THE INTRODUCTION OF CLEANER PRODUCTION TECHNOLOGIES IN THE SOUTH AFRICAN MINING INDUSTRY

A SUMMARY REPORT

Report to the

WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

The mining industry has played a major role in the development of South Africa and has the capacity to do so for many more years. It has had such an influence, that the urbanisation pattern of South Africa is largely influenced by the occurrence, exploitation and beneficiation of minerals. The mining industry is also the largest producer of solid waste[1] in the country and a major contributor to water quality degradation in many of South Africa's important catchments. The mining industry is also a large consumer of water in some of the stressed and drier catchments in South Africa and is a large consumer of electrical power.

The survival of the industry depends on the effectiveness with which it deals with its impacts. The social acceptability of the impacts must be sufficient for the community in which it operates to endorse and encourage its presence otherwise regulators and politicians will not support existing or new mining projects. In a number of areas where there is competition for resources such as power or water the viability of projects also depends on the ability of the mining companies to do more with less. Profitability of many mining projects can be significantly enhanced by having better resource utilisation and by minimising long term impacts, thus reducing financial liability. The effectiveness with which this is done can mean the difference between having a mining project or not. One way of doing so is to implement waste minimisation and Cleaner Production (CP) technologies.

CP is a general term that describes a preventative environmental approach, aimed at increasing resource efficiency and reducing the generation of waste at source, rather than addressing and mitigating just the symptoms by technically treating an existing waste or pollution problem.

It is generally accepted that the best long-term solution to waste management issues is to minimise waste generation at source. The mining industry is unique in that, apart from a few special cases, it is not possible to do so for the bulk of the waste produced. The **focus** for interventions rather thus shifts to the industry being required to **minimise the impacts from the waste**. Also the secondary impacts of water abstraction, water quality deterioration, effect of power usage and on land use changes needs to be dealt with in a proactive manner.

Another unique aspect of the industry is that the impacts from mines can continue to affect communities and biota for millennia after closure of these facilities from impacts such as subsidence and Acid Rock Drainage (ARD).

An analysis of the Water Research Commission's (WRC) past and present project portfolio indicates that most of the research effort to address water and waste management in the mining industry has been devoted to minimising the impact of waste on the environment and to improve the ability to predict and quantify effects as well as to develop technologies to treat polluted waters. Unlike other industrial sectors, **no projects devoted specifically to waste minimisation and CP technologies have previously been undertaken.** Although the mining industry has launched various sustainability-related initiatives such as the *Mining, Minerals and Sustainable Development* (MMSD) project, there is significant scope within the industry as a whole for greater implementation of CP practices. To address this need **the WRC solicited this project aimed at introducing CP to the South African mining industry** and entrenching CP concepts where these are already being practiced.

Project aims and objectives

The overall objective of the project was to introduce CP technologies in the mining industry. The following tools suggested by the WRC to achieve these objectives were to be evaluated during the course of the project:

1. Conduct a scoping level situation analysis of the mining industry that identifies the present level of CP activities and awareness, both locally and internationally;
2. Identify existing water-related threats that could be alleviated by CP technologies and thus represent opportunities to facilitate the introduction of CP approaches in the South African mining industry;
3. Introduce the concept of Waste Minimisation Clubs (WMCs), evaluate their suitability and establish similar appropriate mechanisms and pilot clubs in the mining industry (WMCs could be used as

[1] The largest volume is in the form of tailings material.

vehicles for the training of practitioners in the mining industry in CP technologies and the implementation of CP programmes on participating mines);
4. Conduct focused high level Life Cycle Analysis (LCA) studies at an overall impact level, to determine priority areas for introducing the CP approach, acquaint service providers and industry with the technique and identify areas for the focus of WMCs;
5. Launch a campaign to raise the awareness of the mining industry concerning the benefits and need for adopting CP approaches and the possible methodologies and processes for doing so; and
6. Ensure the future viability and sustainability of initiatives to introduce CP approaches to the mining industry.

In order to address these aims, multi-faceted initiatives were undertaken to raise the awareness in the mining industry of the benefits of, and need for, adopting CP approaches.

The optimal use of resources such as water and energy does not just make a mining operation more viable but could mean the difference between a project being able to operate at all and generating benefits and rewards which are able to be shared by investors, the government and the community.

The following initiatives were undertaken:

Scoping study

This project began with a scoping study with the aim of determining the current status of environmental practices related to CP and to identify areas which need to be focused on to facilitate the industry's move towards more sustainable consumption and production practices. The scoping study also identified areas for conducting specialist studies and for establishing Cleaner Production Forums (CPFs).

The main findings from this study were:

1. The South African mining industry is improving its practices and taking the environmental impacts into consideration in project decisions and for operations;
2. The industry is willing to adopt CP initiatives and realise the benefits of implementing CP technologies;
3. The coal mining industry forum established in the Witbank area operating as the South African Collieries Environmental Practitioners Association (SACEPA) was an ideal place to start detailed studies and a CPF; and
4. Distinct differences in approach were noted between big and small companies. These are:
    a. With the larger companies, the awareness is being driven mainly by the company's policies and the practices of their competitors;
    b. Amongst the smaller companies, the awareness is driven by legislation;
    c. The environmental policies of the larger companies contain CP principles and this was used as a route to encourage cleaner technology in these companies;
    d. With smaller companies, cleaner technology options can be used to assist with complying with legislation and in reducing costs;
    e. The larger firms either already have ISO 14001 certification at all operations or are striving towards ISO 14001 certification; and
    f. The smaller companies were not keen on attaining ISO 14001, mainly due to the lack of capacity and not seeing any benefit in it.

Awareness raising campaign

This aspect of the project was implemented to improve the understanding of CP principles and techniques for the mining industry and authorities, encourage and promote CP and to ensure the effectiveness of the project. These aims were achieved through the following activities:

1. Seminars held for the mining industry;
2. Training workshops held separately for industry and for the regulators;
3. The CP guide developed for the mining sector was made public and copies provided to all participants at the seminars and to major role players; and
4. Presentations on project findings were made at different forums, seminars and conferences to cover all the stakeholders in the mining industry.

Water related threats study

A water related threats study was conducted to ensure that the project funds were directed to areas where there is really a need. Threats posed both **by** and **to** the mining industry were investigated.

It was found that water related threats posed **by the mining industry on the water resources** of South Africa are:

1. Potential contamination of surface water by spills from treatment and processing facilities;
2. The use of water in drier parts of the country increasing competition for scarce resources;
3. Long term contamination of runoff from stockpiles, rock dumps and tailings facilities;
4. ARD resulting in potentially acidic and saline leachates from tailings facilities and mine workings; and
5. Partial or total dewatering of aquifers.

Water related threats posed to the mining industry are:

1. Lack of water resources to expand operations in the drier parts of the country and at existing operations;
2. Lack of legislative clarity and service delivery with respect to compulsory licensing and management requirements;
3. Potential for long term treatment costs for decanting mine water, as the option for dilution, does not generally exist in the dry South African interior; and
4. Increasing cost of water.

The introduction and use of CP principles in the South African mining industry are therefore essential to:

- Reduce energy and water consumption and improve efficiency for each unit of product produced to ensure availability of these utilities for current and future projects;
- Reduce long term water management and treatment costs;
- Reduce chances of spills and runoff contaminating surface water resources;
- Comply with water, waste, environmental and mining legislation.

Cleaner Production Guide for the South African Mining Industry

A guidance document has been compiled to assist those working in and with the mining industry, with a secondary focus on those government departments regulating the mines. The document will assist mining companies in implementing a CP programme, while at the same time, providing the regulators with suggestions on how to promote and encourage the process. It will also assist companies and regulators in identifying where they stand with respect to best practice, where opportunities exist for implementing CP options and where CP technologies have already been implemented.

Consultants to the industry will also benefit from the guidance document as it will provide necessary background information to the sector and suitable CP opportunities and business ideas.

Cleaner Production Forums

WMCs have been used in other industries and countries to assist with the implementation of waste minimisation and CP. They can be formed with companies in the same area or mining the same commodity who are facing similar environmental and economic problems. The members of these clubs share their experiences and work together to achieve improved understanding and implementation of sustainable production and consumption practices. Researchers and trained professionals provide training and other useful input at these forums.

Following discussions with members of the mining industry, a decision was made to change to terminology from Waste Minimisation Clubs (WMCs) to Cleaner Production Forums (CPFs).

Two CPFs were formed during this project (one for coal mining and one for gold mining). The drive in these forums was to share ideas, fight common battles and share success stories. The member companies of the coal CPF have agreed to continue with this forum. The vehicle for implementation and the driver for the coal CPF was the SACEPA. The members have stated that they will make sure that these CPFs do not die when the project is finished. The CPF's have proved to be a good way of achieving the goals of CP and minimising the impacts of the mining industry.

Graduate and Post Graduate Studies Supported

As a means of identifying feasible CP opportunities for the coal mining industry and in particular for the CPF, an M.Sc. (Eng) dissertation entitled '*An investigation of Cleaner Production opportunities in the South African coal mining industry*' was produced by Jane Reddick through the University of Cape Town. The study identified numerous feasible CP opportunities to reduce the **amount of slurry, discards and energy wasted** at the three case study collieries. These three areas were considered to be the prime areas where changes could be made. Many of the suggested interventions, if implemented, are expected to reduce the mines' impacts on the quality of water in the region. None of the interventions proposed involved the use of unproven technologies. For the options that require high capital investments (i.e. investments in excess of R1 million), payback times were found to be less than one year, and the 10 year net present values of suggestions ranged between R10 million and R200 million.

Another M.Sc. student started on research which became an honours dissertation project which attempted to quantify the ecological footprint of gold production and its associated supply chain in South Africa, and determine major areas of impact using the LCA method. The study found that:

1. The Ecological Footprint method can be used to provide a comprehensible and relatively meaningful single indicator score for data captured in an LCA;
2. The ecological footprint of the South African gold mining industry is mainly due to its electricity use, with leachate from tailings disposal a significant second; and
3. South Africa's gold mining industry has an ecological footprint equivalent to about 9% of South Africa's ecologically productive land surface area.

Another study*, Environmental Life Cycle of Fine Coal Use for Power Generation in South Africa*, was conducted by means of two honours level research projects. It was concluded that the main source of pollution was sulphur and the system response was most sensitive to this parameter. Other major impact categories were fossil fuel depletion, gaseous emissions and climate change. The solar drying of fine coal and the subsequent use of this fine coal should be supported. This option is preferable to thermal drying of coal fines. It was thus recommended that solar drying be implemented and that coal slurry be utilised. It is noteworthy that one of the authors (Mondli Guma) has since completed a Masters degree on the development of quantified eco-efficiency indicators in the mining industry, and has now been employed as a sustainability expert by a large South African coal mining company.

In addition to the above mentioned thesis an additional two post graduate students were supported by this project but failed to complete their studies.

Quick Cleaner Production Opportunity Assessments

A practical evaluation of five different mining facilities was conducted using a quick CP assessment technique. This process looks at all inputs and outputs to a facility and has the objective of trying to determine areas where resources can be saved to the benefit of the environment and to save the company money. Many CP opportunities were identified and recommendations were made. Worksheets originally developed by the United States Environmental Protection Agency (US-EPA) were modified to be used practically by the mines and these were used for conducting these investigations. The facilities visited included platinum smelters and concentrators, shaft complexes and gold extraction plants to ensure that as many different people as possible were exposed to the technique and to test out the worksheets for different places.

Financial evaluation and opportunities

Electrical energy has been highlighted as a major constraint for development in the mining industry in South Africa due to recent power shortages. These shortages are expected to continue. The cost of hydrocarbon based fuels has also dramatically increased over the past few years. The improvement in energy efficiency by the mining industry is thus essential, not only to maintain and improve profitability but also to ensure that sufficient energy supplies exist for new projects and developments.

Every percentage improvement in efficiency in the mining industry could produce an additional R2 billion in sales. This could also translate into an additional 4 500 direct jobs. Including the expected multiplier effects this could result in an additional 50 000 people benefiting from wages generated by the mining industry.

At a 7% direct contribution to the GDP and a 18.4% total effect, taking forward and backward linkages into account, the effect of a 1% increase in efficiency is equal to R1.5 billion directly and R4.0 billion in total to the South African GDP (using SA Reserve Bank figures for GDP for the first quarter 2008). It is not inconceivable that improvements in efficiency of 10-15% are achievable.

If improved efficiency is not practiced then a number of mining projects may not be initiated at all as electrical power will not be available for them neither would there be sufficient water available. The value of these projects and the implied multiplier effect on South Africa is enormous. The costs of providing alternative energy using on site generation is extremely expensive and will limit the life of the projects.

Economic development in South Africa is currently severely constrained by the availability of electrical power. Even though new productive facilities are being built rapidly it is likely that it will be many decades before a comfortable reserve margin is built up given current growth rates. Whilst it is possible that additional generation capacity can be constructed for electricity it is highly likely that this will represent a constraint to development for the next few decades. It is thus essential that available resources be used more efficiently.

South Africa is a dry country and the availability of water for consumptive use is finite. In order to meet the expected growth rates of the economy and the expectations of the people for a better life it is imperative that this scarce resource is used in an efficient and effective manner.

More effective use of this country's mineral resources will ensure that they can continue to be exploited for a longer period of time and provide income to the government and communities to enable them to develop a sustainable society through the exploitation of minerals, as mining is by definition an unsustainable activity. The full utilisation of current mine wastes will ensure that environmental liabilities are reduced and the benefits to society are enhanced.

The potential return on investments is plain to see and thus all state institutions and businesses should be encouraging the development of technologies which will allow for the more efficient exploitation of our mineral resources and the optimal utilisation of these resources in the development of sustainable communities.

Discussion and conclusions

The project has succeeded in meeting all its aims and objectives except for possibly ensuring the sustainability and viability of initiatives to introduce CP approaches to the industry. The introduction of CP will have to be pursued by many organisations providing services to the mining industry and by all role players in the industry.

Thousands of people working in the mining industry, or providing services to it, have been exposed to the principles of CP and the tools available to assist with its implementation. The initiatives were generally very well received and this project has provided the basis for many more initiatives to be implemented in the coming years.

Recommendations for implementation:

1. The public and the regulators need to find a way to challenge the mining industry to reduce coal fine wastes and to optimise electricity consumption, particularly in the gold mining sector;
2. The design and implementation of training programmes for regulators in respect of CP needs to be encouraged;
3. The guideline document needs to be widely distributed to the industry, consultants and regulators. Its availability should be advertised in the press and at conferences. Training programmes should be conducted with people who would find it useful;
4. Service providers/consultants interested in the implementation of CPFs should be trained. Managing CPFs is an ideal environmental product as it will provide income for the service providers while aiding the industry in becoming more competitive and sustainable;
5. The WRC needs to continue support for all CP initiatives as the cost saving and ability of these interventions to make a marked difference to the way industry conducts its business is remarkable;
6. There needs to be support for all initiatives to lower the power consumption of SA mines per unit of product;
7. The use of fine coal and initiatives to enhance its calorific value by air drying it should be promoted; and

8. The benefits of utilising various tools such as LCAs, CPFs, etc. needs to be publicised in order to get them implemented.

Recommendations for research:

1. Bursaries should be provided to students for LCA investigations, CP and consumption studies, CPFs and water and energy efficiency studies;
2. There needs to be support for all research initiatives into preventing ARD from occurring from all residue or discard facilities, waste rock dumps and mine workings;
3. Research into the deportment and eventual fate of all sulphur in a coal mine needs to be supported;
4. There should be targeted training programmes and awareness campaigns. A WRC project could include lectures to all local, provincial and national authorities tasked with implementing CP. Awareness campaigns should be developed for the mining industry which can be used at all levels in organisations;
5. There should be sponsorship available for organisations to establish and run CPFs in different areas;
6. Support needs to be given to industrial symbiosis projects whereby different industries co-operate and that CPFs do not just become a mining industry initiative;
7. There needs to be support projects which look at ways of getting water to the drier parts of the country in the eastern and western limbs of the Bushveld Igneous Complex (BIC), particularly if that water comes from mine water and costs may be saved if it is used rather than water which is not saline. This will also save expensive water treatment costs;
8. All work on energy efficiency projects should be encouraged;
9. The WRC needs to continue supporting projects which seek to minimise the water quality impacts from mine waste and mine workings; and
10. The WRC needs to find ways to assist the Department of Water Affairs and Forestry (DWAF) in implementing the law such that give security and assurance to water users.

The Department of Water Affairs and Forestry produced a series of guideline documents for water management in the mining industry which promote the concept of Cleaner Production. These are described in more detail in the Appendix to this report and can be found on www.dwaf.gov.za.

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The Reference Group Committee responsible for this project consisted of the following persons:

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Mr LL Labuschagne	Department of Minerals and Energy
Mr D Salmon	Anglo American Corporation
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The following team members were the main authors for this document and the various specialist sections:

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Prof Harro von Blottnitz	Supervision of post graduate students for the LCA studies and Jane Reddick's CPF Masters. Wrote the report specialist sections on LCAs.	University of Cape Town
Claire Janisch	Managed the awareness raising campaign, general project energiser and report review. Organised training workshops with authorities and industry. Scoping study on awareness raising needs for the regulators.	Own consultancy
Bas Kothuis	Organised CPFs and wrote the report section on this topic.	BECO Institute for Sustainable Development
Priyal Dama-Fakir	Proposal co-ordination, administration and project management for the first half of the project. Scoping report.	Originally Digby Wells & Associates, currently Golder Associates
Skhumbuzo Mzoboshe	Project management for the second half of the project. CP opportunity assessments. Training workshops with authorities and industry.	Originally Digby Wells & Associates, currently Lafarge Cement
Susan Barclay	Guidance document. Liaison with authorities. Scoping study on awareness raising needs for the regulators.	Own consultancy
Graham Trusler	Project manager. Specialist section on Financial Impact. CP opportunity assessments. Water related threats report.	Digby Wells & Associates
Jane Reddick	CPF Masters thesis. Organiser of Coal Industry CPF.	Worked in conjunction with BECO and University of Cape Town.
Andries Wilke	Water related threats report.	Digby Wells & Associates

TABLE OF CONTENTS

EXECUTIVE SUMMARY iii
ACKNOWLEDGEMENTS ix
TABLE OF CONTENTS xi
LIST OF TABLES xvi
LIST OF FIGURES xvi
LIST OF BOXES xvi
ABBREVIATIONS xvii

CHAPTER 1 INTRODUCTION 1
1.1 Background information 1
1.2 Objectives 2
1.3 Project team 3
1.4 Approach 3
1.5 Approaches to specific objectives 3
1.5.1 Scoping study 3
1.5.2 Identify existing water related threats 4
1.5.3 Guidelines for Cleaner Production in the mining industry 4
1.5.4 Incorporating the principles of Life Cycle Assessment 4
1.5.5 Awareness campaign 5
1.5.6 Initiating Waste Minimisation Clubs or Cleaner Production Forums 5
1.5.7 Ensuring sustainability of the Cleaner Production Forums 5
1.5.8 Cleaner Production Opportunity Assessment 6
1.6 Structure of the report 6

CHAPTER 2 THE STATE OF CLEANER PRODUCTION IN THE SA MINING INDUSTRY – SCOPING STUDY 7
2.1 Introduction 7
2.2 Literature review 7
2.2.1 Evolution of environmental responsibility 7
2.2.2 Terminology 8
2.2.3 Benefits of Cleaner Production 9
2.2.4 Cleaner Production techniques 9
2.2.5 Cleaner Production and sustainable development 10
2.2.6 Cleaner Production legislation and policy in South Africa 11
2.2.7 A brief history of Cleaner Production in South Africa 12
2.3 Methodology 12
2.4 Discussion 12
2.5 Conclusion 13

CHAPTER 3 INITIATIVES TO INCREASE THE AWARENESS OF CLEANER PRODUCTION 14
3.1 Introduction 14
3.2 Half-day seminars 14
3.2.1 Presentations 14
3.2.2 Participants 14
3.2.3 Outcomes 15
3.3 Interviews with government departments 15
3.3.1 Summary of interviews 15
3.3.2 Outcome of interviews 15
3.4 Cleaner Production workshops for government departments and the mining industry 15
3.4.1 Overview of workshops 16
3.4.2 Outcome of workshops 16
3.5 Meetings with the Department of Water Affairs and Forestry and the Department of Minerals and Energy 17
3.6 Other seminars and presentations 17
3.7 Conclusions 17

CHAPTER 4 WATER RELATED THREATS THAT PRESENT OPPORTUNITIES FOR THE INTRODUCTION OF CLEANER PRODUCTION INITIATIVES 18
4.1 Introduction 18
4.2 Threats posed by the mining industry 18
4.2.1 Contamination of surface water from spills 19
4.2.2 Exploration activities 19
4.2.3 Process chemicals and service materials 19
4.2.4 Contamination of surface water with runoff from stockpiles, spoil heaps, tailings and settling ponds 19
4.2.5 Acid rock drainage (ARD) 20
4.2.6 Widespread lowering of water levels due to dewatering 21
4.3 Threats posed to the mining industry 22
4.3.1 Water provision 22
4.3.2 Water ingress 22
4.3.2.1 Old mine workings 22
4.3.2.2 Aquifers 22
4.3.2.3 Surface water sources 23
4.3.2.4 Infrastructure placement 23
4.3.3 Financial solvency 23
4.4 Information obtained from industry representatives 23
4.5 Cleaner Production related to water use within the mining industry 24
4.5.1 National strategy 24
4.5.2 Industrial, mine and power generation sectors strategy 24
4.5.2.1 The role of the South African Department of Water Affairs and Forestry 24
4.5.2.2 The role of Catchment Management Agencies 24
4.5.2.3 The role of water users 24
4.6 Implications for water users 25
4.7 Conclusions 25

CHAPTER 5 GUIDANCE DOCUMENT FOR THE IMPLEMENTATION OF CLEANER PRODUCTION 27
5.1 Aim and scope 27
5.2 Target audience 27
5.3 How to use the guidance document 27
5.4 Structure of the guidance document 28

CHAPTER 6 THE ESTABLISHMENT OF CLEANER PRODUCTION FORUMS 29
6.1 Introduction 29
6.2 History and status quo of Cleaner Production Forums in South Africa 29
6.3 Establishment and operation of a Cleaner Production Forum 29
6.4 Benefits of and barriers to Cleaner Production Forums 30
6.5 Creation and members CPFs 30
6.6 Coal CPF 30
6.7 Gold CPF 31
6.8 Motivations for the CPFs 31
6.9 Activities of the CPFs 31
6.10 Success of the Cleaner Production Forums 32
6.10.1 Coal CPF 32
6.10.2 Gold CPF 33
6.11 Lessons learnt 34

CHAPTER 7 AN INVESTIGATION OF CLEANER PRODUCTION OPPORTUNITIES IN THE SA COAL MINING INDUSTRY 35
7.1 Background 35
7.2 Preliminary assessment 35
7.2.1 Wastes produced by the collieries 35
7.2.2 Waste characteristics 36

7.2.3 Methane ... *36*
7.2.4 Dust ... *37*
7.2.5 Slurry ... *37*
7.2.6 Coarse discards ... *38*
7.2.7 Sewage ... *38*
7.2.8 Oil spillages and recovery ... *38*
7.2.9 Other leakages ... *39*
7.2.10 Energy consumption ... *39*
7.2.11 Mining method ... *40*
7.2.12 General and hazardous waste ... *40*
7.3 Waste comparison ... 40
7.4 Slurry, discard and energy detailed assessments ... 41
7.4.1 Slurry assessment ... *41*
7.4.2 Coarse discard assessment ... *41*
7.4.3 Energy assessment ... *42*
7.5 Conclusions ... 43

CHAPTER 8 CLEANER PRODUCTION OPPORTUNITY ASSESSMENTS ... 44
8.1 Introduction ... 44
8.2 Methodology for Cleaner Production Opportunity Assessments ... 44
8.3 Platinum smelter ... 46
8.3.1 Compressed air losses ... *46*
8.3.2 Reprocessing ... *46*
8.3.3 Floors ... *46*
8.3.4 Natural drying ... *46*
8.3.5 Larrox filter ... *46*
8.4 Gold mine plant ... 47
8.4.1 Wet ore ... *47*
8.4.2 Illumination ... *47*
8.4.3 Woodchips ... *47*
8.4.4 High pressure wash water ... *47*
8.5 Platinum concentrator ... 47
8.5.1 Level control indicators ... *47*
8.6 Gold mine shaft complex ... 47
8.6.1 Underground sanitation ... *47*
8.6.2 Oil management ... *48*
8.7 Additional recommendations ... 48
8.7.1 Water audit ... *48*
8.7.2 Energy audit ... *48*
8.8 Existing CP initiatives ... 48
8.8.1 Used oil handling facility ... *48*
8.8.2 Waste separation ... *48*
8.8.3 Rubber liners ... *49*
8.8.4 Steel and power consumption ... *49*
8.8.5 Cyanide consumption ... *49*
8.8.6 Knelson concentrator ... *49*
8.8.7 Water softening plant ... *49*
8.8.8 Reprocessing slag from furnace ... *49*
8.8.9 Lime Addition ... *49*
8.8.10 Energy savings ... *49*
8.8.11 Water line shut-off valves ... *49*
8.8.12 Compressed air shut-off line ... *50*
8.9 Discussion and conclusion ... 50

CHAPTER 9 HIGH LEVEL LIFE CYCLE ASSESSMENTS ... 51
9.1 Life Cycle Assessments ... 51
9.2 Benefits of conducting a LCA ... 51

9.3 The use of LCA as a tool to identify Cleaner Production opportunities 51
9.4 Environmental Life Cycle Assessment of fine coal use for power generation in South Africa 52
9.4.1 Introduction 52
9.4.2 Findings of the study 52
9.5 Quantification of the ecological footprint of gold production in South Africa 53
9.5.1 Introduction 53
9.5.2 Findings of the study 53
9.6 Concluding notes on LCA 54

CHAPTER 10 FINANCIAL EVALUATION 55
10.1 Introduction 55
10.2 Recent developments in South Africa related to resources use and availability 55
10.3 The value of the South African mining industry and what financial benefits may accrue through Cleaner Production 56
10.4 Mines are consumers of electricity and suppliers for thermal electricity generation 57
10.5 Cleaner Production case studies 58
10.5.1 Mine ZZZ 58
10.5.2 Mine YYY 59
10.5.3 XXX Mines 60
10.5.4 Mine WWW 61

CHAPTER 11 DISCUSSION, CONCLUSION AND RECOMMENDATIONS 62
11.1 Discussion 62
11.2 Recommendations 63

REFERENCES 65
BIBLIOGRAPHY 66

APPENDIX 67

DOCUMENTS INCLUDED IN THE CD CONTAINED IN THE BACK SLEEVE OF THIS REPORT

VOLUME 1: A SUMMARY REPORT (This Document) – GRAHAM TRUSLER, SKHUMBUZO MZOBOTSHE

VOLUME 2: THE STATE OF CLEANER PRODUCTION IN THE SOUTH AFRICAN MINING INDUSTRY (SCOPING STUDY) – PRIYAL DAMA AND GRAHAM TRUSLER

VOLUME 3: INITIATIVES TO INCREASE THE AWARENESS OF CLEANER PRODUCTION – CLAIRE JANISCH AND SUSAN BARCLAY

VOLUME 4: WATER RELATED THREATS THAT PRESENT OPPORTUNITIES FOR THE INTRODUCTION OF CLEANER PRODUCTION INITIATIVES – GRAHAM TRUSLER AND ANDRIES WILKE

VOLUME 5: LIFE CYCLE ASSESSMENTS – PROF HARRO VON BLOTNITZ

VOLUME 6: ESTABLISHMENT OF CLEANER PRODUCTION FORUMS MASTERS THESIS – JANE REDDICK

VOLUME 7: CLEANER PRODUCTION FORUMS – BAS KOTHUIS

VOLUME 8: CLEANER PRODUCTION SITE ASSESSMENTS – SKHUMBUZO MZHOBOTSHE, GRAHAM TRUSLER

VOLUME 9: GUIDANCE DOCUMENT – SUSAN BARCLAY

VOLUME 10: FINANCIAL EVALUATION – GRAHAM TRUSLER

DEPARTMENT OF WATER AFFAIRS AND FORESTRY BEST PRACTICE GUIDELINE FOR THE MINING INDUSTRY.

LIST OF TABLES

Table 1: Examples of hazardous chemicals and materials in the mining industry *(Source: Environment Australia, 1997)*....20

Table 2: CPF opportunities for energy, slurry and discard....32

Table 3: Comparison of the seam methane content....36

Table 4: Water used for dust suppression....37

Table 5: Comparison of slurry generation....37

Table 6: Comparison of discards quantity and quality....38

Table 7: Comparison of sewage quantities....38

Table 8: Comparison of quantities of recovered oil....39

Table 9: Comparison of general and hazardous waste generation....40

Table 10: Actual water balance for September 2007 at XXX Mines....60

Table 11: Ideal or “best” water balance for September 2007 at XXX Mines....60

LIST OF FIGURES

Figure 1: Cleaner Production and eco-efficiency: An approach to sustainable development.... 10

LIST OF BOXES

Box 1: Defining Cleaner Production.... 9

Box 2: Phases of the Cleaner Production Opportunity Assessment.... 45

ABBREVIATIONS

AMD	Acid Mine Drainage
ARD	Acid Rock Drainage – in this context the same as AMD
BEE	Black Economic Empowerment
BIC	Bushveld Igneous Complex
CMS	Catchment Management Strategy
COM	Chamber of Mines
CP	Cleaner Production
CPA	Cleaner Production Assessment
CPF	Cleaner Production Forum
CPOA	Cleaner Production Opportunity Assessment
CSIR	Council for Scientific and Industrial Research
CSMI	Centre for Sustainability in Mining and Industry
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DTI	Department of Trade and Industry
DWA	Digby Wells & Associates (Pty) Ltd
DWAF	Department of Water Affairs and Forestry
EPA	United States Environmental Protection Agency
ERPM	East Rand Proprietary Mines
GDP	Gross Domestic Product
HDI	Historically disadvantaged individuals
I&APs	Interested and Affected Parties
IBF	Industrial Burning Fuel
ISO	International Organisation for Standardisation
JPOI	Johannesburg Plan of Implementation
JSE	Johannesburg Securities Exchange
KPI	Key Performance Indicators
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
MMMA	Mine Metallurgical Managers Association
MMSD	Mining, Minerals and Sustainable Development
NCPC	National Cleaner Production Centre
PAC	Packed Air Conditioner
PCB	Poly Chlorinated Biphenyls
PGM	Platinum Group Metals
PRG	Pollution Research Group
ROM	Run of mine
SACEPA	SA Collieries Environmental Practitioners Association
SCP	Sustainable Consumption and Production
TDS	Total dissolved solids
UCT	University of Cape Town
UKZN	University of KwaZulu-Natal
UN CSD	United Nations Security Council
UNEP	United Nations Environmental Programme
UNEP DTIE	UNEP Division of Technology, Industry and Economics
UNIDO	United Nations Industrial Development Organisation
US-EPA	United States Environmental Protection Agency
VSD	Variable Speed Drive
WAD	Weak Acid Dissociable
WC/WDM	Water Conservation and Water Demand Management Strategy
WDCS	Waste Discharge Charge System
WMC	Waste Minimisation Club
WMA	Waste Minimisation Assessment
WRC	Water Research Commission
WSI	Water Service Institution
WSSD	World Summit on Sustainable Development

CHAPTER 1 INTRODUCTION

1.1 Background information

Cleaner Production (CP) is a general term that describes a preventative environmental approach, aimed at increasing resource efficiency and reducing the generation of waste at source, rather than addressing and mitigating just the symptoms by technically treating an existing waste or pollution problem.

Due to its political history South Africa has been in a massive transition phase in all respects since the initiation of democracy in 1994. This has resulted in, amongst others, a major appreciation of the role of development and of the natural resource base needed to support and sustain such development. In the mining industry, these changes have manifested themselves in the adoption of international standards, new legislation, stricter regulations, and increased international competition. South Africa is a water scarce country and although as a whole the mining industry does not consume a large portion of the country's water, in some catchments the competition for use is fierce. The impact of mining and its related activities on water quality can however be severe, owing to both the large volumes of material treated and disturbed during mining and processing, and the potential of many of the materials to release water-borne pollutants over time. The increasing costs for water usage and waste disposal have created a need for an improved practice in the mining industry.

A successful response to such pressures by many business sectors all over the world has been a pro-active engagement, realising that more efficient production can often reduce environmental impacts whilst improving the financial bottom line (De Simone & Popoff, 1997). This approach, involving tools such as waste minimisation, CP, clean technology, pollution prevention and eco-efficiency has been researched in the context of the mining and metals sectors (Hilson, 2000; Hilson, 2002), though to no significant extent in South Africa.

In addition to direct water consumption and impacts on quality the mines impact indirectly to a great extent on South Africa's water resources as they use large amounts of electricity, influence structural development patterns, often divert rivers and their legacy in environmental terms is around for generations. Mines realise that they need to consider alternative production and management methodologies and techniques in order to remain in business, improve profitability and to remain competitive. As a result, within the mining industry there are ongoing drives for interventions and processes for such improvements. The status of such interventions and processes needs to be understood and recognised and the concepts, processes and methodologies of CP and waste minimisation developed and introduced appropriately, effectively and efficiently.

Fundamentally, CP is simple: reduce or eliminate pollution at source rather than after it has been generated: prevention is better than cure. The concept of CP can be applied to the products, processes and services of an organisation.

In numerous CP initiatives around the world, implementation has proven that CP can result in a number of benefits such as:

- Economic benefits through increased efficiency and quality; reduced consumption of water, raw materials and energy; reduced (waste treatment and disposal) costs;
- Environmental benefits, e.g. reduced hazardous waste; and
- Social benefits in the sense of improved company morale and communication, and reduced health and labour risks.

The realisation of cost savings and improved environmental performance can be achieved without major investments by implementing CP. In the future one can anticipate a significant role being played by local and national government in implementing CP via legislation and regulation, and through financial incentives. Local and national government in South Africa have integrated the concept of CP into policy (White Paper on Integrated Pollution and Waste Management, Government Gazette 20978, 2000) and provincial governments in KwaZulu-Natal Natal, Western Cape and Gauteng have recently appointed a number of new posts for CP policy and project coordination. The SA cabinet has recently passed a resolution supporting the principles of CP and promising to ensure that it is incorporated in all government functions and legislation. It has supported the National Cleaner Production Strategy which was compiled after an extensive consultation process with NGO's, government and industry as stakeholders. The principles of CP have recently been included in Waste Management legislation and in the National Water Act and Regulations (Rogers et al., 2005).

Over time several tools have been developed and used to promote the concept of CP, for example Cleaner Production Opportunity Assessments (CPOAs) and Waste Minimisation Clubs (WMCs).

Options for CP can be identified by means of a CPOA. Such an assessment is:

- An analytical tool designed to ensure that the organisation is operating in an environmentally safe and economically efficient manner;
- Used to document the types and quantities of wastes generated by the company; and
- A systematic approach for the identification and evaluation of different CP options.

Other CP tools include Life Cycle Assessments (LCA) and the development of WMCs, or Cleaner Production Forums (CPFs).

It must be recognised that the mining industry in South Africa is diverse and large. It is certain that there are a number of opportunities to improve environmental performance. In order to direct efforts at those sectors where impacts are greatest, and within those sectors at interventions which bring the highest possible return on the effort invested, a systematic way of screening needs to be developed. LCAs conducted at appropriate levels of generalisation can be used to determine priority areas for introducing the CP approach (Forbes et al., 2000). However, this tool has thus far been applied only in a "big-industry" context in the mining/metals industries (internationally, and to a limited extent nationally). The emergence of small-scale (subsistence) mining, individually with small, but collectively with large impacts, adds a new dimension to the challenges of identifying and prioritising impact areas and of initiating preventive or corrective action.

A review of its past and present research portfolio that was conducted by the WRC in 2003, indicated that most of the research effort to address water and waste management in the mining industry was devoted to minimising the impact of waste on the environment, to improve our ability to predict and quantify effects and to develop technologies to treat polluted waters. No projects were devoted specifically to waste minimisation and CP technologies were undertaken. In order to rectify the situation, the WRC solicited research proposals and provided funding for this project.

1.2 Objectives

The overall objective of the solicited research project was to introduce CP technologies in the mining industry. The tools suggested by the WRC to achieve these objectives are outlined below. These tools, or specific objectives, were evaluated during the course of the project and are:

1. Conduct a scoping level situation analysis of the mining industry that identifies the present level of CP activities and awareness, both locally and internationally;
2. Identify existing water-related threats that could be alleviated by CP technologies and thus represent opportunities to facilitate the introduction of CP approaches in the South African mining industry;
3. Introduce the concept of WMCs, evaluate their suitability and establish similar appropriate mechanisms and pilot clubs in the mining industry (WMCs could be used as vehicles for the training of practitioners in the mining industry in CP technologies and the implementation of CP programmes on participating mines);
4. Conduct focused high level life cycle analysis studies at an overall impact level, to determine priority areas for introducing the CP approach acquaint service providers and industry with the technique and identify areas for the focus of WMCs;
5. Conduct CP assessments to identify opportunities for cost saving and waste reduction;
6. Launch a campaign to raise the awareness to the mining industry and mining authorities concerning the benefits and need for adopting CP approaches and the possible methodologies and processes for doing so;
7. Generate the best possible guidelines for the introduction of CP technologies in the mining industry; and
8. Ensure the future viability and sustainability of initiatives to introduce CP approaches to the mining industry.

1.3 Project team

Digby Wells and Associates (Pty) Ltd (DWA) were the lead consultants for the project with their skills in environmental management in the mining and metallurgical industry. The other collaborating organisations include the Pollution Research Group of the University of KwaZulu-Natal with experience in LCA and CP activities, the Chemical Engineering Department of the University of Cape Town with LCA studies, BECO, Susan Barclay and Claire Janisch.

1.4 Approach

The project team consisted of a diverse group of people with various specialised skills and a great amount of experience in CP technologies and of the mining industry. One of the main aims of the project was to transfer these skills and generate the best possible guidelines for the introduction of CP technologies in the mining industry.

At the onset of the project, an in-house workshop was held with representatives from the WRC and mining industry to constitute the Reference Group or Steering Committee. This workshop was facilitated by Andrew Barker. The workshop consisted of presentations by various team members followed by a finalisation on the approach which was taken to achieve the objectives as outlined in the terms of reference.

The following presentations were made at the workshop:

- Chris Buckley of the Pollution Research Group (PRG) and Susan Barclay presented the concepts of CP and the experience gained from other CP projects carried out by the PRG;
- Graham Trusler of DWA provided an overview of the mining industry; discussed problem areas, the use of resources and waste produced;
- Bas Kothuis of BECO discussed the concepts of WMCs and the processes followed in the initiation, operation and maintenance of these clubs and the techniques of CP were presented;
- Andrew Barker introduced the team to value methodology and the Gravesian psychological and human behavioural framework and led discussion on various techniques for information transfer such as picture and poster based learning methods, interactive industrial and street theatre and road shows, conference and seminar processes, electronic and web based technologies, multimedia, video and other media for communication;
- Harro von Blotnitz of the University of Cape Town discussed the process of conducting LCAs and specific problems associated with LCA in the mining sector; and
- Claire Janisch presented the findings on the document she compiled on the *Evaluation of Cleaner Production Activities in the South Africa.*

This workshop started the project off officially and was the initiation of extensive co-operation with the industry.

1.5 Approaches to specific objectives

1.5.1 Scoping study

The scoping study was an essential part of the project as the outcomes of this study were used directly to determine the approach taken in the establishment of WMCs, the awareness campaign and the LCAs. The status of the use and knowledge of CP techniques in the mining industry, both locally and internationally, was obtained by reviewing the literature, and by contacting mining companies, representative bodies, research laboratories/organisations, funding organisations and practitioners in the field. This study was lead by Graham Trusler with the assistance of Priyal Dama and included mining companies, mining industry organisations, research institutions, practitioners, funding organisations and regulating authorities.

Contacts were made by electronic mail, surface mail, telephonically and by personal meetings as appropriate. Initially, an information letter and questionnaire were sent out, but as far as possible personal contact was used to obtain feedback. In order to save time and resources, focus group meetings were held in order to obtain feedback from more than one organisation at a time.

One of the objectives of this project was to build capacity and as such contacts were made with BHP Billiton/Samancor and Anglo-American. The option of creating a project for post graduate study for final year bursary in metallurgical or chemical engineering or in mining and environmental fields who do not have placements at the company yet was put forward. The objective was to ensure that projects actually needed by the companies were investigated; that their students received training in CP technologies, that close contact was maintained with the industry and that after completion of these studies, the person would immediately enter full time employment with the company. This avenue also presented an ideal opportunity to increase the training and employability of Historically Disadvantaged Individuals (HDIs).

Although all the companies contacted were keen to involve their students and environmental people the project never really benefited from this idea. All students used in the various studies originated from DWA or from the universities.

1.5.2 Identify existing water related threats

The outcome of this study was essential in moulding the approach for the rest of the project. The approach followed was similar to that followed in the scoping study. International aspects that were put forward in the scoping study were excluded, but a greater emphasis was placed on discussions with the authorities. The Department of Water Affairs and Forestry in particular was approached for information available on the various catchments affected by mining in the country. The findings of this study were expected to be regionally based (e.g. in the Northern Province, water availability may be found to be an issue of concern, whilst in the Mpumalanga area, water quality may be found to be the major issue of concern). This served as a guide for the approach taken by the WMCs.

1.5.3 Guidelines for Cleaner Production in the mining industry

In order to assist mining companies, regulators to the mining industry and other consultants, a CP guidance document was developed during the course of this project. The aim of this guidance document is to provide background information on CP, a step-wise approach to implementing a CP programme within a mining company, and best practice information against which companies could compare themselves. Checklists and worksheets are also provided to assist in the process. Susan Barclay was responsible for the compilation of this guidance document while other team members provided input based on experiences from other aspects of the project (e.g. CPFs, LCAs and CP audits).

1.5.4 Incorporating the principles of Life Cycle Assessment

Three LCAs were conducted as part of this project. The first LCA commenced at the beginning of the project and run parallel to the scoping study. Findings of this study were utilised to highlight focus areas for CP in the mining industry. Harro von Blottnitz led the LCA studies and supervised all the LCAs. The LCAs were used to identify focus/problem areas in the mining industry and to train up a group of people in how to conduct these assessments. Masters and honours level studies were used to conduct the LCAs as this provided the required research input and training aspect of this study. Students were selected for academic and technical ability and HDIs were selected wherever possible.

Three factors which could influence the course of LCAs study were identified: level (industry or company), sector (e.g. coal, base, ferrous, or precious metals), and size of the operators (multinationals vs. small scale). The LCAs were chosen such that insights were gained into the effect of each of these factors on the way the LCA should best be conducted.

LCA methodology was applied as described by the ISO14040 series of standards, i.e. proceeding in each case through the four steps of goal definition and scoping, life cycle inventory, Life Cycle Impact Assessment (LCIA) and interpretation. It appeared most logical to pitch them at a semi-quantitative level, given the project length and the need to train people.

Data needed in such LCAs was not always available. Where data was generated by taking solid or liquid waste samples and subjecting them to standard characterisation tests, such tests were judiciously included in order to generate key missing information. Air emissions were, in general, calculated from mass balancing around the appropriate unit operations.

A LCIA was performed with the aid of standard methods available in LCA software, but extended to include new impact categories of special significance in South Africa, e.g. salinity, thus putting locally developed LCIA methods to the test (Leske & Buckley, 2004).

It was expected that the interpretation of LCA results will only be possible if national or regional normalisation factors were developed for the various impact categories. This derives from the objective to use the LCA to prioritise interventions, which presupposes that different impacts can be compared, which is only possible if the particular avoidable impact can be expressed relative to a regional, national or global total impact.

1.5.5 Awareness campaign

Key stakeholders and target groups in the mining industry were listed from various sources and contacted. This was undertaken through the scoping study and their participation continued throughout the life of project. The appropriate interventions and technologies were designed and developed with ongoing support and input from the stakeholders.

It was envisaged that current communication and awareness processes and methodologies used in the mining industry would be used to determine the effectiveness of communicating CP issues. These included:

- Safety, Health and HIV/AIDS;
- Peer to peer education; and
- Use of mine induction programmes.

These programmes were to be used to build and improve on what is done and how levels of awareness are raised regarding such issues to bring about learning experiences and behavioural changes.

Whilst these techniques were correctly targeted they were not successfully executed during this project. They needed to be supported by all players in the industry and it is thought that remarkable results could have been achieved by their support.

1.5.6 Initiating Waste Minimisation Clubs or Cleaner Production Forums

Two WMCs or CPFs were set-up, namely one in the coal mines and one in gold mines. Both CPFs were initiated by BECO, with assistance from DWA in terms of input and co-ordination with the mines.

Cleaner Production Forum in the coal mines (CPF1)

During the first half of 2005, several discussions were held with and three presentations given to the South African Collieries Environmental Practitioners Association (SACEPA) to discuss the start up of a CPF in the coal mining industry. SACEPA expressed interest in participating in the WRC project and recommended the project to its members. The CPF for the coal mining industry around Witbank held its first meeting in July 2005. Guided by BECO – Institute for Sustainable Business, the participating companies; Total Coal SA, Xstrata Coal and Sasol Mining started with a total of 9 mines in the project. The three founding member company's were joined by Anglo Coal SA in mid-2006.

Cleaner Production Forum in the gold mines (CPF2)

It was very difficult to get a CPF in the gold mining industry started. Although interest was expressed by regional environmental managers of two different mining houses, both mining houses could not convince the mine managers of the benefits of joining a CPF. Many individual meetings or organizational meetings between 2 to 5 people were held.

1.5.7 Ensuring sustainability of the Cleaner Production Forums

During the running of the CPFs, case studies were drawn up of success stories achieved with CP in the Mining Industry and the CPF concept. This was distributed to other mines to create an awareness of the successes that have been achieved and helped them initiate a CP program.

The case study reports included:

- Industry sector description;
- Description of the company/organisation and the production process or activity that it relates to:
    - Description of the environmental benefits (waste reduction);
    - Description of the financial benefits (money saved).
- Technical and organisational aspects of implementation of the improvement options in the case study company/organisation; and

- Reference to the source of the data and to further information.

1.5.8 Cleaner Production Opportunity Assessment

As part of this research project an allowance was made for the practical evaluation of five different mining facilities with respect to conducting a CPOA. This process looks at all inputs and outputs to a facility and has the objective of trying to determine areas where resources can be saved to the benefit of the environment and to save the company money.

Different mining companies were written letters to ask them to participate in this project by offering up one of its facilities for this type of assessment at no cost to them. The letter explained the objectives of the project and the concept of CP. President Steyn mine, Goldfields and Angloplatinum came forward and offered their facilities. These companies were made aware of the reports that will be generated will form part of our research project feedback to the Water Research Commission which becomes a public document. The companies could choose to have their names made public or not.

An assessment team was set up between the mine and the project team. Sites visits were arranged. A meeting was held with the site representative to introduce the concept of CP and the objectives of the assessment. Interviews were conducted to understand the process and to identify key focus areas. A detailed site inspection was undertaken. The assessment team had a discussion after the site inspection to collate observations and recommendations. A list of questions was compiled and submitted to the site for clarification. A number of savings and improvements were identified which were deemed to be of assistance to the companies. A draft report was then sent to the site representative for comment.

1.6 Structure of the report

Comprehensive Deliverable Reports were prepared for each of the topics addressed under the specific objectives. These are available in electronic format on a CD (Volume 2 to Volume 10) attached to this report.

Only summaries of these comprehensive reports are presented in this report as the results of this investigation. These summaries do not pretend to be complete but endeavour to capture the essence of the findings and lessons learnt under each of the topics that were investigated.

Summaries are presented on the following:

- Chapter 2: The state of Cleaner Production in the SA mining industry – Scoping Study
- Chapter 3: Initiatives to increase the awareness of Cleaner Production
- Chapter 4: Water related threats that present opportunities for the introduction of Cleaner Production initiatives
- Chapter 5: Cleaner Production Guide for the Mining Industry
- Chapter 6: Establishment of Cleaner Production Forums
- Chapter 7: An investigation of Cleaner Production opportunities in the South African coal mining industry
- Chapter 8: Cleaner Production Opportunity Assessment as an opportunity for cleaner technologies
- Chapter 9: The use of high level Life Cycle Analyses
- Chapter10: Financial evaluation

The overall success and lessons learnt through this project is critically evaluated in a discussion, conclusions and recommendations Chapter 11.

Only late in the project did DRD Gold express an interest in forming a CPF with their gold mines. The DRD mines committed themselves to the project and sent very senior representatives to all meetings. In our many years of experience with over 15 WMCs, this was the first time that members consistently delegated representatives of this level of seniority (e.g. mine managers and even the regional manager attended most meetings).

CHAPTER 2 THE STATE OF CLEANER PRODUCTION IN THE SA MINING INDUSTRY – SCOPING STUDY

2.1 Introduction

The project began with a scoping study to determine the current status of environmental practices related to CP in the mining industry and for the industry to identify areas which need to be focused on to facilitate the industry's move towards more sustainable consumption and production practices. The scoping study also aimed to identify where the industry would be best served by the activities and studies to be conducted as part of the broader project, namely:

- Identifying *water related threats in the mining industry:* To ensure that the project funds are directed in the areas which require research;
- *LCAs:* A LCA is a scientific way of quantifying environmental impacts, which can also be used for comparing processes, and is a useful tool to assist decision makers. The scoping study aimed to identify where the industry would best be served by the four proposed LCA studies for this project.
- *WMCs:* Clubs or forums could be formed with companies in the same area or mining the same commodity, or facing similar environmental and economic problems. The members of these forums would be able to share their experiences and work together on achieving improved understanding and implementation of sustainable production and consumption practices. Researchers and trained professionals would provide training and other useful input at these forums. The scoping study aimed to identify where such forums could be established; and
- *Training and Raising Awareness*: Techniques currently employed in training and raising awareness on improved environmental performance within the industry were evaluated in the scoping study.

This Chapter highlights the outcomes of this scoping study, with a detailed report provided in Volume 2 on the CD.

2.2 Literature review

A literature review was carried out at the start of the scoping study in order to understand the concept of CP in order to be able to inform the mines of the purpose of the study, and to determine the current status of CP legislation and implementation within South Africa. This section summarises the main findings of the review.

2.2.1 Evolution of environmental responsibility

Environmental degradation is a burgeoning problem owing to the continual expansion of industrial production and high-levels of energy and material consumption world-wide. The response of industrialised nations to pollutants and environmental degradation evolved as follows:

- Relying on self-recovery of polluted nature;
- Ignoring the pollution problems;
- Diluting wastewater or dispersing the pollutants, e.g. by constructing higher smokestacks to decrease the effects of pollution;
- Trying to control pollution by implementing end-of-pipe technologies;
- Applying CP approach – preventing or minimising pollution at the source where it is generated; and
- Applying the sustainable consumption and production concept – efficiently using non-renewable resources, conserving renewable resources, protecting the human environment and not exceeding the functional limits of the ecosystem.

UNEP's Division of Technology, Industry and Economics (DTIE) Cleaner Production Programme was launched in 1989. The immediate task then was to create awareness of the concept, build institutional capacities and demonstrate its benefits to foster sustainable development. Today, CP is a flagship programme of not just UNEP DTIE, but also of several organisations in the world that have adopted and adapted it. It has truly become a global movement.

Many of the world's industrialised nations are putting more and more emphasis on implementing CP within their own nations as well as supporting the implementation of CP in developing countries. The UN has produced a recent Status Report on CP implementation worldwide (UNEP, 2004). Some of the key findings of this report are summarised in the review of International trends below.

The growing attention on issues of Sustainable Consumption is a natural outcome of decades of work on CP and eco-efficient industrial systems. It represents the final step in a progressive widening of the horizons of pollution prevention; a widening which has gone from a focus on production processes (CP), to products (eco-design), then to product-systems (incorporating transport logistics, end-of-life collection and component reuse or materials recycling) and to eco-innovation (new products and product-systems and enterprises designed for win-win solutions for business and the environment).

The focus on consumption has highlighted the need to address the creation of new systems of production and consumption. Systems that might be truly sustainable from an environmental and economical perspective and that will enhance the quality and equality of cultural, social and physical existence for all people.

2.2.2 Terminology

CP is a general term that describes a preventive environmental approach, aimed at increasing resource efficiency and reducing the generation of pollution and waste at source, rather than addressing and mitigating just the symptoms by only technically "treating" an existing waste/pollution problem. In essence, CP is about:

- Preventing waste and pollution at source;
- Minimising the use of hazardous raw materials;
- Improving water and energy efficiency;
- Reducing risks to human health;
- Saving money;
- Improving efficient management practices; and
- Promoting sustainable development.

CP includes measures to conserve raw materials, water and energy and measures to reduce at source the quantity and toxicity of all emissions and wastes being emitted to air, land and water. Furthermore, this approach embraces the cradle-to-grave principle, the precautionary principle and the preventive principle. CP addresses the problem at several levels at once and it is thus a holistic integrated preventive approach to environmental protection. The CP approach is an integral part of South Africa's Integrated Pollution and Waste Management Policy.

The term "Cleaner Production" is a broad term, encompassing what is sometimes also referred to as waste minimisation, pollution prevention, cleaner technology, waste reduction, non-waste technologies and source reduction, which all form part of the CP approach. Waste minimisation is a key concept driving CP and CP-related programmes and initiatives. Terms such as industrial ecology, green business and eco-efficiency similarly describe aspects of the CP approach to business. All of the terms mentioned above, however, describe a proactive approach that embraces a forward-looking "anticipate and prevent" philosophy.

Box 1: Defining Cleaner Production

Although various definitions of CP exist, the concept (as described above) is relatively straightforward. The definition used in this report is that proposed by the United Nations Environment Programme (UNEP) for CP as:

"The continuous application of an integrated preventive environmental strategy to processes, products, and services, to increase overall efficiency, and reduce risks to humans and the environment. CP can be applied to the processes used in any industry, to products themselves and to various services provided in society. Specifically for:

- *Production processes: CP results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production process;*
- *Products: CP aims to reduce the environmental, health and safety impacts of products over their entire life cycles, from raw materials extraction, through manufacturing and use, to the 'ultimate' disposal of the product; and*
- *Services: CP implies incorporating environmental concerns into designing and delivering services"* (UNEP, 2004).

The term CP has recently been replaced by Sustainable Consumption and Production (SCP) by organisations such as UNEP, UNIDO and UN-Division of Economics and Society. Since Agenda 21 the issues of unsustainable consumption have been addressed through a series of meetings, dialogues, research and publications from UN CSD, UNEP, UNDP and other business, consumer and research organisations. The idea of Sustainable Consumption has been developed and clarified through that process, emerging as an umbrella term bringing together various issues, such as:

"…meeting needs, enhancing quality of life, improving resource efficiency, minimising waste, taking a life-cycle perspective and taking into account the equity dimension; integrating these component parts in the central question of how to provide the same or better services to meet the basic requirements of life and the aspiration for improvement, for both current and future generations, while continually reducing environmental damage and risks to human health" (UNEP, 2004).

2.2.3 Benefits of Cleaner Production

Some of the major benefits of applying CP processes in a company include:

- Economic benefits through increased efficiency and quality; reduced consumption of water, raw materials and energy; reduced waste treatment and disposal costs;
- Environmental benefits, e.g. reduced hazardous waste;
- Complying with legislation in terms of meeting environmental requirements; and
- Social benefits in the sense of improved company morale and communication with adjacent communities, and reduced health risks.

2.2.4 Cleaner Production techniques

CP can be achieved in many different ways. The most important are:

- *Changing attitudes* and finding a new approach to the relationship between industry and the environment;
- *Applying expertise* and know-how by improving efficiency, adopting better management techniques, changing housekeeping practices, and revising policies, procedures and institutions as necessary; and
- *Improving technology* or simply rethinking an industrial process or product in terms of CP may produce the required results without importing new technology.

The mechanism or tools used to implement CP include:

- Measuring and monitoring key performance indicators;
- Waste, pollution and resource efficiency audits;
- Environmental LCAs;
- Process integration;
- Industrial symbiosis;
- Green chemistry;
- Dematerialisation;
- Waste minimisation; and
- Design for environment.

The need to reduce resource consumption in production and products and to provide information to consumers, to improve the effectiveness and quality of product use, is also recognised. Reducing end-of-life waste (usually through recycling) is also a common feature of product stewardship programmes across most industry sectors.

2.2.5 Cleaner Production and sustainable development

In 1987 the concept of sustainable development was proposed to steer Our Common Future (United Nations, 1972). In theory, sustainable development implies meeting the needs of the present generation, without compromising the needs of future generations. The true challenge of sustainable development was how to put the theory into practice.

CP provided a practical way to take issues arising from the conceptual framework of sustainable development towards action. It was more of a preventative strategy and not a curative or reactive approach to address the global pollution problem. CP is not a new concept. It is a logical extension of the desire to conserve materials and reduce waste. It requires people to examine ways that result in increased productivity, reduced resource inputs and waste and, most importantly, reduced risk to the environment. CP is not just an environmental initiative; it supports other productivity-oriented programmes and strategies.

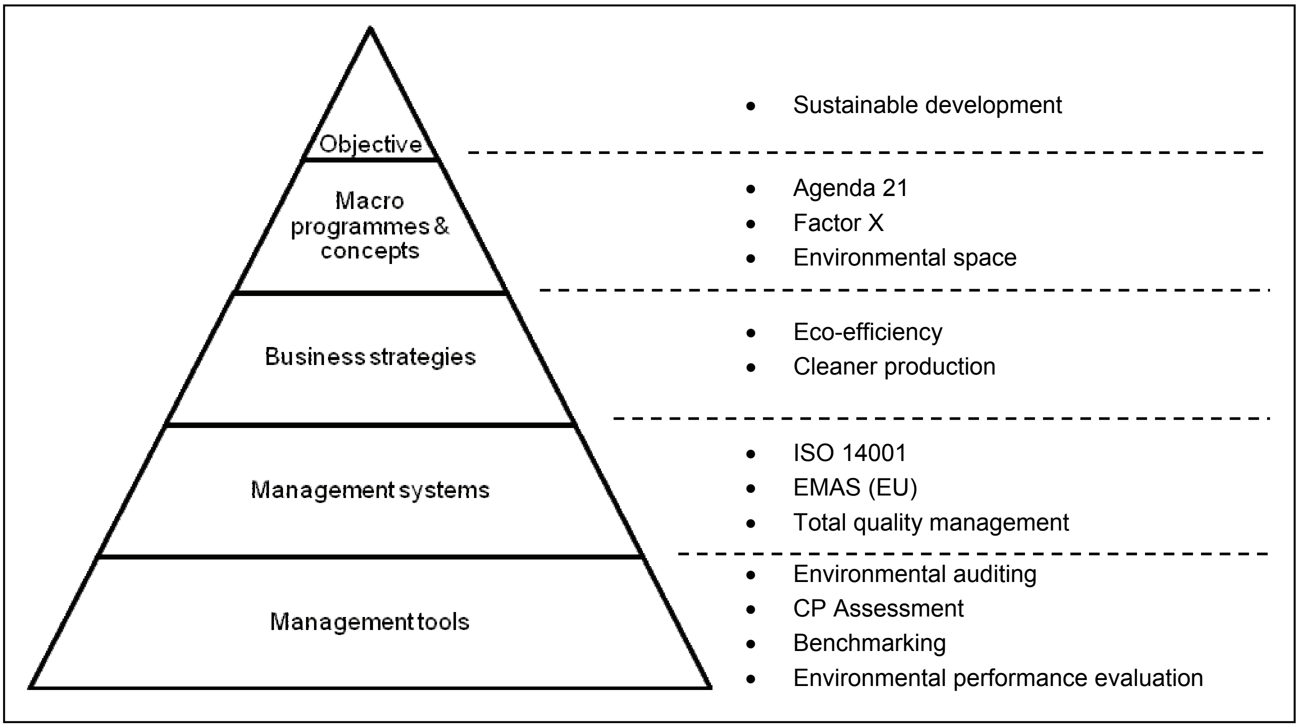

Figure 1: Cleaner Production and eco-efficiency: An approach to sustainable development

In 1992, CP found mention at the Rio Summit (United Nations Conference on Environment and Development – UNCED, held in Rio de Janeiro) as an important strategy to take forward the concept of sustainable development. The commitment of governments to achieving Sustainable Development is set out in Agenda

21 which made significant references to CP and has in fact served as a guiding framework for the implementation of CP. It also provided a direction and focus to the adoption of CP on a multi-stakeholder and multi-partnership basis.

The World Business Council for Sustainable Development sets out the commitment of international business to achieving Sustainable Development through the CP approach:

“The basic business contribution to sustainable development is eco-efficiency: achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth’s estimated carrying capacity”.

The 2002 World Summit on Sustainable Development (WSSD) identified CP as an important area for the reduction of emissions and solid waste and for improving efficiency in resource use. The application of CP as an integrated preventive environmental strategy to production processes, products and services is crucial in achieving the goals of the WSSD Johannesburg Plan of Implementation (JPOI). The JPOI sites a number of options for attaining sustainable development. A critical element of CP is that it typically results in a “win-win” scenario between economy and ecology. With CP programmes in place, companies achieve valuable cost-savings and improved productivity, and society benefits from reduced environmental impacts. A critical review of achievements in pollution prevention, CP and eco-efficiency can point to some real progress since Rio. However, whilst some gains are observable in production, consumption patterns appear to be moving in ways that continue to threaten sustainable development. Globally, unsustainable patterns of production and consumption demand attention and action. Both consuming and producing more efficiently will be fundamental to any successful strategies for eradicating poverty and creating business opportunities in developing countries and countries with economies in transition, such as South Africa.

2.2.6 Cleaner Production legislation and policy in South Africa

During the last decade there has been increasing awareness and adoption of CP related activities within the national economic development arena in South Africa. Whereas the private sector is more focused on the practical industry based implementation of CP projects, the public sector has been actively involved in an array of activities, including (but not limited to) research, policy formulation, project financing and implementation. Moreover, a growing number of local academic, research institutions and privately owned consulting firms are also conducting CP related research, creating awareness and documentation of local and international best practices regarding the emerging CP phenomenon and its potential benefits to the participating industries.

Whilst there are no legislative instruments to directly enforce CP at present, there are a number of policy initiatives in which this approach is proposed and which are likely to be incorporated into legislation in the near future. The constitution sets the stage by declaring that everyone has a right to a clean environment and *“to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures’ including those that ‘prevent pollution and ecological degradation”*.

As regards the promotion of CP, the South African environmental legislative framework is generally fragmented, with no consolidated national statute relating specifically to waste management and the promotion of resource efficiency. Efforts are however underway to address the fragmented administration of pollution management, for example through effective implementation of the National Waste Management Strategy and through finalisation of legislation relating to Integrated Pollution Control and Waste Management. In terms of the NWMS, the priority initiatives were categorised into short- (by the year 2004), medium- (by the year 2008), and long-term (by the year 2012) priorities. A phased approach over the twelve years was proposed for the full implementation with initiatives set out for institutional, legislation, capacity building, and financial requirements. To date, however, that NWMS has yet to be fully implemented. The two main legislative tools that now influence environmental management are the new National Water Act (No. 36 of 1998) and the National Environmental Management Act (No. 107 of 1998). The NEMA seeks to resolve the present confusion of environmental roles and responsibilities between various inter-governmental departments and within differing levels of government.

The Mineral and Petroleum Resources Development Act (Act No. 28 of 2002) has as one of its objectives – to make provision for equitable access to and sustainable development of the nation’s mineral and petroleum resources. Furthermore the Act affirms the State’s obligation to protect the environment for the benefit of present and future generations, to ensure ecologically sustainable development of mineral and petroleum resources and to promote economic and social development. Although it does not refer to CP, CP is one of the key strategies that can be adopted by the mining industry in its effort to work towards sustainable development.

2.2.7 A brief history of Cleaner Production in South Africa

CP forms part of South Africa's commitment to sustainable development. The World Summit on Sustainable Development, held in South Africa during 2002, placed Sustainable Development high on international, regional and local agendas. The world and South Africa's commitment to sustainable development was concretised in the Summit Declaration, entitled the 'The Johannesburg Plan of Implementation', which South Africa is in the process of implementing. This Plan encourages sustainable consumption and production. One of the outcomes of the Summit was the formation of the UNIDO National Cleaner Production Centre (NCPC), formed by an agreement between the DTI, the CSIR, UNIDO and the donor countries of Austria and Switzerland. The objective of this Centre has been to stimulate wider use of CP in South Africa in partnership between Government and other major role players, e.g. industry, agriculture, mining and the consumer.

However, prior to the establishment of the NCPC, a number of (not necessarily coordinated) CP initiatives – by Government, industry bodies, universities, research organisations, and donor agencies (most notably DANIDA and NORAD) – have taken place, mainly as the result of research and demonstration projects.

Overall, there has been a growing trend of CP related activities within the national economic development arena. Whereas the private sector is more focused on the practical industry based implementation of CP projects, the public sector has been actively involved in a broad array of activities including research, policy formulation, project financing and implementation. Moreover, local academic, research institutions and privately owned consulting firms are also actively conducting CP related research, creating awareness and documentation of local and international best practices regarding the emerging CP phenomenon and its potential benefits to the participating industries.

Some of the earliest CP related initiatives were funded by the WRC. The work of the WRC on waste minimisation and water management goes back a long way and with perhaps a more sustainable impact than the more recent and well-known DANIDA initiatives. The majority of these initiatives have been aimed at promoting CP practices in South Africa through research and demonstration projects. While the focus thus far has arguably been most pronounced on the fisheries, metal finishing and textiles industries (largely as a result of the DANIDA intervention) other industrial sectors are also increasingly implementing CP through initiatives such as the Waste Minimisation Forums. There have been some activities that are not specifically CP initiatives, but fall within the scope of CP, e.g. water and energy efficiency initiatives and improved environmental management initiatives that include elements of CP.

2.3 Methodology

An initial meeting was set-up in order to involve key stakeholders in the project, the project aims and methodologies were presented to them. The comments received at this meeting were recorded. A table was set up with the various mining houses in South Africa and their commodities. An information letter was then emailed to environmental managers at various mining houses and Interested and Affected Parties (I&APs) were given the opportunity to register. A questionnaire was set-up as a basis for the scoping study. A second email was sent out to the environmental managers with a short description of the project and a request for a meeting to discuss the questionnaire. The environmental managers were contacted telephonically and meetings were arranged. Internet searches were carried out and the company's annual reports, company policies and environmental policies were reviewed. The results obtained from these interviews were used to determine the status of CP in the mining industry and to guide the process further.

2.4 Discussion

Distinct differences were noted between the larger companies; i.e. BHP Billiton, Anglo, De Beers and Xstrata and the smaller companies; i.e. Crown Gold Recoveries, Trans Hex, ERPM and Diamond Core. The findings from the interviews held indicated that the mining industry was improving its practices and taking environmental impacts into consideration in project decisions and for operations. With the larger companies, this awareness was being driven mainly by the company's policies and the practices of their competitors, whilst legislation was driving the awareness amongst the smaller companies. The environmental policies of the larger companies contained CP principles and this was used as a route the project team could use to encourage cleaner technology. With smaller companies, cleaner technology options were used to assist with complying with legislation and in reducing costs.

The larger firms either already had ISO 14001 certification at all operations or are striving towards ISO 14001 certification. Many interviewees claimed that they were currently too busy trying to attain ISO 14001 certification and were therefore not keen on other projects, e.g. LCAs or WMFs at present. ISO 14001 involves the setting of targets and continuous improvement and appears to be a major driver for the implementation of CP. Cleaner technology was marketed as a tool to achieve these targets. The smaller companies were not keen on attaining ISO 14001, mainly due to the lack of capacity and not seeing any benefit in it. Here CP was marketed as a tool to improve profit margins and reduce the closure costs of operations. One of the comments from most interviewees was a need for a change in the terminology being used. The term “Waste Minimisation” suggested reducing the size of the discard dumps and tailings facilities in the mining industry. This resulted in a negative attitude towards the project. The terminology was reconsidered in order to improve the buy-in from industry to the concepts of CP. Instead of using the term “waste minimisation”, CP was the preferred terminology hence CPFs rather than WMCs were formed.

2.5 Conclusion

Difficulties were experienced in getting industry buy-in into the project. Industrial representation at the initiation workshop was poor. In addition, difficulties were experienced in arranging meetings with industrial representatives in order to complete the questionnaire. Many industrial representatives felt that they were already practicing CP under different terminology and that CP would be another procedure to add to the list of procedures already being followed.

Reasons for the lack of participation by the industry included:

- Internationalisation by large SA mining companies and the time spent on meeting international reporting requirements;
- Focus on ISO systems implementation and Global Reporting Initiative requirements;
- High commodity prices leading to a large amount of new projects;
- Lack of skilled and experienced manpower to deal with all these issues; and
- Stakeholder fatigue from many new initiatives.

The strategy thus was to link on to existing forums and present data and case studies that indicated that CP is a tool that can be used to assist in the attaining of ISO 14001 and in maintaining the certification once it is achieved. CP is also a tool that can be used to assist with the complying with current and future legislation and can assist in the expediting of the licensing processes. The CP concept and the concept on CPF were presented to SACEPA and sufficient interest was raised to set-up the first CPF with members of SACEPA. The concepts of CP, with focus on the water management were presented to the Rand Water Mining Forum. This presentation was also successful as one of the attendees invited DWA to present these concepts at his company. CP requires a pro-active approach rather than a reactive approach. It was thus important to include companies designing mining equipment. Meetings were held with Hatch and MDM and a workshop held in order to present CP concepts and tools to the design teams. The idea was to include CP in the design phases of new projects. The implementation was up to each company.

CHAPTER 3 INITIATIVES TO INCREASE THE AWARENESS OF CLEANER PRODUCTION

3.1 Introduction

The aim of the awareness campaign was to establish an understanding of all aspects of life conditions and environmental influencers, drivers and barriers that will affect, promote and cause the adoption of CP technologies in the mining industry. This was realised through extensive involvement of the mining stakeholders to determine what influences their thinking and behaviour and developing an understanding of their needs and priorities regarding waste management and minimisation. Appropriate interventions and technologies were designed and applied to raise awareness, improve understanding of the benefits and opportunities, address barriers and achieve adoption of suitable CP methodologies.

The objectives of the awareness raising aspect of the project were to:

- Improve awareness and understanding of CP principles and techniques for the mining industry and authorities;
- Encourage and promote CP; and
- To ensure the effectiveness of the project.

These aims were achieved through the following activities:

- Three half-day seminars for the mining industry;
- Presentations at mining conferences and seminars;
- CPOA site visits;
- Interviews with various government departments to determine the level of understanding of CP and to identify their needs; and
- Two workshops (one and half days each) held separately for industry and for the regulators to present on CP and the CP guide developed for the mining sector.

3.2 Half-day seminars

During the course of the Project, difficulties were experienced with arranging meetings with industry with a view to establishing CPFs. The project team found that the industry did not see the benefits of another series of meetings. There was a clear need to define CP and highlight the advantages of CP implementation in the industry. Industry participants also needed to be introduced to the value in participating in the CPF before they would give up time and support these initiatives. A decision was made to hold half-day workshops to better explain the benefits of the CP approach. These workshops were held during May 2006 in Johannesburg, Rustenburg and Witbank.

3.2.1 Presentations

Various presentations were given to promote the concepts and advantages of CP. These included:

- An overview of the Best Practice Guidelines for the Mining Industry by the Department of Water Affairs and Forestry;
- Case studies from two South African companies demonstrating how CP has assisted in meeting legislative requirements and reducing costs;
- The benefits (both financial and environmental) of implementing CP;
- Background information on CPFs and the results of the Witbank Coal Miners forum; and
- How CP can lead to a win-win situation between mining companies and their suppliers.

3.2.2 Participants

Representatives attending were:

- Chamber of Mines;
- Department of Minerals and Energy (DME);
- Department of Water Affairs and Forestry (DWAF);
- Service suppliers to the industry; and
- Mining company representatives.

3.2.3 Outcomes

Direct successes as the result of the workshops included:

- Xstrata showed their support for the CP concept and supplied writing paper for the workshops;
- Xstrata head office encouraged all its environmental managers to attend the workshop;
- Anglo Gold Ashanti contacted Bas Kothuis following the workshops and formed a CPF; and
- Other coal mining companies in the Witbank area joined the SACEPA forum following the workshops.

3.3 Interviews with government departments

In order to determine the needs of these government departments with respect to CP awareness raising an initial scoping study was carried out to determine the most appropriate method of raising this awareness. This was achieved by conducting one-on-one interviews with the key players from National Government to determine (amongst others):

- What is the status with respect to CP in their departments?
- What ideas do they have to take CP in mining forward?
- Do they feel the need for a workshop with other national government bodies to come up with a common approach through discussion?

These interviews were conducted in January 2007 by Susan Barclay and Claire Janisch.

3.3.1 Summary of interviews

In summary the following common points could be made:

- There is currently very little awareness of CP within the government departments – this is mainly due to a high turnover of staff and limited capacity;
- All government departments would like awareness raising events to be carried out with their own departments rather than jointly with the other government departments. The Chamber of Mines was the only organisation that thought everyone should get together. Awareness raising content must be prepared such that it is applicable to the relevant department being trained;
- Most felt that a workshop could be beneficial to introduce the topic of CP and awareness raising and to brainstorm ideas as to how this could be achieved – this should take place at a National level. This may however be difficult to arrange due to time constraints;
- It is important to involve all organisations interviewed in the development of the Guidance document. This could be carried out via email and then a presentation of the draft document within each organisation prior to finalisation;
- Awareness raising should include an introduction to CP and the benefits, workshops to allow the participants to identify how they can promote CP, exercises and examples, site visits and training on how to use the Guidance document;
- It is important to identify the correct people for awareness raising and it must take place at all levels (National, regional and local); and
- Any awareness raising event should take place in a central venue and should be between one and two days in length.

3.3.2 Outcome of interviews

As a result of these interviews, an awareness raising/training workshop on CP in the mining industry was planned for each government department (DEAT, DWAF and DME) and held in August 2007. This is discussed in more detail in Section 3.4.

3.4 Cleaner Production workshops for government departments and the mining industry

The WRC project teamed up with the Centre for Sustainability in Mining and Industry (CSMI) and the National Cleaner Production Centre (NCPC) to deliver the training workshops to the mining representatives and the regulators respectively.

The training was based on the Draft Guidance Document for CP in the Mining Industry compiled by Susan Barclay on the results of the WRC CP Project in the Mining Industry. Participants at the workshop were given copies of the draft document and taken through each section as the core of the training. Feedback from the participants at these workshops and from other stakeholders was then incorporated into the final version of the Guidance Document.

3.4.1 Overview of workshops

Two workshops were held on the 5th and 7th September 2007 for the mining industry and mining regulators respectively. Representatives from the DME attended the workshop for industry on the 5th September, while representatives from DEAT and DWAF attended the workshop on 7th September. The workshops facilitated by Claire Janisch and Bas Kothuis with various guest speakers. Topics covered at both workshops included:

- Background to the WRC project;
- Understanding CP;
- Basic components of a CP programme for the mining sector;
- Best practice for CP in mines;
- Relevant legislation;
- The application of LCAs; and
- Planning a CP programme in a mine (with exercise).

At the workshop held for the mines, presentations were also provided by key sustainability consultants to the mining industry – namely Markus Reichardt of Reichardt & Reichardt, and Tessa Mackay of Hatch. Markus set the context for the day by providing a presentation on where CP fits within the broader sustainability aims of the mining industry. Tessa Mackay gave a presentation on how CP can be incorporated at the design stage of new processes. Two case study presentations from mining houses relating to their CP projects were also presented – one which was as a result of the WRC project, and one which was initiated by the industry on its own initiative. At the regulators workshop, a more specific focus on the role of regulators was included, with pointers on the how to review a CP programme within the mining sector. On both days, a discussion session was held to receive feedback from participants on the Guidance document. In addition, for the regulators, an exercise was planned where participants designed ways to incorporate the learning from the workshop and practical ways to use the Guidance document to support relevant regulatory & policy instruments. Each of the participants for both workshops received a CD with all the presentations from the workshop as well as a copy of the draft guidance document and some other useful background information.

3.4.2 Outcome of workshops

The main outcomes of the workshop were:

- There is a need for training on CP to be incorporated into existing training forums for industry at all levels;
- The Guidance document should also include a list of relevant training institutions for CP and list of all forums/training for mining where CP could be incorporated;
- There is a need for CP to be a consideration within Environmental Impact Assessment;
- It is important to assess the real/true costs of waste and resource as this is one of the key factors that lead to the business case for CP;
- A carrot and stick approach is required in promoting CP for mining industry. For example, the DME Energy Efficiency Accord should also include an enforcement aspect if targets are not met, etc. Similarly, requirements for water balances should also include incentives for incorporating CP into water management plans;
- Enforcement of policies and best practice management guidelines needs to be linked to CP very clearly;
- Government departments can make use of the guidance documents and incorporate CP requirements within water use licenses and integrated waste and water management plans. Government departments can also play a role in awareness raising on CP by organising open days for mines. Specifically, DWAF can influence the MPRDA Amendment to include regulations on pollution prevention or require reporting on CP implementation; and
- It would be beneficial to develop a CPF for Regulators of the Mining Industry which would encourage an integrated approach rather than separate approaches.

The suggestions received were incorporated into the guidance manual and it is recommended that more workshops on this topic be held.

3.5 Meetings with the Department of Water Affairs and Forestry and the Department of Minerals and Energy

Early on in the project meetings were set up with representatives of the DWAF dealing with mining related water management issues. Although very supportive of the initiative very little of substance was achieved because of personnel movements within the department, changing role definitions and functions and because there were so many new initiatives being conducted at a similar time.

The project team never managed to have a meeting with the head of the DME's national environmental function as there was obvious stakeholder fatigue with the preparation of and introduction of new legislation and changes of management within the government department.

3.6 Other seminars and presentations

A seminar organised by Mine Metallurgical Managers Association of South Africa (MMMA) on *"The Application of New Technology in Metallurgy"* was held on the 24th August 2007 at the Randfontein Golf Estates. A presentation on the Introduction of CP Technologies was presented by DWA. MMMA has in excess of 500 members drawn from gold, platinum, coal, base metal and other metallurgical mining operations, was established relatively recently in 1984. With its members from a broad spectrum of mining commodities, it was felt that giving presentation on CP on such an audience will have a big impact in terms of raising awareness on CP. Members were also given a chance to comment on the Draft Guidance Document.

3.7 Conclusions

Based on the awareness raising activities carried out, it can be concluded that the aims of the awareness raising objective for the project have been achieved as follows:

- ***Improve awareness and understanding of CP principles and techniques for the mining industry and authorities***

  This aim has been achieved through the holding of the various seminars, interviews and workshops described in this report for both government departments and industry representatives.

- ***Encourage and promote CP***

  All the awareness raising activities aimed to increase the knowledge on CP methodologies and benefits. The circulation of the Guidance document to all relevant stakeholders has also assisted in this meeting this objective.

- ***To ensure the effectiveness of the project***

  Awareness raising and training is essential to ensure the success of a CP programme within any organisation. It is also just as important to raise awareness within those government organisations that regulate the mining sector. By carrying out these awareness raising activities, all parties became aware not only of the benefits and methodology of CP techniques, but also the overall objectives of the WRC project, which ensured the overall success of the project.

- ***Lack of senior management depth in South Africa and changes in administration***

  The restructuring occurring in the South African government and the severe pressure being put on senior management in the government and industry made it difficult for people to participate in this project. The advent of democracy and legislative and administrative changes combined with an exodus of skills made for a very volatile industry. The project was being executed against a backdrop of many changes and made it difficult for senior managers to give this new initiative their time and attention.

Full reports on each of these awareness raising activities are provided in Volume 3 on the CD.

CHAPTER 4 WATER RELATED THREATS THAT PRESENT OPPORTUNITIES FOR THE INTRODUCTION OF CLEANER PRODUCTION INITIATIVES

4.1 Introduction

Water threats from mines can be considered as direct or indirect threats. Direct threats are posed by the utilisation of water (surface water and groundwater) effectively removing these from the water cycle or by the dewatering of areas reducing water availability for others. This can be accompanied by the degradation of water quality in a resource by mining activities impacting directly on the resource, e.g. water within the mine's dirty water system has a direct impact on the water resource's quality if released.

Indirect threats are those that may lead to limitations on the water use within the system due to upstream mining activities, e.g. the impact of mining on the Upper Vaal River due to Acid Rock Drainage (ARD), or it is an unforeseen consequence of the mining activities, e.g. linking different catchments through underground workings.

Mines are also regulated by a number of local, provincial and national authorities. There have been many recent changes in the legislative environment concerning mining, water and the environment. These changed laws and the accompanying regulations need to be effectively implemented to ensure their success. The mining industry stated that they are battling with achieving effective responses to their submissions and applications and that clarity in regard to their rights is hampering business.

The list of the published report titles in the mining category by the WRC contained:

- 21 general reports (no specific mining sector);
- 8 dealing with ARD (which is the same as acid mine drainage, AMD);
- 10 with coal mining as the main topic; and
- 12 with gold mining as the main topic.

This distribution of topics provides a quick indication of the sectors that pose threats to water resources.

Threats to the mining industry arise in that mining operations require water for mining purposes, processing, as a possible transport medium and for secondary activities (including potable water). A shortage of water of a suitable quality for all required uses will impact on the project cost and could result in the mining project becoming uneconomical. The location of major mineral deposits in arid parts of the country needs to be considered, as the exploitation of these deposits required the importation of large volumes of water into the catchments in question. Such areas are also at greater risk of aggravating competition between the different water users for this scarce resource. The existence of flooded mine workings in areas with a long mine history pose a safety risk to mine workers while overlying aquifers require significant pumping costs to be expended in the event of deep level mining.

4.2 Threats posed by the mining industry

This section describes the most important water threats from the mining industry. All are direct threats relating to pollution of surface and ground waters (physico-chemical and biological), with the exception of widespread lowering of water levels due to dewatering (physical). The threats are:

- Contamination of surface water from spills;
- Contamination of surface water with runoff from stockpiles, spoil heaps, tailings and settling ponds;
- Contamination from reaction with mine workings, backfill, oxidized in-mine minerals; and
- Widespread lowering of water levels due to dewatering.

South African has many mature mining areas and these represent tremendous challenges for closure. The difficulties arise from the large mining voids which are interlinked with one another resulting in a compounding effect on water quantity and quality. Often this means that the last operation remaining in a particular catchment has to pump and treat water from a large area. Decant points are expected from a number large and older mine areas. South Africa has not yet prepared itself to deal with these eventual outflows sustainably. The concentration of mines in certain catchments has also lead to the salinisation of surface water in proximity to these mines due to the limited ability of dilution.

4.2.1 Contamination of surface water from spills

Mining and mineral processing operations often utilise hazardous materials, including a wide range of chemicals and chemical compounds which are potentially hazardous to the environment. These must be handled carefully in transit, storage, in use, and disposal. Spillages (accidental or unplanned release) do occur and due to the large volumes of water, reagents, etc. pose a definite risk to the surrounding environment.

4.2.2 Exploration activities

In exploration activities, drilling operations require sumps to store and contain drilling fluid. Current best practice requires that sumps are lined with plastic sheet and that contact be made with suppliers to identify drilling additives that are least toxic and have the best biodegradability. The transportation and storage of fuels and lubricants poses the greatest threat of contamination during drilling activities. Current best practice dictates that (Environment Australia, 1997):

- Fuels and oils must be isolated in an impervious secondary containment to control spillage;
- Refuelling vehicles away from drainage lines (using automatic shut-off delivery nozzles);
- Well casings prevent petroleum hydrocarbons from reaching aquifers during and after drilling;
- A fenced off: area for storage of waste oil produced; sump for drilling fluids; and dam for water;
- Return of used oil to suppliers; and
- Unsuccessful holes capped with concrete, successful holes capped with concrete with valve arrangement.

4.2.3 Process chemicals and service materials

Commodity prices have recently been at record highs due to increased worldwide demand. There is a trend in some minerals sectors such as base minerals and platinum group metals towards processing lower grade ore bodies, which would previously have been uneconomical, and this has led to an increase in the treatment volumes. Table 1 presents examples of hazardous materials, their function and potential impacts relating to water. Today little is known about the fate and long term impact on the environment of many chemicals used in mineral processing. Many materials hazardous to the environment are not legally classed as hazardous.

With respect to cyanide, current best practice requires that concentrations in tailings dams be kept below 50 mg/l, using ‘weak acid dissociable’ cyanide levels (WAD) as an indicator (World Bank Guidelines, Open Pit, 1995). Cyanide chemicals are used in almost every gold extraction operation and require a great deal of management attention and skill to ensure that no hazards are experienced.

Poor handling of reagents and accidents are the cause of spillages and thus the cause of pollution. This is worsened by the lack of information, the hazardous properties of chemicals and their effects on the environment. Spillages of sewage and poor treatment facilities may also occur, leading to a biological contamination of surface waters. In many cases, sewage treatment plants are not maintained and operated by trained personnel, resulting in downstream pollution.

4.2.4 Contamination of surface water with runoff from stockpiles, spoil heaps, tailings and settling ponds

Mining and mineral processing result in a variety of wastes including waste rock, coal discards slurry, tailings, slag and sludges. Though not necessarily immediately hazardous they can become so over time as they are exposed to oxygen, weathered or as chemical reactions progress. Waste rock or tailings deposits containing sulphide minerals can oxidize if exposed to water, oxygen or an electron donor, resulting in the generation of sulphuric acid in leachate. This generated acid may be neutralised by other basic minerals in the surrounding rock. Their relative abundance, position and availability of the acid and basic rocks dictate whether the resulting leachate solution will be acidic or basic. Even if a neutral water results, it may contain a number of minerals in solution and would contribute to the salinisation of water resources. This leachate is commonly termed ARD and is the most common water threat.

Table 1: Examples of hazardous chemicals and materials in the mining industry *(Source: Environment Australia, 1997)*

Material	Function	Impact if discharged
Sulphuric acid	Acid leaching.	Direct kills of aquatic fauna and flora if concentrated acid is spilt; water pH changes can directly affect biota or mobilize heavy metals.
Sodium hydroxide	pH control in leaching.	Direct kills of biota if concentrated; water pH changes with direct or indirect effects.
Methyl isobutyl ketone	Flotation chemical.	Tests suggest low toxicity.
Ammonium nitrate	Component of explosives (ANFO).	Fertilizer; can stimulate unwanted aquatic growth, leading to eutrophication of water bodies.
Polycarboxylic acid	Water treatment, anti-scalant.	Water pH changes.
Fuels and lubricants	Powering and lubricating of mobile and fixed equipment; component of some explosives.	Direct kills of biota and smothering of communities in large quantities; bioaccumulation in some organisms; groundwater contamination from leaks.
Drilling fluids	Lubricating and hole stability in exploration and production drilling.	Previous petroleum based fluids could lead to biota death or community changes; more recent fluids are water based and have less impact.
Hydroxy oxime	Solvent extraction.	No information readily available.
Sodium Cyanide	Leaching during gold processing.	Toxic to animals in comparatively low concentrations; known to cause bird kills in tailings dams.

In a South African context where most mines are situated in water poor areas and there are no large water flows available to dilute any long or short term seepages the management of the salinisation of water resources is critical. Siltation from these facilities as well as disturbed areas could contribute to the silt loading to the surface water systems and subsequent alteration of flow mechanisms or siltation of reservoirs.

Various other waste streams and stored materials may also have an impact on water. Improper storage, handling and disposal could cause contamination of surface waters. Other stored materials and waste streams include:

- Radioactive material and waste products (radioactive waste products if not properly handled may break down and release radioactive material that may come into contact with surface waters and be transported of the mine site);
- General solid waste;
- Obsolete chemicals, containers and laboratory waste; and
- Old electrical equipment containing Poly Chlorinated Biphenyls (PCBs).

4.2.5 Acid rock drainage (ARD)

ARD is the general term given to an acidic and saline effluent from sulphide containing mining operations. ARD contains sulphuric acid (or products of its neutralisation) and dissolved metals formed by the oxidation of mineral sulphides which generally comes from water that has been in contact with waste dumps, tailings and the surfaces of mine workings. The polluted water is generally characterised by a very low pH (2-3) and a high concentration of total dissolved solids (TDS) and toxic metals. If discharged, untreated, the leachate may degrade aquatic ecosystems and increase the suspended solids content of the receiving water. It may also come into contact with and impact on the quality of groundwater. The acid content in the leachate can cause the mobilization of previously insoluble metals from the rock, resulting in a waste stream with even greater potential impact on the environment.

Tailings are also capable of producing ARD and of producing hazardous concentrations of metals in leachate, as well as concentrations of residual process chemicals. Current best practice requires that such leachate, if discharged, be treated to meet the relevant water quality parameters of the receiving body of water. The South African Department of Water Affairs and Forestry developed a series of Best Practice Guidelines which became available at the end of this project. These guidelines are extremely useful in assisting people in the industry to meet their obligations in terms of CP.

At the moment best practice for ARD management is in development along two lines (Environment Australia, 1997):

- Ongoing research into the geochemistry of sulphide oxidation and the factors influencing oxidation rates; and
- Managing and remediation of current ARD problems.

In order to achieve the latter, it is current best practice to adopt a risk management approach and implement the following strategies (Environment Australia, 1997):

- Minimise oxidation and acid generation rates by regulating oxygen, water, bacteria and isolate higher risk materials from exposure;
- Minimise potential for transport of oxidation products from source to receiving environment; and
- Contain and treat ARD to minimise risk of significant off-site impacts.

It is suggested that to assess a site for sulphide oxidation potential and then implement prevention strategies into the mine planning stage, design, operation and closure would be more cost effective than post (end-of-pipe) treatment. Predictive based techniques used today to provide information on likely metal/sulphide (oxidation products) loads and concentrations include static and kinetic testing of the mine rock. This information may then be incorporated into a geological model and mining schedule to provide for selective handling and disposal of hazardous materials.

Measures taken to prevent and remediate ARD are variations of the following (Environment Australia, 1997):

- Exclusion of oxygen from sulphidic mine wastes with a soil/water cover;
- Control of water flux within wastes and management of site hydrology to minimize potential for transport of oxidation products (sulphate, metals, etc.) with a soil/water cover;
- Neutralisation of acid drainage with alkaline materials (lime, etc.); and
- Monitoring to characterise wastes and determine the effectiveness of remediation measures.

The appropriate prevention/remediation measures are influenced by site constraints and the characteristics of the sulphide containing material.

ARD can be produced at any area where the mine rock has been disturbed and thus in addition to surface waste dumps and tailing impoundments, occurs at the following (Broughton & Healey, 1992):

- Open pits;
- Roads and dams constructed from mine rock;
- Exposed rock faces in rock cuts for roads; and
- Underground mine workings.

ARD from surface waste dumps and tailing impoundments is a problem itself. However, if ARD gains access to the underground mine workings from the surface, it adds to the existing contamination of water from reactions within the mine workings, thus creating a more polluted effluent.

4.2.6 Widespread lowering of water levels due to dewatering

Consequences resulting from the dewatering and lowering of the water table are that the availability of the resource is reduced and this adds to the problem of water scarcity. The impact on groundwater users due to dewatering is usually limited to the immediate vicinity of the area being dewatered with the exception of aquifers with high transmissivity, e.g. dolomitic compartments or primary aquifers. In such areas the impacts of dewatering can be severe and become a regional phenomenon.

The dewatering of dolomitic compartments has got the added risk of removing the hydrostatic support for cavities that have formed below the water table; this could lead to the formation of sinkholes. Sinkhole formation is also linked to infrastructure that is not adequately maintained, due to the relatively large volumes of water used at a mine the risk of long term unreported leaks are great.

4.3 Threats posed to the mining industry

4.3.1 Water provision

One of the single biggest risks posed to the mining industry is a lack of sufficient water to allow for mining, processing or beneficiation in an economical manner. Nationally mining and bulk industrial water uses account for 6% of the total water usage in 2000 (DWAF, 2004a). Water usage for mining and bulk industry varies between catchments from 0% (Berg, Breede, Fish to Tsitsikama, and Mzimvubu to Keiskama) and 23% (Middle Vaal).

Of the 19 water management areas in South Africa, ten areas have a negative water balance as calculated in 2000. Nine of these ten water management areas have mining and bulk industrial activity recorded as a water use. The Limpopo, Olifants, Inkomati, Thukela and Mvoti to Umzimkulu water management areas having more than 10 million m^3/a water use recorded for mining and bulk industrial usage. Expansion of mining activities within the Limpopo and Olifants water management areas is envisaged as these areas contain considerable platinum group metals (PGMs) and coal in addition to considerable resources of other minerals. In addition to mining these resources, these resources need to be beneficiated, with the PGMs requiring milling, flotation and refining; with water required for all these. For coal to be produced in export quality, upgrading by washing is required, for local use the potential exists for electricity production or as by production of synfuels. All these processes require water.

The competition for water resources within the ten water management areas in deficit may hamper the development of mining projects or lead to restrictions on the availability of water, especially during low rainfall periods. Climate change impacts on water resources could lead to a reduction of surface runoff and therefore available yield as early as 2015 within Western portions of South Africa, expanding to reach the Eastern portions by 2060 (Kiker, 2004). The predicted reduction of runoff will have severe economic consequences.

4.3.2 Water ingress

Water ingression into mine workings in small quantities is referred to as nuisance water while large volumes could be life threatening or a threat to operations. There are various sources of water ingress into the workings including near surface aquifers, dolomites and old mine workings.

4.3.2.1 Old mine workings

Mining activities alter the characteristics of the strata being mined, generally leading to an increase in the permeability (ability to allow flow) and void space (volume available for the storage of water). Mining in close proximity to previous mine workings pose the risk that water filled compartments can be intersected. Due to the increase in permeability and storativity the water may be released very quickly and in significant volumes. The risk increases in areas where historic mining occurred by different mining operators and the overall accuracy of mine plans are less than ideal. Certain areas may also contain unmapped mine workings that could be intersected during operations. Tabular deposits that overly one another spatially are at risk for flooding from historic mine workings if deeper deposits are mined, e.g. coal.

4.3.2.2 Aquifers

The South African gold mining sector has a track record of significant influx of mine water due to the overlying dolomitic aquifers. The presence of a major aquifer in close proximity or overlying the proposed mine workings requires that the influx be taken into account. Inflows are generally structurally controlled within hard rock environments and the impact of major structural features difficult to predict. The significant increase in capital and operational costs with an increase in depth results in water management becoming one of the major cost components within deep level mining. The interconnection of various mine workings and the uncoordinated cessation of mining activities within a resource area could quickly lead to mining becoming uneconomical due to pumping costs.

4.3.2.3 Surface water sources

Mine workings are connected to the surface through mine infrastructure (shafts, adits, ventilation shafts, exploration boreholes, rescue boreholes, etc.), areas of subsidence and geological structures. It necessarily follows that the workings could be connected with surface water bodies. The placement of structures within floodlines of water resources have frequently occurred due to the thinner overburden for tabular deposits. This could cause unexpected ingress during high flow events.

There are a number of mining areas in South Africa interconnected by large areas of mine workings. Examples of these include the long line of Witwatersrand gold workings whereby any surface ingression along an outcrop line of more than 80 km will influence all underground workings or in areas of Witbank where a number of different coal mines are interconnected.

Often the last mine continuing operation in these areas has to pay for the pumping and treatment costs for ingression over large areas.

4.3.2.4 Infrastructure placement

The placement of infrastructure within surface water floodlines, close proximity of surface water resources or overlying groundwater resources endanger the water quality as has been stated above or could be a danger to people working underground. Certain of these placements have been deliberately done in the past, e.g. placement of gold slimes dams over dolomitic aquifers to improve under drainage and stability and the placement of valley fill waste facilities to minimise engineering costs. The current financial liability from such facilities due to a strengthening of legislation and international practice could pose a major risk to mining companies.

4.3.3 Financial solvency

The above water related issues and changing legal and environmental framework for a mining operation have got significant implications for the financial solvency of an operation. The environmental liability must be taken into account within the company's financial statements, a substantial component thereof could be water related. Older mining operations may have substantial environmental liabilities that have not been accounted for previously. The current DME requirement that financial provision should be made for closure could lead to a situation where the company liabilities, including the closure liability, exceed the company assets.

4.4 Information obtained from industry representatives

During the interview phase of the scoping study, questions were posed on the water related threats to the mining industry and the water related threats from the mining industry. The responses included:

- Shortage of water was posed as the major water related to the mining industry;
- Obtaining water licenses to continue with operations; and
- The high cost of water.

The shortage of water is an option that can be utilised to drive cleaner technologies in the mining industry. Mines are forced to reduce their water consumption and CP can be used to reduce water losses and thus water consumption.

ARD and increased salt loading were identified as the major water related threats from the mining industry. Mines with an excess of water have to look at end of pipe treatment options in order to be able to discharge this water. These options prove costly and are generally not sustainable. In addition, DWAF is introducing the Waste Discharge Charge System (WDCS). This is based to the polluter pays principle, whereby mines will be charged according to volumes of water being discharged and the concentrations of soluble substances being discharged. The WDCS will initially only look at point source discharge but non-point source discharges will later be included. For marginal producers, these costs could force mines into pre-mature closure.

4.5 Cleaner Production related to water use within the mining industry

The following section deals briefly with CP within the mining industry, specifically focused on water and the implication therefore on water related threats.

4.5.1 National strategy

DWAF issued the National Water Conservation (WC) and Water Demand Management (WDM) Strategy in August 2004 (DWAF, 2004b). WC is defined as the *"…minimisation of loss or waste, the care and protection of water resources and the efficient and effective use of water…"* while WDM is defined in the strategy as the *"…adaptation and implementation of a strategy by a water institution or consumer to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability".*

4.5.2 Industrial, mine and power generation sectors strategy

Four separate strategy documents were developed for the main water use sectors, including one for the industrial, mining and power generation sectors (DWAF, 2004c).The National WC/WDM Strategy aims to promote the principles of WC and WDM with WC being almost synonymous with CP in the water sector. DWAF has created the Directorate: Water Conservation (previously the Directorate: Water Use Efficiency) to ensure sustainable implementation of WC/WDM strategies. The National WC/WDM Strategy has identified the role of WC and WDM in support of the DWAF mission statement and the National Water Resource Strategy. The National strategy should further be seen to compliment the other strategies of the National Water Resource Strategy, e.g. Catchment Management Strategies. The industry, mine and power generation sector strategy identified the various roles of various parties including DWAF, Catchment Management Agencies and water users (DWAF, 2004c). The roles are discussed briefly in the following sections.

4.5.2.1 The role of the South African Department of Water Affairs and Forestry

The role of DWAF with respect to WC/WDM was defined as a generic role covering all water user sectors and includes:

- Co-ordinate national functions;
- Develop generic tools and guidelines;
- Develop policies and regulations;
- Perform general regulatory functions;
- Co-ordinate measures to create an education and water conservation awareness culture throughout South Africa;
- Promote WC/WDM to all Water Service Institutions (WSIs) including Water User Associations;
- Monitor the implementation of WC/WDM by the WSIs; and
- Authorise power generation as a strategic us as recognised by the NWA.

4.5.2.2 The role of Catchment Management Agencies

The role of the Catchment Management Agency with respect to WC/WDM is:

- Include WC/WDM as part of its Catchment Management Strategy (CMS), consistent with the NWRS;
- Set conditions for water use authorisations;
- Ensure implementation of NWA regulations;
- Develop an implementation plan for the WC/WDM component of its CMS;
- Ensure and monitor the implementation of WC/WDM by bulk water suppliers, water services authorities and the major water users of the industry, mine and power generation sectors (who are responsible for their own water supply); and
- Co-ordinate multi sector regional WC/WDM plans, including the setting of targets.

4.5.2.3 The role of water users

The role of the water users within the industry, mine and power generation sectors is to implement, in collaboration with the CMA, the WC/WDM component of the CMS as assigned by the CMA and described in the CMS.

The activities assigned to the water users in terms of the WC/WDM strategy include the following:

- The installation of systems and devices within the water supply systems of users;
- Carrying out yearly audits and monthly water balances;
- Definition of targets and performance indices (which compare with benchmarks within the sector);
- Analysis of audits to measure performance and monitoring of progress from previous audits;
- Population of databases in support of the CMAs;
- Design of processes for benchmarking in conjunction with DWAF and CMAs;
- Implementation of benchmarking as pilot projects in sub sectors (initially), full implementation in all subsectors (later) in conjunction with DWAF and CMAs;
- The determination of WC/WDM opportunities, cost benefit analyses, development of WC and WDM programmes and the generation of awareness and education of employees and other relative parties about WC/WDM; and
- To assist DWAF, CMAs, etc. in designing a national campaign for the sector and developing resource materials to be used in training as well as the implementation of the training programme.

4.6 Implications for water users

The above outlines the various roles with regards to WC. It is expected that over the next number of years the various CMAs will be established, and where they are already established they will implement the aims of the WC/WDM strategy as set out above. The active participation of the mining sector within the CMAs is therefore essential to set realistic objectives and targets as part of the CMS for WC and in effect CP.

4.7 Conclusions

The introduction of CP could have prevented the large scale problems the country is experiencing in dealing with interconnected old mine workings for both gold and coal mines. These lessons should be applied to new mining areas being developed such as the Waterberg coal fields.

Opportunities may arise in using water from mining areas which are decanting or being kept dry by pumping to areas where water is scarce. This does need the construction of large pipeline networks.

To reduce water threats to mining operations measures relevant to the particular operation need to be identified and implemented. Some measures may involve the reduction of the volume of water entering the mine environment. Incoming surface runoff water can be diverted away from the mine to the watercourse downstream of the mine, adjacent flood plains or nearby streams. Dewatering of adjacent aquifers can redirect incoming ground water. Within the mine environment water can be managed by a system including: drains, sumps, a pumping network and a storage basin. The capacity of this water management system may be severely stretched or even overloaded if planning doesn't include accurate assessment and prediction of maximum flows.

A further limitation of the water management system is the economic constraint associated with pumping costs. The proper planning and design of a water management system is the first step towards removing water threats, with the emphasis on accurate flow data acquisition, improved understanding of site specific geology and realistic prudent estimate of operating costs.

In order to reduce the levels of pollution emanating from underground mine workings the following measures could be implemented:

- Remove pollutants from the surface water;
- Control and reduce the quantity of surface water flow to the mine workings; and
- Treat polluted extraneous water on the surface.

To achieve the removal of pollutants from the surface water end-of-pipe treatment techniques exist. For the control and reduction of the quantity of surface water flow entering the mine workings, better design of the openings of holings (collars) and capping upon closure can be used. Outcrop working need to be sealed where surface water can flow into these workings and water ingression into strip mines needs to be minimised.

CP techniques and principles are needed to be able to manage the inputs from past, current and future mining operations. Water shortages can curtail future development of the industry thus the enhancement of water efficiency is critical.

The long term impacts possible from mining operations mean that the current planning and management measures need to be implemented as the long term financial implications for the mining companies can be severe. The influence of mining operations on water quality and availability in certain areas is large and CP technologies can reduce these impacts.

CHAPTER 5 GUIDANCE DOCUMENT FOR THE IMPLEMENTATION OF CLEANER PRODUCTION

5.1 Aim and scope

A guidance document aimed at promoting the implementation of CP technologies within the mining industry was developed as part of this project. Volume 9 on the CD contains the complete guidance document and the document is also published as a separate document and as standalone product emanating from this project.

The aim of the guidance document is to assist the mining industry and its regulators, in determining the benefits of implementing CP and the methodology involved. Case studies and examples are incorporated to demonstrate how CP has been implemented successfully in mining companies, both locally and internationally, and check lists are used to guide the user through each stage of the CP process. A brief review of relevant legislation is also included and a comprehensive list of recommended readings and web addresses is provided. The guidance document focuses on the main minerals being mined in South Africa; namely coal, gold and platinum, but the methodology described is applicable to all minerals and mines.

5.2 Target audience

The guidance document is aimed primarily at those working in and with the mining industry, with a secondary focus on those government departments regulating the mines. The document will assist mining companies in implementing a CP programme, while at the same time, providing the regulators with suggestions on how to promote and encourage the process. It will also assist companies and regulators in identifying where they stand with respect to best practice, where opportunities exist for implementing CP options, and where CP technologies have already been implemented. Consultants to the industry will also benefit from the guidance document as it will provide necessary background information to the sector and suitable CP opportunities.

5.3 How to use the guidance document

This guidance document is intended to assist mining companies, regulators to the mines and consultants in how to implement a programme of CP, how to identify CP opportunities, and how to sustain such a programme through promotion and awareness raising. In order to achieve this, the following process is recommended:

- Understand the main mining processes in South Africa and the associated environmental and health impacts;
- Ensure you have a good understanding of the concept of CP;
- Familiarise yourself with the legal and policy framework relevant to the implementation of CP in the mining sector;
- Familiarise yourself with the main steps involved in implementing a structured CP programme within an organisation;
- Make use of the checklists/worksheets provided to enable you as a mining company to implement each stage of a CP programme, and as a regulator, to identify where opportunities for CP exist, or have been undertaken;
- Make use of the tools of CP such as monitoring and targeting, identifying the true cost of waste generated and life cycle thinking;
- Identify the possible barriers to implementing CP and ways in which these can be overcome;
- Understand how CP can be incorporated into existing environmental management programmes;
- Investigate the possibility of joining or creating a CPF to allow for the exchange of information and advice on CP activities;
- Identify suitable CP practices for various mining operations based on best practice by making use of the checklists provided;
- Be aware of the importance of raising awareness at all levels of staff in CP practices;
- Understand your role as a mining company, regulator or consultant in implementing and promoting CP; and
- Make use of the extensive list of references, internet resources and case studies available.

5.4 Structure of the guidance document

The guidance document is divided into six Chapters and seven Appendices as shown below:

Chapters

Chapter 1: Introduction to the mining industry in South Africa, together with an overview of the associated environmental impacts.

Chapter 2: A review of relevant legislation with a focus on laws and regulations that promote CP, and also where CP will assist companies in complying with legislative requirements.

Chapter 3: An introduction to CP, its benefits, the methodology of implementing a CP programme, and how to identify and overcome barriers.

Chapter 4: An introduction to some CP tools, including monitoring and targeting, Life Cycle Assessment, CPFs and raising awareness.

Chapter 5: Guidance as to how to incorporate CP into existing environmental activities within the mining industry, with an emphasis on environmental management systems and international best practice.

Chapter 6: Aimed primarily at the regulators to provide guidance on how to identify when CP is being implemented and to further promote CP practices.

Appendices

Appendix 1 Checklists/worksheets for each stage of the CP process (for use with Chapters 3, 4 and 5)

Appendix 2 Checklists aimed at each role player in the mining industry

Appendix 3 Cleaner Production opportunity checklists

Appendix 4 Cleaner Production reporting format (UNIDO)

Appendix 5 Mining by-products and wastes

Appendix 6 References, recommended readings and sources of further information

Appendix 7 Useful contacts

Case studies are included throughout the guidance document to illustrate the steps to implementing CP and the related benefits. Summary points are provided at the end of each chapter and relevant recommended readings listed. Checklists / worksheets are provided in the Appendices to give step-by-step guidance in working through each stage of implementing a CP programme. This document is available as a separate document for reference purposes.

CHAPTER 6 THE ESTABLISHMENT OF CLEANER PRODUCTION FORUMS

6.1 Introduction

CPFs are voluntary partnerships of companies that have been devised to promote the exchange of experience and information about the implementation of CP measures. Outside the mining industry, they are known as WMCs. The members of a CPF can either come from the same industrial sector (e.g. food, mining, textiles), or be from the same geographical region, therefore sharing similar concerns.

A CPF consists of 5 to 15 enterprises that hold meetings on a regular basis, approximately every two months. The forums are normally facilitated by an external facilitator, i.e. a consultant. He is in charge of organising the meetings, providing training in CP methodology and facilitating discussions. In most cases, the consultant will also assist the companies in carrying out CP assessments. Moreover, he can be responsible for issuing periodic newsletters for the forum members so as to inform them about the current state of the CPF and other relevant information about CP issues. Membership fees finance the forums' activities (unless external funders are involved). Members also sign a formal declaration of commitment to CP.

6.2 History and status quo of Cleaner Production Forums in South Africa

The concept of CPFs was first developed in Great Britain in the early 1990s, due to problems with poor water quality of the rivers in industrial areas. This model was soon exported, and in 1998, the first two forums were established in KwaZulu-Natal. One was for the metal finishing sector, the other one was a cross-sectoral forum in the Hammarsdale region. Members of the cross-sectoral forum implemented about 40 of the 100 identified CP options, and total savings exceeded R10 million. Nowadays, more than 25 forums have been run or are still operating nationwide.

6.3 Establishment and operation of a Cleaner Production Forum

Forming and running a CPF comprises the following stages:

- *Phase 1:*

The need for a CPF has to be identified. Certain drivers may lead to the formation of a CPF, such as new, stricter environmental legislation, enforcement by a regulator or rising costs of waste and effluent disposal.

- *Phase 2:*

The awareness of companies must be raised by informing them about the concept and the benefits of a CPF.

- *Phase 3:*

Members of the forum are recruited. Frequently, this is carried out in cooperation with industrial associations.

- *Phase 4:*

Involves the organisation for action during which the forum structure and management roles need to be fixed, e.g. the frequency of forum meetings, responsibilities and issues like an optional forum constitution.

- *Phase 5:*

On-site assessments are conducted in order to collect and analyse data and to generate CP ideas. The forum facilitator gives training sessions on how to gather the relevant information from the different departments within a company.

- *Phase 6:*

Recommendations deriving from the previous stage are implemented.

- *Phase 7:*

It is important to proceed to an analysis of the successes of the CPF and to quantify results so that lessons can be learnt for further forums. The external facilitator is most suitable for this task.

6.4 Benefits of and barriers to Cleaner Production Forums

Apart from the benefits achievable by the implementation of CP measures that are mentioned earlier, the surplus value of the membership in a CPF lies in the following factors:

- Companies are exposed to training in CP methodology;
- Companies have the possibility of interacting with other enterprises that experience similar environmental pressures and requirements;
- The exchange of information and ideas can save time and money for every single member, as a possibility found by one company is often applicable to the operations of others; and
- Through the external facilitator, companies can get assistance with data collection and obtain advice about any issues arising relating to the implementation of CP options.

Common barriers to running a CPF are often the non-attendance of meetings, the lack of progress on-site, a lack of perception of the need for CP and competition between forum members. The activities of forums are designed to overcome these barriers step by step.

6.5 Creation and members CPFs

The CPF concept is one approach that was used in this project to educate mining companies in CP and associated environmental matters. For the purpose of this project, we have called WMCs and CPFs. CPFs have been used successfully to educate companies in CP in other industry sectors in South Africa (Barclay et al., 1999). However, due to the uniqueness of the mining industry, other approaches were identified, implemented, evaluated and examined for their effectiveness and efficiency. The term waste in the mining industry in South Africa had connotations which were not intended with the term WMC hence it was decided to use the term CPF.

Two CPFs were set-up, namely one in the coal mines with Sasol, Xstrata Coal, Total Coal and Anglo Coal SA, and the other with goldmines The participating companies in the Gold CPF were the DRD group of Gold mines; Blyvooruitzicht, East Rand Proprietary Mines (ERPM) and Crown Mines. These forums were guided by BECO – Institute for Sustainable Business and DWA.

Volume 7 on the CD contains a detailed report on the development, management and results of the CPF formed under this project. The main outcomes are highlighted in this section.

6.6 Coal CPF

During the first half of 2005, several discussions and 3 presentations were held to SACEPA to discuss the start up of a CPF in the coal mining industry. SACEPA expressed its interest in participating in the WRC project and recommended the project to its members. The CPF for the coal mining industry around Witbank held its first meeting in July 2005. Guided by BECO – Institute for Sustainable Business, the participating companies Total Coal SA, Xstrata Coal and Sasol Mining started with a total of nine mines in the project. The three founding members were joined by Anglo Coal SA in mid-2006.

During their first meeting, the enterprises decided to hold meetings approximately every two months. The meeting venues were rotated amongst the members and the host would include a plant tour at the end of the meeting. The CP assessments were executed by BECO, assisted by students recruited by BECO. Jane Reddick did her M.Sc. thesis at the Chemical Engineering department of UCT, on CP in the coal mining industry. She performed detailed CP Assessments in 3 of the participating coal mines, and assisted the other coal mines with their CP efforts. The mines provided accommodation, salary and transport for these students. Every mine assigned a team dedicated to assist the students with data collection and other necessary activities.

6.7 Gold CPF

It was very difficult to get a CPF in the gold mining industry started. Although interest was expressed by regional environmental managers of two different mining houses, both mining houses could not convince the mine managers of the benefits of joining a CPF. Many individual meetings or organizational meetings between two to five people were held.

Only late in the project did DRD Gold express an interest in forming a CPF with their gold mines and showed serious commitment to the project by sending very senior representatives to all meetings.

The gold mine members committed from the beginning to the CPF, but requested a shorter time period as they had less time available. This was possible because firstly the usual time for the growing of the members to trust each other and be ready to exchange experiences (which normally takes on average about three meetings, or six months) was not necessary in this CPF because the member new each other very well already. Secondly, the senior mine manager members of the CPF were used to a very efficient and intense exchange of information and were not used to, nor interested in the more relaxed kind of meetings as they were held in other CPFs and WMCs.

This Gold CPF held its first meeting in June 2007. The Gold CPF project had taken more than two years to get up and running at the time of the first meeting. Due to the fact that the members wanted a more condensed, faster and more intensive project, it was decided that monthly meetings were in order. The meeting venues were rotated among the members. The CP assessments have been carried out with support from students recruited by BECO. The mines provide accommodation, salary and transport for these students. Every mine was asked to assign a team dedicated to assist the students with data collection and other necessary activities (see Volume 6 and 7 for the details of these investigations).

6.8 Motivations for the CPFs

Coal mining and processing industries are responsible for significant local and regional environmental impacts, particularly those on water quality: There is evidence of the effects of ARD in the Witbank area. Air-related impacts include methane emissions and coal dust release.

The size of the South African coal sector is impressive, coal being not only a major source of foreign income for the country, but constituting also the basis of the primary energy supply, covering 76% of the country’s needs. According to Eskom, 90% of South Africa's energy is generated from coal. This dependence, coupled with the country's extensive coal reserves, indicates that the eminent role of the coal mining industry is not likely to change in the near future.

As a result of the environmental impacts and the high importance of coal in South Africa, the pressure on the industry is increasing exponentially: Mining rehabilitation is becoming more and more costly, legislation is becoming more stringent, and public concerns are rising continuously. Consequently, the coal mining industry is recognising the importance of proper environmental management.

The most significant motivation for the formation of the Gold CPF was the reduction of costs. The mining and production of gold is expensive because of the large quantity of ore processed in order to liberate relatively small amounts of gold; in one ton of rock approximately 5g of gold is recovered. It was mentioned at the first Gold CPF meeting that CP is particularly attractive to the Gold Mines due to the potential savings. The DRD mines expressed special interest in energy and water optimisation in their mining operations.

6.9 Activities of the CPFs

The members of the coal CPF met approximately every two months during a two-year period so that 12 meetings were held in total. Sessions included training in how to identify and how to implement CP measures, feedback on the various steps towards CP measures in every company, as well as eleven presentations of guest speakers. Over the same period, 12 newsletters were distributed to the member companies, containing updates on the current state of the CPF, case studies about member companies or others and other industry-related CP issues.

The pre-assessments performed by students identified three focus areas for the detailed assessment: slurry, a mixture of process water and ultra-fine coal; discards, a high ash coal waste; and energy. Sasol, who used a different assessment method, concentrated on oil, water and slurry. The disposed slurry, that is considered too low in value to dewater it, causes several serious environmental problems, such as ARD, dust release and spontaneous combustion. Their high ash proportion makes the discards a product of poor quality that is therefore dumped. Brain storming meetings were held with all participating mines on the selected three focus areas. The brainstorms and literature studies identified numerous CP opportunities available to reduce the amount of slurry, discards and energy wasted at the three case study collieries. After a feasibility assessment on the generated CP ideas for the focus areas, it was found that the feasibility requirements were fulfilled by five improvement options referring to the slurry, four referring to the discards and five referring to energy. They are displayed in Table 2 below.

Table 2: CPF opportunities for energy, slurry and discard

Energy	Install electricity meters.
	Compile detailed liquid fuel and energy balances.
	Minimise the electricity consumption of the end-users.
	Introduce an educational / training programme.
	Introduce incentives to reward employee energy saving efforts.
Slurry	Increase the crusher top size to reduce the proportion of ultra-fines that are generated.
	Optimise the classifying cyclones to perform sharper, more precise separations.
	Install an automated flocculent make-up system.
	Beneficiate using flotation, thermal drying and export the arising ultra-fines.
	Solar dry and sell the unwashed existing ultra-fines to local power stations.
Discard	Improve the performance of the drums and cyclones.
	Thermally dry the cyclone product.
	Wash the fines using spirals and thermally dry the product.
	Dewater and sell the spiral discards.

Apart from these options that are demonstrably feasible, other possibilities were presented by guest speakers or investigated by the companies themselves. The guest speakers included several recyclers, e.g. for rubber (She's Waste), oil (ROSE Foundation) and fine coal (Waste Energy Recovery and Management). Joy Mining spoke about their measures aiming at reducing the oil losses of mining machines, and Anglo Platinum explained its oil recovery measures. Two guests were invited to expose the mechanism and the possibilities of Cleaner Development Mechanism projects in the mining industry (Camco, EcoSecurities). An ABB representative talked about energy saving devices, particularly variable speed drives (VSD). BECO Johannesburg gave some insights into the flocculation and coagulation of fine coal particles, and General Electric presented the processes of Micro-filtration, Ultra-filtration and Nano-filtration through Reverse Osmosis. A senior scientist in sustainable development from the University of Tennessee commented on how to ensure that CP is a continuous process rather than a once-off measure.

Investigations led by the companies comprised: the use of methane for energy production, (which was financially not viable in the participating mines because of too small amounts of methane generated in these mines), the re-use of oil for diesel production (impossible) and as component of explosives; and the optimum utilisation of fine coal particles.

6.10 Success of the Cleaner Production Forums

6.10.1 Coal CPF

The outcomes of brainstorming sessions in the different companies dedicated to generating CP ideas have been widely appreciated as a valuable contribution to the process of CP.

Based on these sessions and on the CP options suggested thanks to the mine assessments, various CP measures have been implemented by the participating companies.

Sasol Mining installed several energy efficiency measures in its South African facilities, such as improving the power factor and the installation of variable speed drives on the conveyor belts. An improved peak demand management system was also established.

Similarly to Sasol, most of Anglo Coal's measures focused on the area of energy and included the following:

- Various collieries were equipped with new light bulbs, solar panels, variable speed drives (on conveyor belts and fans) as well as with geyser blankets;
- In mines and offices, automatic day-night-switches were installed on lights and air conditioners; and
- Dozer machines were modified to have a 5 minutes idle period before being switched off completely, so that the high energy demand for switching the dozers on could be avoided.

Several awareness raising initiatives aimed at the staff were initiated. For example:

- Employee bonuses linked to energy and water efficiency;
- A half day energy day in the second half of 2007 for the whole of Anglo Coal to show to the staff energy saving options;
- The distribution of a booklet called "Energy matters to you" to all employees to educate them about energy saving opportunities (at the workplace and at home); and
- The top-down-energy structure consists of energy champions, energy committees and monthly energy meetings in every mine.

The monitoring of the energy consumption − which is essential to identify the main consumers and find counteractive measures − was also introduced; i.e. the diesel consumption of vehicles is now monitored and various electricity meters have been installed. The data is recorded in the so-called Energy Register and compared to 2003 baseline data.

Water is re-used and the volume of recycled water is expected to grow significantly over the next years, because of the Emalahleni water treatment plant, which shall in the near future be able to purify the water of three Anglo collieries.

Oil is recycled in cooperation with the ROSE Foundation (Recycling Oil Saves the Environment).

Xstrata Coal also paid most of their attention to energy efficiency, in line with its worldwide efforts in this area. They made use of external help on power factor reduction and on the development of software to construct a good process action plan. An extended monitoring study was conducted to identify the major energy consumers which are conveyor belts, motors and compressors. Referring to water recycling, the comparison of Xstrata's global operation in 2006 shows that Xstrata Coal South Africa achieved the highest improvement in recycled water thanks to improved recycling of water for processing and dust suppression.

In contrast to the companies mentioned before, Total Coal concentrated mainly on the focus areas of slurry and discards, after having set up a committee of five people charged with identifying possible savings and to set targets. All five CP options regarding slurry and three of four options concerning discards were investigated on-site, including test work. As it was found that it is technically feasible and not disturbing for the customer, the option of increasing the coal size in the crusher from 80 mm to 90 mm was approved and implemented. This reduces the amount of ultra fine coal, as well as the optimisation of the classifying cyclones: In order to prevent coarse coal from being disposed, particles more than 300 µm do not exit in the slurry any more. Several other CP options, such as the installation of energy saving devices, have been regarded as too expensive because of the short remaining life time of the Dorstfontein Colliery (2-3 years), but these options are to be implemented at the new mine that is planned.

The member companies of the CPF have spoken about plans for numerous other measures, in particular, wastewater treatment which is a big concern. This can be seen as a positive trend and an indication of the growing environmental consciousness in the coal mining industry. The discussion about CP opportunities will be pursued by the council of SACEPA.

6.10.2 Gold CPF

The Gold CPF has been successful. An existing awareness of water issues and a growing awareness of energy issues have been galvanized into concrete action and projects in the participating mines. The gold CPF members have implemented and are implementing several of the resulting technology changes as discussed in the CPF meetings. One mine is currently almost finished with the installation of an advanced water treatment plant that allows for the mine water to be reused as potable water on the mine site and in the mine's own mine villages. Another mine is very far advanced with a serious feasibility study into the use of electric drills, as a direct result of the information exchange that took place in the CPF meetings. A third mine has finished a complete water balance of all its operations, and is in the decision making process for the implementation of some of the recommendations from the project.

6.11 Lessons learnt

Several barriers to the adoption of CP in the South African coal industry have been revealed in all member companies of the CPF. These included:

- A general lack of awareness of the concept of CP, even among environmental managers;
- Environment is rather seen as a cost than as an opportunity factor, and the focus lies most often on an end-of-line-approach rather than on prevention;
- Budget and time restraints were considerable – e.g. due to the companies' policies, it is very difficult to get authorization for high capital investments, even though short payback periods as calculated for the CP options found in the context of the CPF increase the likelihood of such approvals;
- Performance data was hard to obtain, as monitoring of energy and waste streams was hardly done and the available information was not compiled in a structured way. Though, detailed monitoring data is the basis for finding the most valuable CP options;
- The slow incorporation of CP concepts into South African mining legislation, as legislation is a main driver for South African mining companies to adopt CP measures. Members of the CPF felt that it was quite complex to get the necessary approval for Cleaner Development Mechanism projects from the Designated National Authority for South Africa (The Department of Minerals and Energy); and
- A temporary challenge was that all the suppliers of geyser blankets that Anglo Coal presented to the CPF members were out of stock when several mines wanted to order such blankets.

Key Achievements of CPFs are:

- Several energy efficiency measures were implemented, such as a power factor correction and the installation of variable speed drives on the conveyor belts. An improved peak demand management was also established at some mines;
- To save energy, various collieries have been equipped with new light bulbs, solar panels, and with geyser blankets;
- Slurry and discards assessment are being undertaken to identify possible savings and to set targets;
- One mine is currently almost finished with the installation of an advanced water treatment plant that allows for the mine water to be reused as potable water on the mine site and in the mine’s own mine villages; and
- Another mine is very far advanced with a serious feasibility study into the use of electric drills, as a direct result of the information exchange that took place in the CPF meetings.

CHAPTER 7 AN INVESTIGATION OF CLEANER PRODUCTION OPPORTUNITIES IN THE SA COAL MINING INDUSTRY

7.1 Background

This chapter provides a summary of the approach and results of the investigation into CP options for the coal mining industry. The full report is available in Volume 6 on the CD.

The coal mining and processing industry in South Africa is responsible for significant local and regional environmental impacts, most notably those on water quality. As a result, legislation is becoming more stringent, public concerns are increasing and mine rehabilitation costs, which are incurred by the mining companies, are increasing. In response to this, the coal mining industry is recognising the importance of proper environmental management. However, the focus is still largely on end-of-pipe solutions. CP, which is a continuous preventative approach to environmental issues, has been demonstrated to be a cost-effective means of reducing wastes, increasing process efficiencies and improving the resource utilisation of coal mines in several countries, as well as certain South African industries. It is therefore expected that CP can provide the South African coal mining industry with an efficient, cost-effective approach to minimising its environmental footprint, and to meeting present and future legislative requirements. This chapter aims to investigate whether this is in fact the case, by investigating and proposing feasible CP interventions for the coal mining industry.

To this end, CP assessments were carried out at three representative case study collieries. The procedure utilised followed the five generally accepted phases: planning and organisation, pre-assessment, detailed assessment, feasibility assessment and implementation and monitoring. In the planning and organisation phase a small project team was set up to ensure the continuation of CP after the completion of this research project. The outcome of the pre-assessment phase, designed to identify the wastes on which to focus in the remainder of the assessment, was that at all three collieries the slurry, discards and energy wastages should constitute the focus areas. There were, however, significant differences in performance of the three collieries in terms of waste generation and resource utilisation. There are therefore opportunities for the mines to learn from, and benchmark against each other.

In the detailed assessment phase, more comprehensive analyses where conducted through literature surveys, sampling and laboratory test-work, walk-through audits and brainstorming sessions in order to generate potential CP ideas to reduce the waste at the three focus areas. These ideas were then submitted for feasibility assessments to eliminate any options that are not environmentally preferable and financially favourable and technologically viable. Through this process, feasible CP interventions could be identified for the case study collieries. The final phase, which involved the actual implementation and monitoring of the progress, is largely the responsibility of the mines concerned and was thus not addressed as part of this study. However, methods were suggested to overcome the various barriers that are likely to hinder the implementation of CP interventions in the coal mining industry.

7.2 Preliminary assessment

This section presents the findings of the pre-assessments conducted at each case study colliery. The purpose of the pre-assessment is to gain an understanding of the nature and origin of the wastes at the collieries, and to determine which wastes to focus on in the CP assessment. By conducting pre-assessments at the three representative case studies collieries, a general qualitative understanding of the wastes generated at South African collieries was gained. This is necessary before CP interventions can be proposed and the key questions of the research answered.

7.2.1 Wastes produced by the collieries

Based on the site visits and colliery documentation, the following significant wastes have been identified at the case study collieries. The term ‘waste’ refers to any solid, liquid or gaseous substance that is not regarded as having any value by those who produce it.

All wastes apply to all three collieries. These wastes are:

- Methane;
- Dust;

- Slurry;
- Discards;
- Sewage;
- Oil leakages and spillages;
- Other leakages;
- Excess energy use (source of waste);
- Reclaimed oil;
- General waste; and
- Hazardous waste.

These wastes are described and discussed in more detail in the following section. The energy consumption was included in this list because wastes brought about by energy consumption are either generated off-site, as in the case of electricity, or are difficult to quantify, e.g. vehicle emissions.

7.2.2 Waste characteristics

This section discusses the various wastes in more detail and compares the relative quantities of waste generated at each mine. The quantities are expressed per ton of mined coal so that they can be compared between the collieries. The lowest relative quantity for each waste can be viewed as a benchmark for the other two collieries because it represents a lower, achievable waste production rate. Options to reduce wastes can be arrived at by establishing why one colliery produces less waste than another. Therefore, comparing the quantities of wastes generated at each mine, and establishing the reasons for the differences, is a meaningful exercise.

Difficulties in obtaining the quantities of waste produced were experienced at all three collieries. This is due to a number of factors. Firstly, there is minimal monitoring of resources and wastes at the collieries, resulting in a shortage of information. Besides water balances at Collieries A and C, no mass or energy balances have been conducted for the washing plants or for the colliery as a whole. In the case of colliery A, accurate process flow diagrams of the washing plant were not available. Secondly, the information that is available is not necessarily documented or consolidated in a single document. Water-meter readings, equipment specification sheets, interviews with employees, daily and monthly reports and invoices were therefore resorted to in order to obtain the relevant information. Thirdly, the available information is not made easily accessible to the various employees of the respective collieries. In some cases, such as the coal flows at Colliery A contradictions in reported values were noted. These difficulties in obtaining useful information reduce the effectiveness of the CP assessment because a waste cannot be managed if little is known about it.

7.2.3 Methane

The methane contents of the seams that are mined at the various collieries are listed in Table 3. The average methane content of South African coal seams in general is also included in the table.

Table 3: Comparison of the seam methane content

Collieries	**A**	**B**	**C**	**SA**
Average methane content (m^3/t coal)	0.03	0.02	0.3	0.6

The table indicates that the seam methane contents are well below the South African average, especially in the case of Collieries A and B. These emissions are particularly low considering that South African mine methane emissions are relatively low in relation to the rest of the world. Due to the low methane emissions, none of the case study collieries captures or drains the methane prior to excavation. Instead the methane is emitted into the atmosphere with the ventilation air. Thus, the methane emissions are not being used as an energy source by the collieries.

7.2.4 Dust

The case study collieries are all underground mines, where dust is less of a problem than in open cast mines. Dust particles located on stockpiles and roads become airborne predominantly due to disturbances by the weather or by vehicles. Front-end loaders and pre-wet crushers are also responsible for releasing fine coal particles into the atmosphere. Dust is prevented from becoming airborne by spraying water on the various exposed surfaces, particularly roads. Significant quantities of water are consumed suppressing dust regardless of the weather conditions. Table 4 indicates these quantities per ton of run-of-mine (ROM) coal.

Table 4: Water used for dust suppression

Collieries	**A**	**B**	**C**
Water consumed to suppress dust (m^3/t ROM)	0.009	0.008	0.01

Colliery A uses de-pressurised fire-hydrant water to suppress the dust. This is both an environmental and safety hazard, as a pressurised fire water supply is not readily available in the case of an emergency. Colliery B utilises chemical dust suppressants to assist with the dust suppression, thereby reducing water requirements. Mine B also covered the ROM stockpile so that it is no longer exposed to the atmosphere. Collieries A and B utilise product silos, rather than stockpiles, thereby preventing the fine particles from becoming airborne. Due to its complex nature, dust generation has not been quantified. However, even in the worst case scenario, i.e. a ‘very heavy’ dust fallout rate of 1200 mg/m^2 per day, the dust produced would be less than 10 000t/a.

7.2.5 Slurry

The ultra-fine coal is discarded because the collieries perceive that the high cost of dewatering the ultra-fine coal exceeds its value. Hence, the ultra-fines are discarded together with process water in the form of slurry. Mine A disposes of the slurry underground in old mine shafts. Boreholes are located at a deeper level so that some of the seeping slurry water can be recovered. Mines B and C dispose of the slurry on co-disposal discard dumps, which allow roughly 40% of the water to be recovered. Prior to dumping, the slurry is partially dewatered at all three plants in a thickener. The water thus recovered is recycled back into the plant. An efficiently operated thickener is capable of reducing the water content to roughly 75% (Reddy, Personal Communication). However, at all three collieries, the thickened slurry is approximately 85% process water, therefore excess water is being unnecessarily being disposed of in the slurry. Because it is viewed as a waste, very little information is available regarding the slurry. The quantities of slurry produced were obtained from the plant mass balances and are shown in Table 5.

Table 5: Comparison of slurry generation

Collieries	**A**	**B**	**C**
Slurry produced (ton per ton of ROM)	**0.32**	**0.27**	**0.27**

The table indicates that Colliery A disposes of more slurry than the other collieries. Colliery B sells part of the unwashed <10 mm ROM coal. Since this coal contains ultra- fines, less ultra-fine are available to be purged in the slurry. Colliery C crushes the coal to a top size of 80 mm, compared with 40 mm and 50 mm at Collieries A and B respectively, resulting in fewer ultra-fine material being produced. It is therefore expected that colliery A will produce more ultra-fine material and, therefore, slurry. None of the collieries samples and monitors the quality of the ultra-fine coal, and are therefore unaware of the quality of the coal they are discarding. To obtain the coal quality data, samples were taken at each mine and were analysed for calorific value and ash content (see Appendix 6 for details).

7.2.6 Coarse discards

The discarded coarse rock, referred to as the discards, is disposed of because of its high ash content, i.e. poor quality. At Colliery A, the discards are disposed of on a discard dump, and at Collieries B and C they are disposed of together with the slurry on a co-disposal tailings dam. None of the case study collieries has conducted a study to predict or quantify the environmental impacts caused by the discard dumps. Table 6 indicates the quantities and qualities of the discards at each colliery.

Table 6: Comparison of discards quantity and quality

Collieries	**A**	**B**	**C**
Discards disposed of (t / t ROM)	0.39	0.29	0.19
Discard air-dry calorific value (MJ/kg)	13	13	10
Discard air-dry ash content (%)	50	52	61

Table 6 indicates that there are considerable differences in the quantity of discards generated at each mine. Almost 40% of the mined coal at Colliery A is discarded, while only 19% is discarded at Colliery C. The coal seam type is largely responsible for these differences between the mines.

7.2.7 Sewage

At Collieries A and B the sewage is treated in an on-site sewage treatment plant. At Colliery A, the treated solids are used in a responsible manner as fertiliser to assist with the rehabilitation of the mine. Since the solids add value to the mine, they are not considered a waste. Half of the treated water is recycled back into the mine, while the other half is released into a nearby river. At Colliery B, the treated liquid is recycled back to the plant and the solid waste is collected by outside contractors. Colliery C, which is situated near a small town, pipelines the combined untreated sewage waste to the local municipality treatment plant. Thus, 'sewage waste' refers to the half of the treated liquid effluent that is released into the river for Colliery A, the solid material for Colliery B, and the untreated liquid-solid waste for Colliery C.

Table 7: Comparison of sewage quantities

Collieries	**A**	**B**	**C**
Sewage (g/t ROM)	14 000	1.2	44 000

Table 7 indicates that treating the waste on-site and recycling the treated water back into the mining operations, significantly reduces the amount of sewage disposed of. During the cold months at Colliery C, the underground mine workers open the shower hot taps to generate steam to heat up the rooms prior to showering. This accounts for a significant portion of the sewage water that is generated at this colliery.

7.2.8 Oil spillages and recovery

Oil that is consumed at the collieries is burnt in the vehicle engines, recovered and recycled, or wasted due to spillages and leakages (mostly pipe bursts). The percentage of used oil that is recovered and then recycled by an outside contractor is indicated in Table 8 for each mine. This oil is recovered from vehicle oil sumps.

Table 8: Comparison of quantities of recovered oil

Collieries	A	B	C
Recovery of oil (%)	8	3	3.5

Table 8 indicates that less than 8 % of the total oil consumed is recovered, while the remainder is combusted in engines, spilt or leaked. Based on discussions within the coal CPF, these figures appear to be typical of the industry. Although generally unknown, some of the causes of oil spillages have been identified, such as the overfilling of oil into the various components and into the storage tanks, resulting in oil spilling onto the ground. The underground workers then leave the empty oil drums on the surface, where the drums are no longer their responsibility. Residual oil may drain out onto the ground as the drums are not necessarily placed upright. Another identified source, more difficult to address, is the problem of pipe bursts of hydraulic equipment. It is estimated by the mine workers that pipe bursts are the largest cause of oil losses. The quantity of oil that is wasted due to spillages and leakages is unknown. However, the total quantity of oil consumed at each colliery does not exceed 10 000t/a, which means that the amount lost as leakages will also be less than 10 000t/a. Spilt oil, especially after use, is however known to be highly toxic to the receiving environment (Rwodzi, 2000).

7.2.9 Other leakages

'Other leakages' refers to any aqueous leakages that are not recovered and recycled back into the mining processes. Such leakages may originate from leaking taps, overflowing equipment or burst pipes. Leakages that occur within the washing plants are recovered by sump pumps located on the bottom floor. Leakages that occur outside the plant, such as dripping taps and leaking hoses, are recovered by a network of canals that redirect the flows to storage dams. However, some of these canals are simply dug-out trenches that allow water to pass through them into the ground. As this contaminated water is not recovered and re-used, it is considered a waste. Although the quantities of water lost in this manner are unknown, it is estimated that the losses are not likely to exceed 10 000t/a. This is partly due to the relatively small amounts of water that are leaked, and partly due to the canal systems effectively recovering most of the leaks. The canal system also serves to keep clean surface run-off water separate from the coal-contaminated water used on the mine, thereby preventing further contamination of water.

7.2.10 Energy consumption

The energy sources utilised at the collieries are petrol, diesel, oil and electricity. At all three collieries, only the total consumptions of each energy source are recorded. None of the mines has an electricity monitoring system in place to monitor the end-user consumptions, and none has conducted liquid fuel balances. Petrol consumption at all three collieries is negligible. Only energy consumed on-site is considered, as energy used to transport the coal to its final destination is outside the scope of this assessment.

Electricity is the principal energy source, accounting for more than 60% of the total energy consumed at all three collieries. Information gained from the mines also indicates that Colliery C consumes notably more energy than the other two. Colliery C transfers its product coal to stockpiles via conveyor belts and employs front-end loaders to transfer the coal from the stockpile to the transport vehicles. The other two collieries transfer the coal via conveyor belts to the product bins from where they drop via gravity into the trains. The product handling at Collieries A and B is therefore less energy consuming. Colliery C mines at roughly 80 m below the surface, which is at a greater depth than Collieries A and B (40 m and 60 m respectively) and is located where the coal seam is particularly thin (1.5 m compared with 3.6 m and 3.5 m at A and B, respectively). Hence excavation at Colliery C is more energy intensive than at the other mines. Considering the product handling, excavation practices and economies of scale at Colliery C, it is expected that the energy consumption will be higher than that of the other two mines.

7.2.11 Mining method

Underground mining was found to leave a large amount of coal underground and not extract it. The exact volume varied depending on the geotechnical issues but it could vary from 30-60 % of the coal not being mined and left in situ.

7.2.12 General and hazardous waste

Outside companies are contracted to remove and dispose of the general and hazardous wastes produced by the collieries. Colour-coded containers designated to the different waste types are distributed around the collieries and are collected on a weekly basis. If hazardous waste is found in the incorrect bins, the colliery is financially penalised by the disposal companies. If general waste is disposed of in the hazardous waste bins, the colliery pays unnecessarily high disposal costs for its disposal. Table 9 compares the general, hazardous and combined wastes for the three different collieries per ton of ROM mined.

Table 9: Comparison of general and hazardous waste generation

Collieries	**A**	**B**	**C**
General Waste (kg/t ROM)	0.11	0.076	0.028
Hazardous Waste (kg/ t ROM)	0.009	0.004	0.023
Total (kg/t ROM)	0.11	0.080	0.051

Table 9 indicates that Colliery A generates the largest quantities of general waste. Although Colliery C generates the least amount of combined waste; the quantities of hazardous and general waste collected are fairly similar. Since it is unlikely that the amount of hazardous waste produced is similar to that of the general waste, this suggests that there may be a waste separation problem at Colliery C. The mine workers are responsible for separating and placing the wastes in the correct bins.

7.3 Waste comparison

In order to determine on which three wastes to focus in the CP assessment, a waste comparison was carried out for each colliery. A waste comparison is a ‘quick and dirty’ preliminary analysis that is used to refine the focus of a CP assessment. Therefore, the comparison is predominantly based on educated estimates, rather than on detailed and precise calculations. This process allows the focus wastes to be identified at each colliery, so that the detailed CP analysis is limited to the wastes most in need of further investigation.

The wastes are rated from 1 to 5 (5 being the most wasteful) in five different categories:

- Quantity
- Cost
- Environmental impact
- Potential for CP interventions (rated 1-3)
- Other

Other includes the mine’s compliance with present or known future regulations and any safety or health hazards it poses to the mine employees and surrounding areas. At all three mines, methane, dust and hazardous wastes were allocated a score of 1 for the other category due to the health risks that these wastes pose. Recycled oil was allocated a score of -1 in the other category because it is recycled off-site. The options with the best ratings were selected for technical and economic feasibility analyses. Slurry, discard and energy had the best ratings hence they were selected.

7.4 Slurry, discard and energy detailed assessments

7.4.1 Slurry assessment

Slurry was identified as a waste in need of a detailed CP investigation at all three mines. In response to this finding, this section aims to identify feasible CP opportunities to reduce the amount of slurry that is discarded by presenting the findings of the detailed and feasibility stages of the assessment for the slurry. Since the slurry comprises both water and solids (ultra-fine coal), both of these aspects were investigated. The ultra-fine slurry solids are the source of several significant environmental problems, including ARD, dust release and spontaneous combustion. Therefore, by reducing the quantity of slurry that is disposed of, these impacts on the environment can be reduced. Most of the water consumed in the coal washing plants is lost via the slurry. By recovering and recycling this slurry water, and hence reducing the quantity of slurry disposed of, the amount of water consumed in the plant is reduced.

Several CP options to reduce the amount of slurry that is wasted were identified in this section. The following options were identified as being feasible at all or some of the case study collieries. For each option, the type of CP intervention is indicated in brackets:

- Increase the crusher top size to reduce the proportion of ultra-fines that are generated(Good house-keeping);
- Optimise the classifying cyclones to perform sharper, more precise separations (Good house-keeping);
- Install an automated flocculent make-up system (Technology change, internal water recycling);
- Beneficiate using flotation, thermal dry and export the arising ultra-fine (Technology change, Product change, internal water recycling); and
- Solar dry and sell the unwashed existing ultra-fines to local power stations (Product change: resource use optimisation).

Since all five options are not mutually exclusive, there is no need for further elimination. Owing to the complex, high-cost and site-specific nature of the last two options, it is recommended that detailed techno-economic studies be conducted and slurry monitoring systems be put in place at each mine prior to implementation. Of the five feasible options, two (or 40%) are high cost and complex options, and one option requires establishing a contract agreement with an outside company (Eskom). None of the options involves the introduction of novel technologies because thermal drying and flotation are well established technologies that have been recognised as being effective on the South African Witbank and Highveld coals for many years.

As mentioned earlier on, most of the water consumed in the coal washing plants is lost via the slurry. By recovering and recycling this slurry water, which can be achieved by installing the automatic flocculent make-up system and by dewatering the slurry product, the amount of water consumed in the plant is reduced.

There were several options that were eliminated because they are not feasible at present, these being:

- Convert the ultra-fines to a low smoke fuel;
- Solubilise the ultra-fines to produce methane and polymers;
- Produce a coal-water fuel from the slurry; and
- Combust the slurry in a fluidised bed combustor.

7.4.2 Coarse discard assessment

The discarded coarse waste rock, referred to as the discards, was identified as a waste to be focused on in the CP assessment. In response to this finding, this section aims to identify feasible CP options to reduce, eliminate or utilise this discard waste by presenting the findings of the detailed and feasibility phases of the assessment for the discards. The discards are a source of ARD and of air pollution through spontaneous combustion. Therefore, by reducing the quantity of discards that are disposed of, the extent to which ARD occurs can be reduced. As mentioned earlier on, there is no site-specific data available quantifying the pyrite content and hence the potential for ARD of the discard dumps at any of the three mines. Therefore, reductions in environmental impacts brought about by decreasing the quantity of discards could not be quantified.

Based on the analysis, the following options have been identified as being feasible CP options to reduce the quantity of discarded coal material at the case study collieries. For each option, the type of CP intervention is indicated in brackets:

- Improve the performance of the drums and cyclones (Good house-keeping);
- Thermally dry the cyclone product (Technology change, product change);
- Wash the fines using spirals and thermally dry the product (Technology change, product change); and
- Dewater and sell the spiral discards (Product change: resource use optimisation).

Of these options, half require high capital investments. One option requires establishing a contract agreement with an outside company (brick manufacturing company). None of the options involve the introduction of novel technologies, as thermal drying is a well-established technology that has been recognised as an effective means of dewatering coal for several years. All four options are relatively complex in nature, particularly those involving technology changes, and therefore require further technical and/or economic investigation. Detailed LCAs should also be conducted to ensure that the net environmental impacts are reduced, particularly with regards to the impacts of the increased electricity consumed by the introduction of thermal driers. Since all four options are not mutually exclusive, there is no need for further elimination. However, the option to thermally dry the spiral product is incorporated into the option to thermally dry the spiral and flotation products that is discussed in Slurry Assessment. Since the latter is predicted to result in lower discards generation and higher NPV, it is recommended that this option be implemented. The discards are a source of ARD. Therefore, by implementing the above options the extent to which ARD occurs can be reduced. The following CP options have been identified to reduce slurry waste but also happen to reduce the quantity of discards wasted:

- Wash the fines using spirals, wash the ultra-fines using flotation and thermally dry the combined products (Technology change, product change); and
- Sell the rewashed discards (Product change: resource use optimisation).

7.4.3 Energy assessment

It was identified that energy consumption and the reduction thereof should be one of the foci of the CP assessment. In response to this finding, this section aims to identify feasible methods to reduce energy consumption at the three case study collieries by presenting the findings of the detailed and feasibility phases of the assessment for energy. The DME aims to reduce the industry and mining sector's energy demand by 15% by 2015. Based on international best practice, the DME estimates that savings of 11% can be achieved by implementing low-cost or medium-cost interventions; and that a further 5% to15% savings can be achieved by using no-cost or low-cost interventions (DME, 2005b). The target of 15% is therefore believed to be realistic and attainable, and can be used as a benchmark for energy reductions at the coal mines.

Based on the analysis, and because none of these options is mutually exclusive, the following have been identified as being feasible CP options to reduce energy consumption at the case study collieries:

- Install electricity meters (Good-house keeping);
- Compile detailed liquid fuel and energy balances (Good house-keeping);
- Minimise electricity consumption of the end-users (Good house-keeping, Technology changes);
- Introduce an educational / training programme (already implemented at mine C) (Good-house-keeping); and
- Introduce incentives to reward employee energy saving efforts (Good house-keeping).

Since all five options are not mutually exclusive, there is no need for further elimination. Of the five feasible options, none is a high cost option. None of the options involves the introduction of novel technologies. Most of the energy savings can be achieved through improved house-keeping practices and are relatively simple to implement. Significant reductions of the environmental impacts caused by coal-fired power stations can be achieved by simply implementing low-cost, no-cost interventions.

7.5 Conclusions

The assessments identified numerous feasible CP opportunities available to reduce the amount of slurry, discards and energy wasted at the three case study collieries. Many of these options are expected to reduce the mines' impacts on the quality of the water in the region. None of the options proposed involves the use of unproven technologies. For the options that require high capital investments (i.e. investments in excess of R1 million), payback times were found to be less than one year, and the 10-year net present values ranged between R10 million and R200 million.

Most of the proposed options are applicable to all three collieries. Since the case study collieries are relatively representative of the industry, it can be concluded that there are in fact opportunities available to implement cost-effective CP interventions in the South African coal mining industry. More specifically, it can be concluded that there are opportunities to implement CP interventions in other collieries, with a significant potential of reducing the industry's impacts on the quality of water. However, the industry will only be able to fully embrace the CP approach once several economic, technological, managerial and legislative barriers have been overcome. Co-operation, a change of company policies and innovation are required by the coal mining industry, coal utilisation industries, government and minerals tertiary institutions to overcome these barriers.

CHAPTER 8 CLEANER PRODUCTION OPPORTUNITY ASSESSMENTS

8.1 Introduction

As part of this research project an allowance was made for the practical evaluation of five different mining facilities with respect to conducting a CPOA. This process looks at all inputs and outputs to a facility and has the objective of trying to determine areas where resources can be saved to the benefit of the environment and to save the company money.

Different mining companies were written letters to ask them to participate in this project by offering up one of its facilities for this type of assessment at no cost to them. The letter explained the objectives of the project and the concept of CP. President Steyn Gold Mine, Goldfields and Anglo Platinum came forward and offered their facilities. These companies were made aware of the reports that will be generated will form part of our research project feedback to the Water Research Commission which becomes a public document. The companies could choose to have their names made public or not.

An assessment team was set up between the mine and the project team. Sites visits were arranged. A meeting was held with the site representative to introduce the concept of CP and the objectives of the assessment. Interviews were conducted to understand the process and to identify key focus areas. A detailed site inspection was undertaken. The assessment team had a discussion after the site inspections to collate observations and recommendations. A list of questions was compiled and submitted to the site for clarification. A number of savings and improvements were identified which were deemed to be of assistance to the companies. A draft report was then sent to the site representative for comment.

The following facilities were surveyed:

- A platinum smelter;
- A gold mine plant;
- Two platinum concentrators; and
- A gold mine shaft complex.

This chapter summarises the outcomes of the assessments at each of these facilities. A full report is provided in Volume 8 on the CD provided.

8.2 Methodology for Cleaner Production Opportunity Assessments

Options for cleaner production were identified by means of a CPOA or CP assessment. Such an assessment is:

- An analytical tool designed to ensure that the organisation is operating in an environmentally safe and economically efficient manner;
- Used to document the types and quantities of wastes generated by the company; and
- A systematic approach for the identification and evaluation of different CP options.

The main stages involved in the assessment phase are summarised in **Box 2**.

Box 2: Phases of the Cleaner Production Opportunity Assessment

- *Phase 1: Assessment overview*

Summarises the overall assessment procedure.

- *Phase 2: Program organisation and team make up*

Record key members in CP assessment program task force and the CP assessment team, include list of potential departments when selecting a team.

- *Phase 3: Site description*

List background information about the facility, including location, products and operations.

- *Phase 4: Process information*

This is the checklist of useful process information to study before starting an assessment.

- *Phase 5: Personnel*

Record information about the personnel who work in the area to be assessed.

- *Phase 6: Input material summary*

Record input material information for a specific production or process area. This includes name, supplier, hazardous component or properties, cost, delivery and shelf life information, and possible substitutes.

- *Phase 7: Product summary*

Identifies hazardous components, production rate, revenues, and other information about the product.

- *Phase 8: Individual waste stream characterisation*

Record sources, hazardous, generation rate, disposal cost and method of treatment or disposal of each waste stream.

- *Phase 9: Waste stream summary*

Summarises all the information collected for each waste stream. This can be used to prioritise waste streams to assess.

- *Phase 10: Option generation*

Record options proposed during brainstorming or nominal group technique sessions.

When the assessment phase was completed, an assessment report with recommended option was generated and submitted to the mines for comments. Usually, the assessment phase is followed by a Feasibility Analysis Phase and Implementation but the scope of this study was limited to generation of options. It was the responsibility of the individual mines to undertake the feasibility assessments and implementation.

8.3 Platinum smelter

8.3.1 Compressed air losses

Compressed air is required on site for many different purposes. It is very important that the compressed air is dry to ensure the efficiency of the process. For this reason, compressed air lines are purged at regular intervals. Several compressed air lines were noted. There was generally no formal maintenance procedure for these lines. People working on the site report any leaks that they hear and these are then repaired.

Monitoring for pressure drops will result in leaks being identified and repaired sooner. Studies conducted by the Centre for Excellence in CP at the Curtin University of technology indicate that leaks in compressed air pipes can be responsible for up to 20% of compressed air consumption.

The production and transport of compressed air is a high energy user. The following measures can be implemented to reduce energy consumption as the result of compressed air usage:

- Reduce the temperature of intake air. A 3°C drop in temperature can reduce energy consumption by up to 1%;
- Reduce operating pressure if possible. A 100 kPa drop in operating pressure can result in an energy saving of up to 8%;
- Repair leaks as soon as possible; and
- Remove compressed air lines that are not being utilised and reduce the length of operational lines as far as possible.

8.3.2 Reprocessing

In order to reduce product losses at the Platinum Smelter operation, the system is run as a closed loop operation and everything is recycled. While this process is effective in reducing product losses, it results in an increase in resource utilisation.

It is recommended that employees are encouraged to prevent spills and losses from occurring. Knowing that everything is recycled sometimes results in poor housekeeping practices.

8.3.3 Floors

The floors in the production areas have a rough surface. These floors are difficult to clean and result in product losses. It is understood that the rough floor is required in certain areas. Where possible, floors should be coated with a resin or smooth concrete cover, in order to obtain a smooth surface which can be easily swept clean. This will also reduce the need for water sprayers in several areas, as it will then be possible to clean floors by sweeping instead of hosing.

8.3.4 Natural drying

Material from the Larrox filter is piled in an empty building prior to being dried in the flash drier. The volume of coal required to dry the material to a suitable level can be reduced by spreading the material and allowing natural drying before flash drying. It is understood that the staff would prefer not exposing this material to rain fall events. This could result in lost material and would mean that the material will need to be filtered again. It is suggested that a retractable room be constructed on the current building housing this material and mechanical rakes or support staff to spread this material across the floor of the building allowing for natural drying prior to flash drying. This will results in a saving on the coal required by the flash driers.

8.3.5 Larrox filter

The Larrox Filter system was highlighted by the site environmental coordinator as a system that required additional investigations at the Platinum Smelter. The filter cloth tears frequently, resulting in both a loss in production time and a high cost in terms of replacing the filter cloth. The introduction of the filter system has however improved the overall energy efficiency at the operations as it reduces the moisture content of the ore entering the dryers.

Several initiatives can be considered for reducing the operational losses incurred by Larrox filter cloth tears:

- Investigating the effect of fines in the Larrox filter cloth. It is possible that the tears are as the result of fines clogging the cloth, hence resulting increased strain on the cloth;
- Using high quality water on the filter cloth. It is possible the fines found in recycled water clogs these cloths resulting in tears; and
- Setting up a commercial agreement with the Larrox supplier whereby, payments is made per ton of material filtered, instead of filter cloths purchased. The supplier's profits will improve if the efficiency of the filter cloth improves. This will encourage the supplier to improve the quality of the cloths or improve the efficiency of the cloths.

8.4 Gold mine plant

8.4.1 Wet ore

The ore arriving at the plant from the various shafts at the Gold Mine Plant is some of the wettest and finest the authors had seen and at the time of the site visit had porridge like consistency. There must be a reason for this at the underground mines, e.g. inadequate pumping facilities, over blasting, lack of scrapers, etc. This wet ore is difficult to handle in the plant and spillages are common. It is likely that the gold losses are much higher with this wet ore than if it were drier. The source of this wet ore should be investigated together with the mining personnel and we are sure that it can be produced in a form that is easier to handle.

8.4.2 Illumination

During the assessment it was realised that the lights were still on during the day. There is a potential for energy savings by switching off all unneeded lights during the day. This could be achieved by the installation of light sensitive switches. The use of energy efficient light bulbs must be looked at.

8.4.3 Woodchips

During underground operation, wood are used in the gold mines to support the fall of ground. The mined ore together with the wood get hoisted into the processing plants and milled. The woodchips are separated and sold to companies that recover gold from woodchips. It was noted that the woodchips are dumped into tailing facilities. It was recommended that the selling of accumulated woodchips to companies like Goldplat Recovery and Waste Product Utilisation be investigated, as it is currently difficult to separate wood coming from underground with the ore. The money received should compensate the energy used to mill the wood.

8.4.4 High pressure wash water

During the assessment, it was observed that there was too much hosing of spillages into the sump. The sump was then pumped into water reclamation facilities. High pressure hoses should be used for hosing down; this will reduce volumes of water used for cleaning and hence reduce the cost of circulating the water. This also applies to showers as by using less water the energy needed to heat the water will also be saved.

8.5 Platinum concentrator

8.5.1 Level control indicators

Collections of mine water often also involve pumping from intermediate sumps through the workings. It is common to use submersible pumps for this duty and not uncommon for these pumps to be poorly controlled, sucking air. During the assessment, it was noticed that some pumps were sucking air. The assessment team is of the opinion that sump pumps should be controlled by level switch wherever possible to reduce energy use, maintenance and wear and tear.

8.6 Gold mine shaft complex

8.6.1 Underground sanitation

A primitive dry tank latrine was inspected underground and found to be an unpleasant item to be near or use. The full sanitation tanks are hoisted to surface to be processed in the sewage plant. A new sanitation plant is planned to be introduced. The current system is so unpleasant that people would avoid using it and also it takes up time to hoist at the shaft. There are probably a number of health issues which arise from people using old stopes as toilet facilities instead of this old system. With the impact of HIV/Aids on the workforce the health impacts are expected to get worse over time. The mine should consider using a different toilet system.

One of the options may be a urine diversion toilet, with the drying of faeces and urine evaporation. There will be less waste to carry up the shafts and will represent an improved system and will be more pleasant for people to use. There will be health benefits for workers. The use of worms to reduce faecal volume is a topic being considered by a number of researchers at present and is being used at a number of sites in Europe and could have applicability at the gold mine shaft as the worms do not need to work in light.

8.6.2 Oil management

At the Gold Mine Shaft, the major source of leaked oil seems to be hydraulic fluid and the root cause is leaking seals on hydraulic pumps in the loco's underground. The maintenance and specifications for seals needs to be checked. There are no records kept of oil brought out of the mine however the stores records all the oil going down the mine. Oil going out of the mine must be recorded and comparison be made of comes in and comes out and an oil balance generated.

8.7 Additional recommendations

Recommendations that are applicable to all of the sites visited include the importance of undertaking water and energy audits.

8.7.1 Water audit

One of the well known CP principles is, "you cannot manage what you cannot measure." It is recommended that additional meters are installed to gain a better understanding of water usage at the smelter and identify high water users and areas with higher water losses. This information will be useful in improving water efficiency at the smelter.

8.7.2 Energy audit

As with the water audit, understanding the energy circuit better will assist in improving energy efficiency of the operation. It came very strongly in our assessments that energy contribute largely on the total operating cost of the operation, more especially in milling plants and smelters.

8.8 Existing CP initiatives

Some CP initiatives had already been implemented at some of the sites visited. These described briefly in the sections below.

8.8.1 Used oil handling facility

At the platinum concentrator, there is oil separation equipment to separate oil from water. The separated water is returned into the plant for re-use and oil is sent to the used oil bay. Oil is collected from all sections of the plant and pumped into storage tanks. Once the storage tanks are full, Oilkol comes to collect the oil and uses it as a raw material for the production of Industrial Burning Fuel (IBF).This is a state of the art facility and is well maintained.

8.8.2 Waste separation

Waste separation is practiced at other sites, e.g. steel is placed into telecoms marked steel, wood into telecoms marked wood, etc. In gold plants, waste separation is for specific kings of waste otherwise it is mixed and separated at the salvage yard due to security reasons

8.8.3 Rubber liners

The installation of rubber liners in the mills helped reduce the gold lockup there by 85%. Relining is now done less frequently and is not driven by the need to recover gold. Liners currently last for two years. Previously gold lockup was estimated to be 75 kg. The liner and lifter configuration was optimised to benefit the production needs of the Gold Plant.

8.8.4 Steel and power consumption

At the Gold Mine Plant, the use of a fully autogenous milling system means that the mine has not been affected by the recent steep increase in steel ball prices. The mill power draw also came down when steel usage was discontinued. A system is in place not to operate large items of equipment during peak power demand times. The mills are also stopped during these times as there is sufficient capacity to make up production during low use times. An Enermax meter has been installed to be able to check electrical consumption. Power factors have been improved but more savings are possible.

8.8.5 Cyanide consumption

At the Gold Mine Plant, cyanide consumption has dropped through the use of an automated dosing system.

8.8.6 Knelson concentrator

The installation of the concentrators is one of the really innovative things the plant has implemented. It reduces gold lock up in the mills and fewer chemicals are used. The mine tailings improved from 0.28g/t to 0.2g/t. A savings of 8 kg of gold a month (currently valued at R16 million per year). This site was the first in the Free State to install this equipment. The use of local bearings instead of imported ones has resulted in a considerable cost savings in the maintenance of these concentrators.

8.8.7 Water softening plant

The Knelson concentrators use large volumes of high quality water and previously potable water had been used for this purpose. A water softening plant has been constructed to treat the process water. The treated softened water is then able to be used in the concentrators. With this initiative a significant savings on water has been observed. Water charges have dropped from R170 000 per month to R10 000 per month from Rand Water and softener costs are R27 000 per month resulting in a net savings of R133 000 per month.

8.8.8 Reprocessing slag from furnace

At Platinum Smelter the slag produced is crushed and reprocessed. In the past, slag was transported to slag dumps and reprocessed later. This practice reduces the need for a slag dump and thus the costs associated with maintaining a slag dump. The transport costs and environmental impacts associated with transporting slag to a slag dump are also reduced. Studies carried out indicate that the platinum concentrations in the slag makes the reprocessing a viable option. Further investigations are necessary to quantify the savings incurred by reducing the need for a slag dump.

8.8.9 Lime Addition

At Platinum Smelter, lime was previously added at the start of the process. This resulted in scaling in pipes. The lime is now added to the product bins before smelting. This reduces maintenance costs upstream of the product bins and results in a reduction in the quantity of lime used.

8.8.10 Energy savings

The flash dryers are stopped for four hours every morning at Platinum Smelter. This results in a reduction on energy demand from Eskom during the peak period in the morning. In addition to this, it reduces energy losses. The driers are used at their capacity.

8.8.11 Water line shut-off valves

Automatic shut-off valves have been fitted to chilled water lines. They can be closed remotely from the surface. A by-pass allows a minimum flow to continue through the cooling coils.

8.8.12 Compressed air shut-off line

The compressed air lines are being fitted with automatic shut-off valves, with a small diameter by-pass, so that the air can be shut off at the end of a shift. The bypass is sized to provide sufficient air to the rescue chambers (which is a legal requirement).

8.9 Discussion and conclusion

Management and environmental coordinators were introduced to the concepts on CP at the opening meeting. It was found during the assessment that providing background information prior to the site visit would have been beneficial.

Several commendations were noted during the inspection. Positive changes are constantly being made at the operations in order to improve productivity and reduce the impact to the environment. Management saw CP as a tool that can be used to achieve these objectives.

Several potential projects were identified at the assessment. These would require further investigations in order to assess the feasibility of these options. The aim of this study was to conduct a screening assessment and highlight any possible savings and this was achieved during the visit. One of the main objectives of the project is to compile a guideline document that can be used by the industry to practice CP in-house. This assessment technique allows the project team to identify key focus areas and provide information that can feed into the guideline document.

It can be concluded that the first assessment was successful in that the team was able to:

- Introduce the concepts of CP to the operation personnel (plant manager, plant engineer and environmental coordinator);
- Identify and highlight potential savings at the operations; and
- Identify and highlight existing CP activities.

CHAPTER 9 HIGH LEVEL LIFE CYCLE ASSESSMENTS

9.1 Life Cycle Assessments

LCA is a "cradle-to-grave" approach for assessing industrial systems. "Cradle-to-grave" begins with the gathering of raw material from the earth to create the product and ends at the point when all materials are returned to earth. LCA evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g. raw material extraction, material transportation, ultimate product disposal, etc.). By including the impacts throughout the product life cycle, LCA provides a compressive view of the environmental aspects of the product or a process and a more accurate picture of the true environmental trade-offs in product selection.

Specifically, LCA is a technique to assess the environmental aspects and potential impacts associated with product, process, or service, by:

- Compiling an inventory of relevant energy and material inputs and environmental releases;
- Evaluating the potential environmental impacts associated with identified inputs and releases; and
- Interpreting the results to make more informed decision.

LCA is a technique for assessing all the inputs and output of a product, process, or service (Life Cycle Inventory); assessing the associated wastes, human health and ecological burdens (Impact Assessment); and interpreting and communicating the results of the assessment (Life Cycle Interpretation) throughout the life cycle of the products or processes under review. The term" life cycle" refers to the major activities in the course of the product's life span from its manufacture, use, maintenance, and final disposal; including the raw material acquisition required to manufacture the product.

9.2 Benefits of conducting a LCA

The benefits of conduction a LCA include:

- An LCA will help decision makers select the product or process that result in the least impact to the environment;
- This information can be used with other factors, such as cost and performance data to select a product or process;
- LCA data identifies the transfer of environmental impacts from one media to another (e.g. eliminating air emissions by creating a wastewater effluent instead); and
- It also identifies the transfer of environmental impacts from one life cycle to another (e.g. from use and reuse of the product to the raw material acquisition phase).

If LCA was not performed, the transfer might not be recognised and properly included in the analysis because it is outside of the typical scope or focus of product selection process.

For example, when selecting between two rival products, it may be appear that Option 1 is better for the environment because it generates less solid waste than Option 2. However, after performing an LCA it might be determined that the first option creates large cradle-to-grave environmental impacts when measured across all three media (air, water, land) (e.g. it may cause more chemical emissions during the manufacturing stage). Therefore, the second product (that produces solid waste) may actually produce less cradle-to-grave environmental harm or impact than the first technology because of its lower chemical emissions.

9.3 The use of LCA as a tool to identify Cleaner Production opportunities

A LCA was conducted to determine the environmental footprint of gold production in South Africa and then to attempt to extrapolate these findings to the remainder of the SA gold mining industry. This study was started off by Neil Robinson and he was supported by Goldfields of South Africa as part of a Masters degree. This study did not finish in a degree but was completed by the UCT Department of Chemical Engineering with Marlon Bowman and Nalisha Chetty submitting the report as an Honours Degree Thesis.

Two further projects using LCA were completed by students at UCT. The topics were based on findings by Jane Reddick who completed the first assessment of CP opportunities as part of her Masters degree. These projects achieved the goal of exposing a number of new students to these concepts. It was found that the utilisation of coal discards generated by coal mining will become increasingly important in the future as a result of diminishing coal reserves. Environmental concerns over discard dumps and ultra-fine dams also fuel the need for CP interventions to be implemented. The coal LCA studies focused on key findings of the environmental feasibility of one such intervention, proposed by Reddick (2006), namely Ultra fines are reclaimed and dewatered either by solar drying or thermal drying, to be sold to local South African power plants as a blended coal product.

The first honours project was carried out by Mondli Zuma and Nokuzola Sofute and the second by Megan Scholtz and Christina Trautmann.

A brief description of each of these projects and the main findings of the studies are provided in this Chapter. Volume 5 on the CD contains the detailed reports.

9.4 Environmental Life Cycle Assessment of fine coal use for power generation in South Africa

9.4.1 Introduction

The first honours project looked at the beneficiation and use of coal fines in a South African power station and the alternative export of these fines for use in a German power station. The key difference is that flue gas desulphurisation is practiced in German power stations. Primary data was gathered from a colliery participating in the Coal CPF, and fed into the LCA along with literature data. The main shortcomings of this report were that the study was too case specific; sulphur speciation was not adequately assessed; and ash produced by power generation was excluded. The findings of this report were that it was better to not utilise the coal fines in a South African power station as the non-capture of sulphur would exacerbate the acidification of air and soils over a large area but that in a German context the use of fines is environmentally beneficial over business as usual (dumping the fines)[2].

The second investigation was conducted with the aim of extending and optimising the previous study by:

- Assessing a more typical South African colliery as well as a general South African case;
- Expanding the system boundary to include ash dumps; and
- Providing a comprehensive sulphur balance.

A cradle-to-grave approach was employed, including mined coal to the end use of local power generation. The major environmental concerns associated with the mining process were found to be resource depletion, air quality impairment as a result of spontaneous combustion and ARD arising from coal waste disposal, while power generation contributed to harmful gaseous emissions and leachate generation arising from ash generation and disposal.

The tool used to determine the environmental feasibility of the intervention was a LCA since it allowed for the simultaneous assessment of multiple damage categories over a broad system boundary. Data from the previous study were complemented by more site work, on a different colliery. A damage approach impact assessment was used for the assessment phase since the transferral of environmental burdens to a different category and their impact needed to be weighed up in order to decide whether the intervention is in fact environmentally preferable.

9.4.2 Findings of the study

The use of coal fines was beneficial in all cases from the perspective of extending the coal reserves in the country by better utilisation of coal deposits.

It was found that ultra-fine coal reclamation in the South African coal mining industry will be environmentally preferable to the current disposal of the coal fines at the studied colliery (Trautmann & Scholtz, 2007). It was

[2] It is worth noting that one of the authors, Mondli Guma, enrolled for a Masters degree and completed a dissertation in which he developed life cycle based quantified eco-efficiency indicators in the context of minerals processing design. After completing the dissertation he was employed by a major South African coal mining company.

concluded that the main source of pollution in the system was sulphur and the system was most sensitive to this parameter. The major impact categories were fossil fuel depletion, inorganic gaseous emissions and climate change. The proposal of using solar drying proved to be environmentally preferable to the current disposal underground for both the studied colliery as well as the general case. The underground disposal was, however, preferable to the use of coal after thermal drying.

It was thus recommended that solar drying should be implemented, and the fine coal used in a power station.

9.5 Quantification of the ecological footprint of gold production in South Africa

9.5.1 Introduction

The concept of an ecological footprint has become a popular indicator for assessing the aggregated environmental impacts of individual or city-wide consumption – more recently Carbon Footprints have also been widely used in production. This honours level thesis presented an early attempt to quantify the ecological footprint of gold production and its associated supply chain in South Africa. The footprint was constructed within a LCA framework using SimaPro software package and the footprint was complemented with a single score output LCA analysis.

The primary objectives of this study were to:

- Compare the ecological footprint and LCA of an individual, modernised gold operation with a system approximating the entire South African gold industry;
- Identify sectors in the industry where a reduction in resource intensity or emission release may be achieved and consequently provide first approximation outcomes of these reductions; and
- Assess the strength of the ecological footprint as a sustainability indicator for heavy industry.

The study made use of mine-specific input-output data sets put in the public domain by Goldfields, and compared these to the more generic data sets published by Stewart and Petrie (2007) in the Journal of CP that were being extended at the same time in another WRC project (K5/1550, Solid Mineral Waste Impact Predictions).

In addition to the comparison of the two data sets, scenarios for energy efficiency and renewable energy use were developed and analysed by means of the LCA/EF models. These included (1) An increase in energy efficiency and (2) Diverting the energy to a coal desulphurisation model, run-of-river hydro-electric power model, wind power model and solar power model.

9.5.2 Findings of the study

The following results were reported:

- The LCA and ecological footprint methodology favour the individual operation as it uses newer technology and is not weighed down by ‘unclean’, energy-inefficient, antiquated processing methods and inputs;
- Both sustainability tools (the Ecological Footprint and the LCA) found the energy sector to be the major conduit of impact, with the impact of acidic leachate from tailings facilities a significant second, but much more uncertain (i.e. it does not occur equally in all operations, and might only manifest after closure); and
- As energy land makes up 60% of the South African footprint, and the gold industry utilises 15% of South Africa’s energy, this industry is responsible for 9% of the country’s total ecological footprint.

It was found that by having a portion of the energy consumption being generated by wind or hydro-electric power produces eco-point and footprint reductions equivalent to improving energy efficiency by the same amount diverted (Bowman & Chetty, 2006). Thus, alternative energy strategies exist with which the gold industry can sustain its current energy usage and, at the same time, decrease its overall environmental burden. Secondly, it was found that desulphurisation of fossil fuels would improve air quality, thereby improving its eco-points score, but would require energy to operate, thereby increasing the footprint at a rate of 0.5% per 5% of the energy consumption used by this desulphurisation energy. We conclude that the ecological footprint of the gold as a fraction of South Africa's total ecological footprint is larger than its share of GDP, and that the major strategies to reduce it would have to centre round energy efficiency and renewable energy.

The viability of the ecological footprint method as a heavy industry sustainability indicator is promising, provided the area of analysis does include energy concerns, as energy land will inevitably dominate the result. This study has found that complementing the footprint with LCA illuminated not only the resource based sustainability agenda of the footprint, but also the ecological and human impact theme of the LCA. In evaluating an industry from this hybrid perspective, more sustainability targets can be assessed, measured, and hopefully, met.

9.6 Concluding notes on LCA

Whilst much of the other research conducted in this project focused on the use of CP techniques to improve the environmental and economic performance (a.k.a. "eco-efficiency") of existing operations, it is evident that the studies summarised here involving the use of LCA are more "academic" in nature. They ask how one could intervene, how things should be done in the future. LCA thus provides an opportunity to give inputs to the concept development for new projects in the industry, specifically to advance projects that can have significantly different ecological performance in terms of the big themes: energy use, greenhouse gas emissions, resource use efficiency and regional air quality. A key feature of LCA, as evidenced by the examples summarised in this chapter, is the value-chain view: the best place to improve the performance of a particular industry might not be in the mining or processing operation itself: often it lies outside the originally set narrow system boundary. As such, LCA also provides a powerful starting point for developing strategic partnerships for advancing the minerals-energy sustainability agenda.

CHAPTER 10 FINANCIAL EVALUATION

10.1 Introduction

The objectives of this section of the WRC project named "*Financial evaluation of the difference the project has made"* in the original proposal to the WRC was described as:

"An auditor from a reputable auditing firm (PWC, KPMG or Ernest and Young) will be used to compile a baseline evaluation of the mining industry with respect to use of reagents, consumables and services and the actual output of product. The auditor will once again in the final quarter of the project audit these costs and note any savings. It is possible that this will only be successfully achieved after the completion of the project and it may necessitate an extension to the current project. The objective will be to quantify the savings due to this project. The savings realised will be believed by industry managers if these have been audited by a reputable auditing firm.

It is not possible to determine which firm will be used as some companies may be sensitive to divulging information to rival auditing firms. If possible, the existing auditors from various companies will be used as they will already have knowledge of the company and may merely need to be guided on what data to present.

We know that some multinational companies already have existing data and some smaller companies do not collect this type of information."

Discussions were held with the major accounting firms and none of them took up the offer of participating in this study with other members of the project team. It was felt that the budget allocation was too small to get the job done adequately and that the required information was too large to get the work completed in a meaningful way.

It was also decided that as this project was due to run over a three to four year period this was too short a time period in which to evaluate an improvements due to initiatives proposed by the project team resulting from findings from the various studies. It was thus requested from the WRC, and subsequently approved, that instead of having two parts to the financial evaluation there would just be one evaluation at the end of the project and that most of the budget allocation for the first financial assessment would be used in actually conducting CP assessments at various sites. These site visit findings are reported on Chapter 8. This chapter thus attempts to summarise savings found in the studies conducted for this project and also to document the potential savings which could result from the introduction of CP in the SA Mining Industry.

10.2 Recent developments in South Africa related to resources use and availability

When the project was started in 2005 the main issue tackled was water and waste and it was mentioned by mining companies that energy and especially electricity usage was not being considered a major impact by the industry but should be. During the course of the project however, SA has been subjected to numerous blackouts and load restrictions and electricity generation and consumption issues have rocketed to being daily headline news. There is a realisation that without sufficient generation and wise use the livelihoods of numerous citizens is affected and the country's economic growth goals will not be met.

Also during this project the use of waste water in the drier areas of the country was mentioned as something which could encourage developments to the Eastern and Western limbs of the Bushveld Igneous Complex (BIC). It appeared that the approval has been given by the Department of Water Affairs and Forestry for the construction of a pipeline to Rustenburg and beyond to the Lephalale area. This initiative will allow the exploitation of numerous platinum and chrome reserves on the BIC and also for the new power stations and possible coal to liquids plants in the Waterburg coal field.

The price of oil has increased during the course of this project from \$25.00 per barrel to a peak of \$147.00 per barrel, prompting numerous strikes and riots throughout the world as this increased energy costs affects all nations (Chamber of Mines, 2008). Alternative energy sources such as coal and uranium have risen in sympathy. Since that peak constraints have lead to a major economic downturn.

The optimal use of resources such as water and energy thus does not just make an operation more viable but could mean the difference between project being able to operate at all, between the generation of the benefits of a mining project proceeding and the rewards being able to be shared by investors, the government and the community or not.

10.3 The value of the South African mining industry and what financial benefits may accrue through Cleaner Production

CP is a tool to promote environmental and social sustainability but the main drivers for its implementation is that business benefits financially in the short and longer term by conducting their operations in a more efficient and better manner. The mining industry has been a significant driver of economic growth in South Africa for a number of years and any improvements to this industry benefits South Africa as a whole.

The mining industry is vitally important to South Africa as it:

- Accounted for 7% of gross domestic product (GDP) directly, although the indirect multiplier effects take the contribution to about 18.4% of GDP;
- Directly accounted for 6.5% of total fixed investment and for 9.1% of the total private sector investment;
- Continues to act as a magnet for investment in South Africa. As at 29 December 2006 the mining sector accounted for R1.6 trillion, or 31.2%, of the value of the Johannesburg Securities Exchange (JSE);
- About R15.6 billion was paid to investors in the form of dividends;
- Contributed R140 billion to South African exports, representing 32.3% of the country's total merchandise exports and accounting for 25.2% of the country's total foreign exchange earnings;
- Concluded R24 billion worth of empowerment deals making the resources sector the largest contributor to black economic empowerment (BEE) deals;
- Directly employed an average of 458 600 workers in 2006. Around five million people are directly dependent for their daily subsistence on mine employees;
- Paid R40 billion in wages and benefits to employees, which accounted for about 5.4% of the total compensation paid to all employed people in the country in 2006. This contributed substantially to domestic demand in the economy;
- Paid R16.2 billion in direct taxes and a major portion of indirect taxes to the fiscus in 2006. Mining direct taxes accounted for about 12.4% of total company tax (and secondary tax on companies) paid to government;
- Was the world's largest producer of PGMs, gold, chromium, ferrochrome, vanadium, manganese and vermiculite; and
- The industry was also a major supplier of aluminium (world rank 9), antimony (7), coal (5), ferromanganese (4), ferrosilicon (6), iron ore (7), manganese ore (2), nickel (9), phosphate rock (10), silicon (8), titanium minerals (2), uranium (11) and zirconium (2).

Gold mining has been in decline for a number of years in South Africa due to the ore bodies becoming more difficult and costly to access. Coal has recently overtaken gold in terms of earnings for the country but both of these have been dwarfed by the enormous growth in the mining and beneficiation of Platinum Group Metals. It is likely that this sector will represent the largest future growth area for minerals in South Africa. There are abundant resources and a large demand for the products as the major demand stems from applications linked to the improvement of emission quality.

Electrical energy has been highlighted as a major constraint for development in the mining industry in South Africa due to recent power shortages. These shortages are expected to continue for a number of decades if current economic growth rates are maintained. The cost of hydrocarbon based fuels has also recently dramatically increased over the past few years. The improvement in energy efficiency by the mining industry is thus essential, not only to maintain and improve profitability but also to ensure that sufficient energy supplies exist for new projects and developments.

Sales by the South African mining industry were R195 billion in 2006. This figure has increased dramatically since then due to the sharp increase in commodity prices. Thus every percentage improvement in efficiency could produce at least an additional R2 billion in sales. This could also translate into an additional 4 500 direct jobs. Including expected multiplier effects this could result in an additional 500 000 people benefiting from wages generated by the mining industry.

At a 7% direct contribution to the GDP and a 18.4% total effect, taking forward and backward linkages into account, on the GDP the effect of a 1% increase in efficiency is equal to R1.5 billion directly and R4 billion in total to the South African GDP (Using SA Reserve Bank figures for GDP for the first quarter 2008). It is not inconceivable that savings of 10 to 15% are achievable.

If improved efficiency is not practiced then a number of mining projects may not be initiated at all as electrical power will not be available for them neither would there be sufficient water available. The value of these projects and the implied multiplier effect on South Africa is enormous. The costs of providing alternative energy using on site generation is extremely expensive and will limit the life of the projects.

South Africa is currently severely constrained by the availability of electrical power. Even though new productive facilities are being built rapidly it is likely that it will be many decades before a comfortable reserve margin is built up given current growth rates. Whilst it is possible that additional generation capacity can be constructed for electricity it is highly likely that this will represent a constraint to development for the next few decades. It is thus essential that available resources be used more efficiently.

South Africa is a dry country and the availability of water for consumptive use is finite. In order to meet the expected growth rates of the economy and the expectations of the people for a better life it is imperative that this scarce resource is used in an efficient and effective manner.

More effective use of this country's mineral resources will ensure that they can continue to be exploited for a longer period of time and provide income to the government and communities to enable them to develop a sustainable society through the exploitation of minerals, as this is by definition an unsustainable activity. The full utilisation of current mine wastes will ensure that environmental liabilities are reduced and the benefits to society are enhanced.

The potential return on investments is plain to see and thus all state institutions and businesses should be encouraging the development of technologies which will allow for the more efficient exploitation of our mineral resources and the optimal utilisation of these resources in the development of sustainable communities.

10.4 Mines are consumers of electricity and suppliers for thermal electricity generation

The South African mining industry accounted for a substantial amount of the supply and demand for energy (Chamber of Mines, 2008). The industry consumed 31 800GWh, 15.3% of Eskom's local electricity sales, whilst 112 million tons of coal was mined and used for electricity generation, which accounted for about 93% of the electricity produced in the country. The mining industry used about 762 million litres of diesel in 2006, or 9% of the total amount of diesel used in the country in that year. About 43.7 million tons of coal was first mined and then used in the manufacture of synthetic fuels and accounted for about 37% of local liquid fuel supply. This represents an annual savings of foreign exchange of more than R30 billion annually.

Mines have taken initiatives to manage their own electricity demand. In addition to shifting some load to low demand periods, a number of energy saving measures were introduced. These include the installation of energy efficient lighting and electric motors; variable speed drives on electric motors; and improved control of compressed air and electric rock drills. It was reported that during the period from March 2005 to March 2007, twenty five demand side management projects in the mining industry resulted in savings of 125.2 MW. Electricity is an important input for all forms of mining. It is a major energy source for the transport of personnel, material and ore, production machines and mineral processing. In addition it is the exclusive power source for vital health and safety related applications such as the pumping of water, ventilation and refrigeration.

Most underground mines experience an inflow of groundwater. This water has to be pumped out to maintain safety in the workings. Some gold mines in South Africa are situated in an area where the ore body is overlain by water bearing dolomitic strata. One such mine pumps some 70 Mℓ of groundwater per day to surface. The workings of mines are ventilated to remove dust and fumes and provide healthy atmospheres for workers. A survey of South African gold mines indicated that the average quantity of ventilating air circulated was some 6 m^3/s for every 1 000 tonnes of rock mined per month. A mine producing 200 000 ton per month would therefore circulate 1 200 m^3/s. That is 1.2 ton of air per second.

The virgin rock temperature increases with depth. The rate of temperature increase, or the geothermic gradient, varies according to the type of rock and therefore differs from place to place.

In mine workings, heat flows from the exposed rock surfaces to heat up the air that is in circulation. In order to provide a safe environment for workers in deeper mines it is necessary to cool the ventilating air. This is achieved by refrigeration plants which supplies chilled water that is in turn used to cool the air. A survey conducted in 1993 indicated that the installed refrigeration capacity in South African gold mines exceeded 1 400 MW of cooling power. In underground gold operations these health and safety applications may consume in excess of 55% of the total electricity used.

On the average gold mine the cost of electricity amounts to some 11.4% of the total working cost. On collieries the average cost of electricity amounts to some 8% of the total cost for underground mines and 6% for opencast mines. The use of diesel is higher in opencast mines as more fuel is used to drive earthmoving machinery. In 1999 the mining industry consumed 31 352GWh or 18.4% of the electricity sold in South Africa.

National Electricity Regulator statistics for 1999 revealed that there were 1 039 mining electricity consumers in South Africa of which 1 002 obtained their electricity directly from Eskom. This situation came about for a number of reasons, e.g.:

- Many mines had been established in areas before the local Municipality was formed; and
- Local Municipalities were unable to meet the requirements of mines in respect of electricity supply and service.

Because of Municipal electricity prices were mostly higher than those of Eskom; mines were also reluctant to enter into electricity supply agreements with Municipalities. Through the years Eskom and the mining industry have developed a thorough understanding of each other's needs and concerns that resulted in formal agreements, negotiated through the Chamber of Mines, which provide benefits to both parties. For example Eskom will, in the case of shortages of electricity, as far as is reasonably possible, allocate the available electricity to the pumping, winding and ventilation requirements of mines. In return mines agree to shed load when Eskom experiences under-frequency conditions in its system.

Because mines can control their electricity demand to some extent they are able to make use of tariff options that minimise their cost of electricity. These tariff options are Eskom's Megaflex time-of use tariff and Night save, a tariff that does not impose a demand charge during off-peak times, i.e. at night.

For this reason the average price of electricity purchased by mines from Eskom during 2000 was US$1.86 per kWh (R12.91 per kWh) compared to the average price for all customers of US$1.91 (R13.23 per kWh)[3].

During 2000 Eskom burnt some 92 289 Mt of coal. This was 40.8% of South Africa's total coal sales for that year making Eskom the largest single consumer of coal in the country. The revenue to the mining industry amounted to US$590.35 million (R4 097 million).

It is therefore clear that the mining industry, and especially the coal mining industry, has a special interest in the well being of the electricity supply industry.

10.5 Cleaner Production case studies

10.5.1 Mine ZZZ

Mine ZZZ is located in Carletonville, South Africa. In July 2007, the Mine ZZZ was particularly concerned about increasing electricity costs. Compressed air production was one of the main expenses, making up 33% of the total electricity bill. Over 70% of the compressed air was used for operation of the pneumatic drills. In the study undertaken by BECO it was found that there were many leaks in the compressed air system leading to gross inefficiency. In addition, the study also investigated the use of electric drills instead of pneumatic ones. Electric drills were found to decrease electricity consumption per rock drill operator from approximately 18 kWh to 2.2 kWh. At the time there were over 350 rock drill operators and the potential savings of replacing pneumatic drills with electric ones was R2 million per year.

Compressed air was used by mine workers to cool down since there is a shortage of ventilation in some areas underground. Compressed air losses due to lack of ventilation was estimated to be as much as R35 623, assuming that underground compressed air hose valves were kept open for ±16 hours per day. Valves could also have been left open due to lack of energy awareness measures by the mine workers. Electricity driven fans could be an alternative to expensive ventilation.

[3] Note – the average exchange rate during 2000 was R694 per US$1.

Inefficient chiller operation results in insufficient cooling in the mine. It was proposed that a further chiller be installed in series with the others. Insufficient cooling resulted in wastage of compressed air by workers in an attempt to cool off.

It was found that inefficient lighting was used underground at ZZZ. Every 500 light bulbs replaced with energy efficient bulbs would lead to a saving of R49 000 per year. Above ground lighting is constantly illuminated, even during the day, despite the fact that there is enough natural daylight to light up offices. An average of 4 tube lights (36 W) at 50 offices will save about 86 kWh per day if they are switched off for 12 hours a day.

Geyser systems in the mine villages of Blyvooruitzicht and Doornfontein make use of boilers which consume between 300 W and 400 W per boiler. This results in a total energy consumption of 50.4 kWh at Blyvooruitzicht and 84.4 kWh at Doornfontein. It was suggested that solar water heaters be installed to decrease the electricity costs of the geysers.

Investigations into co-generating electricity, specifically hydroelectricity, were carried out. At Shaft 5 at mine ZZZ approximately 2.5 Mℓ per day of water descends into surface dams. The best case scenario for power generation at mine ZZZ is water flowing through a 14" pipe at a rate of 2 500 m^3 per day from a height of 1 757 m. Assuming this occurs for 6 hours the power generated is 573 kW.

10.5.2 Mine YYY

Mine YYY is located in Boksburg. The problem statement for the study performed at YYY mines was "How can Mine YYY lower its production costs and become more efficient?" Specific areas researched were; the ice plant, compressors, water, electricity and lighting, the same factors as investigated at mine ZZZ.

The monthly average ice-production by the ice plant is 1 700 m^3 per month. Two tube and one plate ice makers are operated 24 hours per day, 7 days per week. The ice is used to cool water underground. The cooled water supplies the heat-exchangers, the main air coolers, underground. There was insufficient maintenance of the ice plant, resulting in worn valves and broken parts of the ice-making equipment. At the time of the first visit, it was observed that from the five ice making units, only 3 are working. The water meters were broken and thus efficiencies of operation of either the tube or plate ice makers could not be estimated. Of a total of 1 440 spray nozzles, 214 were broken (15%). At present the spray nozzles of the tube ice makers are unblocked, increasing the efficiency of ice-making, meaning less water was needed to make the same amount of ice. However, although there are relative savings in costs per ton of ice, absolute savings are not realised as Rand savings because, although more efficient, the production of ice has increased from 1 800 ton ice to 2 100 ton ice per month. Currently mine YYY are looking to replace the tube ice makers with plate ice makers, as these are more efficient.

Currently four compressors supply the mine with compressed air. One compressor operates 24 hours per day, seven days per week, supplying 25 000CFM (cubic feet per minute), the other three operate during drilling hours (8am-2pm) and produce 1500CFM. Loss of compressed air due to leakages equates to R727 780 per year. The mine workers use compressed air for cooling and ventilation purposes results in losses of R98 618 per year per compressed air hose opened. The 100 rock drills used on site use 40% of the compressed air. Replacing all pneumatic rock drills with electric ones will reduce compressed air usage. Mine YYY was at the time installing a new compressor to replace three rented Rand air compressors. This creates opportunities for air storage to avoid compressed air production in peak hours. Underground storage would provide the most effective storage. At the time about 6 million kWh/month was used at mine YYY.

Installation of solar panels would decrease reliance on Eskom and reduce electricity costs which are about R1 million per month and decrease CO_2 emissions (±6 000 ton CO_2). The Kyoto protocol makes it possible for South Africa to sell carbon credits which can possibly yield R150 per ton CO_2. Water is mainly used for ice production. Underground ammonia chillers can be used for cooling water and underground cooling is insufficient.

Lighting above ground is all incandescent. Only when a fluorescent tube needs replacement is the ballast and tube replaced with the energy saving version. Some 100 W bulbs are still used. Lights can be switched off above ground during the day since there is sufficient sunlight. At mine YYY there is no electricity/ energy management system and no energy awareness is carried out for staff working at the mines. Currently mine YYY use 50 MW of electricity. There is the perception that energy management and changes such as energy efficient lighting and energy awareness campaigns will not significantly contribute to the 10% decrease in electricity required by Eskom. During the peak of the recent electricity crisis it was calculated that by switching off all the lights in the mine YYY village would only save 100 kW. Mine YYY is looking for energy efficiency measure for major equipment, which would aid them in reaching the 10% decrease in electricity target set by Eskom. Mine YYY pumps out 50 Mℓ of water from underground per day using four large pumps. Four pumps consume 18 MW altogether, and during the rainy season every single one is required to operate at maximum capacity in order to pump the water from underground otherwise production is compromised. Outside of the rainy season one pump may be switched off, which will then result in the 10% electricity decrease desired by Eskom, but this is only at a certain time of the year. It is not a constant, practical result as it depends on the rain. The pumps operate at maximum capacity or not at all, therefore Variable Speed Drives are seen as unnecessary. Mine YYY is looking for assistance with respect to energy efficiency measures for large electricity consuming equipment.

10.5.3 XXX Mines

XXX Mines is located in Johannesburg, South Africa. The aim of the study undertaken at XXX Mines was “To determine a good overview of water “waste” situations at XXX Mines to achieve CP”. The objective of this investigation was to analyse the process of water usage at XXX Mines. To indicate where and why water is wasted with the aim to eliminate, recycle and reduce the abuse of water, in order to lower the production cost, to preserve enough water for the future and to be able to look after the well-being of nature. A water balance at XXX Mines over the month of September was performed. This was compared to the ideal or “best” balance for the same month. Comparing the actual water balance and “best” balance leads to conclusions on less water consumption from reclamation (generated water), more generating and less addition water at the plant. XXX Mines is interested in the generated and the additional water (Rand water) at the plant, because the other topics (like water usage reclamation) are already known.

Table 10: Actual water balance for September 2007 at XXX Mines

Water balance (m^3)	Water in	Generated water	Additional water	Water out
Reclamation	550 722			
Thickeners		13 019		
Plant			149 145	
City Deep	232 593			
Residue				919 441
Total	783 315	13 019	149 145	919 441

Reclamation density is 1.362 kg/ℓ, cyclone underflow density is 1.567 kg/ℓ, thickener underflow density is 1.274 kg/ℓ and residue density is 1.339 kg/ℓ.

Table 11: Ideal or “best” water balance for September 2007 at XXX Mines

Water balance (m^3)	Water in	Generated water	Additional water	Water out
Reclamation (1450)	365 792			
Thickness (1450)		17 714		
Plant			123 224	
City Deep	232 593			
Residue (1415)				703 895
Total	598 385	17 714	123 224	702 895

Reclamation density is 1.450 kg/ℓ, cyclone underflow density is 1.800 kg/ℓ, thickness underflow density is 1.450 kg/ℓ and residue density is 1.415 kg/ℓ. Accuracy is 80%. Generated water is that reclaimed from mine dams, by controlling the underflow and overflow densities during recycling of the dam water it is possible to increase the amount of water reclaimed/generated. If the amount of water generated by recycling is increased then less water needs to be purchased from Rand water. The best possible scenario is presented in Table 11.

Results of the study revealed that the total cost of Rand Water in September 2007 was R1 043 694 and that the total saving of Rand water in September can be R520 310. This can be achieved by improved housekeeping without additional capital outlay.

10.5.4 Mine WWW

The Mine WWW receives final concentrate from Plant VVV and metallic concentrate directly from some concentrators in the Group and joint ventures. The concentrate is refined into the respective PGMs and gold to high degrees of purity, which is customised to meet market requirements. Through this activity, Mine WWW generates 350 m^3 of 4.5N HCl. This is regarded as waste acid, but it has to be neutralised to pH 8 before it is sent into the evaporation dams. A lot of lime was being used to adjust the pH to 8. Metsep are contracted to provide Mine WWW with 10N HCl which is used in different stages during the extraction of PGMs.

An agreement was reached between Mine WWW and Company UUU to collect the waste acid and used it as the raw material during production of concentrated HCL. With this project, Mine VVV saved money that would have used to buy lime, time, inconvenience and the risk associated with hazardous waste.

CHAPTER 11 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

11.1 Discussion

The project was initially scheduled for three years (2004 to 2007) but due to difficulties that were experienced during the scoping study in getting industry buy-in into the project, it was later extended to four years (2004 to 2008).

Industrial representation at the initiation workshop was poor. In addition, difficulties were experienced in arranging meetings with industrial representatives in order to complete the questionnaire. Many industrial representatives felt that they were already practicing CP under different terminology and that CP would be another procedure to add to the list of procedures already being followed. Reasons for the lack of participation by the industry include:

- Internationalisation by large SA mining companies and the time spent on meeting international reporting requirements;
- Focus on ISO systems implementation and Global Reporting Initiative requirements;
- High commodity prices leading to a large amount of new projects;
- Lack of skilled and experienced manpower to deal with all these issues; and
- Stakeholder fatigue from many new initiatives.

The strategy thus was to link on to existing forums and present data and case studies that indicate that CP is a tool that can be used to assist in the attaining of ISO 14001 and in maintaining the certification once it is achieved. CP is also a tool that can be used to assist with the complying with current and future legislation and can assist in the expediting of the licensing processes.

An awareness campaign was carried out with all stake holders in the mining industry, e.g. mining houses, Chamber of mines, academic institutions, mining consultants, DEAT, DWAF and DME. The stakeholders were given a chance to comment on the draft CP guidance document for the mining industry and their comments were integrated into the final document.

Barriers hindering the adoption of CP technologies in the South African mining industry were identified during the course of the project, the main ones being economic, technological, managerial and legislative barriers. But through cases studies presentation and benefits of CP, methods of overcoming barriers were developed.

Two CPFs in the mining industry were formed – one in the coal mines and the other in the in the gold mines. The drive in the forums was energy efficiency, water recycling, water quality and reclamation of fines and discard. The LCA, CP assessment and water related threats studies also identified a number of CP opportunities within the mining industry and many ideas and technologies have been implemented through this project. These include:

- The installation of variable speed drives on the conveyor belts;
- The installation of new light bulbs;
- The installation of solar panels and geyser blankets;
- The introduction of a 5 minutes idle period on the Dozer machines before being switched off completely, so that the high energy demand for switching the dozers on can often be avoided;
- The initiation of several awareness raising initiatives;
- Improved recycling of water for processing and dust suppression;
- Maximizing the coal size in the crusher from 80 mm to 90 mm to reduce the amount of ultra fine coal;
- The optimisation of the classifying cyclones to prevent coarse coal from being disposed;
- The installation of an advanced water treatment plant that allows for the mine water to be reused as potable water on the mine site and in the mine's own mine villages; and
- An investigation into the use of electric drills.

The findings of the studies and activities conducted during this project confirm that there are several CP opportunities for implementing CP interventions in the mining industry.

11.2 Recommendations

CP technologies need to be implemented to ensure that scarce resources, especially water and energy are saved, and are essential to ensure that new projects can be implemented in the dry areas where a lot of the new developments will take place.

Recommendations to the industry and associated stakeholders Include:

- Each mine to appoint champions that are responsible for leading and carrying out CP. An environmental engineer, production manager, or plant process engineer may be a good candidate for this role. Regardless of who takes the lead, this champion must be given enough authority to effectively carry out the program;
- Measure and record mine mass and energy flow (i.e. install monitoring systems, conduct mass and energy balance) (Reddick, 2006);
- Modify company policies to encourage the adoption of CP by facilitating the approval of CP ventures, by implementing training programmes and by providing incentives for the employees to practice CP; and
- Involve vacation work students in on-site CP studies to enhance the environmental education of future mining and mineral processing engineers.

Recommendations for further research and monitoring CP projects includes:

- The public and the regulators need to find a way to challenge the mining industry to reduce coal fine wastes and to optimise electricity consumption, particularly in the gold mining sector;
- The design and implementation of training programmes for regulators in respect of CP needs to be encouraged;
- The Guideline Document needs to be widely distributed to the industry, consultants and regulators. Its availability should be advertised in the press and at conferences. Training programmes should be conducted with people who would find it useful;
- Service providers/consultants interested in the implementation of CPFs should be trained. Managing CPFs is an ideal environmental product as it will provide income for the service providers while aiding the industry in becoming more competitive and sustainable;
- Bursaries should be provided to students for LCA investigations, CP and consumption studies, CPFs and water and energy efficiency studies;
- The WRC needs to continue support for all CP initiatives as the cost saving and ability of these interventions to make a marked difference to the way industry conducts its businesses is remarkable;
- There needs to be support for all initiatives to lower the power consumption of SA mines per unit of product;
- There needs to be support for all research initiatives into preventing ARD from occurring from all residue or discard facilities, waste rock dumps and mine workings;
- The use of fine coal and initiatives to enhance its calorific value by air drying it should be promoted;
- Research into the deportment and eventual fate of all sulphur in a coal mine needs to be supported;
- There should be targeted training programmes and awareness campaigns. A WRC project could include lectures to all local, provincial and national authorities tasked with implementing CP. Awareness campaigns should be developed for the mining industry which can be used at all levels in organizations;
- The benefits of the utilisation of the various tools such as LCAs, CPFs, etc. to the industry needs to be publicised in order to get them implemented;
- There should be sponsorship available for organisations to establish and run CPFs in different areas;
- Support needs to be given to industrial symbiosis projects whereby different industries co-operate and that CPFs do not just become a mining industry initiative;
- There needs to be support projects which look at ways of getting water to the drier parts of the country in the eastern and western limbs of the BIC, particularly if that water comes from mine water and costs may be saved if it is used rather than water which is not saline. This will also save expensive water treatment costs;
- All work on energy efficiency projects should be encouraged;
- The WRC needs to continue supporting projects which seek to minimise the water quality impacts from mine waste and mine workings; and
- The WRC needs to find ways to assist the Department of Water Affairs in implementing the law such that give security and assurance to water users.

Generally this project has achieved its aims and objectives by ensuring that many more parties have been made aware of the benefits of adopting CP approaches and that the tools have been tried and tested in the South African mining industry. So much more still needs to be done to assist the industry in performing better than it does at present and to assist in the very necessary task of employment and wealth creation. The potential benefits of increasing the efficiency of the SA mining industry are so enormous that every effort in this regard deserves the support of all government and industry agencies.

REFERENCES

BOWMAN, M. and N. CHETTY (2006) Quantification of the Ecological Footprint of Gold in South Africa. Research Report, Faculty of Engineering and Built Environment, University of Cape Town.

CHAMBER OF MINES (2008) The South African Mining Industry's Sustainability and Transformation Report. Johannesburg: SA Chamber of Mines.

DWAF (2004a) National Water Resource Strategy. Pretoria: Department of Water Affairs and Forestry.

DWAF (2004b) National Water Conservation and Water Demand Management Strategy. Pretoria: Department of Water Affairs and Forestry.

DWAF (2004c) Water Conservation and Water Demand Management Strategy for the Industry, Mining and Power Generation Sectors. Pretoria: Department of Water Affairs and Forestry.

ENVIRONMENTAL AUSTRALIA (1997a) Best Practice Environmental Management in Mining – Managing Sulphidic Mine Wastes and Acid Drainage. Australia Environment Protection Agency.

ENVIRONMENT AUSTRALIA (1997b) Best Practice Environmental Management in Mining – Hazardous Materials Management, Storage and Disposal; Onshore Minerals and Petroleum Exploration; Managing Sulphuric Mine Wastes and Acid Drainage. Australia Environment Protection Agency.

FORBES, P., H. VON BLOTTNITZ, P. GAYLARD and J.G. PETRIE (2002) Environmental Assessment of Base Metal Processing: A Nickel Refining Case Study. South African Institute of Mining Metallurgy, Journal Transactions, 100(6), 347-53.

HILSON, G. (2000) Barriers to Implementing Cleaner Technologies and Cleaner Production Practices In The Mining Industry: A Case Study Of The Americas. Minerals Engineering, 13(7), 699-717.

HILSON, G. and V. NAYEE (2002) Environmental management system implementation in the mining industry: A key to achieving cleaner production. International Journal of Mineral Processing, 64, 19- 41.

KIKER, G.A. (2004) South African Country Study on Climate Change, Synthesis Report for the Vulnerability and Adaptation Assessment Section. In KIKER, G.A (Ed): Climate Change Impacts in Southern Africa. Report to the National Climate Change Committee, Department of Environmental Affairs and Tourism, Pretoria, South Africa.

LESKE, T. and C. BUCKLEY (2004) Towards the development of a salinity impact category for South African life cycle assessments: Part 3 – Salinity potentials. Water SA, 30(2), 253-64.

REDDY, A. (2005) Personal communication, November 2005. Accounts Manager, Senmin.

ROGERS, D.E.C. and I. BANOO (2005) National Cleaner Production Strategy. Pretoria: Department of Environmental Affairs and Tourism.

RWODZI, B. (2000) An environmental assessment of recycling options for used lubricating oil in South Africa. Research Report, Faculty of Engineering and the Built Environment, University of Cape Town.

TRAUTMANN, C. and M. SCHOLTZ (2007) Environmental Life Cycle Assessment of Fine Coal Use for Power Generation in South Africa. Research Report, Faculty of Engineering and the Built Environment, University of Cape Town.

UNEP (2004) Sustainable Consumption and Production Activities in Africa. Regional Status Report (2002-2004).

World Bank Guidelines, Mining and Milling – Open Pit, 1995

UNITED NATIONS (1972) Our Common Future: Report of the World Commission on Environment and Development. Oslo: United Nations.

BIBLIOGRAPHY

BARCLAY, S.J. and C.A. BUCKLEY (2006) Applicability of Waste Minimisation Clubs in South Africa – Results from Pilot Studies. *Water Research Commission, TT 161/05.* Pretoria: WRC.

BARCLAY, S.J. and C.A. BUCKLEY (2007) Facilitators' Manual for Establishing and Running Waste Minimisation Clubs in South Africa. Water Research Commission – To be published.

CEST (1995) *Waste Minimisation – A route to profit and cleaner production. Final Report on the Aire and Calder Project.* London: Centre for Exploitation of Science and Technology.

COMMON GROUND and DE VILLIERS BROWNLIE ASSOCIATES (2003) *A waste minimisation guideline document for environmental impact assessment (EIA) reviews.* Cape Town: Department of Environmental Affairs and Development Planning.

DE SIMONE, L.V. and F. POPOFF (1997) *Eco-Efficiency: The Business Link to Sustainable Development.* Cambridge: MIT Press.

DEAT (2005) *South African National Cleaner Production and Sustainable Consumption Strategy, Version 2, Draft 3, August 2005.* Pretoria: Department of Environmental Affairs and Tourism.

DOYLE, W.S. (1976) Strip mining of coal – Environmental solutions. Park Ridge: Noyes Publications.

EEEB Best Practice Programme (1998) *Good Practice Guide 112 – Monitoring and Targeting in Large Companies*. Oxfordshire: Energy Efficiency Enquiry Bureau.

ENVIRONMENT AUSTRALIA (1995a) *Best Practice Environmental Management in Mining – Mine Planning for Environment Protection.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (1995b) *Best Practice Environmental Management in Mining – Planning a Workforce Environmental Awareness Training Programme.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (1995c) *Best Practice Environmental Management in Mining – Environmental Management Systems.* Australia Environmental Protection Agency.

ENVIRONMENTA AUSTRALIA (1998a) *Best Practice Environmental Management in Mining – Noise, Vibration and Air blast Control.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (1998b) *Best Practice Environmental Management in Mining – Cyanide Management.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (1998c) *Best Practice Environmental Management in Mining – Dust Control.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (1999) *Best Practice Environmental Management in Mining – Water Management.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (2000) *Best Practice Environmental Management in Mining – Cleaner Production.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (2002a) *Best Practice Environmental Management in Mining – Energy Efficiency.* Australia Environmental Protection Agency.

ENVIRONMENT AUSTRALIA (2002b) *Best Practice Environmental Management in Mining – Training package (Volumes 1, 2 and 3).* Australia Environmental Protection Agency.

ENVIROS CONSULTING (1999) Waste Minimisation Training Modules. http://www.enviros.com. (Accessed February 2009).

KLEIN, J. (2007) Personal Communication, 30 October 2007. Plant Superintendent – Middelburg Mine.

REDDICK, J. (2006) An Investigation Of Cleaner Production Opportunities In The South African Coal Mining Industry. Research Report, Faculty of Engineering and Built Environment. University of Cape Town.

RASOWSKI, L. (2001) Changes of Groundwater chemistry caused by the flooding of Iron Mines (Czestochowa, Southern Poland). *Journal of Hydrology, 244*, 17-32.

UNEP (1996) Cleaner Production: A Training Resource Package. Paris: United Nations Environmental Programme.

UNEP (1998) Cleaner Production in Pulp and Paper Mills: A Training Resource Package. Paris: United Nations Environmental Programme.

UNEP (2000) Government Strategies and Policies for Cleaner Production. Paris: United Nations Environmental Programme.

APPENDIX:

Best Practice Guidelines for Water Resource Protection in the South African Mining Industry (Department of Water Affairs and Forestry, Series A, G and H)

The Best Practice Guidelines for Water Resource Protection in the South African Mining Industry were prepared for all mines and regulators to the mining sector. The aim of these Guidelines documents is to *(DWAF, 2006):*

- Be utilised by the mining sector as input for compiling water use licence applications (and other legally required documents such as EMPs, EIAs, closure plans, etc.) and for drafting licence conditions.
- Serve as a uniform basis for negotiations through the licensing process prescribed by the National Water Act.
- Be used specifically by DWAF personnel as a basis for negotiation with the mining industry, and likewise by the mining industry as a guideline as to what the DWAF considers as best practice in resource protection and waste management.
- Inform Interested and Affected Parties on good practice at mines.
- There are three series of Guideline Documents:
- A series which relate to mining activities or aspects and address prevention and management of impacts. All guideline documents in the A series contain a summary of relevant legislation and best practice checklists relevant to the particular issue being discussed. These checklists can be used in conjunction with the checklists provided in Appendix 3 of this Guideline document;
- G Series which dealing with general water management strategies, techniques and tools which could be applied cross-sectorally; and
- H series which deal with aspects of DWAF's water management hierarchy.

A list of the documents together with a summary of the aims is provided in Table A below. Copies of these Best Practice Guideline Documents can be obtained from the DWAF or downloaded off their web site **(www.dwaf.gov.za)**

Table A: Summary of DWAF Best Practice Guideline Documents

Guideline Document	Aims of Document
Series A: Activity Guidelines	
A1: Small Scale Mining – User Format (2006) (available in English, Zulu and Sotho) Standard format also available for regulators	• To provide a simple guide to the licences, permits or authorisations required by a small scale miner; • To outline the responsibilities a small-scale miner has to ensure protection of water resources; • To assist in identifying potential areas of concern and impact for each type of small-scale mining; • To describe the main basic measures needed to prevent and minimize the impact on water resources; • To clarify what is required by the Department of Water Affairs and Forestry (DWAF) regulators to satisfy them that water pollution prevention and minimization measures has been correctly applied at each stage of the life cycle of the mine; • To describe the use of an Environmental Management Plan (EMP).
A2: Water Management for Mine Residue Deposits (2007)	• To provide practical guidance and steps on water management best practice over the full life cycle of the MRD or the mines MRD requirements; • To provide clarity on legal requirements and compliance and to provide guidance on the legal requirements for water management, in terms of the prevailing South African legislation; • To minimise potential impacts on safety and the environment over the life of the MRD or mines MRD requirements through the use of best practice guidelines for water management; • To cover water management aspects for various types of MRDs • To provide guidance on appropriate tools to be used for water management on MRDs, to complement those that are covered in other BPGs • To provide examples of some of the water management aspects for MRDs.
A3: Water Management in Hydrometallurgical Plants (2007)	• To promote a strategic water management approach at hydrometallurgical processing plants that views and manages water as a key business asset with social, cultural, environmental and economic value. • To provide a practical and logical process whereby water management within hydrometallurgical can be optimized, including pollution prevention at source and the application of cleaner technologies.
A4: Pollution Control Dams (2007)	• To provide guidance on water management best practice for PCDs • To inform DWAF officials and other users of the BPG on the procedures involved in the specification and design of PCDs • To provide guidance on the philosophy of the planning and operations of PCDs and the integration of these into the overall mine water management system • To ensure that potential impacts on safety and the water resource are acceptable/managed over the life of the PCD, in a consistent manner throughout South Africa, through the use of best practice guidelines for water resource management, and • To provide guidance on appropriate tools for the design and management of PCDs, to complement those that are covered in other BPGs.

Guideline Document	Aims of Document
A5: Water Management for Surface Mines (2008)	• To provide an overall context for water management which will illustrate the integration between water management in the broader catchment and the mine-specific water management • To explain the hierarchy of water management and its applicability to surface mining • To provide practical guidance on the water management measures to be included in the mines Environmental Management Plan (EMP), Integrated Water Management Plan (IWMP) and Integrated Water Use Licence Application (IWULA) documents. • To provide practical guidance and steps on water management best practice over the full life cycle of a surface mine • To cover water management aspects for various types of surface mines and mining methods • To assist in ensuring efficient water use on a mine, and • To provide guidance on appropriate tools to be used for water management on surface mines, to complement those that are covered in other BPGs
A6: Water Management for Underground Mines (2008)	• To provide DWAF officials with an understanding of the water management issues involved in underground mining operations in order that they are able to interact with mine water managers on a more proactive basis with regard to water management issues that have their origin in the underground mining operations. • To provide information to water managers with the mining industry that will provide clarity on information that DWAF officials will be seeking from them. • To promote a strategic water management approach at underground mining operations that views and manages water as a key business asset with social, cultural, environmental and economic value. • To provide a practical and logical process whereby water management within underground mining operations can be optimized. • To provide guidance on factors that need to be considered when planning for all life cycle phases and particularly closure of underground mining operations.
Series G: General Guidelines	
G1: Storm Water Management (2006)	• To provide a practical procedure to develop a SWMP. • To define the contents of a management system that will ensure compliance with the targets and objectives of the SWMP. • To define where the expertise of suitably qualified persons is required at the various stages of plan development, implementation, operation and review/audit. • To reference relevant legislative and policy issues that need to be considered in a SWMP.
G2: Water and Salt Balances (2006)	• To develop a practical procedure to develop balances. • To define what should be contained in the balances. • To give guidance on the level of detail that a balance should contain. • To define best practice for design, implementation and continuous management of a water and salt balance. • To provide an assessment of tools that can be used to develop water and salt balances. • To provide a practical worked example of a water and salt balance in which the principles discussed here have been applied.
G3: Water Monitoring Systems (2007)	• To provide clear guidelines on how to design an effective monitoring programme that meets defined management needs. • To provide guidelines on how to implement a monitoring programme such that the acquired data is reliable and supportive of the defined management needs. • To provide guidelines on how to interpret, manage and report the data obtained from implemented monitoring programmes.

Guideline Document	Aims of Document
G4: Impact Prediction	• To present the impact assessment and prediction framework and methodology based on risk assessment principles. • To provide specific guidance on the types of questions that need to be considered and answered when undertaking impact predictions and evaluating management options for different mining scenarios at different stages in the mine life cycle, in order that appropriate decisions can be made. • To give a brief overview of physical, chemical and biological processes involved in generation of acidic, neutral and saline drainages, as well as groundwater flow and contaminant migration. • To describe the capabilities and limitations of different approaches, tools and techniques available for impact prediction. • To describe the elements of uncertainty that are inherent in any impact prediction, given the nature of the process (source term, pathway and receptor) being evaluated, the assumptions and uncertainty inherent in a data collection exercise and the limitations and assumptions inherent in prediction tools. • To provide guidance on the nature of a monitoring, predictive model validation and calibration programme and independent review necessary to give the required confidence in the impact prediction. • To provide guidance on the contents of a water resource impact prediction report. • To provide capacity building for DWAF officials in the review and understanding of impact prediction exercises.
G5: Water Management Aspects for Mine Closure (2008)	• To ensure that all stakeholders have their water resource-related interests considered during the mine closure process. • To ensure that the closure planning process, from a water management perspective, is undertaken in a logical, orderly, defensible, cost-effective and timely manner throughout the mine life cycle. • To ensure that appropriate tools and specialists have been utilised to make long-term post-closure predictions of water management risks, that these predictions have been validated and verified. • To ensure that clear water resource-related closure objectives are defined and agreed upon and that these consider sustainable land use and environmental water balance issues and that the mine has provided clear accountability and adequate resources for the implementation of its closure plan to meet the agreed closure objectives. The defined closure objectives must have built in conservatism to allow for uncertainties and to allow for continuous improvement and future use and development. • To ensure that the costs associated with water management actions, both for decommissioning and post-closure, are adequately and correctly represented in the mine's financial provisions and that the community / DWAF / taxpayer is not left with a residual water management liability. • To ensure that a set of indicators are established which will demonstrate the successful completion of the closure process and attainment of the agreed closure objectives in a sustainable manner and that will enable approval of the mine closure application process. • To provide guidance on information that DWAF needs to have access to in order to be able to review and assess a mine closure application.

Guideline Document	Aims of Document
Series H: Hierarchy Guidelines	
H1: Integrated Mine Water Management (2008)	• To ensure that it is understood that, in the planning and implementation of integrated mine water management, cognizance needs to be taken of integrated water resource management aspects at national, regional and site-specific levels in addition to the source-directed actions mainly addressed in the BPGs. • To present and promote the concepts and benefits of integrated mine water management throughout the mine life cycle, using practical examples to illustrate the application of the key principles. • To ensure that DWAF personnel, mining proponents and consultants understand the role of the BPGs and how and when to use them in implementing integrated mine water management. • To define the minimum contents of an IWMP, the level of detail required and the role of specialists in preparing and reviewing IWMPs.
H2: Pollution Prevention and Minimization of Impacts (2008)	• To ensure that pollution risks and pollution prevention opportunities have been identified, optimized and implemented during the exploration, planning, operation and closure phases of a mining project. • To ensure that measures implemented and decisions taken at any point in time, consider the effect of those decisions throughout the remaining life cycle. • To present a process to identify the pollution risks and opportunities that remain after optimization of pollution prevention measures, which are then • Addressed in terms of impact minimisation. • To define procedures that can be utilized to identify and assess pollution prevention and impact minimisation management actions. • To promote the consideration of the impacts of a management action over the full life-cycle of the mining operation in order that pollution prevention is maximized over the full life-cycle.
H3: Water Reuse and Reclamation (2006)	• To clearly define the process that should be applied by a mine when developing a mine water reuse and reclamation plan and that will be applied by DWAF when reviewing/evaluating a mine water reuse and reclamation plan within the bigger context of the mine's IWWMP. • To define a process that, when applied, will clearly indicate to DWAF that water reuse and reclamation have been applied effectively and that the mine may move to negotiations regarding discharge or disposal if required. • To define the structure and content of a report or section of a report (section of IWWMP) or product that must be submitted to DWAF to enable the review/evaluation of the mine water reuse and reclamation plan or IWWMP.
H4: Water Treatment (2007)	• To clearly describe the technical methodology that should be applied by a mine to identify the constituents of concern that may require mine water to be treated to enable sustainable reuse or discharge (in accordance with an approved water use licence, catchment management objectives, etc.). • To describe a methodology that, when applied, will enable the identification of suitable types of water treatment technology for the removal of constituents of concern and safe disposal of residues (brine and sludge management) thereafter. • To enable the mine to prepare the relevant sections of an IWWM plan that deals with water treatment.