiatives should be taken up and implemented by the private sectoral part and governmental portion of mining. In this paper, the interpretation of sustainable development in the mining context is made and the key points are outlined about

how the companies and the governmental organizations would contribute to sustainable development.

#### Table 1. Diverse Definitions for Sustainable Development

\* Environmental care "married" to development

\* Improving the quality of human life while living within the carrying capacity of supporting ecosystems

\* Development based on the principle of intergenerational inter-species and inter-group equity

\* Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

\* An environmental "handrail" to guide development

\* A change in consumption patterns toward more benign products, and a shift in investment patterns toward augmenting environmental capital

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## 2. INTERPRETATION OF SUSTAINABLE DEVELOPMENT IN THE MINING SECTOR

Although the Brundtland Report globally delineates the sustainable development, it fails to explain how to implement and continue it in the mining sector. This is because different countries will comprehend and achieve this term in a wide spectrum due to the variations in economic, environmental and political circumstances throughout the world (NRC, 1995). This vague characteristic of the report has urged in time several academics and industrialists to build a chain of guidelines and "indicator sets" in order to ease its implementation for diverse sectors. In an analogous manner, several experts related to mining have made precious attempts to outline exactly how sustainable development applies to mining activities and mineral-based commodities. Most of these interpretations seem to mention the nonrenewable character of mineral deposits and contamination effect of mine over the environment.

The term "sustainable development" is generally taken for the term "environmental protection" in mining. This creates frequently deceptive situations because, if it is only interchanged with environmental contamination then the 2 other components, economic and social aspects happen to be ignored (Da Graaf et al., 1996). This comes out because many of the previous sustainable development evaluations in the mining sector focus on the environment protection alone. For example, Carbon (1997) argued that in case environmental problems at a mine were significantly discarded, then the mining industry would contribute a lot to the sustainable development. Nonetheless, social benefits and economic aspects should be considered at least as important as the environment contamination. Only this concern has even become very helpful with regard to mining industry, and because of the rising sustainable development concept, environmental policies have become more comprehensive and stricter during passing years.

Many researchers have put forward theories that are based upon the nonrenewable nature of the mineral deposits as referred in the text before. One of the outstanding theories about this topic has been argued by Tilton (1996). He presented two different viewpoints on nonrenewable sources and sustainable development. The former opinion of him suggests that according to this trend, Earth will not be able to cope with the demands for minerals and other exhaustible resources in the future. This idea is rather skeptical about the future of natural resources

and attempts to calculate the time duration for any given commodity. The latter idea of Tilton is not concerned with resource exhaustion. Opposingly, it defends that particularly metallic ores are not entirely consumed but recycled or transformed into other forms. It also claims that since the easiest accessible deposits that are close to the surface are initially extracted, it might be foreseen that there is still a great deal of mineral reserves well beyond the anticipated levels at underground depths within the Earth's crust.

The mineral depletion has been assessed in association with sustainability also by Auty & Mikesell (1998), extensively. These authors and the supporters of mineral exhaustion theory discuss that mineral deposits are finite and therefore sustainability policies should be constrained so that mineral exploration and production should be limited in order to give the prospective generations an opportunity for sufficient resources. This might solely look possible by slowing down the mineral production domestically and by delaying and decreasing the export capacity for mineral selling countries.

However, Crowson (1998) states that if a mine is considered from an aspect of resource exhaustion only, then no operation is sustainable. Unlike the general accepted opinion for mine operators, many companies have joined other industries in order to contribute to sustainable development by strengthening the relationship between industry, environment and the society. In the recent years, big mining firms even happen to volunteer for policy-making in sustainable development more than identified in the literature and try to minimize the environmental impacts of mining by taking extra measures and improving social and economic liaisons with the stake holders. Therefore, sustainable development should not be perceived as the lifetime of mineral resources or a prolonged mineral wealth for a country. Practically, it is best to eliminate the environmental impacts of mining and ensure that the community is potentially kept satisfactory by additional social incidents.

## 3. SUSTAINABLE AGENDA FOR MINES

In order to make contributions to sustainable development, all mining operations must in the first hand be devoted to environment issue (Hilson, 2000). These operations should include resource control, monitoring and consumption rate, which are, classified under environmental management

techniques that apply to sustainable development. Within the framework of environmental management techniques, necessary changes are obliged to be made starting from the extraction until processing and beneficiation phases. Potential damages of a mine can be listed as dust problem, visual contamination, water pollution through heavy metal contamination and acid mine drainage, soil erosion, landform changes, vegetative demolition and noxious gases and sustainable development emphasizes that these problems need to be immediately solved before they turn into environmental crises at large scale.

Nevertheless, sustainable development means much more than simply complying with environmental standards. Principle 1 of The Rio Declaration says, "human beings are at the center of concerns for sustainable development" (Epps, 1997). Therefore, another essential element of sustainable development is accepted as the social responsibility, which has to take into consideration the needs of stakeholders. Mining companies are in touch with more stakeholder groups when compared to other industries. Positive relations have to be established with fund supplying foundations like banks and financial organizations and also social efforts have to be spent to set good liaisons with the residents in which the mine site is located. This close relation is usually a tough task for the investors because the community realizes the damages of mining as destructive and even irreversible. The persuasion of the society that the environmental damage is temporal and by providing donations for local organizations and even employment benefits, make the community to accept the mining activities more comfortably and with less complaints. This warm mutual relation is bound to lead to sustainable development naturally and undoubtedly.

The priority of mining companies like most trading firms is the maximization of profits and showing strong competition among other rivals in the national and international markets. In addition to such goals, increased environment awareness and socioeconomic correspondence also supply an amount of economic return, although in the long run. For instance, involving the local society in a range of mining activities return to the company in the form of easier exploration and production attempts at the other sites nearby. It is a fact that commitment to sustainable development in the mining context should satisfy all parties and the companies that choose to follow the sustainable development guidelines are likely to reduce the probable environmental impacts and enhance their relations with the stakeholder groups and the community.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

Mining sector and indirectly the minerals are very essential for the growth and progress of the countries due to their wide range of utilization possibilities as raw materials. With the increasing environment consciousness among public in the last two decades, sustainable development concept has been extensively pronounced in the mining context also.

Sustainable development, which is defined as the meeting of the current needs of the present generation without jeopardizing the resources of the future ones, implies that every activity in mining must serve environment conservation, social responsibility and economic benefits as in other sectors.

Environment protection is best accomplished by a proper and effective environment management policy. During exploration stages, necessary measures have to be taken to avoid any damage to the ecosystem (fauna and flora of the site) and to prevent pollution of surface, ground water and streams. During excavation, clear mining technologies that emit well-treated waste should be employed and for this aim, the equipment has to be modified or even substituted. During mine closure, reclamations study must be imperative so that the degraded land is restored and planned for after uses.

With respect to the socioeconomic agenda, mine operators should first try to collect information about the opinions of the community on mine development and calculate the way of life, relationships and social resilience within the community. They should identify the benefits and negative impacts to the society beforehand and determine the participation of local people within the mentioned mine project. Provided that a mine is economically investigated, a mine can provide employment benefits, local services and make financial donations to some charitable organizations in the community. Here, it can be concluded that in order to speak of a desired sustainable development in mining sector, environmental protection, social benefits and economic profits are always supposed to walk collaterally. Furthermore, it would be convenient to suggest the inclusion of a "sustainable development lecture" within the mining engineering curriculum at universities to raise more proficient young engineers.

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## Towards A Sustainable Mining Industry: Actions and Tools

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**ABSTRACT:** This paper examines the sustainability concept within the mining industry and additionally aims to briefly discuss available tools for making the mining sector actions more sustainable on project, programme and policy level. The first section of the paper looks at the early works and actions aimed to integrate and intertwine the concept of sustainability into mining operations. While second section focuses on the possible tools, which can be implemented on the organizational and project levels, as well as on the policy, programme and plan levels. Strategic Environmental Assessment (SEA), although not long in the practice, has so far shown promising results when implemented on the highest decision-making levels, policy, programme and plan levels. While the implementation of Environmental Management Systems (EMS) and Environmental Management Plan (EMP) in the organizational practice, together with the Environmental Impact Assessment (EIA), as a part of EMS, can significantly contribute to the mitigation of environmental impacts on the project level.

### 1 ACTIONS TOWARDS A SUSTAINABLE MINING INDUSTRY

Rather than trying to give a new definition of sustainable development, this section aims to discuss the sustainability concept in the mining industry operations and early actions towards making the industry more 'sustainable'. In the text, 'sustainable' means that "economically viable, financially profitable, environmentally sensitive and socially responsible" operations (UNEPMD et al. 2001-2002: 11) on project, plan, programme and policy levels.

The section starts with brief discussion about why the concept of sustainability is important and necessary for the mining industry. Following parts look at what sustainability covers in the context of the mining industry and the cursory literature research, focusing on the different approaches aiming to integrate and intertwine the concept of sustainability into mining operations.

#### 1.1 Why a sustainable mining industry?

Due to the environmental degradation caused by its operations, social tension-conflict within different interest groups, and also some badly managed operations, the mining industry is one of the most

criticised industries in the public and thus the public opinion is widely negative (Horsvill et al. 2001, IIED 2002, UNEPMD et al. 2001-2002).

Although this fact is partly true, it should also be considered that today's industry and economic development is still highly dependant on the non-renewable resources, because the mining industry supplies not only the raw materials, such as iron, copper, lead, aluminium, zinc, to the industries, but also the energy production highly rely on some mining products, such as coal and lignite in many parts of the world.

For instance, approximately 40% of the world electricity was produced from coal and lignite in 2001 (EA, 2004). Additionally, the US Department of Energy, Energy Information Agency's study on "International Energy Outlook 1997" shows that the use of the coal for energy production had steadily increased from 1970 to 1997, and this trend will most probably continue until 2020 (USDE 2000, cited in Fay & Golomb 2002: 15). Therefore, it is clear that the need for the mining products will continue in the near future.

Additionally, the economically extractable reserves in less sensitive areas have already been exploited or are being exploited. Therefore, the activities of the mining industry would shift from ecologically, socially and culturally less sensitive to high sensitive areas, or around them. As a result, for

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the potential mining operations around sensitive areas, the operations must be "economically viable, financially profitable, environmentally sensitive and socially responsible" (UNEPMD et al. 2001-2002: 11).

Furthermore, as Hinde (2000 cited in Nippa & Lindsay 2001: 27) comments that the exploration activities shift more to remote and less developed geographic regions, which are rich in mineral and metal resources, such as Zambia, South Africa, Niger and Guinea in Africa, Brazil, Chile, Peru in Latin America, and China Indonesia and India in Asia (IFC & WB 2002, IEED 2002). In some of these regions and countries, the distribution of the mineral wealth benefits to different interest groups is generally problematic (IIED 2002). This also contributes the diminishment of the trust for the mining industry and its operations in many parts of the world.

In addition to these, the consequence of environmental consciousness in developed countries, the legislative structures of these countries has been changed, with the aim to reduce the environmental footprint of production and consumption behaviours (UNEP 2002). For instance, actions aiming to 'reduce', 'reuse' and 'recycle'; the standards and the directives on eco-management, environmental taxes and eco-labelling and similar actions should be considered in this context.

Therefore, industries, which are doing business with/in these countries, have to follow and fulfill these codes and guidelines. If to achieve all these requirements, a 'sustainable' management approach has to be also implemented by the mining industry.

In recent years, the rapidly rising environmental consciousness in developing countries and relatively slow rising in non-developed countries, public opinion and participation is becoming more important for all the development projects. As a result, successful mining operations highly require the acceptance and support from the public (ICMM 2002), and besides not only from the communities where the operation will take place but also from the regional and national public in general.

For these reasons, the mining industry is facing a great challenge to meet the concept of sustainable development, set at the UN Conference on the Environment and Development in Rio de Janeiro (1992) and in Johannesburg (2002).

To meet this challenge, it is important to take into account public concerns, such as the environment, the social welfare and cultural heritage of the communities, where the activities are carried out, because as Horsvill et al. (2001:1) discusses that "environmentalists believe that we [the mining

industry] are major polluters, and social activists believe that we [the mining industry] don't contribute our fair share to society's well-being".

In short, to contribute to the sustainability, and consequently become a 'sustainable' industry is not a choice for the mining industry but a compulsory action to rebuild its reputation and re-establish the trust in mining operations, their contributions to economic endowment and social welfare with a less environmental footprint.

However, for achieving the goal of "an economically feasible, financially profitable, environmentally sensitive and socially welfare" (UNEPMD et al. 2001-2002: 11) mining industry development, firstly understanding of what sustainability means in the context of the mining industry and secondly sector and political willingness to introduce and implement necessary tools into action, are needed.

## 1.2 Earlier works on sustainable mining industry

On the one hand, the pressure from the external stakeholders, including citizens of mining communities, special interest groups, aboriginals, regulators and investors (Decision Partners Inc. 2000), to contribute to a transition for reducing negative impacts of the mining industry on environment and society, rises currently on the industry.

The internal stakeholders, on the other hand, including CEOs, mine managers and sustainable industry experts (Decision Partners Inc. 2000), who have the aim to strengthen the industry's image, competitiveness and market accession, also put pressure on the mining industry's actions.

As it is clear that the priorities of these two groups are different and as it is pointed out in the MAC'S Internal and External Stakeholder Analysis Research on Sustainable Mining Initiative (Decision Partners Inc. 2000:1) "a consensus also emerged, and was clearly understood by members [of the initiative], that these challenges are not simply a communications problem."

Therefore, the members of the mining industry must consider these priorities and critics about their actions in the future operations because "the mining industry is facing growing challenges to its social license to operate" due to the different priorities of the different stakeholders groups (Decision Partners Inc. 2000:1).

As it is mentioned earlier in this section (sec. 1.2), the problem is not sourced simply from lack of communication and misunderstanding of mining

operations in the public. The problem is basically sourced from the badly planned and managed operations in the past, which can be termed as non-sustainable actions.

The cyanide spill into the river Tisza from the damburst at Baia Mare goldmine in Romania, 2000, created a poison plume of pollution in Donohue; or the Aznalcollar accident in Spain, 1998, where a tailings dam failure poisoned the environment of the Coto Donana National Park (COM-265 final 2000: 8) and caused visible effects on the surrounding ecosystems are only two examples of these non-sustainable actions of the industry in the near past.

Other than these two examples, as Commission of the European Communities' report on "Promoting sustainable development in the EU non-energy extractive industry" (COM-265 final 2000: 8-9) mentions "a legacy of abandoned mine sites and unrestored quarries bears witness to the unsatisfactory environmental performance of the industry in the past".

As a whole, these and similar reports and studies prove that the mining industry has to stop considering the watchdogs, environmentalists and NGOs as the source of increasing social resistance against operations, and at the same time, to see and to accept the emerging prejudice about the industry's operations in the local and global level. These prejudices should be taken as indicators of sustainability issues for the mining industry.

In this respect, in the recent years, several workshops, conferences and researches have been carried out and a number of reports, scientific articles and directives have been prepared and published by governmental, non-governmental and international organizations.

The summary of the early actions aiming and contributing to the 'sustainable' mining industry can be found in Table 1. Although all activities, studies, projects, conferences and initiatives had been tried to consider and mentioned in Table 1, it is not possible to say that this aim could be completely achieved.

### 1.3 Sustainability concept in the mining industry operations

Regarding the highlighted points in the studies given in Table 1, in the context of the mining industry, the concept of sustainability can be framed as a group of activities, contributing to economical and social development at the local, national and global level, that aim to supply today's mining and mineral needs in a way that

- protects the environment,
- » ensures an equitable distribution of its costs and benefits,
- ◁ takes into account the social and cultural values,
- ® considers the public opinion, covering different interest groups, i.e. aboriginal and indigenous people, through the decision-making process of whether or not to mine,
- » optimizes the contribution to the well-being of the current generation without reducing the potential for future generations to meet their own needs (extended from IIED-Executive Summary (ES) 2002: xvi)

For the mining industry in particular, achieving sustainability primary means the minimization of negative impacts on the environment and the society. Secondly, the mining industry should guarantee the creation of benefits for the local societies that extend long after mining activity has ceased (Horsvill et al. 2001). Additionally, an equal distribution of both the costs and benefits within the society must be also considered.

At the same time, as a business, economical viability and financial profitability of the mining operations must be considered within the sustainability concept in the mining industry.

#### 1.3.1 Environmental Issues

First, when the environmental issues are considered, some mismanaged and badly operated projects or simply due to the lack of willingness and awareness of the investors and governments for protecting the environment have caused adverse impacts of a large magnitude in the natural resource rich regions, especially in developing countries.

As a result of these, strong environmental movements that promote environmental protection and protest against the industry have been created in the global public opinion in last decades (Thanh and Tam 1992).

Most of the environmental problems sourced from the mining industry are currently well known. The negative environmental impacts of a mining operation can be summarized very shortly as; land-degradation and ecosystem disruption due to the top soil and sub soil removal, slope failures, loss of productive land and soil erosion because of the removal of the vegetation, change in existing topography, acid mine drainage, dust, emissions, tailings, ground water removal, chemical leakages,

Table 1 The summary of the early works contributing to the sustainable development in the mining industry

| Organization    | Contributor's)      | Directive/Project/Report   | Year | Content   |
|-----------------|---------------------|--|------|---|
| EU*             | European Commission | Council Directive 85/337/EEC   | 1985 | The Directive on environmental impact assessment (EIA)  |
|                 |                     | Council Directive 89/391 /EEC  | 1989 | Introduction of measures in the health and safety of workers  |
|                 |                     | Council Directive 91/156/EEC   | 1991 | Amending Directive 75/442/EEC on waste  |
|                 |                     | Council Directive 92/104/EEC   | 1992 | The minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries   |
|                 |                     | Council Regulation (EEC) 1836/93   | 1993 | Eco-Management and Audit Scheme (EMAS) ( voluntary participation by companies)  |
|                 |                     | Council Directive 96/61/EC   | 1996 | The Directive concerning integrated pollution prevention and control (IPPC)   |
|                 |                     | Council Directive 1999/31/EC   | 1999 | The Directive on the landfill of waste  |
|                 |                     | COM (2000) 66  | 2000 | White Paper on Environmental Liability  |
|                 |                     | Council Directive 2000/60/EC   | 2000 | Water Framework Directive (WFD)   |
|                 |                     | Council Directive 2001/42/EC   | 2001 | The directive on Strategic Environmental Assessment (SEA)   |
|                 |                     | Council Regulation 2001/761  | 2001 | EMAS II   |
|                 |                     | Council Directive 2003/4/EC  | 2003 | Public access to environmental information  |
|                 |                     | Council Directive 2003/35/EC   | 2003 | Public participation directive for drawing up of certain plans and programmes relating to the environmental and amending with regard to public participation and access to justice  |
|                 |                     |  |      | Proposal for a Directive of the European Parliament and of the Council on the management of waste from the extractive industries  |
| IGED & WBCSD ** | HED, WBCSD          | The Mining, Minerals and Sustainable Development Project (MMSD) (2000-2002)-<br>Breaking New Ground Mining, minerals & sustainable development | 2002 | The report proposes an agenda for change with recommendations for immediate and future actions, such as creating a 'Declaration on sustainable development' embodying a commitment to a 'Sustainable development code' and also encourages companies to adopt a 'Sustainable development policy', a 'Review of end-of-life plans at existing operations' and Community sustainable development plans' |

Table 1 (continued)

| <b>Organization</b>                    | <b>Contributor(s)</b>  | <b>Directive/Project/Report</b>   | <b>Year</b>    | <b>Content</b>   |
|--|--|---|----------------|--|
| UN***                                  | UNDESA<br>UNDES/DSD,<br>UNEP, CDG,<br>DSE, HBS,<br>German<br>Government      | Berlin Guidelines -<br>The first edition of<br>Environmental Guidelines for<br>Mining Operations                                  | 1994           | These Guidelines address mining and sustainable development, regulatory frameworks, environmental management, voluntary undertakings, and community consultation and development, as applied to all stages of a mining operation<br>The workshop was the first international meeting to consider the many issues surrounding the topic of abandoned mines<br>Workshop on environmental regulation for accident prevention in mining-tailing and chemicals management<br>Workshop on how government regulations interface with voluntary initiatives to improve the environmental performance of the mining sector<br>The Report provides an overview of the UNEP, World Bank, and Mining Minerals & Sustainable Development (MMSD) initiative investigating the role of financial institutions in improving the environment and social performance of the <u>mining sector</u> |
|  |  | The Berlin Roundtable on<br>Mining and the Environment  | 1999           |  |
|  | UNEP,<br>COCHILCO  | Abandoned Mines Workshop  | 2001           |  |
|  | UNEP, Australian<br>Government   | Mine Regulators' Workshop 1   | 2000           |  |
|  |  | Mine Regulators' Workshop 2   | 2002           |  |
| UNEP/DTDE,<br>UNEPFI, WB,<br>IFO, MMSD | Finance, Mining and Sustainability<br>Workshop                               | 2002  |                |  |
| UN*                                    | UNEP/DTIE,<br>UN/OCHA, ICME,<br>EU, Romanian<br>Government, EPA,<br>ILO, WHO | Accident Prevention and<br>Emergency Preparedness in<br>Mining Initiatives  | 2000           |  |
|  |  | Code for Cyanide Management in<br>the Gold Industry- Cyanide<br>Workshop  | 2000           |  |
|  |  | Emergency Preparedness and<br>Disaster Response- Awareness and<br>Preparedness for Emergencies at<br>Local Level (APELL) Workshop | 2000 &<br>2002 |  |
|  |  | Improving the Effectiveness of<br>Regulation for Accident<br>Prevention in Mining Regulators'<br>Workshops                        |                |  |
|  |  | Contingency engineering or 'fail-<br>safe" features for Tailings Storage<br>Facilities  |                |  |

Table 1 (continued)

| Organization | Contributor(s)   | Directive/Project/Report                    | Year      | Content   |
|--------------|--|---|-----------|---|
| MAC*         | Member Canadian Companies engaged in mineral exploration mining smelting refining and semi fabrication | Towards Sustainable Mining Initiative (TSM) |           | A strategy for improving the mining industry's performance<br><br>A process for finding common ground with MAC communities to build a better mining industry <u>today and in the future</u> |
| ISO*****     |  | ISO 14000 series standards                  | From 1993 | ISO standards lay out tools and systems for the management of numerous environmental obligations and the conduct of product evaluations   |

Sources \*EC [http://europa.eu.int/comm/environment/policy\\_en.htm](http://europa.eu.int/comm/environment/policy_en.htm) <€. COM 2000 265 final  
 \*\* IÜ3D <http://www.ned.org/mmsd/> & WBCSD <http://www.wbcd.org>  
 \*\*\*MRF (Mineral Resources Forum) <http://www.mmeralresourcesforum.org/workshops/mdex.htm>  
 \*\*\*\* MRF [http://www.mmeralresourcesforum.org/news\\_events/whoswho/whoswho.htm](http://www.mmeralresourcesforum.org/news_events/whoswho/whoswho.htm) &  
<http://www.mmeralresourcesforum.org/initiatives/index.htm>  
 \*\*\*\*\* MAC <http://www.mining.ca/enghsh/>  
 \*\*\*\*\*Casio et al (1996 1 9)

toxic dusts, compounds of carbon/sulphur/nitrogen metal particulates and creation of new land use for dumping, storage and construction purposes (Auty & Mikesell 1998, Dutta et al 2004)

These impacts affect the local communities directly and they can also contribute to some regional and global environmental problems

Additionally, as Kiss & Shelton (1997: 37) highlight "inequalities sharpen when environmental problems increase and poorer areas often suffer disproportionately." Therefore, the environmental consideration is one of the most important essentials in the sustainability issues of the mining industry

### 13.2 Social Issues

Secondly, the mining industry operations affect the society widely in two different ways. The first group of effects are sourced from the environmental impacts of mining operations. While the second is sourced from the economical impacts of the operations on the society.

The local society is directly affected from the negative environmental impacts of the mining operation, some of these impacts are given earlier in section 1.3.1. Loss of agricultural land, changes in surface and/or ground water access, quality and quantity, impacts on air quality, disturbance of scenic views, noise and vibration are some examples for the direct impacts of a mining operation on the locals (Dutta et al 2004)

In contrast to the negative impacts, possible positive environmental impacts of the operation are

potential gain for the society. For instance, reclamation and post mining use of a site, creation of recreation opportunities, such as fishing, boating and picnicking, promenade sites are just some examples for possible positive outcomes of the environmental changes on the society (Dutta et al 2004)

The second group of effects is sourced from the economic impacts of the operations on the society that should be also discussed as positive and negative changes. On the one hand, in their study on the "Social impact" Becker et al (2004) point out some examples of the positive social and organizational indicators as new job opportunities, higher income and social security occasions for the local employees, developments in the infrastructure, such as, better motorway connections, social services, including health, safety and education can be given.

On the other hand, change in community population, rise of living cost, change in ethnic diversity and prevalent values of community, changes in family stability, customs and lifestyle, crime and community safety, quality of political and civic leadership, trends in family farming and farm size and also the change in dryland farm income and ability to respond to change are some of the negative social and organizational indicators related with mining operations.

The first positive effect of economic changes on the society is the increasing economic diversity of the area. Besides traditional activities, such as agriculture or fishery, the operation itself and the

auxiliary industries in and around the mining area support economic and consequently social improvements

As an example, in their article "Case studies in mining and sustainability", Horsvill et al (2001) give a number of examples from North America where mining was the key element to economic growth and development of cities, towns and communities and they add also that this economic growth and development has played a major role in the growth of nations

However, the decision-makers must also consider that once the mining operation decision is given the economy of that region will most probably become highly dependent on the operation, which means the local economic activities would change dramatically. Possibly, such a transformation of the local economic activities would be followed by next generations during lifespan of the mining operation

But "the cycle of rapid economic growth during development and operation followed by severe economic downturn after closure has been the rule rather than the exception for natural resource development in the rural areas" (Horsvill et al 2001 9)

Therefore, as Thanh & Tam (1992 2) discuss "[ ] considering environmental impact in the physical and biological context—such as tropical forests, tropical wild life, the mangroves, the corals—is not adequate. The human factor—humans themselves, their behaviours, structures—also needs to be considered." Based on this discussion, it can be concluded that together with environmental issues, social issues must also be seriously considered for the future operations of the mining industry in the sustainability issues

## 2 TOOLS FOR A SUSTAINABLE MINING INDUSTRY

This second section focuses on the possible tools, which can be implemented on the organizational and project levels, as well as on the policy, programme and plan levels, to contribute to the sustainability issues in the mining industry operations

### 2.1 Contributing to the sustainability issues on the project level

Minimization of the negative impacts of the operations on the environment and the society needs different actions and tools at local and regional level. Before to discuss more in detail about project level environmental protection and mitigation tools,

Environmental Impact Assessment (EIA), Environmental Management Plan (EMP) and Environmental Management Systems (EMS), and how these can improve the sustainability performance of the mining industry on the project level, to have a look at what EIA, EMP and EMS are may help for further discussions

"EIA is a procedure to ensure that adequate and early information is obtained on the likely environmental consequences of development projects and on possible alternatives and measures to mitigate harm" (Kiss & Shelton 1997 123-124)

"EMS is that facet of an organization's overall management systems that address the immediate and long-term impact of the organization's products, services and processes on the environment" (Cascio 1996 8)

The definition of EMP given by World Bank (WB) (1999) is "the set of mitigation, monitoring and institutional measures to be taken during implementation and operation to eliminate the adverse of the environmental and social impacts, offset them, or reduce them to acceptable levels. The plan also includes the actions needed to implement these measures"

The EMP includes following components (WB 1999),

- Mitigation procedure EMP identifies feasible and cost-effective measures that may reduce potentially significant adverse environmental impacts to acceptable levels. Summary of the significant adverse impacts can be taken directly from EIA. Whether or not EIA considers, each mitigation measures, designs, equipment descriptions, and operating procedures must be described with technical details
- Monitoring The EMP identifies monitoring objectives and specifies the type of monitoring, with linkages to the impacts assessed in the EIA report and the mitigation measures described in the EMP
- Capacity development and training The EMP provides a specific description of institutional arrangements—who is responsible for carrying out the mitigatory and monitoring measures (e.g., for operation, supervision, enforcement, monitoring of implementation, remedial action, financing, reporting, and staff training). To strengthen environmental management capability in the agencies responsible for implementation, most EMPs cover one or more of the following additional topics: (a) technical assistance programs, (b) procurement of

- equipment and supplies, and (c) organizational changes
- Implementation schedule and cost estimation For all three aspects (mitigation, monitoring, and capacity development), the EMP provides (a) an implementation schedule for measures that must be carried out as part of the project, showing phasing and coordination with overall project implementation plans, and (b) the capital and recurrent cost estimates and sources of funds for implementing the EMP.
- Integration of EMP with project the institutional responsibilities for integrating and implementing the EMP should be assigned within the overall project plan

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To enable to answer this question, the characteristics, weak and strong points of EIA, EMP and EMS should be examined Concerning this, the characteristics and comparison of EIA, EMP and EMS can be seen in Table 2

At the local level, in other words on project level, EIA is the most widely known and used tool for environmental impact prediction and mitigation of development projects since 1969 (Kiss & Shelton 1997, Dutta et al 2004)

The introduction of EIA gave significant acceleration to environmental consideration and protection in development projects, for instance mining projects, because "it is generally a prerequisite to decisions to undertake or to authorize designated construction, processes or activities"

Table 2 The characteristics and comparison of EIA, EMP and EMS

|                                 | EIA  | EMP   | EMS   |
|---------------------------------|--|---|---|
| Type of instrument              | Obligatory for the mining and mineral operations in many countries, systematic process   | Detailed, systematic process, not obligatory except specific projects of development banks and aid agencies   | Voluntary, consensus, private-sector standard   |
| Project stage                   | Design   | Implementation  | Operation   |
| Objective                       | Attempt to ensure that proposed actions environmentally sound  | To describe all the relevant actions taken by developer to ensure that proposed actions environmentally sound   | Guidance for developing a comprehensive approach to environmental management and standardizing some key environmental tools for analysis  |
| Focus                           | Environmental analysis and impact consideration  | Maximum efficient use of resources, identify, evaluate the adverse impacts and prevent, attenuated, or compensated  | Focuses on continual improvement, lay out tools and systems for the management of numerous environmental obligations  |
| Application                     | Project specific activities that seeks to blend administration, planning, analysis, and public involvement in assessment through the decision-making process   | Project specific, integration of EMP with project for implementing and for supervising the responsibilities within the overall project plan   | Organization decides to apply to the whole or part of the organization, or its activities, products and services  |
| Structure                       | Proposal, normative activity, adheres to 'analyse-consider- plan-act'  | Part of EIA following the process scoping or as a separate document, EIA is a part of EMP   | Part of the overall management system, adheres to 'plan-do-check-act' type to business model  |
| Elements                        | Screening, preliminary analysis, scoping, review of alternatives, identify significant issues, impact assessment, identify impacts, predict and evaluate impacts, scrutiny of findings, decision on proposal, implementation, monitoring | Several technological and managerial interventions, such as, recycling and conservation of resources used in the operations, pollution control measures, monitoring, capacity development and training, implementation schedule and cost estimation | List of potential environmental impacts, environmental policy and planning, management system documentation, document control, operational control, training, monitoring and measurement, corrective action, internal auditing communications and emergency preparedness and response |
| Action by competent authorities | EIA review and approval Approval of the EIA and EMP at the project approval stage  | Implementation, monitoring and ex post evaluation Audit/monitor during and after implementation   | Environmental audit-internal and external Audit/inspect/monitor throughout operation  |
| Sources                         | Cascioetal (1996 3 8 24 26 27) Borrow (1997 1 5 101)   | Moddk& Biswas (1999 124 127), George (2000 179)   | (Kiss & Shellon   |



At the same time, developments in technology and modern practices contribute to reduce or to avoid environmental impacts of the mining operations with an EIA on the project level.

Unfortunately, different studies (see Ortolano and Shepherd 1995, Russo 1999:363, George 2000, Joyce and MacFarlane 2001, Partidario and Clark 2002:3, João 2005: 6) show that EIA is insufficient on its own for covering some major negative impacts through the stages of the development projects, such as cumulative, transboundary and social impacts (Barrow 2003: 65, Modak & Biswas 1999: 6-9, 209-211, Glasson et al. 2004 cited in João 2005).

However, aim of the environmental impact assessment should be to ensure that the environmental impacts, during all steps of the project(s), are understood and are acceptable before the project is approved. Therefore, the effective EIA needs to include provisions for further checks throughout all the stages of the life cycle of the project (George 2000).

Although it is an application problem, EIA is often seen as a way of justifying a development, not reducing problems (Barrow 2003) and putting the main effort on the preparation the paper documentation that reduces the efficiency of the EIA for consideration of entire project life cycle.

Additionally, as Kiss & Shelton (1997:123-124) and George (2000:179) mention, EIA ensures early information and impact prediction of the project on the design stage. For this reason, to enable to improve environmental sensitiveness of mining projects, consideration and monitoring of entire steps of a project must be covered by the EIA with the help of EMP and also the performance of the operator should be followed with EMS.

The life cycle of a mining project consist of 6

main steps, which are

1. Exploration
2. Project Design
3. Project development
4. Mine operation-Extraction
5. Processing
6. Mine closure and reclamation

When these steps are considered, EIA is insufficient on its own as a comprehensive environmental management tool. Therefore, EIA must be supported with other tools, i.e. EMP and EMS, enable to consider the whole project life cycle and to improve the efficiency of controls that can be named as integrated environmental management (IEM).

IEM is a combination of a group of actions that aim to consider the whole activities and their consequences of a project on the environment. Also it intends avoiding or reducing the negative consequences to the acceptable levels during the entire project life cycle.

The elements, EIA, EMP and EMS, of IEM and how these elements can contribute to the environmental consideration for different phases of mine operation cycle are demonstrated schematically in Figure 1.

As it is demonstrated in Figure 1, EIA covers the activities before die project approval stage comprehensively. In some cases preliminary EIA is necessary for exploration step as well.

Commonly used way of EIA through the project design is; environmental impact prediction of the project, determination of design alternatives to mitigate negative impacts or reduce them to acceptable levels and also including the necessity and willingness of the project owner regarding mine closure and reclamations, generally without detailed

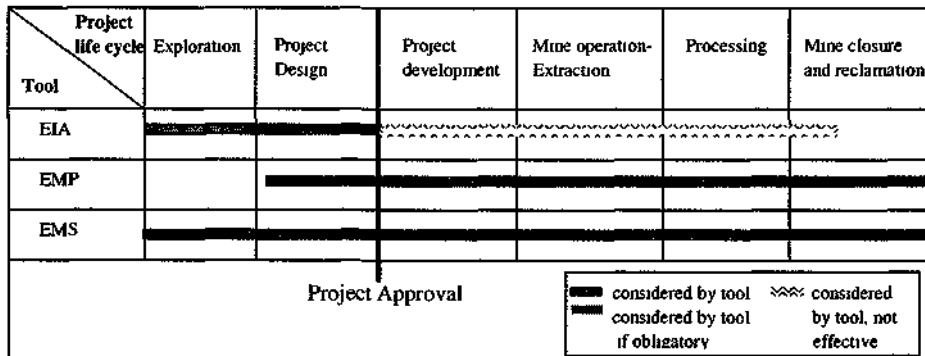


Figure 1 : Compression of EIA, EMP and EMS based on the project phases and elements of IEM

plans. Based on the selection of the 'best' of all alternatives, project is approved or not, by the responsible authority.

But due to the limited or lack of consideration of monitoring, remedial action and reporting of the mine development, operation and mineral extraction and processing steps after project approval, and, in addition, generally no detailed studies on what is the most efficient, useful mine closure and reclamation and how to finance them; EIA does not guarantee the success of the prevention and mitigation of the negative environmental impacts, so showed with dash lines after project approval in Figure 1.

On the contrary to EIA, as it is discussed in the early part of the section 2.1, components of EMP cover the entire steps of the project life cycle with a detailed plan. In addition to the summary of potentially significant adverse impacts, which can be taken directly from EIA, monitoring and reporting, training the staff, to define the responsibilities that who (project owner, the main contractor or sub-contractors) will carry out these responsibilities and proposed mitigation measures' cost estimation procedures are clearer in the EMP procedure.

Therefore, clear responsibility distribution within the project management, covering project owner, main contractor and sub-contractors; clear environmental impacts liability of the operator, regular and efficient control of the project cycle, financial guarantee, which would be bonds obtained from the project owner for the complete and successful mine closure, reclamation and long term monitoring, EMP would cover entire project life cycle as it is given in Figure 1.

Additionally, as it is shown in Figure 1, EMS covers all the projects steps from the exploration to mine closure and reclamation because operator must consider the environmental policy of the organisation for all its operations that means it is not project specific so shown by continuous line. The details of EMS are discussed in section 2.1.3.

In short, integrating the Environmental Management Plan (EMP) and Environmental Management Systems (EMS) on the project level, with the EIA as an integrated environmental management, will most probably give satisfactory results in terms of sustainability issues of the mining industry.

### *2.1.2. What EMP promises for sustainability issues in the mining industry operations?*

"Effective environmental assessment should be a process rather than an isolated event and is itself part of the broader process of environmental planning

and management" (George 2000: 179). For that reason, after the project approval, EIA process must continue on the implementation and further stages of the mining project.

In this regard, to force the future environmental protection liability, EIA;

- must totally cover monitoring and mitigation measures, after project approval and,
- must contain detailed planning and cost estimation of the mine closure and reclamation activities with bonds or guarantees that is given by the project owner

To explain these in details; firstly, the monitoring and mitigation measures during the project development and operation stages are problematic within EIA. As George (2000:180) points out "although several developing countries and countries transition include requirements for monitoring in their EIA procedures, few are as explicit as they might be."

Additionally, in many of the developing and under-developed countries, the monitoring activities within the EIA procedure are not followed through a schedule or a programme. This makes EIA inefficient, because there is no guarantee that the EIA recommendations will be considered during the implementation of the project; due to the lack of coordination, overlapping of responsibilities between numerous authorities and lack of staff of the authorities (George 2000).

As a solution, George (2000: 186) highlights that "if monitoring reports are being provided by the developer in accordance with a sound EMP, and if there is a close coordination between the competent authorities, a small number of spot-check visits by the appropriate authorities should be sufficient" for environmental protection of a development project.

Secondly, detailed planning with an implementation schedule and cost estimation obligation of EMP, makes the environmental protection and prevention of negative impacts more realistic because the cost estimation could prevent some unrealistic promises for mitigation actions given by developer before project approval. In other words, for a satisfactory, or 'sustainable', mine closure and reclamation requires not only enthusiasm and plans but also money.

As it is known that mitigation, mine closure and reclamation actions might be very costly so these costs must be included in the developer's financial appraisal for project viability. Otherwise, project could be unsuccessful due to the miscalculated costs so the negative environmental impacts would not be

prevented and mitigated. Therefore, at the project approval stage, responsible authority should ask bonds or guarantees from the developer to avoid the risk of bankruptcy before or during the mine closure and reclamation activities (George 2000).

Due to the fact that, EMP is more comprehensive and realistic than EIA regarding to the monitoring and mitigation of negative environmental impacts of the whole project cycle that converts the environmentally sound design to environmentally sound operation.

At the same time, EMP may help to reduce potentially significant adverse environmental impacts to acceptable levels by identifying feasible and cost-effective measures and it ensures that resources are used with maximum efficiency (WB 1999, Modak & Biswas 1999).

#### *2.1.3. Environmental Management Systems (EMS)*

"EMS is the part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy" (ISO 2004).

Different than EIA and EMP, EMS is not a project specific action because it is a part of the overall management system of an organization, which can be "a company, corporation, firm, enterprise, authority or institution that has its own functions and administration" (ISO 2004).

EMS is a voluntary action, aiming to improve the environmental performance of an organization. Environmental performance is measurable results of the EMS, related to an organization's control of its environmental aspects, based on its environmental policy, objectives and targets.

Additionally, EMS is also about improving the organizational aspects, such as, minimising liability risks, better organization and documentation ability, improving energy and resource use, cost reduction and achieving better image.

The purpose of the EMS is basically preventing the badly managed operations. Therefore, EMS's real benefit is that an organization should follow its environmental policy, which is a statement that shows the organization's intentions and principles related with its overall environmental performance, providing a framework for action and for the setting of the organization's environmental objectives and targets, without distinguishing any of its operations, to enable to fulfill the EMS certification procedure.

As a result, EMS is a very effective tool for prevention and reduction of the negative

environmental impacts of a mining operation, because it forces the operator to think about whether or not his normal management procedures are really suitable to achieve the environmental policy of the organization.

Additionally, why EMS is an effective tool is that EMS is a continuous approach (see Fig. 2) not an event. It aims to improve the environmental performance of the organization during its operations with the help of the internal and external audits controls.

For these reasons, as it is pointed out in Figure 1, the activities of whole project cycle of a mining project would be followed and considered by project owner (internal audits) and also external bodies (external audits) from exploration to end of reclamation effectively.

Other than effective monitoring of the operation; improvement in the internal and, most importantly, external communication and cooperation between the operator, regulatory authorities and public is another potential positive outcome of EMS for the mining industry because some problems, sourced from overlap or missing responsibilities in legislation and lack of public participation, can be effectively overcome even in developing and under-developed countries.

#### *2.1.4. How to integrate EMS with EIA and EMP?*

Integration of the EMS with EIA and EMP can be summarized within a framework, given by George (2000: 179). As a design stage action by developer or operator, EIA can provide all potentially significant adverse impacts of the proposed project to the EMP process and "at the project approval stage, the competent authority for environmental assessment can ensure that the developer makes suitable provisions for appropriate management and monitoring during all the later stages of the project's life cycle by requiring an EMP at the same time with EIA."

The audit and monitoring procedures of EMP, such as, checks of approval conditions and contract requirements, during and after the implementation of the project, can support to achieve the environmental policy of the operator's EMS during whole project life cycle (George 2000). In other words, outcomes of the EMP feed into the continuous improvement process of EMS (see Fig. 2) (AusAID 2003).

As it is given in Figure 2, EIA findings can be used in the EMS planning stage for the project. At the same time, EIA findings might be useful for the implementation and also for the control stages of the EMS as a database and baseline study. In addition,

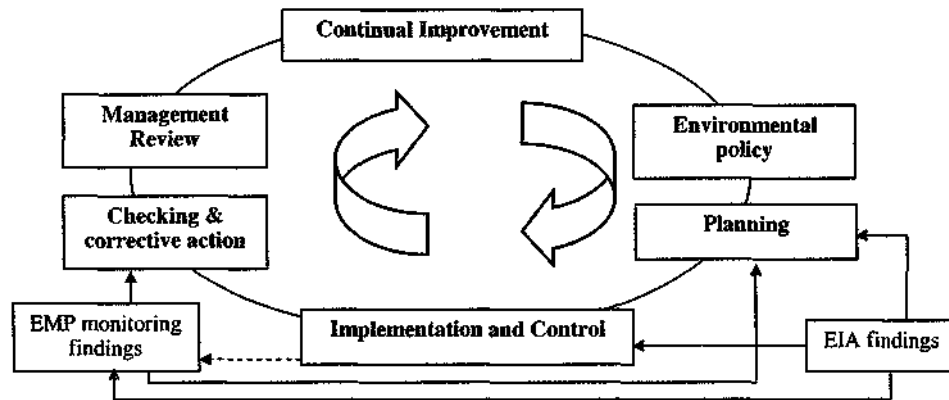


Figure 2: The major components of an EMS and integrating EMP and EIA with EMS (modified from: Harbour 2000)

EMS's environmental policy is a guarantee of implementing the EIA's findings and predictions for avoiding losses of environmental resources and values.

The monitoring mechanism of EMP is another important contributor for the EMS's continual improvement system because as Modak & Biswas (1999:125-126) point out "appropriate monitoring mechanism and in-plant institutional reporting system of EMP would provide a regular and continuous assessment".

At the same time, with implementation of EMS and its regular control findings would be useful data to improve the EMP's monitoring and reporting system. Together with these findings from EMP monitoring and EMS controls will be used for the checking and corrective action purpose as it is seen in Figure 2.

Additionally, one of the most important pillars of EMS is documentation. In this respect, regular reporting of the monitoring actions with EMP will most probably be helpful for a successful EMS in the organization.

As a result of this simple hierarchy between EIA, EMP and EMS, providing the information from detailed impact studies of EIA and monitoring and reporting procedures of EMP during the operation and then feeding the continual improvement circle of the EMS of the mining operator with this information improves the sustainability performance of the mining industry.

## 2.2 Contributing to the sustainability issues on policy, plan programme level

In addition to project level, policy, programme and plan (PPP) level consideration is necessary to enable to avoid and mitigate negative impacts of the mining industry on the environment and society. In other words, concerning the environment, the relevant alternatives, the society priorities and the public participation at the possible earliest stage in the planning and in the decision-making process, PPP level consideration can contribute to the sustainable development in general and also in the mining industry actions.

In this regard, Strategic Environmental Assessment (SEA) can be a very useful tool for contributing the sustainability issues in the development projects, plans, programmes, and policies (Modak & Biswas 1999).

SEA can be described as "a systematic, proactive process for evaluating the environmental consequences of policy, plans and programme proposals in order to ensure that the environmental consequences are fully included and addressed at the earliest appropriate stage of decision making on par with economic and social considerations" (Miller 2001:33).

After widely acceptance of the benefits of EIA for projects, the growing belief that EIA for policies, plans, and programmes (PPPs) is also necessary to consider alternatives and impacts which can not be completely covered on the project level (Modak & Biswas 1999).

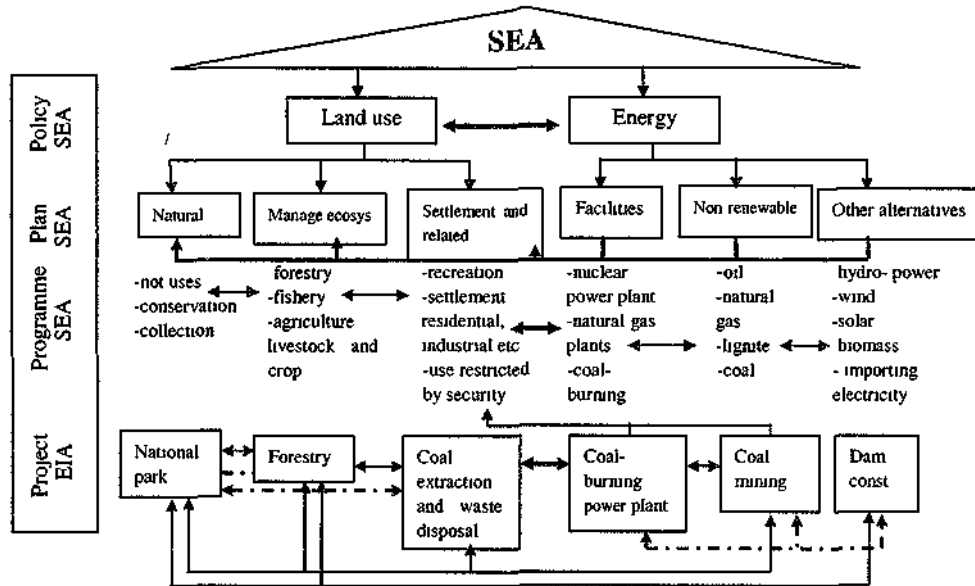


Figure 3 Tiering and links between SEA and EIA within energy and land use policies

Consequently, during 1990s, although it is much slower than EIA, SEA regulations and practices have been expanding not only in developed countries but also in developing and under-developed countries (Lee 1995, Sadler & Verheem 1996, Thérival & Partidario 1996 cited in Lee & George 2000)

There are two key principles of SEA for environmental protection and hazard mitigation of different PPPs are pointed out by João 2005 7,

- "SEA -must- clearly identifies feasible PPP options (or alternatives) and compares them in an assessment context
- SEA -must- improves, rather than just analyse, the PPPs"

Different than EIA, SEA decision making hierarchy for alternatives, considers if development can be obviated firstly, and if not, than considers how it can be done more environmentally friendly. This stage is followed by the consideration of alternatives and where and when development investment will be made (João 2005)

Another important point of alternative consideration and comparison in SEA process is that SEA does not cover only "either-or" alternatives (i.e. coal burning power plant-renewable energy) but also "mix-and-match" options (i.e. isolation of buildings and reduce energy demand, and so reduce coal extraction) (Thérival 2004 12 cited in João 2005 8)

Hence, with SEA "no action" option becomes more applicable for the decision-makers

Additionally, as Partidário (1999 cited in João 2005 6) points out "EIA enters decision-making process too late that decisions at PPP level that could influence the type and amount of the projects have already been taken"

Therefore, to enable to cover the cumulative and transboundary impacts, indication of development alternatives for the mining related industries, such as, energy projects, primary raw material user and recycling industries, land use alternatives and priorities of different stakeholders in the decision-making process, should also be considered together at whole decision-making levels (see figure 3)

As it is illustrated in Figure 3, the decision-making processes for different PPPs and also for projects are complex. As an example, when land use and energy policies are considered, both may affect the mining industry operations directly or indirectly. Additionally, for these two policies, there are several different plan and programme alternatives and thus a great amount of project options, such as, dam construction, wind farms or electricity import, coal mining and coal-burning power plant, agriculture or forestry projects so on, exist

Some of these options have direct impacts on others, which are showed with solid rows in Figure 3. For instance, if energy policy and consequently

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plans are developed for non-renewable energy alternatives, than the impacts of coal, lignite and/or gas extraction projects would have direct impact on land use plans, such as on forestry. Other than direct impacts, some decisions about energy have indirect impacts on other options, showed with dash lines.

For instance, electricity demand can be supplied from either non-renewable (e.g. coal) or renewable (e.g. hydro power) resources. In this regard, once coal burning power plant has been chosen than dam construction may not be necessary. Therefore, the connection between these two alternative projects relation is showed with a dash line.

Shortly, the complexity and interdisciplinary characteristics of most of the development PPP and projects, a wider consideration of alternatives and impacts are necessary. Additionally, with higher level consideration allows for a systematic and effective reflection of environmental and social consequences at higher tiers of decision-making. Finally, more consultation and participation of the public from the possible earliest stage can be achieved with SEA (Fischer 2002 cited in João 2005).

### *2.2.1 The importance of SEA for the mining industry*

SEA is a strong tool for the consideration of cumulative impacts (Modak & Biswas 1999). Firstly, on the project level polluter pays policy is used for avoiding or mitigating the impacts of an activity. However, at the regional level, for instance, although pollution of several operations may be separately lower than the accepted limit, the accumulation of the pollution might be higher than regulated limit.

In such a case, the polluter pays approach on project is not effective to overcome the problem because without earlier analysis and higher level of planning, the cumulative impact prediction may be inefficient. In addition, as Barrow (2003:113) discusses "cumulative impacts may be experienced after long delays and at a distance from their causes". Therefore, SEA can deal with these difficulties with its ability of looking from the top.

Secondly, to enable to avoid serious future pollution, the activities must be followed as early stage of the operation as possible. This is important not only for the environmental protection but also for the economically feasibility of the operation, because once pollution appears; it would be very costly to cover it.

For example, recovering the acid mine drainage (AMD) costs multimillion-dollar for the mining industry and for the governments in North America

(Ersan et al 2003). Also Tremblay and Hogan (2001 cited in Ersan et al 2003: 12) estimate that the total world wide AMD liability is around US\$100 billion. Therefore, SEA can serve as an early warning system to such environmental impacts (Nierynck 2000:4).

Thirdly, the mining industry operation has social impacts as a consequence of environmental and economical changes in the operation area as it is discussed in section 1.3.2. As a basic rule of the sustainable development, welfare of the society must be considered as much as economic development.

As it is discussed in section 1.3.2, due to operation itself and auxiliary industries, traditional economic activities is changing and economy of the area becomes highly dependent on the mining operation, especially in rural areas. For this reason, to avoid serious social welfare loss after operation ends, realistic development plans, programmes and projects must be developed by governments and competent authorities.

By itself, EIA is not enough for an effective social impact consideration (Ortolano and Shepherd 1995); therefore social impact assessment (SIA) could be useful with EIA. However, these two assessments consider the problem on the project level and the possible solution options are limited and most of the time insufficient to transform the society from a mining dependent to self-sufficient society.

For this reason, before implementation of projects, long term planning should be done by governments with the cooperation of state agencies, academicians, mining and society experts, locals and so on. In addition to insufficient social impact consideration of EIA on policy, plan and programmes (PPPs), the need of the public participation at the possible earliest stage for such decisions become more and more important in decision-making process towards sustainable mining.

For instance, the control, the use and the management of land is one of PPP needed key areas for the mining industry concerning the public participation. This is because there are many actors, including government, governmental agencies, investors, NGOs, local communities, indigenous people, having vital interests how land is used and who gives the decisions regarding the land use (IIED 2002: 25).

Therefore, instead of the project level, with SEA, PPP level public participation on such topics, i.e. use and management of land and energy connected mining investments, may be more effective to get reasonable results for all the stakeholders.

Finally, as a PPP assessment, SEA is a useful tool for economic development of countries, because in highly cyclical and capital-intensive industries, like the mining industry, with a long lead time between initial investment and commercial production, investors prefer economically and politically stable countries for the investment.

Therefore, the countries where the social and political instability is a problem, long-term mining policy would be very useful to guarantee the no change in the conditions. According to this policy, plans and programmes could be developed by regional and local governmental agencies and projects would not be postponed or cancelled due to the later political instability, public rejection due to the lack of trust in the public, speculations, misguidance and prejudice against to the mining industry.

As an example, after the change of the related mining law in 1985, there were 17 international gold companies started to search gold deposits in Turkey. However, the political instabilities and public rejection against the Bergama-Ovacik goldmine project after project approval due to the lacking sense of public trust and credibility in the decisions of agencies, in 2000 only three of these international gold companies have started to investment. The other 14 companies left Turkey after deciding conditions were not suitable for investment (General Directorate of Mineral Research and Exploration of Turkish Republic 2004).

As it can be seen in this example, before considering and discussing proposals on the project level, a platform is needed to discuss costs and benefits of the extraction of the minerals and to prevent mismanagement of the non-renewable resources. In addition, such a platform would also help to build a consensus among different or opposing interests through the different levels of the PPPs, before specific project proposals.

Therefore, SEA does not serve only as environmental protection and social development tools but also an effective economic development instrument in countries, where the political and social stability is lacking.

As it is summarized above, due to capacity of considering cumulative impacts, avoiding future environmental pollution, early public participation and also as an economical development tool, "decision-makers increasingly believe that Strategic Environmental Assessment has the capacity to influence the environment and sustainability nature of strategic decisions" (Parfidário and Clark 2000:3).

### 3 CONCLUSION AND RECOMMENDATIONS

Due to the changing patterns of production and consumption for the sustainable economies, the industry, as one of the most important actors of the environmental, social and economic issues globally, has to revise its actions considering the broad principles and spheres of sustainable development.

As a part of the global industry, the mining industry has also been changing for better manage - environmentally and socially sensitive, economically feasible and financially profitable - operations in the context of sustainable development.

Consequent of this change, several international organizations, such as WB, UN, OECD, institutions, such as, HED, WBCSD, chambers of the industry, i.e. MAC, and companies world wide had been organized conferences, implemented projects and prepared reports for understanding, developing and implementing the sustainable development principles and actions for the mining industry.

The outcome of these studies towards a 'sustainable' mining industry can be summarized as, the mineral and mining sector have to

- protects the environment,
- ensures an equitable distribution of its costs and benefits,
- takes into account the social and cultural values,
- considers the public opinion, covering different interest groups, i.e. aboriginal and indigenous people, through the decision-making process the whether or not to mine,
- optimizes the contribution to the well-being of the current generation without reducing the potential for future generations to meet their own needs

To enable to take into consideration these highlighted points in the future operations and so to improve the mining industry's environmental performance and its image, different actions are needed on the project level as well as policy, plan and programme (PPP) levels.

On the one hand, an integrated environmental management should be developed and implemented to contribute to sustainable development principles on the project level. As a very widely used environmental management tool, environmental impact assessment (EIA) must be strengthen with social impact assessment (SIA) and environmental management plan (EMP) for exercising and considering the social and economic consequences as well as environment on the project level.

Environmental management systems (EMS), on the other hand, most probably improve performance of such an integrated environmental management approach by integrating environmental responsibilities into everyday management practices. It provides a structured method for company management and the other authorises to control the performance of the project through the life cycle (IIED 2002)

Additionally, EMS might be a very useful tool to develop and contribute to the sustainable development policies for operators by its environmental policy and the continual improvement circle through the project cycle

Besides these, it must be also considered that implementation of EMS in an organization or any of its operations does not mean immediately and completely 'sustainable' business, in fact, "EMS is a universal indicator to assess an organization's good-faith effort to achieve reliable and consistent environmental protection" (Cascio et al 1996: 8)

On the PPP level, strategic environmental assessment (SEA) provides the potential opportunity to avoid the preparation and implementation of inappropriate plans, programmes and projects. At the same time, it assists in determination and evaluation of project alternatives and prediction of transboundary and cumulative effects of the project.

Additionally, SEA would help to build a consensus among different or opposing interest groups and also help to build a sense of public trust and credibility in the decisions of the department or agency by the possibility of public participation before the vital decisions have been given, such as, control, use and management of land, social and economical development alternatives after mining operation and management of the mineral resources.

### *Recommendations*

Governments should review, develop and implement effective policies to make the access to information and public participation easier and effective with clear procedures for more transparent decision-making processes, especially in developing and non-developed countries. It will also improve the communication and coordination between governmental agencies and public.

Additionally, governments and international community should support the voluntary initiatives, aiming to implement environmental standards, i.e. the ISO 14000 series and EMAS, especially in small and medium scale mining companies. For the products, eco-labels and life cycle assessment applications for the mining and processing sector

should be applied widely especially by international companies.

On the business side of the sustainable development issues in the mining industry, "organizations should establish sustainable development policies that incorporate other company policies such as those on worker health and safety, employee integrity, human rights, community relations so on" (IIED 2002: 393)

Furthermore, for more effective environmental and social assessment on the project level, instead of two different assessments, EIA and SIA should be implemented as a combined environmental assessment. "Such an assessment should become an inclusive, dynamic, on going process of integrating knowledge of on potential impacts into decision-making and management practices" (IIED 2002: 399)

Last but not least, contributing to the sustainable development issues for the mining industry, regional and national partnerships, effective governance systems at the national level and further studies, workshops and initiatives at the global level should be initiated. This is also needed for increasing the number of efficient, effective and successful examples of environmentally sensitive, socially welfare, economically feasible and financially profitable mining operations, concerning the sustainable development in the mining communities.

### *Acronyms and Abbreviations*

|          |  |
|----------|--|
| AMD      | acid mine drainage   |
| CDG      | Carl Duisberg Gesellschaft (Germany)                       |
| CEO      | chief executive officer                                    |
| COCHILCO | Chilean Copper Commission (Chile)                          |
| DSE      | Deutsche Stiftung für Internationale Entwicklung (Germany) |
| EIA      | environmental impact assessment                            |
| EMAS     | eco management and audit scheme                            |
| EMP      | environmental management plan                              |
| EMS      | environmental management systems                           |
| EPA      | Environmental Protection Agency (United States)            |
| EU       | European Union   |
| HBS      | Heinrich Boell Stiftung (Germany)                          |
| IEM      | integrated environmental management                        |
| IED      | International Institute for Environment and Development    |
| IFC      | International Finance Corporation                          |
| ILO      | International Labour Organisation (Switzerland)            |
| ISO      | International Organization for Standardization             |
| MAC      | The Mining Association of Canada                           |
| MMSD     | Mining, Minerals and Sustainable Development (UK)          |
| NGO      | non-governmental organization                              |



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|           |  |
|-----------|--|
| OECD      | Organization for Economic Co-operation and Development |
| PPP       | policy, plan and programme                             |
| UN        | United Nations   |
| UNDESA    | UN Department for Economic and Social Affairs          |
| UNDESD    | UN Decade of the Education for Sustainable Development |
| UN/OCHA   | UN Office for the Coordination of Humanitarian Affairs |
| UNEP      | United Nations Environmental Programme                 |
| UNEP/DTIE | UNEP Division of Technology Industry and Economics     |
| UNEPFI    | UNEP Finance Initiatives                               |
| SEA       | strategic environmental assessment                     |
| SIA       | social impact assessment                               |
| WB        | World Bank   |
| WBCSD     | World Business Council for Sustainable Development     |
| WHO       | World Health Organization                              |

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## Sustainable Development in Mining (Iron & Steel Sector-Erdemir)

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**ABSTRACT:** More than half of the world's iron and steel production is based on the integrated method of transforming ore into steel. The second foremost method of producing steel is through electric arc furnaces that recycle scrap. Due to environmental effects as well as cost concerns that arise from mining activities, efficiency of the process of integrated steel production has to be maximized to the utmost extent. Despite efforts for «cultivation and conservation following mining activities, it is evident that recycling scrap steel is beneficial for preserving limited natural resources for future generations. The notion of sustainable steel finds meaning with modern ways of mining that exercise environmentally friendly methods and makes maximum use of limited available resources throughout the longest possible time span with the highest quality products attainable. The use of scrap for the production of final steel products will induce significant contributions to this line of reasoning.

It is only possible to preserve our resources for future generations and fulfill the contemporary parameters of development by the complete implementation of the concept of "Sustainable Development". As investment decisions made by modern investors are not limited to financial performances of companies, stock exchanges have recently developed approaches which reflect the sustainability of companies so as for them be able to carry on with their respective activities in the future. The Dow Jones Sustainability Index is an example of such an approach. Taking this as a point of origin, identifying and monitoring indicators that reveal financial, environmental and social performances will serve to attain an important place in global commerce.

### 1 SUSTAINABLE DEVELOPMENT

#### 1.1 What is the Sustainable Development?

It has become the ambition of mankind throughout history to attain more comfortable and modern standards of living. With the increase of global population, nations all over the world that serve this intention have come to realize in the early 90's that resources such as air, water and soil that were once thought to be of endless supply are being exhausted with an increasing pace. With the prevailing pace of consumption of the world's resources for the sake of attaining a more comfortable and modern life, the concern of not being able to find a world at all has led mankind to seek various ways for a solution. The notion of Sustainable Development that has arisen as a result for the quest for a solution, calls for programming contemporary and future ways living without exhausting resources and making them available for future generations by establishing a balance between mankind and nature. The notion of Sustainable Development consists of social, ecological, economic, and cultural dimensions.

#### 1.2. Sustainable Development Elements

Sustainable development is primarily monitored under three main headings. The basis of the line of reasoning is placed on economic, environmental and social indicators that promote the utilization of resources efficiently (Figure 1).

The performances of companies are identified by sub factors that are under the three basic indicators whereby playing a significant role on the decisions made by investors.

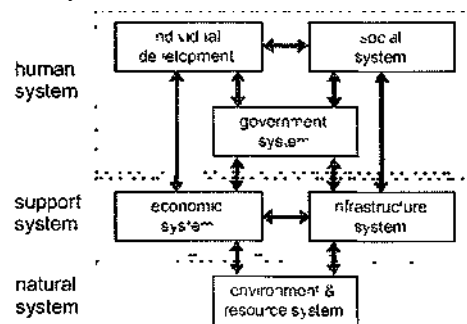


Figure 1 Sustainable Development Indicators

## 2 DOW JONES INDEXES FOR SUSTAINABLE DEVELOPMENT

Apart from production quality and environmental responsibility, those companies that seek to leave operational companies for future generations are continuously carrying on with their work regarding the subject. Indexes that intend to compile performances of different companies under similar evaluation criteria, serve as a means for comparison. The indexes enable stock exchanges, private organizations and institutions to compare and monitor companies from similar or differing sectors.

The following reports are examined throughout the company analysis that are made for the ranking prepared by the Dow Jones Sustainable Indexes

- o Environmental reports
- o Health and safety reports
- o Social reports
- o Annual financial reports
- o Special reports (e.g. on intellectual capital management, corporate governance, R&D, employee relations)
- o All other sources of company information; e.g. internal documentation, brochures and website.

The Dow Jones Sustainability Indexes that operate integrally to the Dow Jones Stock Exchange and the indexes developed by the IISI (International Iron & Steel Institute) in 2004 can be shown as examples to the work achieved regarding the issue.

## 3 SUSTAINABLE DEVELOPMENT IN MINING (Iron & Steel Sector)

### 3.1 Activities that are carried out by the IISI (International Iron and Steel Institute)

The concept of evaluating the performances of companies by sustainability indexes have been adopted by the International Iron & Steel Institute in 2003.

In this respect, as a result of the extensive work accomplished, 11 indicators that represent the dynamics of the steel sector have been identified. This has developed a format by acquiring the data gathered from 42 IISI members that come from 30 different countries and represent 30% of the world's steel production. The indicators act as a means of comparison.

Table 1. Sustainability Criteria for Dow Jones Sustainability Indexes

|             | Criteria   | Weighting (%)       |
|-------------|--|---------------------|
| Economic    | Codes of Conduct/Compliance / Corruption&Bribery | 4.2                 |
|             | Corporate Governance                             | 4.2                 |
|             | Customer Relationship Management                 | 30                  |
|             | Investor Relations                               | 3.6                 |
|             | Risk & Crisis Management                         | 4.2                 |
|             | Scorecards / Measurement Systems                 | 4.2                 |
|             | Strategic Planning                               | 4.2                 |
|             | Industry Specific Criteria                       | Depends on Industry |
| Environment | Environmental Policy / Management                | 48                  |
|             | Environmental Performance (Eco-Eficiency)        | 3.6                 |
|             | Environmental Reporting*                         | 1.8                 |
|             | Industry Specific Criteria                       | Depends on Industry |
| Social      | Corporate Citizenship/ Philanthropy              | 24                  |
|             | Stakeholders Engagement                          | 3.6                 |
|             | Labor Practice Indicators                        | 3.0                 |
|             | Human Capital Development                        | 30                  |
|             | Knowledge Management/ Organizational Learning    | 30                  |
|             | Social Reporting*                                | 1.8                 |
|             | Talent Attraction & Retention                    | 30                  |
|             | Standards for Suppliers                          | 2.4                 |
|             | Industry Specific Criteria                       | Depends on Industry |

### 3.2. IISI Sustainability Indicators

#### 3.2.1. Investment in new processes and products

This indicator covers Capital and Research & Development expenditures of a company. Capital

expenditures include money used to acquire or improve long term assets, such as property, plant and equipment. Research & Development expenditures, paid by the company, includes money used for discovering new knowledge about products, processes, and services, and then applying that knowledge to create new and improved products, processes, and services that fill market needs. The investment in capital and research & development should be based on direct company spending and included in the year it was spent.

$$\text{Investment in new processes and products} = \frac{\text{CE + RDE}}{\text{Annual Revenue}}$$

CE: Capital Expenditure  
RDE : Research and development expenditure (direct)

### 3.2.2. Operating Income

A measure of a company's earning power from ongoing operations, equal to earnings before deduction of interest payments and income taxes, called operating income or EBIT (earnings before interest and taxes).

Companies should provide the result based on their annual financial reporting and indicate the method used for calculating operating income.

$$\text{Operating Income} = \frac{\text{Operating Income}}{\text{Annual Revenue}}$$

### 3.2.3. Return on Capital Employed (ROCE)

A measure of the returns that a company is realizing from its capital. Calculated as profit before interest and tax divided by the difference between total assets and current liabilities. The resulting ratio represents the efficiency with which capital is being utilized to generate revenue. Values to be based on reporting year-end.

$$\text{ROCE} = \frac{\text{Total Assets} - \text{Current Liabilities}}{\text{Operating Income}} * 100$$

### 3.2.4. Value Added

Economic Value Added Analysis measures the value creation to shareholders by a company or business unit. The analysis measures a company's or business unit's ability to earn more than its total cost of capital.

$$\text{Value Added} = \frac{((\text{ROCE} - \text{WACC}) * \text{CE}) / 100}{\text{Annual Revenue}}$$

WACC : Weighted Average Cost of Capital  
CE : Capital Employed

### 3.2.5. Greenhouse Gas Emissions

The emission of greenhouse gases due to direct and indirect steel manufacturing. As identified in the Kyoto Protocol, Annex A, the greenhouse gases considered are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF<sub>6</sub>). The steel industry indicator will include CO<sub>2</sub> in the first instance.

$$\text{GHG} = \frac{\text{CO}_2 \text{ Emissions (Ton)}}{\text{Crude Steel Production}}$$

The carbon dioxide emissions include direct emissions from the crude steel production processes and indirect emissions from energy consumption. Emissions resulting from iron ore mining, coal mining, oil production, etc are not included. Credit is given for by-products, such as slag used in road building.

### 3.2.6. Material Efficiency

This indicator shows the ratio of material waste and economic or physical output, where waste includes those materials that ultimately end up in a landfill or are incinerated. This does not include utilities waste.

This indicator measures the amount of material sent to landfill or incineration, whether offsite or onsite and without regard to whether the incinerator has heat recovery or not. The idea is to capture the amount of material sent for permanent disposal.

$$\text{GHG} = \frac{\text{CSP} - (\text{MSL} + \text{MSI})}{\text{Crude Steel Production}} * 100$$

CSP : Crude Steel Production  
MSL : Material Sent to Landfill  
MSI : Material Sent to Incineration Plant

### 3.2.7. Energy Intensity

This indicator shows the ratio of energy consumption and economic or physical output. The energy intensity includes direct energy consumption from the crude steel production processes. Resulting from iron ore mining, coal mining, oil production, etc are not included. Credit is given for by-products, such as BFG, COG and OG.

$$\text{Energy Intensity} = \frac{\text{Total Energy Consumption (GJ)}}{\text{Crude Steel Production}}$$

### 3.2.8. Steel recycling

The ratio of recycled (scrap) steel used in the steelmaking furnace (basic oxygen or electric arc), including pre-consumer and post-consumer recycled (scrap) steel, and crude steel production.

$$\frac{\text{Steel Recycling}}{\text{Scrap*} + \text{Crude Steel Production}}$$

Total scrap charged to steelmaking furnaces

### 3.2.9. Environmental management systems

This indicator shows the certification to a recognized international environmental management system standard such as ISO 14001. Companies should provide data for those facilities 100% owned and not to include joint ventures.

$$\frac{\text{Steel Recycling} \sim \frac{\text{Number of Employees and Contractors Working in Registered Production Facilities}}{\text{Total Number of Employees and Contractors Working in Production Facilities}}}{\text{Total Number of Employees and Contractors Working in Production Facilities}}$$

### 3.2.10. Employee training

Instruction to bring about skilled behaviour of employees, which may include various methods such as classroom instruction, written instruction, computer-based instruction or on-the-job instruction. Companies should report the data available to them. Guidance on the definition of training to be provided. Number of contractors and contractor training are not to be included for this calculation.

$$\frac{\text{Employee Training} \sim \frac{\text{Total Days of Training}}{\text{Total Number of Employees}}}{\text{Total Number of Employees}}$$

### 3.2.11. Lost time injury frequency rate

A lost time injury is an industrial injury causing loss of time from the job on which the injured person is normally employed beyond the day or shift on which the injury occurred. In addition, cases where loss of time does not immediately follow the injury, but where there is a direct relation between absence and injury, are generally regarded as lost time injuries.[2] The lost time injury frequency rate is the number of lost time injuries for each 1,000,000 working hours.

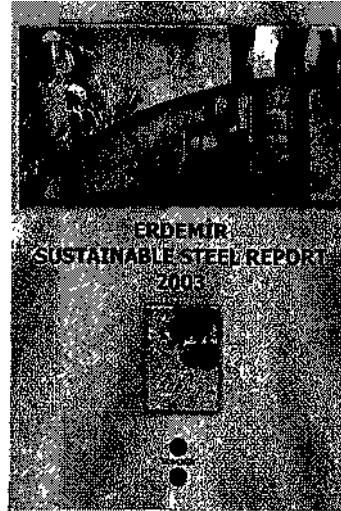
$$\text{L TIFR} = \frac{\text{Number of Lost Time Injuries}}{\text{(Total Number of Hours Worked/1000000)}}$$

## 4. ERDEMIR SUSTAINABLE STEEL REPORT

Ereğli Iron Steel Works Co. (ERDEMFR), has issued its Sustainable Steel Report in 2004. This has enabled Erdemir's indicators to be comparable with other steel producers worldwide.

The report, which is composed of the three basic elements of Sustainable Development, consists of the following company information:

1. *With the Environmental Performance Indicators, the importance given to the effective preservation of the environment by the careful and precautionous utilization of resources.*
2. *With the Economic Performance Indicators, the thought of sustaining economic growth and creating dependable employment opportunities.*
3. *With Social Performance Indicators, the reduction of social poverty, providing equality, the improvement of living quality, and the improvement of occupational health and safety.*



Şekil 1. ERDEMIR Sustainable Steel Report 2003

In revealing the three basic indicators, the IISI criteria have been taken as a point of origin. The criteria have been supplemented with Sustainability indexes that are unique to Erdemir to give a broader picture. These criteria are given as:

- Increase in Capacity'
- Investments
- Value Addition since the establishment

- Environmental Strategies
- Environmental Investments
- Energy Balance
- Dust Emissions
- « SO2 Emissions
- NOx Emissions
- Usage of Recirculation Water
- Specific Water Consumption
- Recycled iron from BOF slag
- Blast Furnace Fuel Consumptions
- Energy Management Center
- « Environmental Performance Index
- Number of Intern Students
- Educational Programs
- Social Responsibility Projects

## 5. CONCLUSION

The notion of Sustainable Development and hence performance indicators have been established parallel to the vision of a world in which companies that produce for the future will prevail. The iron and steel sector has defined its respective performance indicators as of the year 2003. The indicators are continuously being monitored and controlled as to enable companies to prevail in the future by increasing their profit shares.

The Mining sector, which happens to be in a very important position in terms of environmental effects, should monitor and control their performances not merely in terms of profit but also in terms of contributions to the environment and society.

**Table 2. Erdemir Sustainability Indicators**

| Sustainability indicators - Summary |  |       |  |
|-------------------------------------|--|-------|--|
| No                                  | Indicator                                | Value | Units  |
| 1                                   | Investment in new processes and products | 0,11  | us\$/us\$ Revenue  |
| 2                                   | Operating Income                         | 0,19  | US \$ / US \$ Revenue  |
| 3                                   | Return on Capital Employed (ROCE)        | 13,66 | %  |
| 4                                   | Value added                              | 0,08  | US \$ / US \$ Revenue  |
| 5                                   | Greenhouse Gas Emissions                 | 0,65  | tonnes of CO <sub>2</sub> / tonne of crude steel produced  |
| 6                                   | Material efficiency                      | 82,39 | %  |
| 7                                   | Energy intensity                         | 13,52 | GJ / tonne crude steel produced  |
| 8                                   | Steel recycling                          | 0,23  | tonnes scrap / tonne crude steel produced  |
| 9                                   | Environmental management systems         | 1,00  | Number of Employees and Contractors in Registered Production Facilities / Total Number of Employees and Contractors in Production Facilities |
| 10                                  | Employee training                        | 6,57  | Training Days / Employee   |
| 11                                  | Lost time injury frequency rate          | 6,70  | Frequency/1,000,000 Hours Worked   |

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