CHAPTER ONE: INTRODUCTION

1.1. Background to the Study

Mining involves excavation, drilling, blasting, smelting, and refining processes (International Labour Organisation, 1999) that reduce the quality of the physical and working environments and pose risks to lives of both human and non-human species. It generates large quantities of dust, fumes and toxic substances that cause the deterioration of human health and loss of aquatic, floral and faunal life. Mining companies develop environmental management systems (EMSs) to combat these impacts, comply with legislation, assure stakeholders that their production processes are safe and command a place on the international market. Effective environmental management programmes (EMPs) are needed to protect the environment, for the companies to be abreast with modern trends in mining and to safeguard them from legal liabilities.

Mining companies in the developed world implement effective programmes in response to pressure from an alert community which demands integration of economic activities with environmental management (EM) (Tolba, 1982). In developing countries, there is mounting pressure from international markets for companies to institute EMSs for their products to be competitive on the global market. Some environmental conservation pressure groups also demand that processing and manufacturing companies ought to reduce or eliminate environmental degradation from their operations. It has thus become imperative for companies to design effective EMSs so as to meet the demands of an aggressive economic environment. Thus an EMS has become an inseparable part of today's modern industrial development (Hart, 2001).

The implementation of the EMPs, however, poses a great challenge to many companies in the short term. The companies have to commit huge financial resources, engage environmental conservation experts, tie up loose practices and periodically train their manpower for them to be abreast with the demands of the EMPs (Natoli, 1995). Management has to provide resources, equipment and spare parts so that their operations are efficient and the emission control devices are kept in working condition. These operational practices have to be put in place to ensure that environmental aspects are contained and the desired objectives are achieved. In the long term, Cascio (2000) contends that effective EMS enables companies to realise lower production costs from more efficient processes that reduce input consumption and waste generation. However, the challenges alluded to have scared away some companies from implementing the well-documented EMPs and the environment continues to be exposed to the harmful impacts of the mining processes.

Unless the EMS is integrated into the mainstream business activities, the environment continues to suffer from the harmful impacts of mining operations (Anderson, 2003: Wells et al, 1994). The pressing issue in modern mining practice is to treat EM as part of the core activities of the mining concern. In doing so it is realised that EM serves a dual purpose: it protects the environment from degradation and reduces the volume of resources, such as electricity and water, consumed in operations thereby making a saving in operational costs (Johnson 1998, Smith, 1991). Effective EMSs are necessary for the mining companies to realise these benefits and to enhance production. Determining the performance of management systems is necessary in identifying strengths and weaknesses for mapping the way forward in designing and implementing effective EMPs.

1.2. Statement of the Problem

The impacts of mining on the near and distant environment are immense. At Trojan Nickel Mine (TNM) and Bindura Smelting and Refinery (BSR) over 1,500 workers and their dependents, villagers/farmers and their animals/crops and water sources - Pote and Mazowe Rivers - are vulnerable to emissions from mining and mineral processing operations. People are exposed to dust that causes pneumoconiosis and to irritant gases such as sulphur dioxide (SO_2) that affect respiratory functions and aquatic, faunal and floral life to toxic pollutants that endanger their existence. Bindura Nickel Corporation (BNC) developed an EMS but International Labour Organisation (1999) contends that, often, there exists some discrepancy between policy statement and what is practised. In addition, literature on the impacts of mining on the environment abounds but is scarce on the effectiveness of EMS at operating mines. This research strives to fill the emerging gaps, evaluate EMPs' performance and make recommendations on the design of effective EMPs at TNM and BSR and for the mining sector.

1.3. Objectives

1.3.1. General Objective

The main objective of the study was to evaluate the effectiveness of major environmental management programmes at Trojan Nickel Mine (TNM) and Bindura Smelter and Refinery (BSR).

1.3.2. Specific Objectives

The specific objectives of the study were:

- ♦ To identify the major EMS components and assess their contribution to environmental management at TNM and BSR.
- ♦ To determine the environmental performance indicators of the major environmental management programmes at TNM and BSR.
- ♦ To evaluate the performance of major EMPs at TNM and BSR.
- ♦ To make policy recommendations on the design and implementation of effective EMPs in the mining industry.

1.4. Definition of Terms

ISO 14031 (1999: 1-3) defines the following key terms as they are used in environmental management.

Environmental Aspect (EA) - element of an organisation's activities, products or services that can interact with the environment.

Environmental Condition Indicator (ECI) - specific expression that provides information about the local, regional, national, or global condition of the environment.

Environmental Management System (EMS)- the part of the overall management system that includes the organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.

Environmental Objective (EO) - overall environmental goal, arising from the environmental policy, that an organisation sets itself to achieve, and which is quantified where applicable.

Environmental Policy (EP)- statement by the organisation of its intentions and principles in relation to its overall environmental performance which provides a framework for action and for the setting of its environmental objectives and targets.

Environmental Target (ET) - detailed performance requirement, quantified were practicable, applicable to the organisation or parts thereof, that arises from environmental objectives.

Management Performance Indicator (MPI)- environmental performance indicator that provides information about the management efforts to influence an organisation's environmental performance.

Operational Performance Indicator (OPI) - environmental performance indicators that provide information about the performance of an organisation's operations.

1.5. Justification of the Study

A lot of researchers have written about the environmental impacts of mining in the form of land, air, noise and water pollution. Little, however, was written on the effectiveness of the EMPs instituted by mining companies to reduce or eliminate the cause of the impacts. This research documented and assessed the effectiveness of the control measures that were put in place at a local mining environment, TNM and BSR. The findings provide a source of reference on the evaluation of EMSs and reading material for planning and monitoring needs which Dayal-Clayton (1996) regards as inadequate.

The attainment of ISO 14001 by TNM and BSR in 2003 was an achievement. It was an indication of the company's commitment to continually improve environmental conditions at the immediate and distant environments from its operations. The implementation procedures such as training and awareness among the employees were reviewed, as they are fundamental in the implementation of the EMS. The research sought to give some insights into the extent of the progress that was made in reducing the amount of pollutants that was discharged into the environment. The findings were meant to help the company improve where there was need and reinforce where it was doing well.

The research makes some recommendations on effective implementation of EMPs at mines. The findings become a basis upon which policies for the protection of the environment and integration of economic production and environmental conservation could be developed. In the end, the research develops insights among researchers and policy planners on what is needed to develop effective programmes for sound economic and environmental development.

1.6. Scope and Limitations of the Study

The study looked into the management of environmental aspects at TNM and BSR that were of major significance according to the company's ranking in the aspect register. A broad range of aspects were managed at TNM/BSR, but four - effluent discharge, sulphur dioxide emission, oil spillage and dust emission - were studied. The time available was limited, it could only accommodate a few aspects to be studied. The aspects were studied at source of generation and the near environment (Figures 3.1 and 3.2, pages 28 and 30 respectively). The effectiveness of the EMPs was judged using ISO 14031 standards, that is, what was recorded in EMS documents for 2003 and what was measured in 2004 against set targets or WHO recommendations. Furthermore, compliance with local legislation was also a criterion used to judge the effectiveness of the EMPs.

Three parameters - management (MPIs), operational (OPIs) and environmental condition (OCIs) indicators were used to determine the effectiveness of the EMPs. The MPIs among other issues entailed the commitment of the management, the programmes that were designed and the financial resources that were committed to the EMS. The OPIs entailed the practices, that is, what was done for instance recycling, plant maintenance and monitoring to ensure that set objectives were achieved. The ECIs entailed the state of the environment as desired by the company in the EMP documents. The research determined these indicators then used them together with the data that were collected from the field through measurements to assess the effectiveness of the EMS.

The study experienced some difficulties that made data collection difficult. The costs of analysing oil concentrations in water and soil were prohibitive thus basic minimum number of samples, 8 for water and 5 for soil, were taken for the insitu study. The study of SO_2 was the first of its kind at the study area thus there were no past records to refer to. The study of fallout dust was deterred by the long rainy season that continued until mid April 2004. It was measured once and for lack of any other comparative measurements, it was left out of the study The study was conducted in one season thus did not cater for variations in wind direction and speed that affected the dispersal of SO_2, one of the variables.

1.7. The Study Area

TNM and BSR together with Shangani in Matebeleland are part of BNC whose main business is nickel mining and processing. Mining and ore concentration are done at Trojan and Shangani then delivered to BSR for smelting and refining. The study area is discussed in two perspectives: its location and the operations that generated the aspects managed.

1.7.1. Location and Characteristics of the Study Area

TNM and BSR are located ninety (90) kilometres north east of Harare, nine kilometres south of Bindura Town in Mashonaland Central, Figure 1.1, along the Musana/Bindura Road. It lies within a 7km by 7km piece of land in agro-ecological region 2, deep in a crop farming and animal rearing area. Maize, cotton, soya bean and winter wheat are the main crops that are grown while cattle, goats, sheep and donkeys are bred in the nearby farming areas. There are A1 resettled farmers 1.5 kilometres to the southeast at Bowker, communal farmers to the south in Musana and Masembura Communal Lands and large-scale commercial farmers east, north and west of the study area.

The climate of the area is generally wet and warm in summer - October to March - and cool and dry in winter - May to August. It receives between 700mm to 1200mm per annum and the prevailing winds are NE to NW, often gentle in summer and slightly stronger in winter.

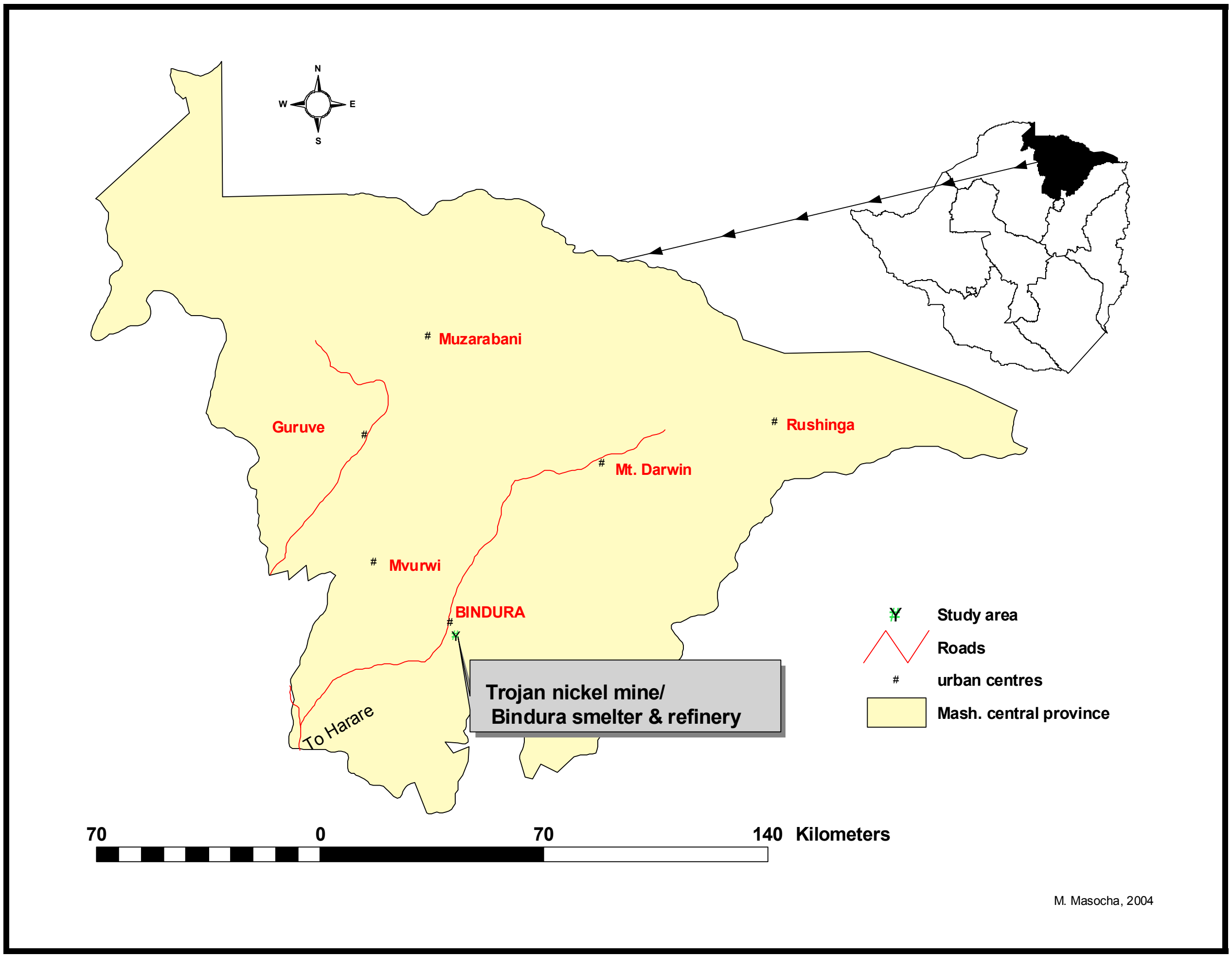

Figure 1.1: The Location of TNM and BSR, The Study Area.

Two rivers and their tributaries, Pote and Nyaure, drain the area and serve a host of commercial farmers downstream before flowing into Mazowe River. The nickel deposit occurs in the upper greenstones of the Mazowe Greenstone belt, situated north and north west of Chinhamora granite batholiths.

Nickel was discovered in 1956 along road cuttings, exploration began then and Major Aubrey J. Hilton, under Anglo-American, pegged the mine in 1965. The first load of nickel concentrates was delivered in 1968 for smelting at BSR. Monthly production of nickel ore rose from 50,000 tonnes in 1968 to 96,000 tonnes per month in 2004. In 2002, Mwana Africa, a consortium of Africans, took over the corporation and maintained the operations. The mining concern was listed on the Zimbabwe Stock Exchange and exported most of its output to European countries and Japan.

1.8. EMS at TNM and BSR

Bindura Nickel Corporation mooted the idea of an EMS in 2002 in a bid to combat the environmental impacts of its mining processes. The company intended to comply with local legislation and the best mining practice of integrating EM with its core business. Anglo-American, the former owner, was geared to upgrade the production processes to international standards and to be competitive on the global market. The company also wanted to protect itself from legal liabilities that emanated from the contamination of air and water resources from its operations. The company wanted to put an end to persistent complains from nearby commercial farmers about the level of pollution from its operations.

The company started of by identifying environmental aspects that were over 60 then developed a register in 2002. The significance of each aspect was determined and EMPs were developed for the significant ones. Any aspects that had a value of more than 40 were regarded as significant. The EMS was put into full operation in 2003 and was registered with Standards Association of Zimbabwe (SAZ) in October 2003. The thrust of an EMS is continual improvement, (SAZ, 1996), hence the need to determine the extent of implementation progress and evaluate the effectiveness of programmes in operation at TNM and BSR.

1.9. Operations at the Study Area

The company was involved in processes that included mining, concentration, smelting and refining. It also processed nickel concentrates from Tate, Botswana and at times, South Africa and Australia. The operations and the associated aspects are discussed in more detail in this section.

1.9.1. Nickel Mining

The extraction of ore was done at Cardiff Hill using the underground mining method. At the time of the study, January to May 2004, mining operations were at 29th level, about a kilometre beneath the earth's surface. The mining process, Figure 1. 2, entailed removal of waste rock to create a way for accessing the ore body and extracting it.

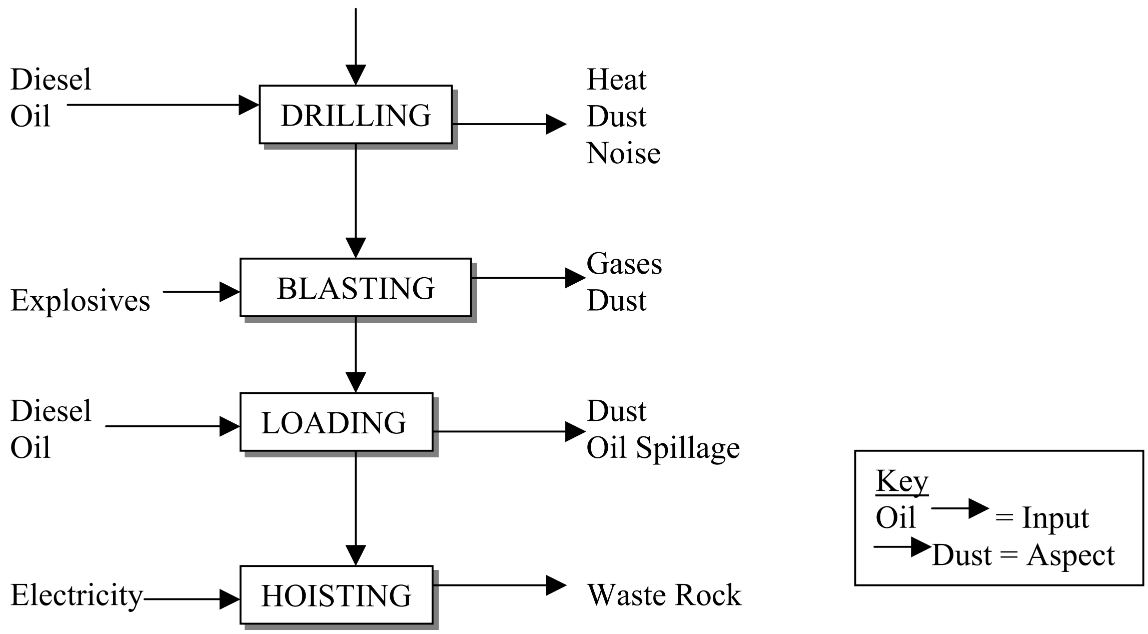

Figure 1.2: The Mining Flow Chart **Source: TNM and BSR EMS Documents**

Drilling rigs were used to bore holes in the rocks and ore for blasting. Scoop trams loaded the blasted materials onto diesel or electric locomotives that ferried and loaded it onto a skip for onward hoisting to the surface. When waste rock reached the surface, it was transported by conveyor belt to waste rock dumps for disposal. The ore was taken to the crushers at the concentrator for crushing and the liberation of minerals.

The mining processes generated some environmental aspects as illustrated on Figure 1.2. The drilling rigs and scoop trams took-up a lot of oil that spilled when the hoses burst and during maintenance. Dust emission occurred in most of the processes when dry ore was moved from one point to the other. Large volumes of dust were also produced when the dry ore particles crushed against each other when loading.

1.9.2. Nickel Ore Concentration

The concentration processes, Figure 1.3, occurred soon after the ore was delivered by a skip from underground and were meant to upgrade it to 8% nickel and 15% moisture content.

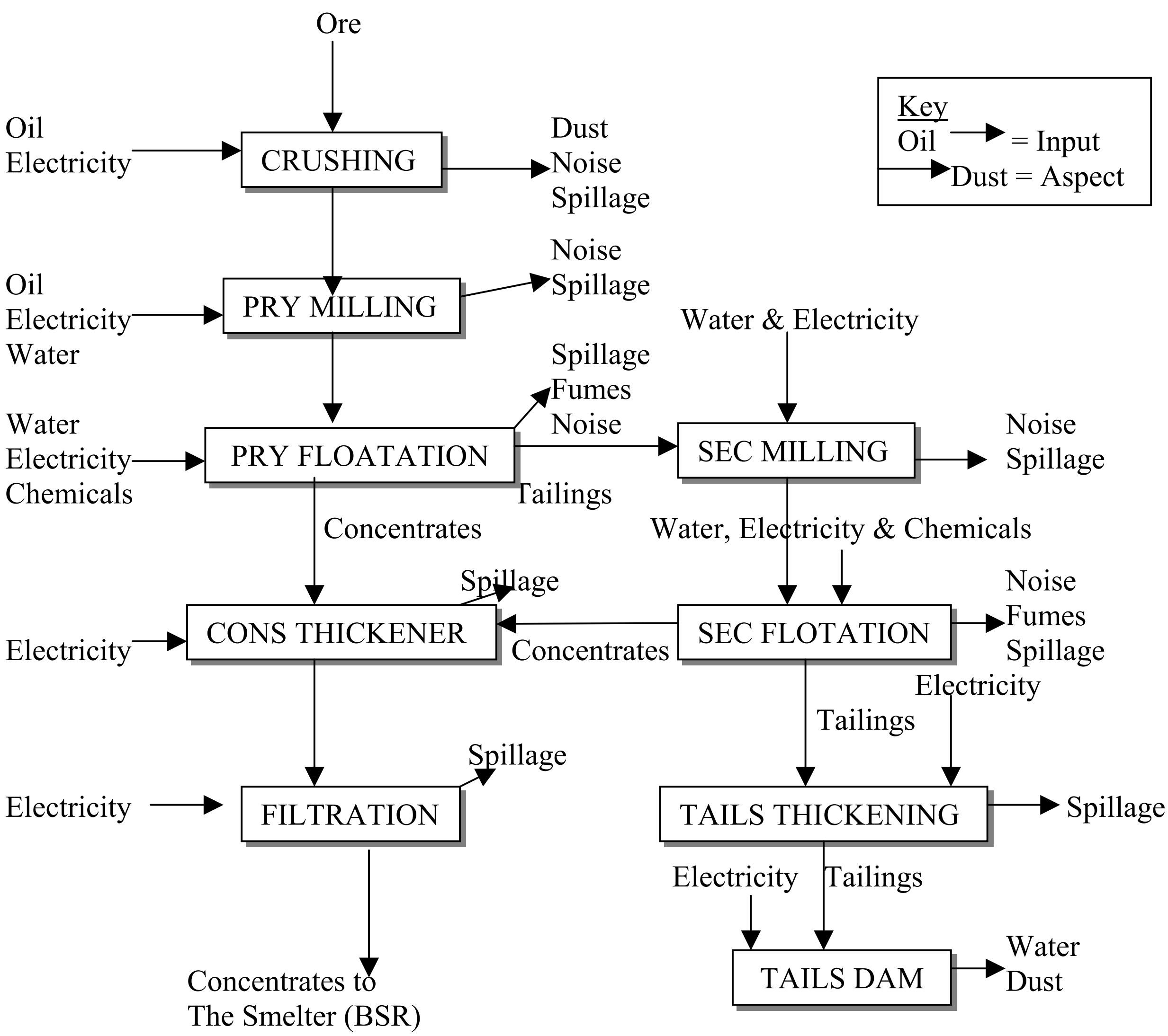

Figure 1.3: The Concentrator Flow Chart **Source: TNM EMS Documents**

The ore was crushed in stages - primary, secondary and tertiary - until the desired particle size of 8mm in diameter was achieved. The ore was transported from crusher to crusher by open conveyor belts then deposited via a chute onto a stockpile. It was then fed into ball mills for milling into fine powder so as to liberate minerals from the waste.

The floatation process used chemicals – frother, activator (copper sulphate), collectors and depressants - and water to agitate and separate the nickel from the fine waste. In primary floatation, ore was lighter, floated and was removed in bubbles as concentrates while waste (slimes) was heavier thus moved along with water to the ball mills for further milling. The collected concentrates were transported by pipeline to the concentrate (cons) thickener. In the secondary floatation stage, the concentrates were taken to the cons thickener while the slimes were taken to the slimes thickener. The concentrates were thickened then taken to the filtration stage for filtering. The end product was concentrates of about 8% nickel and 15% moisture content and was ready for the next stage of processing, smelting.

The major environmental aspects associated with concentration were emission of dust and noise, discharge of chemicals and effluent, Figure 1.3. Dust was emitted as the ore was crushed into smaller particles and as it was transported on open conveyor belts during windy days. The concentration stage was one of the largest producer of dust at TNM and BSR. The chemicals that were used for floatation were at times spilled thereby contaminating the environment. The tailings that were discharged as a waste product of floatation, contained some chemicals and were transported by pipeline for disposal at the tailing dams. During the dry windy season, dry and uncovered tailings posed problems of dust pollution.

1.9.3. Smelting

The drying, smelting and converting processes, Figure 1.4, constituted the main smelting processes that were done at BSR, about a kilometre from the concentrator. The concentrates of varying grades and moisture content from the company's mines were delivered at the cons shed where they were blended at a ratio determined by the grade of the ore. The blend was fed into a rotary dryer drum, moved through it and lost moisture to evaporation. Heat from a coal oven at temperatures above 120ºC was drawn into the dryer to heat the concentrates. They left the dryer at moisture content of about 5% then stored in silos for onward transmission to the smelter. The waste gas and dust particles passed through a gas scrubber for capturing dust. The captured dust was taken to the scrubber ponds where it was mixed with water then sent back into the system for recycling via the blending shed.

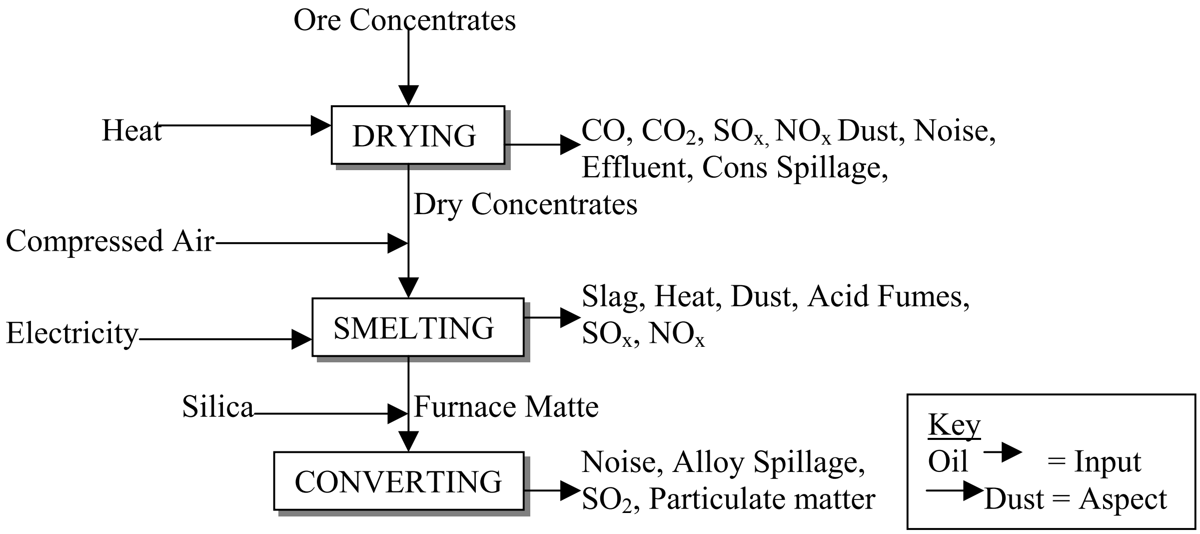

Figure 1.4. The Smelting Processes **Source: TNM and BSR EMS Records**

The dried blends and reverts were fed into an electric furnace from the surge bin. The furnace had six self- baking soderberg electrodes that were powered by three single-phase transformers. The blend was smelted when the slag resisted the supplied current and generated enough heat for smelting. The smelting process caused physical and chemical changes that resulted in waste (slag) floating on the denser crude matte. Slag was tapped on one end, granulated by spraying some water then disposed of at a nearby slag heap. Matte was tapped at regular intervals and fed into ladles for transmission to the converters. Gases and fumes from the furnace passed through the electrostatic precipitator where dust was recovered then sent to the agglomerator and blending shed for drying. Gases escaped through the stacks as fumes and waste.

The furnace matte, leach alloy, scrap and flux were fed into the converter where compressed air from the blower house raised the temperature. Iron was removed by oxidation and was continuously tapped until almost all of it was removed. Dropping some reverts in the matte controlled converter temperatures. More matte was added and the process was continued until the converters were filled with white metal, leach alloy. The second blowing stage, leach blow, was meant to reduce sulphur levels. Leach alloy, the converter end product, was granulated by spraying some water then dispatched to the refinery for further processing. Dust and gases passed through the electrostatic precipitator where dust was recovered for recycling as the waste gases escaped through the stacks.

The drying, smelting and converting processes were associated with emissions, Figure 1.4, of dust, heat from the coal oven and fumes that were discharged into the environment. Water was used for trapping dust in scrubber units before it was discharged as effluent into nearby ponds. The pH of the water was frequently monitored and controlled so that it remained within the recommended levels. The water was reused but some of it overflowed into the environment during the wet season. The major environmental aspects that the mining company had to contend with at the smelter were SO_2 and dust emission.

1.10. Conclusion

The main thrust of the research was to explore the effectiveness of EM at TNM and BSR focussing mainly on four major EMPs from mining, concentration and smelting. Nickel refining was done at the study area but left out of the study since the process did not generate most of the major aspects in the study. The environmental performance indicators of the EMPs were the basis upon which the programmes were evaluated. Literature was explored on the effectiveness of the programmes that were employed elsewhere so as to draw insights into a local programme and make meaningful recommendations for a local mining concern.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

Literature reveals that the corporate world developed and implemented EMSs the world over to combat the undesirable impacts of their business activities (Andrew et al, 1998). The mining sector also realised its contribution to the increasing loss of life - human, fauna, flora, and aquatic - due to its activities thus followed suit. The main thrust has become the desire to integrate environmental management into the mainstream planning of the companies (Starkey, 1998; Pearce and Ozdemiroglu, 1997, Natoli, 1995). This chapter reviews literature on the nature of an EMS and its history, an effective EMS, need for effective EMSs and experiences in EMS implementation in some parts of the world.

2.2. The Components of an Environmental Management System

An EM identifies environmental risks from a company's/mine's operations and strives to reduce or eliminate their impacts on the environment (ISO, 1999; QSU, 2002). The EMS manages significant aspects to reduce environmental risks and damage to the environment. Tolba (1982:24) contends that environmental management (EM) is "not management of the environment, but management of all those human activities that have a significant impact on the environment." Pearce and Ozdemiglu (1997) contend that lasting economic production cannot take place without EM and EM cannot be possible without economic production - they are interdependent. The emerging viewpoint is that an EMS has a variety of planned activities that are meant to blend production processes with EM. Natoli (1995) asserts that environmental procedures should work with existing procedures rather than becoming a new layer of controls that obstruct staff from their routine duties.

An EMS is a broad system that is made up of several components that make it complete. Natoli, (1995) identifies the components at Heathcote Gold Venture, Australia, as follows:

♦ Organisational Commitment – All workers, from the chief executive to the grounds staff, need to be committed to the EMS process so as to realise the EMS potential benefits.

♦ Environmental Policy – This concise public statement tells the community, company employees and other stakeholders the environmental goals and the level of performance the organisation intends to achieve. It provides a framework for setting objectives, targets, EMPs and future action plans.

- Environmental Impact Assessment (EIA) – An EIA is done at the beginning of mining operations and assesses the potential impacts of the mine on the community and the environment. It outlines strategies that minimise and control the adverse environmental effects. The findings are a basis for the formulation of initial objectives, targets and procedures an EMS performance has to meet or exceed.
- Objectives and Targets – The mining company develops targets and long term objectives to meet EIA, environmental audit recommendations and regulatory requirements.
- Environmental Management Plan –The plan outlines the methods, procedures and responsibilities meant to achieve environmental targets and the short and long term objectives.
- Documentation – The environmental strategies, policies, procedures, programmes and initiatives carried out as part of the EMS are compiled in an Environmental Manual. It is a useful reference to all stakeholders as proof of the company's commitment to EM.
- Operational and Emergency Procedures – Procedures for aspects that have significant impact on the environment are developed and documented to ensure that site operational and emergency procedures are environmentally compatible. The exercise helps in worker induction, allows workers to share experience and serve as a source of reference.
- Responsibilities and Reporting Structure - Responsibilities are assigned to the personnel with the requisite knowledge and abilities to ensure that the tasks are carried out appropriately and timeously.
- Training - The operational staff undergo training on environmental awareness and other EMS courses to empower them with skills and the motivation to implement an EMS (SAZ: 1996). This is a crucial component of an EMS.
- Environmental Impact Compliance and Review Audits - The EMS ensures that mines are operated and rehabilitated in compliance with EIA and deviations require a review of programmes and modification of company practices to suit the requirements. Environmental Audits, internal and external, identify potential problems, assess impacts of environmental aspects and determine the action needed to meet targets and comply with regulation.
- Emissions and Performance Monitoring - Regular monitoring is needed to assess performance against regulatory requirements, objectives, targets, EIA and previous audit

requirements. Johnston and Murray (1995) note that monitoring at Cunnington, Australia, BHP Minerals managed to control acid mine drainage by employing an EMP that ensured zero effluent discharge.

An EMS is also characterised by a set of EMPs for managing significant environmental aspects. The EMPs are a set of related discrete activities at specific locations that give effect to policy objectives (HMSO, 1991). Trittin (2002) observes that significant aspects interact with environment and give rise to a change in its quality; hence the reason for having EMPs. Each programme, characterised by objectives, targets and performance indicators, is designed to reduce the impact of specific environmental aspects (SAZ, 1999). Programmes are subsystems of the EMS, however, their demands and implementation may vary greatly from one to the other though within the same EMS.

2.3. History of EMS

The environment was a waste sink since the Industrial Revolution until discharge of pollutants came under review in the latter half of the twentieth century (Andrew et al, 1998). The new developments were a result of changes in ozone and climate as well as resource depletion that threatened the habitability of the earth. Tolba (1982) notes that the UN Conference on Human Development and the Environment of 1972 in Stockholm gave birth to United Nations Environmental Programme (UNEP), a world body responsible for EM and conservation. The Brundtland Commission Report of 1987 and the World Conference on Environment and Development of 1992 in Rio, Brazil, raised the greatest concern for the need for EM (UN, 1992). The latter half of the twentieth century saw the formation of international environmental conservation bodies, NGOs, conventions, and protocols (Natoli, 1995). Two notable historical developments, however, were approaches to the management of pollutants and the formation of bodies or standards for EM and certification.

The approaches to EM are end of pipe, waste recovery and reduction of pollution at source that came into force as from 1974, although environmental awareness was raised in 1964 (Hart, 2001). The end of pipe approaches that include proper disposal of generated waste and treatment before disposal did not cater for gaseous emissions. Starkey and Welford (2001) note that waste recovery, recycling and reuse introduced later reduced the volume of the waste discharged into the environment and enhanced the conservation of resources. Focus on using resources to meet the needs of the present without compromising the needs of future generations in sustainable development (Chenje et al, 1998; UN, 1992; WCED, 1987), gave impetus to EM in the'90s. Cleaner production (CP), the latest approach to EM, was introduced to minimise and prevent pollution in all forms – liquid, solid and gaseous – at source (UNEP, 1998; Yap, 1999). Hale (1996) notes that research on a zero emission factory, for use even in mining when fully developed, that would eliminate pollution and enhance EM is ongoing.

EM and certification bodies were formed to offer guidelines on the development and implementation of EMS. British Standard BS 7750 first issued in 1992 was the first to be formed (Natoli, 1995) and Eco-Management and Audit Scheme (EMAS) followed in 1995 but was site specific (Welford, 1994). The ISO 14000 series started operating in 1996 and offered comprehensive guidelines on standards that pertain to EM, auditing, labelling, environmental performance and evaluation, life cycle assessment and product standards (Starkey, 1998; McCotter, 1995). At regional level environmental bodies such as SABS and at Zimbabwe level, SAZ, were formed but are based on the principles laid down by the international standards. Mining companies develop EMSs and register them for certification with these bodies on voluntary basis. In Zimbabwe, BNC was the first mining concern to have its three entities, TNM, BSR and Shangani Mine ISO 14001 certified in October 2003.

2.4. The Nature of an Effective EMS

Hornby (1989:389) defines the term effective as "having an effect or producing the required results." An effective EMS is expected to conserve resources used in the mining process such as water and energy and to reduce or prevent environmental degradation (Andrew et al, 199; McCotter, 1995). Trittin (2002) argues that an effective EMS adopts a holistic view of economic development and strives to balance financial gains with sustainable use of the environment and its natural resources. The major thrust of the EMS is to meet environmental targets, accomplish set objectives and satisfy the requirements of all its components (Johnston and Murray, 1995). Anderson (2003), Cullen (1999) and SAZ (1996) assert that an effective EMS has to achieve set standards that are quantifiable and measurable to determine the level reached and what is still to be done.

An effective EMS strives to continually improve the quality of its production processes so as to reduce pollution, resource input and increase efficiency of company operations (ISO, 2002). It desires to better its environmental performance by being continuously engaged in planned activities as illustrated by the four boards in Figure, 2.1.

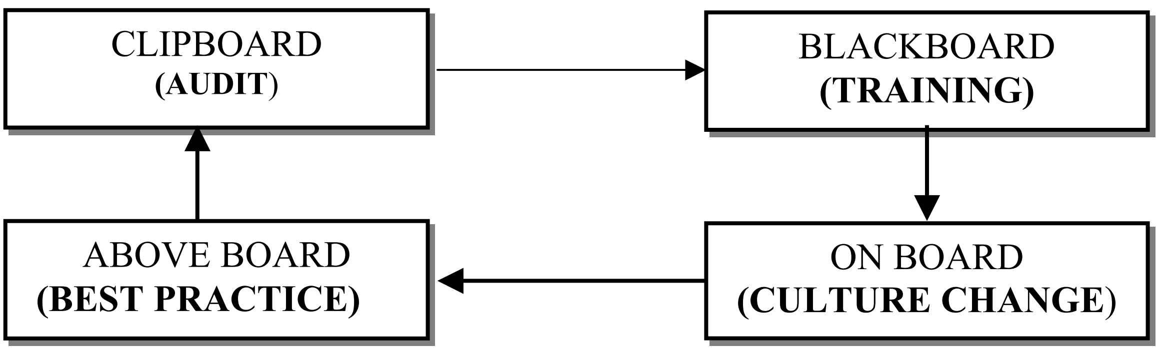

Figure 2.1: Environmental Management Cycle. (After Brown and Laurenson, 1995:13)

The effective EMS brings about a change throughout the organisation in terms of attitude towards EM as continual training and auditing (Brown and Laurenson, 1995) back it. The training enables the employees to implement EMS and the audits identify new challenges and propose emergency procedures that need to be in place to contain the unexpected events and enhance the performance of the EMS (Dayal-Clayton, 1996: Hale, 1996). In addition, Andrew et al (1998), Tolba (1982) and Gray et al (1995) argue that an effective EMS continues to develop new ideas and technologies for EM and strives to ensure that consumption of natural resources (NR) declines to levels far beyond legislative requirements. Brown and Laurenson (1995) note that Clarence Colliery, Australia, adopted water treatment technology and produced zero pollution; more effective than applying for a licence to pollute. The emerging indications are that an effective EMS is characterised by a variety of facets from which its effectiveness can be determined.

2.5. The Need of an Effective EMS

Mining companies develop and implement EMSs to achieve the objectives of the corporate policy (SAZ, 1996; HMSO, 1996). Various sectors of the community demand responsible use of resources in and discharge of waste from the mining activity. The EMS, a tool made of planned and coordinated business activities, is an answer to the problems of environmental degradation and resource depletion. It is fundamental in reducing the mineral specific impacts, environmental protection, fulfilling legislative and mandatory requirements, market conditions, stakeholder interests, credit worthiness and making some savings.

2.5.1. Reduction of Nickel Related Impacts

An EMS is needed to control exposure limits since any values above $15\mu g/m^3$ of nickel compounds in refineries are a health hazard to people (QSU, 2002). IARC (1990) observes that excessive exposure causes nasal or lung cancer, loss of the sense of smell, pulmonary irritation and decrease in lung function leading to death. Sunderman (1998) also notes that nickel compounds can be classified as carcinogenic to people and high exposure leads to renal tubular dysfunction. Deaths from cancer at a nickel mine, Falconbridge, Canada, increased sharply due to increased exposure in a smelter (IARC, 1990; United States Department of Health, Education and Welfare, 1977). An effective EMS is thus needed to reduce exposure levels and to save lives in the nickel-mining environment. In Zimbabwe, BSR is the sole nickel smelting and refining company, whose management programmes are yet to be evaluated.

2.5.2. Environmental Protection

The major reason for developing an EMS is to protect the environment from damage and conserve NRs for the present and future generations (Wells et al, 1999; Cullen, 1994). The mining sector uses a substantial amount of NRs and its emissions cause great damage to the environment, the base upon which all life and business activities depend. EMPs with key variables – sulphur dioxide (SO_2), dust, effluent and oil spillage – are to be dealt with in this section.

2.5.2.1. Effluent Discharge

Effluent that is discharged from mining processes such as milling, floatation, washing machines and cleaning up of spillage, contains toxic chemicals that affect water sources (Sunderman, 1998; Johnston and Murray, 1995). The effluent is later drained into surface and ground water sources thereby affecting aquatic life and the availability of safe water to other life forms (Sinkala, 1994). Mtetwa (1994) asserts that effluent discharged into water sources poisons the environment and produces dead lakes, for example in Canada 14,000 lakes have been reported dead. Tailings dams that are not properly designed to contain the effluent deposited in them discharge toxic water into nearby streams and would continue to do so long after the mines close down (Brown and Laurenson, 1995). An effective EMS needs to be planned and implemented to contain discharge of toxic chemicals during operation and long after the mine closes down.

2.5.2.2. Emission of SO_2

Although SO_2 is also emitted by other sources, an EMP is needed to protect the environment from emissions in smelting and refining processes of mining (GOZ, 2003). SO_2 emissions cause respiratory diseases and make it difficult for people suffering from bronchitis, asthma, and emphysema to breathe thereby causing increased mortality rates among the vulnerable (Gibbons, 2001; Wells, 1994). Sinkala (1994) and Lack and Lambert (1997) note that SO_2 emissions from smelting and refining in South African mines caused acid deposition that damaged vegetables and plants as they had difficulties in photosynthesising. Acid deposition lowers pH values to 2 thereby making it difficult for plants and microorganisms to survive (Smith, 1981). Great concern is raised by Dayal-Clayton (1996) who observes that there is inadequate and lack of data needed for planning and monitoring of pollution in Southern Africa. Thus, research on the effectiveness of an EMP on emissions to fill this gap is long over due.

2.5.2.3. Oil Spillage

Oil spillage from faulty machinery, generators, transport systems and careless oil handling has severe impacts at the workplace and when drained into water sources. Mtetwa (1994) notes that inhaled oil vapour causes damage to the central nervous system, lungs and the liver. Akpoture (2000) asserts that in relatively still waters, in the Niger Delta, oil was toxic to frogs, reptiles, waterfowl and affected a series of interconnected species that lived in or nearby. Oiling affects plants and grass rooted in or floating on water and the animals that feed on them, as they would have ingestion difficulties. Mtetwa (1994) observes that birds in contact with oil freeze to death as insulation is reduced and when nesting grounds are destroyed, their regeneration patterns are greatly affected. An effective EMS is therefore needed to save the diverse forms of life cited above and their habitats from severe damage.

2.5.2.4. Dust Emission

An EMP is needed to manage dust emitted by crushing, milling and drying processes so as to reduce damage to people and plants. David (1998); McCotter (1995); IARC (1989) note that when dust is inhaled it accumulates in the lungs, irritates the respiratory organs and causes diseases such as pneumoconiosis. Fall-out dust from the processing of sulphidic minerals such as nickel, generates acids that damage plant leaves (Eisenriech, 1981). It also causes loss of aesthetic value as it accumulates on properties and vegetation. There is therefore need to determine the extent to which EMPs have reached in controlling the emissions.

2.5.3. Legislative Requirements

An EMS is needed to protect the mining company against legal obligations, liabilities and to conform to legislation (Trittin, 2002; SAZ, 1996). The mining companies are compelled by legislation to meet minimum standards laid down at international, regional and national levels. Regional legislation such as the SADC Water Protocol forbids the pollution of shared water sources by member states (Zhou, 2000). The Zimbabwe national legislation, Environmental Management Act (EMA), stipulates the minimum requirements for the emission of waste, noise and radiation (GOZ, 2002) among other issues. In Zambia, a mining company was taken to court for discharging high concentrations of copper into Chingola River that poisoned cattle (Chenje et al, 1994). The company had to pay compensation, litigation and clean-up costs as well as incurred some embarrassment that could have been averted had the company put in place an effective EMS.

2.5.4. Market Conditions

An EMS is needed to demonstrate sound business management by showing concern for the environment so that a company is able to sell its products on a competitive level on the market

(ISO, 2002). Customers in the developed world prefer goods that are produced in a way that conserves the environment, that is, they demand to consume 'green' products (Trittin, 2002). ISO (1999) notes that trade is easier for companies that have an EMS in place as it is a marketing tool that attracts customers to buy their products. An effective EMS thus gives the mining company a more competitive position on the market.

2.5.5. Savings

Mining companies that develop an EMS reduce operational costs and realise substantial savings (Natoli, 1995). Mining companies that employ recycling, waste recovery and CP technologies strive to make maximum use of resources and generate very little waste. Waste recovery and recycling enable the companies to lower production costs as energy and water are used within the production process hence demand for fresh inputs is cut (Cascio, 2000). Companies that employ cleaner production technologies become efficient in their production processes and reduce the amount of inputs they use and the waste that is generated (Yap, 1999). An effective EMS is thus a resource and cost saving tool that enables mining companies to produce quality products and make substantial savings in input costs.

2.5.6. Insurance Premiums and Loans

Mining companies that have EMSs pay lower insurance premiums and are able to access loans from financial institutions easily as their operations are regarded as less risky (Trittin, 2002). Financial institutions - banks and investors - give priority to mining companies that have effective EMSs when they seek for loans because they are seen as having limited liabilities (Bond, 2000; Andrew et al, 1998). An effective EMS is crucial as it demonstrates the mining company's commitment to sustain its operations and to honour obligations of any sort.

2.5.7. Public Image and Stakeholder Confidence

A mining company needs to promote a positive public image to its stakeholders, that is, the surrounding community, non-governmental organisations and trade associations (Brown and Laurenson, 1995). An EMS is a necessary tool that enhances stakeholder participation in the company’s management of environmental activities and makes them confident to co-exist with the company (SAZ, 1996). Johnson and Murray (1995) argue that an effective EMS considers stakeholders as key partners in EM and demonstrates to them that the policy objectives and targets are met.

2.6. Examples of Effective EMS

Effective EMPs have been developed, implemented and achieved the targets and objectives that had been set. Examples of such programmes are drawn from both the developed and developing countries.

2.6.1. Effective EMS in the Developed World

Effective EMSs that produce the desired results have been studied in the developed world. ISO (2002) notes that in the developed countries a 'green' market or 'green consumerism' is encouraged – only the commodities produced in an environmentally responsible manner are chosen. Hale (1996) observes that in the developed world, besides the quality of the products, customers consider how the production process used all the input factors. The mining companies are forced to employ EMSs by the environmental conscious customers who demand green labelling and the products not labelled are avoided as they are regarded as contaminated. This section focuses on two examples of effective EMS in Alberta, Canada, to manage SO_2 and at Ranger Mine in Australia to manage effluent discharge.

An EMP has been designed and employed in Alberta, Canada, to contain acidic emissions of SO_2. The major OPI is put forward by Slubik (1996) as a flue gas desulphurisation process whereby waste gases were scrubbed with limestone to reduce the concentrations of SO_2 that were emitted into the atmosphere. Limestone and water were mixed to produce a slurry that absorbed SO_2 and the slurry was oxidised to produce calcium sulphide (gypsum) for use in the building industry. In this case, waste was turned into a useful product thus in one way reducing environmental pollution and in the other supplying the building industry with a useful building material. Gibbons (2001) also points out that in Ontario, Canada, selective catalyst reduction combined with plant scrubbers were used to reduce SO_2 by 90%. The success of the programmes was attributed to the financial resources that were committed to them and the practice of converting waste into a useful product to ensure that the objectives of the environmental policy were achieved.

In Australia, an EMS was employed at Nabarlik and Ranger Uranium mines to protect Kalahagu National Park in the Alligator River's region from pollution by the mine effluent (Brown and Laurenson, 1995). The mining company, local authorities, local community and other stakeholders made their representations at meetings. The review meetings identified the flaws and all stakeholders worked together to solve any emerging problems. Acidic effluent was neutralised by adding lime to ensure that it was safe before discharging it into the environment. The success of the EMS was attributed to cooperation from the stakeholders who made their contributions on what they expected to be done and treatment of effluent. The mining companies were also committed to conserving the environment and to sticking to the laid down programmes.

2.6.2. Effective EMS in Africa

The level of success for companies in the developing world needs to be determined, as the economic and technological settings are different. A range of effective EMSs have been designed and implemented in Africa but this section focuses on dust, SO_2 and effluent management in South Africa for which literature could be found. Wells et al (1994) note that the Mines and Works Act Section 27 of 1956 backed by the country's Environmental Management Policy stipulates the maximum permissible pollution levels. Companies that contravene the regulations suffer a fine that is "stringent enough to overcome the motive of economic gain" (Wells et al, 1994:347). The fine is raised substantially, at times fourfold, for any further conviction.

In South African mines, EMPs have been designed to capture dust and reduce emissions by inertia and electrostatic separators. The emissions were reduced by 70 – 90 %. The mines also managed SO_2 by reducing the sulphur content in coal by wet and dry insitu post combustion treatment that recovered sulphur and other by-products. The wet scrubbing in coal also reduced sulphur dioxide emission by 90%.

Environmental Management programmes were also instituted to manage water and effluent discharge for conservation purposes and prevention of pollution. Luther and Ramsden (1994) observe that wastewater was re-used in the mining processes after treatment and pollution abatement technology was employed to reduce pollution at source. All the wastewater was discharged after treatment and samples were taken and tested to ensure that no pollutants were discharged into the water sources. The regulatory requirement was that effluent could only be discharged in a form that is not injurious or likely to become injurious to aquatic life or their food (Sinkala, 1994). Mining companies dug canals right round their premises to capture surface water that drained from their premises then stored it for transporting tailings. The mining companies lined tailings dams properly, collected leachate and treated it before discharging it into public streams and installed monitoring boreholes to check on seepage of toxic effluent.

The success of the cases cited above is attributed to the stringent environmental legislation which was backed by a sound policy and the resources that were allocated to the programmes. The mining companies thus developed effective EMS to safeguard themselves against legal liabilities. The studies indicate that there are some effective programmes that were developed and implemented in Africa and that it is possible to determine their effectiveness.

2.7. EMS in Zimbabwe

Monitoring of the implementation of EM in Zimbabwe is the responsibility of the Department of Natural Resources (DNR) in the Ministry of Environment and Tourism (GOZ, 2003). Interested ministries such as MOH, Mines, Transport and Energy and Water and Infrastructure Development assist the department. The national environmental pieces of legislation that guide monitoring and implementation include the following acts: Water, Atmospheric Pollution Prevention, Pneumoconiosis, Public Health and the all embracing EMA of 2003. The acts stipulate the conditions - effluent, noise, pollutants in air and water and radiation among others - which have to be met by the mining companies before discharging. The environmental management policy which is supposed to guide the implementation of EMSs in the country is still at the second draft stage (GOZ, 2003) hence the companies do not have properly documented national guidelines on EM. SAZ and others such as South African Bureau of Standards (SABS), TUV Raiment, Certification Systems of Africa, SGS and EAQA do the assessment and certification of EMS in the country (Muswinu, 2002).

The adoption and implementation of EMS is recent in Zimbabwe since Circle Cement was the first to be ISO 14001 certified in 2002 (Muswinu, 2002). In mining, TNM, BSR and Shangani, were the first to be certified in 2003. As at the end of February 2004, only six mining concerns had their systems ISO 14001 certified by SAZ. The emerging indication is that most of the certified mines in Zimbabwe are still to have their EMS evaluated.

2.8. Conclusion

The foregoing discussion reveals that an EMS is made up of a variety of planned activities, requires adequate planning and substantial financial commitment from the implementing company and stakeholders. The major thrust is to harmonise the mining processes with the environment, that is, to achieve sustainable development. In the developed countries and some parts of Africa, there are mining companies that have implemented effective programmes. In Zimbabwe a few companies had their EMS certified but are yet to have their effectiveness determined.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

The thrust of this chapter is to look at the methods that were used to collect primary and secondary data for the study. Although each method collected specific type of data, the methods were complementary; one method confirmed, verified and reinforced the findings obtained by the others (Shipman, 1988; Smith, 1975). The methods that were used to analyse the collected data are also discussed.

3.2. Primary Data Collection

Primary data were collected to verify the data that was kept in EMS records at TNM/BSR in order to determine the effectiveness of the EMPs. The methods used in this research were observations, field measurements, questionnaires and interview schedules.

3.2.1.Observations

Observations were made in the underground section where oil was managed, at the concentrator for dust and at the smelter for dust and sulphur dioxide management. Observations were made on whether the employees followed work instructions that were designed to achieve environmental targets. However care was taken, to ensure that workers did not alter their working patterns. During EMS training sessions, the researcher noted the responses of the participants that demonstrated how they valued the EMS. The important findings were written down then used in analysis and discussion of data.

3.2.2. Field Measurements

The significant aspects at the study area - effluent discharge, sulphur dioxide emission, oil spillage and dust emission - were measured in the field from January to April 2004, the study period. The samples were collected four times per sampling point, at least once per month, then averaged to arrive at the value for each point shown in the results presented in Chapter Four. However data for calculating confidence levels were not averaged to avoid the bias that is associated with means (Gregory, 1978).

3.2.2.1 Effluent Discharge

Effluent was studied by collecting samples from surface water outlets and from boreholes (Figure 3.1) and by measuring the amount of discharge into these surface streams.

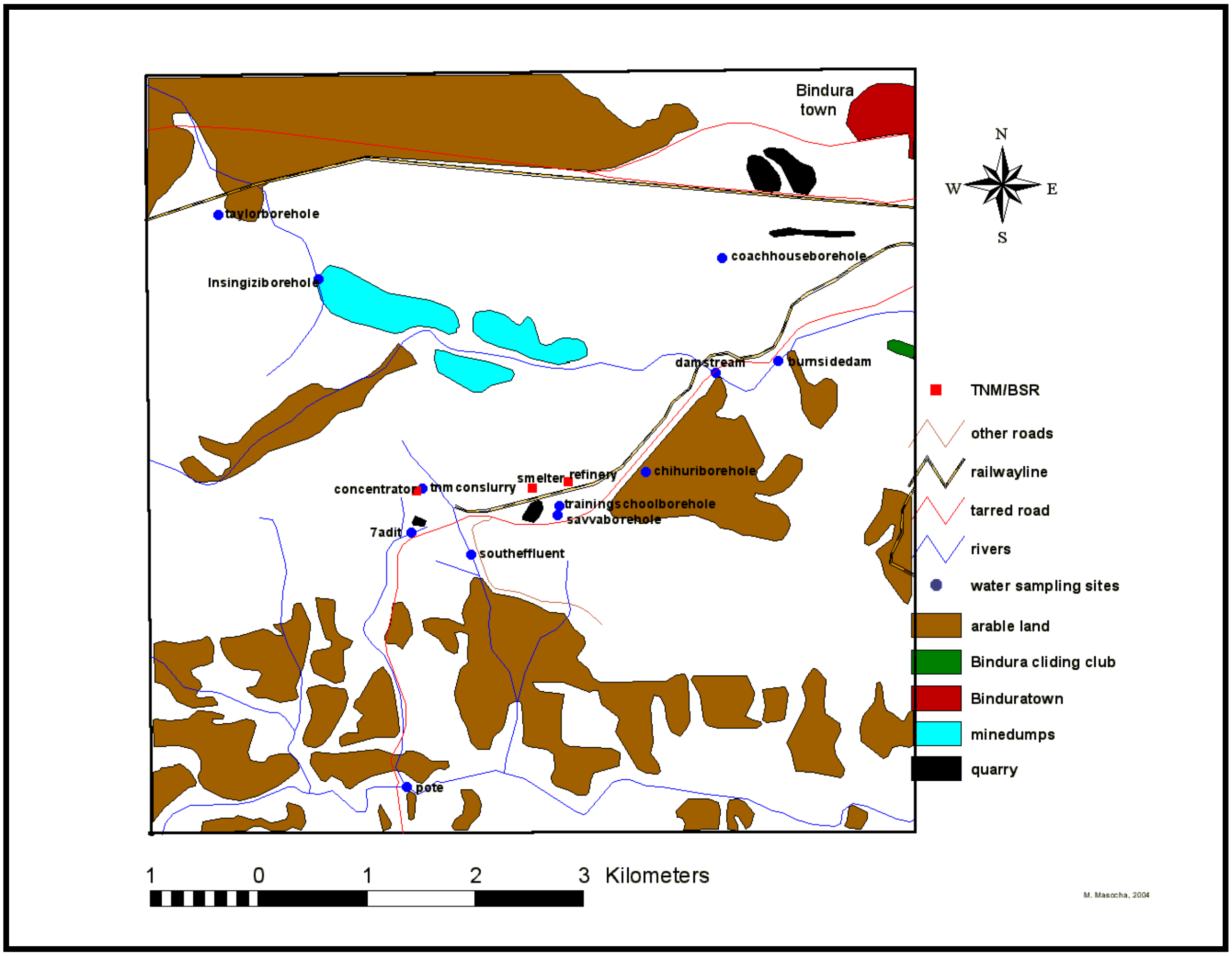

Figure 3.1: Water Sampling Points

Water samples were collected four times in the third week of each month as from January to April in 2004. The researcher fitted into the water sample collection schedule that was in operation at the company so as to take advantage of the transport, labour and the two litre sample containers that were provided by the company. The sampling points, shown in Figure 3.1, were selected to determine the flow of pollutants from the process points downstream. Seven Adit, South Effluent and Dam Stream sample points were immediately after the operations - mine, concentrator and the slimes dams respectively - and TNM Cons Slurry was a point where water from the tailings thickener was discharged into slimes dams. Pote and Downstream Burnside

Dam were selected to check the quality of water that was discharged into public streams by the two effluent streams.

The amount of recycled and raw water was taken from water meters at the process points. The volume of discharge was recorded at fixed recording points that were put on the surface streams just before the wastewater was discharged into public streams. The readings were done once a month. The researcher also took advantage of the company's meter readers and moved along with them as they did their weekly readings.

Samples for ground water were taken from monitoring boreholes and others on private land, Figure 3.1, for water supply at the same time as those for surface water. The monitoring boreholes, Savva and Training School, were adjacent to the refinery where a lot of chemicals were used in the nickel refining process. The other, Insingizi, was adjacent to the largest dam that was in operation at the time of the study. Samples from the private boreholes - Chihuri, Coach house Inn and Taylor - were collected to check whether the company's operations contaminated ground water that was used by residents and farmers in the neighbourhood.

Sample containers were labelled as the samples were collected, packed in trays and sent to Zimbabwe National Water Authority (ZINWA) laboratories by company truck soon after collection for analysis. The parameters that were selected for the study were nickel, cobalt, copper, arsenic, pH levels, sulphate and grease/oil since these were related to the company's operations. Nickel, copper and cobalt were found in the nickel ore that was mined and processed at the study area. Sulphate was used in copper leaching and the chemicals that were used in nickel processing had the potential of affecting the pH levels of wastewater. Grease/oil was used as a lubricant in machines in the various processes at the study area. Arsenic was produced from the pressure leach process, at the refinery, that generated iron arsenate as an extremely toxic waste product. Chances of wastewater draining these parameters into water sources were high hence the need to determine their concentrations in wastewater that was discharged from TNM and BSR operations.

3.2.2.2. Measurement of SO_2

SO_2 was produced in larger quantity at the smelter from smelting the sulphidic ore and in smaller quantity at the boilers from the combustion of coal. A portable gas analyser was used to measure the concentration levels at and near the source of the gas, Figure, 3.2.

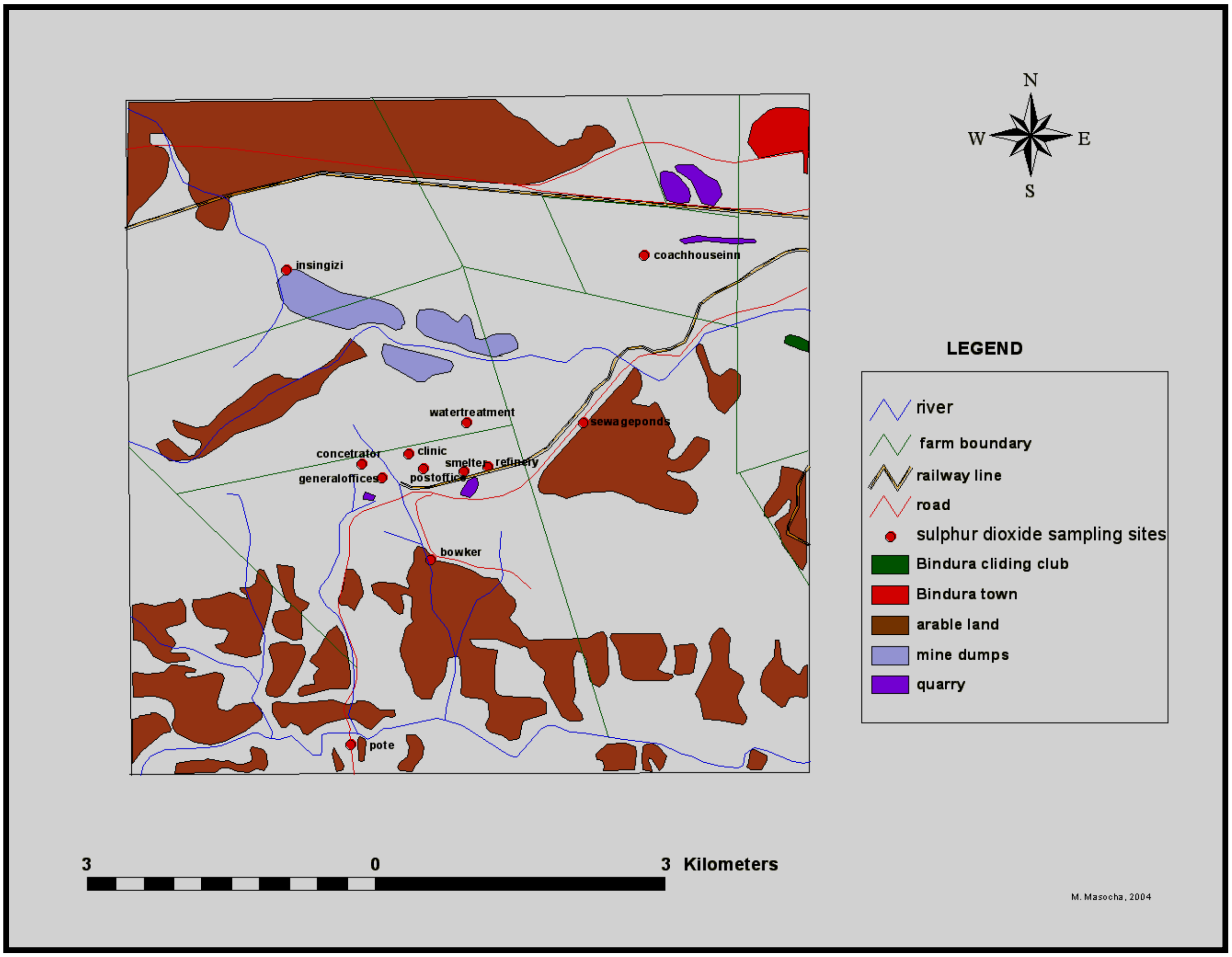

Figure 3.2: The Sampling Points for Sulphur Dioxide

The analyser recorded the concentrations in parts per million of sulphur dioxide which had to be converted to mg/m^3 for the findings to be comparable with the recommended target of $30mg/m^3$. A formula, $mg/m^3 = (ppm \times M)/24.04$ where M = 64.1 as surface tension of SO_2 and 24.01 as a constant (Commonwealth of Australia 2000) was used to convert the collected data to the desired units (Tables 4.5 and 4.6 page 54 and 55 respectively).

The gas was measured four times – two times in March and two times in April, at the sampling points on Figure 3.2, at the work area and in the neighbourhood. Confidence interval of proportions derived from a computer statistical programme was used to cater for the measurement error. The findings were then averaged to determine the value for each point shown in Tables 46 and 4.7, pages 54 and 55 respectively. At the furnaces it was measured at all the floors, that is, ground, first and third floors so as to see whether the concentrations varied with height. The converters were the other source while the dryer, boilers, smelter offices, refinery offices and tankhouse were within the premises where the gas was produced. These sampling points were critical because they were used to determine whether the gas was dispersed from the point of generation into the atmosphere since that was purpose of the precipitator and the stacks.

The post office, beerhall and water treatment plant, Figure 3.2, which where almost at the centre of a nearby residential area, were selected so as to determine the level of SO_2 concentrations in the residential area that was near the smelter. The concentrator and the general offices were further up the prevalent wind direction of the source of the emissions. Bowker, Pote, Insingizi, Sewage Ponds and Coach House Inn were selected to determine whether the gas affected villagers, farmers and residents in the neighbourhood.

3.2.2.3. Oil Spillage

The study of oil spillage was done in the mining section where drilling rigs and scoop trams used a lot of oil for their hydraulic systems. The focus of this study was the Diesel Workshop in 23rd level, sub-workshops underground, the oil traps that were set up and the ramps from levels 23 to 29 on which the underground machines worked and moved on their way to the workshop for repair. Water samples were collected from the Diesel Workshop pipe drain, in and outflows at 25/3, 25/0 and 27/0 level separation ponds and 7 Adit Pump. This was done to determine the effectiveness of oil separation that took place in the oil treatment ponds.

Soil samples were collected from the middle of 23 and 27 ramps and three from the oil farm. Soil samples were also taken from the Oil Farm for the initial soil deposits of August 2003, intermediate of December 2003 and the recent of April 2004. The samples were packed and taken to a laboratory at Chinhoyi University for oil analysis to determine the effectiveness of the oil management strategies. A friend who was a chemist at the above institution offered to do the analysis at an affordable charge.

3.2.2.4. Measurement of Dust

A gas calibrator was used to measure the volume of total and respirable dust that was generated at the concentrator and smelter. Data were collected from the three crushers at the concentrator once a month from January to April 2004 then averaged to get the readings for the concentrator, (Tables 4.9 and 4.11- pages 65 and 66). At the smelter, averages were calculated for the readings taken from the dryer, furnace and at the screening section where the dust was generated during the same period as the concentrator (Tables 4.10 and 4.12, pages 66 and 68 respectively).

3.2.3. Questionnaires

Questionnaires with simple-tick response questions were administered to elicit for information about environmental management (EM) from the employees and farmers nearby. The questions were meant to determine the workers' level of awareness of the EMPs, the training they had gone through and the impact of the environmental aspects, (Appendix 3). The target groups for employee respondents were 15 from the underground for oil, 20 from the concentrator for dust and from the smelter 20 for dust and 20 for SO_2 management. Ten respondents were selected 5 from the concentrator and the other 5 from the smelter for effluent. The sample that was eventually chosen constituted 10% of the population which Contreau-Levine (2000) and Alreck (1985) concur is adequate to draw statistical inferences. The respondents were divided into strata according to their grades and systematic sampling was used to select the sample in each grade and shift.

3.2.4. Interviews

Structured interviews were employed to collect data from management and from heads of sections responsible for ensuring that the objectives of the EMS were achieved, (Appendix 4). The environmental officer, Safety Health and Environment (SHE) officers for the underground, concentrator and smelter were interviewed. The foremen for these sections were also included since they were directly involved in the generation and management of the aspects.

The interviews were also carried out with the health personnel at the local clinic, Department of Natural Resources (DNR) personnel and the responsible authority, Bindura Rural District Council (BRDC). The local health personnel were asked to relate the changes they observed since the inception of the EMS in terms of the health cases that were reported to the clinic. The other interviewees were meant to explain their observations on the impact of the EMS on pollution reduction, crop growth and livestock rearing. The interviews sought for the stakeholders' understanding of the EMS and the part they played in its implementation.

3.3. Secondary Data Collection

The secondary data from company records were collected using a checklist and some data sheets. The main thrust was to identify the environmental performance indicators (EPIs) and to establish whether they were effective in enhancing EM.

3.3.1. Checklist

A checklist, (Appendix 5), was used to collect data on EMS components. It sought for the nature of the components, their adequacy, clarity and conformance with ISO 14001 standards. The thrust of the checklist was to determine the components and assess their contribution to EM.

3.3.2. Data Sheets

Data sheets were used to collect data on the major environmental aspects outlined below for January to April 2003 to be able to compare with data from the field for the same period in 2004 and the set targets.

- Effluent Discharge – Quantities of fresh and recycled water, pollutant concentration for the parameters outlined on 3.2.2.1 and the volume of discharge.
- SO_2 Emissions - The quantities emitted and target.
- Oil Spillage – The quantities of oil that were used in the Diesel Workshop and the amount of oil that was recovered since January 2003.
- Dust Emission – Levels that were recorded in 2003 at the crushing plant and smelter and the quantity of dust that was recovered from the implementation of the EMPs.

The data were essential for determining the level of success that had been achieved by the EMPs when compared with field measurements. The secondary data were also used to determine the

OPIs such as recycling, reusing and the emergency procedures as well as the ECIs in form of the specifications proposed by the EMPs.

3.4. Data presentation and Analysis

The collected data are presented in tables, graphs and flow diagrams. The graphs were meant to compare trends of the recorded data for 2003 with what was derived from the field in 2004 and set targets. The environmental targets were compared with the field measurements to determine the progress of the EMS. Confidence intervals for proportions were used to cater for measurement error at 0.05 confidence level. The results of findings were compared with the set targets that happened to be Zimbabwe National Water Authority (ZINWA) and World Health Organisation (WHO) standards.

CHAPTER 4: PRESENTATION AND DISCUSSION OF DATA

4.1. Introduction

The EMS at TNM and BSR was ISO 14001 certified in October 2003. It had an environmental aspect register that covered over 60 aspects, whose significance and value were determined. Aspects that had a value above 40 were regarded as significant thus had a management programme put in place. There were more than 20 EMPs at the study area but this research focused on four – effluent ranked 64, SO_2 ranked 63, dust ranked 54 and oil ranked 42.

This chapter is divided into two sections; one looks at an overview of the major EMS components and the other at the four EMPs. The EMS components constitute the overall initiatives made by the company to ensure that EMPs were implemented. Components exclusive to each aspect together with other pertinent variables are then discussed separately in the subsequent section.

4.2. Major EMS Components

This section identifies the major EMS components and assesses their contribution to EM. The research revealed that the EMS at TNM and BSR were environmental policy, planning and resource allocation; EMS training and awareness; procedures, emergency requirements and corrective action; and documentation as the key components.

4.2.1. Environmental Policy, Planning and Resource Allocation

These three components formed the pillars upon which the company's EMS was developed. BNC developed an environmental policy (see appendix 1) that is meant to govern the environmental performance of its three entities – TNM, Shangani Mine and BSR. The company pledged its commitment to comply with legislation, periodically set objectives and targets, prevent pollution, continually improve environmental performance, involve stakeholders in environmental management (EM) and conduct EIA for new operations. Six managers – the chief executive officer, SHE and environment managers, Shangani, TNM and BSR managers – and a workers' representative, signed the policy. Management declared their commitment to policy implementation in their various capacities and acknowledged the importance of employees by including a representative on the policy signatories. Contrary to a good policy statement that cites the key stakeholders (Natoli, 1995; SAZ, 1996) the study found that the environmental policy at TNM and BSR did not cite its key stakeholders. The employees, contractors, customers and suppliers of goods and services were critical in EM, but were not on the statement.

The research revealed that the company complied with legislation by applying for licences to discharge wastewater and emit fumes into the environment according to EMA (GOZ, 2002). However the practice contradicted the Polluter Pays Principle (PPP) that requires the polluter to bear the full cost of damaging the environment (Dommen, 2002). The company paid to government departments that did not rehabilitate the damaged environment. The objectives and targets for the EMPs, section in 4.3, were set and reviewed annually to enhance continual improvement. An EIA was conducted in 2004 for the disposal of iron arsenate cake, a toxic substance, to prevent water contamination.

The research found out that the company made some effort to communicate its environmental policy to stakeholders and put an organisational structure, Figure 4.1, in place for effective policy implementation.

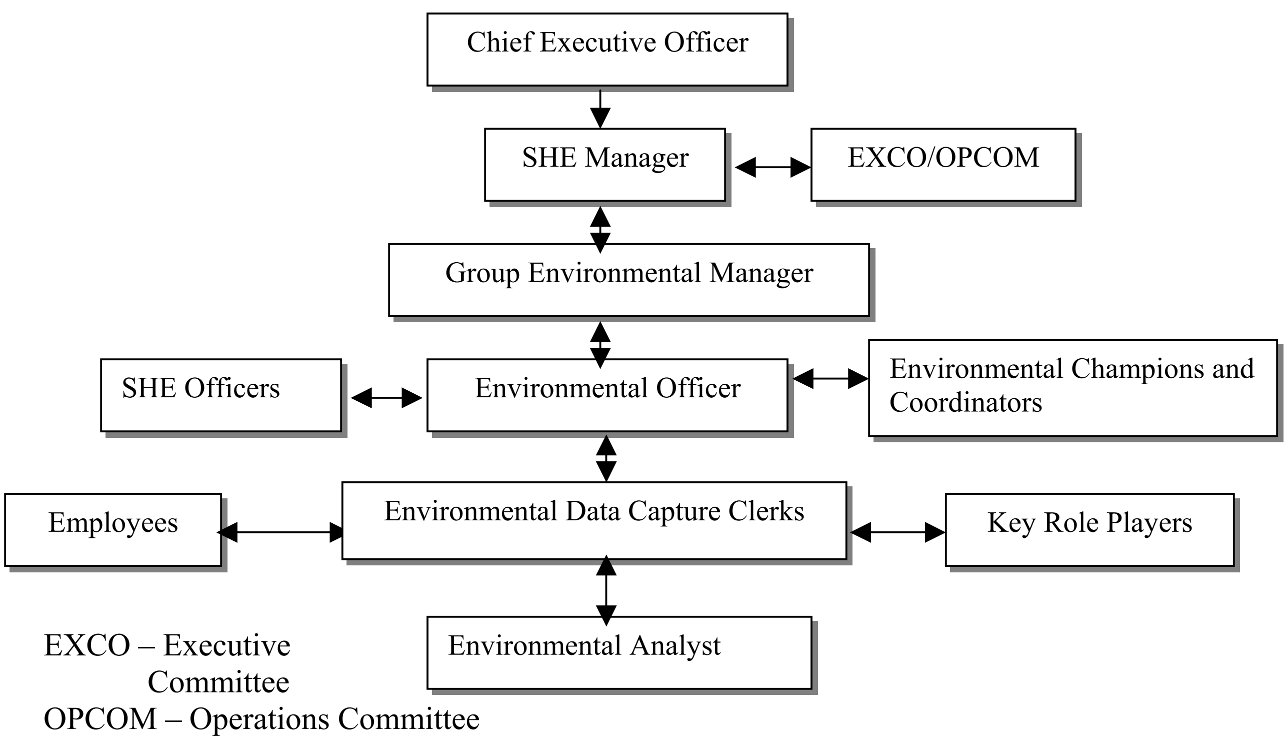

Figure 4.1: TNM/BSR Organisational Chart **Source**: **TNM and BSR EMS Records**

A copy of the policy was displayed on notice boards of almost every office and verandas where it was easily accessible to employees and other stakeholders. It was written in local languages – Shona, Ndebele and English– for all to understand and uphold the values enshrined in it. The environmental organisational structure, (Figure 4.), communicated the policy and showed the various levels at which environmental issues were tackled.

The study revealed that the highest level, EXCO/OPCOM met once a month and the lowest level, the key role players met once a week to check on environmental progress and decide on the action to overcome challenges. The levels inter-related in a two-way communication system that allowed free consultation with one another resulting in a clearer understanding of environmental objectives. The top management defined the policy and supplied the necessary resources for EM while the lower levels implemented and monitored progress in EM then freely reported the progress to the next level. The study showed that each level had a part to play in EMS implementation in line with sound policy implementation advocated by ISO (2002) and Smith (1991). Lack of commitment by any one level impeded progress in policy implementation.

The research found out that a budget (Table 4.1) was set annually as an integral part of the company's business activities. It enhanced environmental performance since the requisite resources were provided and the employees were motivated to move on.

Table 4.1: Budget for TNM and BSR Environment Department

Item	Allocation in Z$'000	% of Total
Training	52,450	9.4
Travel Expenses	56,940	10.4
Water act Compliance	150,000	27.5
Air Pollution	16,000	2.9
Waste Management	120,000	22
Rehabilitation of Slimes Dams	38,000	7
Addressing Environmental Aspects	18,000	3.3
Environmental projects	7,000	1.3
Annual environmental Competitions	3,000	0.6
Certification, Surveillance Audits	85,000	15.6
Total	**545,390**	**100**

Source: TNM and BSR EMS Records

Note: Z $4,500 at auction rate and Z$800 as official rate =US $1 at the time of the study, June 2004.

The company records showed that water management and waste management (WM), critical in reducing effluent discharge into surface and ground water bodies, took up almost 50% of the budget. Training, also important in equipping employees and other stakeholders with the requisite skills to tackle environmental problems, took up almost a tenth. Although air pollution was allocated 3%, funds were made available to secure a gas analyser to monitor SO_2 at a cost of SAR30, 000,000.00 in March 2004. The analyser enabled the company to monitor sulphur dioxide emission levels so that it could design appropriate management programmes. The other components of the budget such as rehabilitation and environmental projects were at various stages of implementation so as to restore the damaged land to its original state.

The study showed that the budget committed a substantial amount of money to EM that demonstrated that the company attached a high value to environmental conservation. The environmental projects outlined above were planned for and implemented on the basis of the resources that were made available. The environment department at the company confirmed that, they were spurred to work hard by the unwavering support they got from management although the resources allocated to them were not sufficient for their EM needs. The TNM and BSR environment department confirmed that they used the budget for planning and developed confidence needed to ensure that environmental conditions were improved.

The study showed that an Environment Department that had its own staff compliment was set up at TNM/BSR to enhance environmental performance. The Group Environment Manager headed the department at company level and an environmental officer at TNM and BSR level. Four SHE officers, each responsible for a section – mine, concentrator, smelter and refinery - and data capture clerks were also part of this department. The setting up of the department demonstrated the seriousness EM was regarded at TNM and BSR. The department was treated like any other at the company and was tasked to draw up EMPs, training, rehabilitation and environmental projects/programmes in consultation with section heads. The department strived to ensure that EMPs were implemented and drew up some audit programmes for monitoring and enforcing corrective action.

The findings showed that BNC put in place an audit system that comprised internal and external auditors who periodically monitored the performance of the EMPs in a bid to enhance continual improvement. SHE officers, environmental co-ordinators, champions and key role players did the internal audits. Internal audit teams were made up of superintendents, foremen and mine captains who enhanced the effectiveness of the EM since they were fully aware of the production processes. External audits were carried out by people from SAZ and from the Association of Mine Managers of Zimbabwe in an effort to buttress internal efforts in EM. The audits brought about what Cullen (1999) and Hart (2001) regard as a change in environmental behaviour in business operations. The audits kept the employees busy in trying to meet set EM targets and instilled some sense of seriousness and commitment among them. - they strove to avoid a non-conformance charge. These audit programmes showed that departmental audits were carried out monthly, internal quarterly and external half yearly. As a result the EMPs were implemented and the environment continued to improve in accordance with EMS requirements for the ISO 14001 certified companies (ISO 2002; SAZ, 1996).

4.2.2. Training and Awareness

The study showed that training was under the Environment Department and was designed to raise EMS awareness among new and old employees. It also updated them on the company's environmental values and what they were expected to do in EM and policy implementation. The training programme catered for all categories of employees however the courses were designed to meet the specific needs of each worker category as shown in Table 4.2.

Table 4. 2: The Training Programme for TNM and BSR.

Course	**Target**	**Date**	**Venue**	**Trainees**	**Duration**	**Total Manhours**
EMS CP and SD	All Employees	19.02.03	Mine School	56	2 hrs	112
Environmental Law and Legal Compliance	Senior Management	02.03.03	Coach House	31	8hrs	992
EMS CP and SD	Admin and HR	14.04.03	Coach House	16	4hrs	64
Environmental Cost Management	SHE Officers	19.04.0 4	Country Club	8	8hrs	64

. C.P. – Cleaner Production . H.R.- Human Resources Managers

. S.D. – Sustainable Development . SHE Safety, Health and Environment

Source: Extracts form TNM and BSR Records

The findings revealed that SD courses were designed for all employees to keep them abreast with modern trends in EM and to ensure, according to Andrew et al, 1998 and WCED 1987, that the need for intergenerational and intragenerational distribution of resources was understood. The courses were meaningful to the target groups who were trained to tackle the challenges they faced in their specific working environments. New employees were inducted before they started work, a critical exercise, however the study revealed that the induction programmes did not engage the participants in active interaction with the EMS concepts. An induction course the researcher went through before carrying out the research was a mere routine drill that did not seek for a clearer understanding of the learnt concepts.

The training courses varied in duration, took up some time from the routine production duties and drew some financial resources from the company budget (Table 4.1). The duration of the courses varied from two hours to a week so as to cater for the varying needs of the participants and to accommodate the breadth of the concepts that were covered. The longer courses were designed for management and environmental champions who were prepared to impart the learnt skills and concepts to employees. The facilitators also varied and some of them were from outside the company and Bindura to eliminate monotony and enhance participation. The training programme (Table 4.2) reveals that training sessions took up a large amount of productive man-hours since the employees were trained during the normal working time. The company sponsored the courses and allowed its employees to attend which demonstrated what Anderson (2003) regards as a company's commitment to EM.

The research revealed that employees of all age groups and level of education had the chance to attend EMS training courses see Appendix 3. About 95% of the sample (85) confirmed that they had been trained on EMS while 75% had attended more than one session since 2003. The outstanding five percent had served the company for more than ten years yet had not been offered the chance to train on EMS. The implication is that the training programme was active but there was need to fill the outstanding 5% gap for all the employees to tackle environmental challenges from the same viewpoint. All the workers who had attended training sessions (100%) acknowledged that their understanding of environmental issues was attributed to the training they had received. They also confirmed that they were allowed to suggest their training needs hence were motivated and owned the training sessions in which they actively participated as what was witnessed by the researcher in one of the EMS workshops he attended.

The questionnaire survey showed that the level of awareness essential for EMS implementation was variable among employees and stakeholders. Except for SO_2 management, 100% of the sample confirmed full awareness of the EMPs for the other three aspects. For SO_2, 70 % were aware, 30% of confessed lack of knowledge of the EMP and 10% confidently said there wasn't any programme in place. The emerging indications were that the EMP for SO_2 was not clear to the key participants in its implementation, a situation that negates the development of what Johnston and Murray (1995) refer to as the stakeholder confidence in EM.

The study revealed that most of the employees did not know the targets for the EMPs of the major environmental aspects in their departments. When asked to identify the targets, the following results showing those who were able to do so were obtained; SO_2 0%, dust 15%, oil 47% and effluent 75%. The results show that none of the groups of respondents for the four significant aspects scored 100% level of awareness. The results suggest that the accomplishment of objectives and targets in this light was difficult since the people who were directly involved in managing the environmental aspects were not sure of what they had to achieve. Training was lacking in updating employees so that they focussed on achieving set tasks.

The study also showed that contractors, customers and other service providers were trained on the need to observe the company's environmental values in issues such as disposal of waste, handling of oils and transportation of raw materials. The courses were designed for all the service providers so that they became partners with the company in EM. In instances where technical knowledge was required in handling particular products or raw materials, BNC's environment department and the supplier's technical department met and mapped the way forward. This arrangement that sought for the involvement of suppliers and service providers saw effective design and implementation of programmes such as oil management at a lower cost since expertise was readily available.

The interview survey revealed that the level of awareness of the EMS at TNM and BSR among farmers and other key stakeholders was also variable. The Department of Natural Resources (DNR) and Ministry of Health (MOH) confirmed that they were fully aware and were at times asked to facilitate in training sessions organised by the company. The involvement of the DNR and MOH yielded what Brown and Laurenson (1995) refer to as a positive environmental image for the mining company. However, the findings found that only 25% of the local farmers were aware that an EMS was in place at the study area. The local authority, Bindura Rural District Council (BRDC), confessed ignorance of the system except that an EIA was undertaken on the disposal of iron arsenate cake in 2004. The environment department at TNM and BSR confirmed that the two - farmers and responsible authority - were in the past left out but had realised the need to work with them in line with requirements of ISO14001 standards. Lack of full involvement of the local farmers and the responsible authority negated the company's policy statement that called for the participation of stakeholders. It also confirms the need for them to be cited on the statement as some of the key stakeholders.

4.2.3. Environmental Procedures, Emergency Requirements and Corrective Action

The company drew up environmental procedures for performing critical tasks that led to proper EM of environmental aspects and documented them in the environmental procedure manual for reference. The study revealed that the environmental procedures were clear, defined the specific task, assigned responsibility for the tasks, defined terms and described the method involved step by step. The procedures enabled a follow up to be made easily since there was someone to consult when there was a problem. Work instructions were put at the site where the tasks were to be performed thereby enabling the employees to do the task well since they referred to the notes when they were faced with some problems. The person in charge was accountable to ensure that the tasks were performed according to the company's defined expectation to avoid a non-conformance charge that could be made against him.

The research showed that emergency procedures were developed to handle potential disasters that were identified to avoid environmental degradation. The employees were continuously engaged once a month in mock disaster exercises seen by Natoli (1995) as necessary to test the effectiveness of the procedures and remind the employees of the appropriate action to take when disaster struck. The employees were compelled to have the requisite personal protective equipment (PPE), corrective equipment and materials ready so that when an emergency bell rang, they reacted without delay. The researcher witnessed the emergency plans put in action to contain chemical spillage from rusty containers at the concentrator and slimes spillage from broken pipes in the nearby forest by the teams that were in place 24 hours a day.

The findings revealed that mechanisms were put in place to remedy an event and to ensure that it did not recur. An incident report was written for every emergency such as oil spillage, wastewater pipe burst and accidental emission of waste into the environment. The company policy was that when a major event occurred, the operations that were directly involved were temporarily stopped until the problem was rectified The event was reported to the SHE section of the department that would advise the environment officer for immediate action. The incident was thoroughly investigated to detect the cause and where poor workmanship was the root cause, the responsible employee was cautioned or even fined for carelessness. The written report cited the cause of the incident, the corrective action that was taken and what could be done to avert the recurrence of the same problem.

4.2.4. Documentation

The research revealed that EMS documents were kept as sources of reference in the implementation of the EMPs. A filing system was prepared to ensure that the requisite documents were kept and the important detail was captured. Among the documents kept at TNM and BSR were environmental procedures, training manuals, emergency procedures, audit and incident reports, water balances, water analyses, records of emissions and EMPs. The documents were annually reviewed and new detail was added to update them. The documents at TNM and BSR were filed for easy access and complied with the requirements of ISO 14001. Management, in this regard, prepared enough documents to see effective implementation of its EMPs.

4.3. Major Environmental Management Programmes and their Indicators

An EMP is designed to cater for the management of a specific environmental aspect HMSO (1991). The EMP is made up of targets, objectives and performance indicators that entail provisions, activities and change in environmental conditions. The thrust of this section is to determine the performance indicators of four major EMPs and evaluate their performance in EM soon after they are identified so as to enhance coherence in the flow of the presentation and discussion. Data from in records for 2003, findings from field measurements in 2004 and the targets that were set by the company were used to determine and evaluate the progress in EMS implementation.

4.3.1. Effluent Management

BNC designed an EMP for wastewater generated during the production processes and was or could have been discharged into the environment. The study revealed that the effluent EMP focussed on the reduction of effluent discharge and the level of contaminants in the wastewater that was eventually discharged into water sources shown in Figure 4.2.

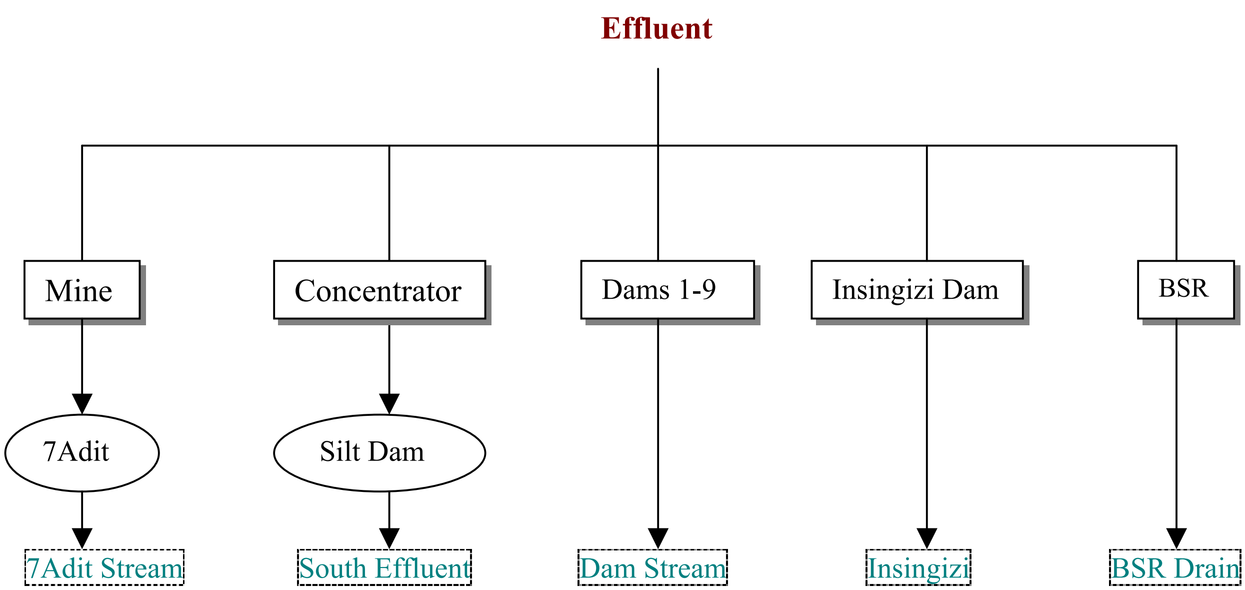

Figure 4.2: Sources of Effluent and Effluent Streams **Source: Research Findings**

Effluent management was the responsibility of all the sections that generated it. They had to ensure that it did not contaminate water sources.

4.3.1.1. Effluent Management Targets and Objectives

The EMS documents revealed that the target was to achieve zero effluent discharge. The main objective of the effluent EMP was to comply with the requirements of the Environmental Management Act (EMA). The research found that although the target was clear, measurable and achievable, the time frame was not embodied in it, rather it was in a separate column. It is necessary to have the time frame as part of the target to maintain focus. The objective was not specific and clear; it did not specify the provisions of the legislation it intended to comply with. The act, EMA, referred to has two requirements: one of obtaining a licence to discharge and the other not to pollute water sources (GOZ, 2002). The mining company needed to be clear of its EM intentions so that trends in EM could be followed. However, the study revealed that the company obtained a licence to discharge its effluent into public streams in compliance with EMA, Section 60.

4.3.1.2. The Effluent EMP Management Performance Indicators (MPIs)

The study found out that the company drew up an effluent EMP and provided the requisite resources to enhance its performance. Management purchased and installed borehole equipment, water pumps and meters for recycling wastewater. The company also secured some chemicals such as lime for water treatment to neutralise it before it was discharged into public streams.

The research revealed that a private company was hired to sink five boreholes: one at the following places; downstream of Insingizi valley; slimes dams 4 5, 6 and 9; slimes dam 7; near Savva; near training school and at Chihuri Farm. Two of the boreholes, Savva and Training School, Figure 3.1, were mainly for monitoring ground water contamination. The other three served a dual purpose: they were for monitoring purposes and provision of water for recycling and other uses. The boreholes had been sunk and were critical in determining the quality of ground water for planning corrective action such as liming to reduce pH values. The MPI was effective in that the boreholes had been drilled and were in operation.

The findings showed that the company committed resources to the purchase of water pumps and pipes for recycling water from the boreholes, slimes dams and oxidation ponds to various workplaces. The pumps were set up at dams 1, 2 and 3; 4 5, 6 and 9; Insingizi borehole; floatation pump on Insingizi Dam; 7 Adit; Burnside Dam; slimes thickener, concentrate thickener, smelter and BSR. They were meant to pump water that was recycled for the various processes at the company. The company also installed some water meters at points where water was brought in the plant and where it left so that it was quantified. The accomplishment of the

MPIs was attributed to the adequate resources such as funding alluded to in 4.2.1, and presented in Table 4.1, that were provided for effective EM.

4.3.1.3. The Effluent EMP Operational Performance Indicators (OPIs)

The research showed that three operational indicators – wastewater recycling, treatment and monitoring - were in practice to dictate the performance of the EMP. Recycling of water was a major operation that affected raw water consumption and the volume of wastewater discharge. Monitoring was for surface and groundwater that was done by collection of samples for laboratory analysis to determine the level of pollutants. The major water treatment operation was addition of lime to the wastewater to reduce pH values.

The findings revealed that the target for recycled water at TNM and BSR was 3% over the 2003 average of 87,000 m^3 of water per month. The trends in consumption of raw and recycled water at the mining company were as shown on Figure 4.3.

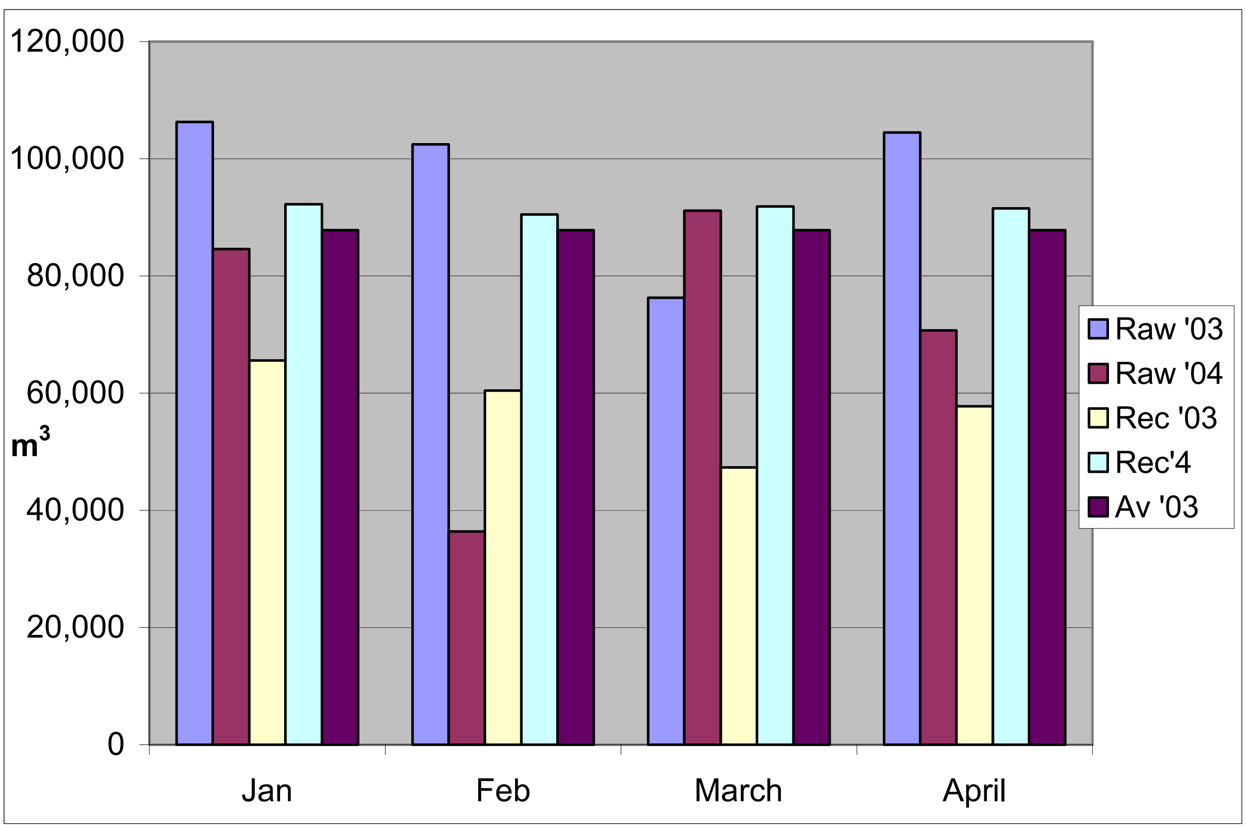

Figure 4.3: Raw and Recycled Water, '03 and '04 **Source: Research Results**

Figure 4.3 shows that consumption of recycled water increased by an average of 4.2% throughout the four months in 2004 thereby exceeding the target by 1.2%. Slightly over 80,000 m^3 of water were recycled per month in 2004. The increase in the use of recycled water implied that the volume of discharge was reduced and the EMP was towards achieving its objectives. The level of consumption of recycled water reflected that there was continual improvement throughout 2004. More recycled water was used in 2004 than in 2003 which implies that the volume of raw water drawn from Mazowe River was reduced.

The results, Figure 4.3, reveal that there was a decline in the consumption of raw water in 2004 except in March when levels exceeded those of 2003 but below recycled levels. The implication was that there was a reduction in the volume of raw water that was put into circulation and that it was conserved for future use or for other users in line with the concept of resource conservation (Starkey and Welford 2001; Andrew, 1998). The reduction in raw water input into circulation meant that ultimate discharge was also reduced as reflected on discharge results, Figure 4.5.

The research found that the mining company treated its wastewater by adding some chemicals such as lime to neutralise it before it was reused or discharged into the environment. Ponds such as the Silt Pond at the concentrator, Figure 4.2, and others at places where process water was discharged were constructed. Water samples were taken hourly from the ponds and sent to the company's laboratory for analysis. The analysis results determined the amount of chemicals that were needed to treat the water. The treated water was eventually discharged into the environment after having satisfactorily met the required pH values. The treated water became safe as Brown and Laurenson (1995) confirm that treating water at Ranger Uranium Mine, Australia, protected Kalahagu National Park from acidic pollution.

The findings revealed that the mining company had a water sample collection schedule for monitoring pollutant discharge. Water samples were taken from 11 surface water points and 8 boreholes for monitoring purposes twice a month. The samples were sent to Zimbabwe Water Authority (ZINWA), the responsible national body, for analysis. The results for the surface water analysis on Table 4.3 and for ground water on Table 4,4 enabled the company to plan and design strategies for the treatment of water. ZINWA visited the sampling sites annually to verify the condition of the water that was discharged into the environment.

4.3.1.4. Effluent EMP Condition Indicators (ECIs)

The EMP intended to achieve zero effluent discharge into the environment. Results showed that the target was partially achieved; 3 out of 5 effluent outlets had zero discharge and the other two continued discharging into surface streams. The three that remained dry each time samples were taken were 7 Adit, BSR Main Drain and Insingizi discharge outlets, Figure 4.2. The zero discharge condition in these outlets was attributed to recycling of wastewater. It was noted that at each point of discharge -7 Adit, Insingizi and BSR - there was a pond and a water pump for returning the used or collected water to the plant for reuse.

The research found that a licence was obtained for the two streams, South Effluent and Dam Streams, that were discharging into surface streams. This was done in compliance with EMA of 2002, section 60 which stipulates the conditions required to obtain a licence but does not specify the level of pollutant concentrations in the discharge. Besides obtaining the licence to emit, the company strived to reduce the volume of wastewater discharge into the two streams, Figure 4.4.

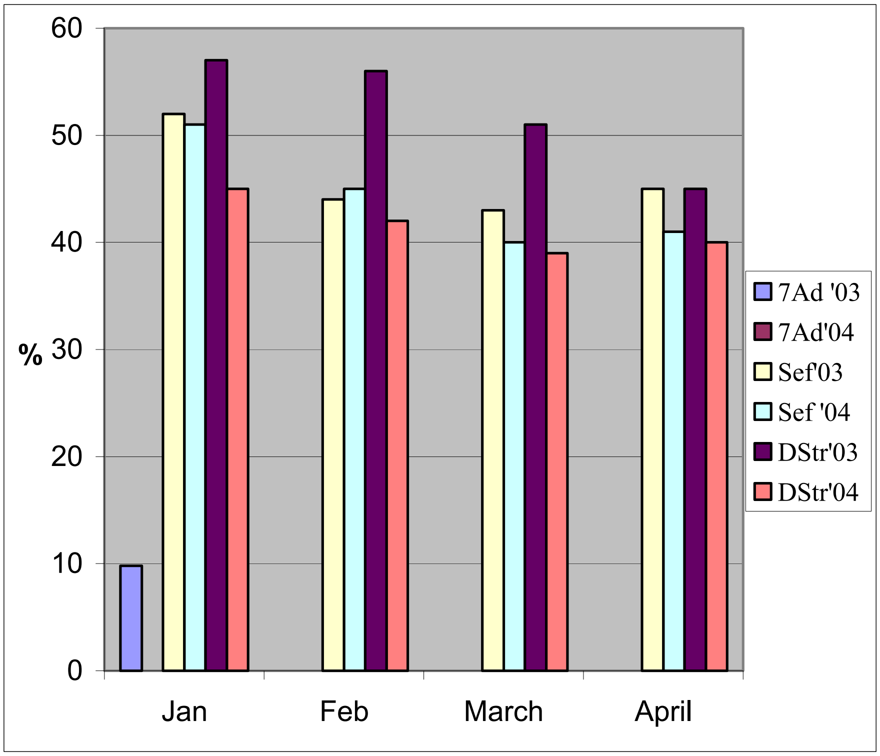

Figure 4.4: Percentage Effluent Discharge at TNM and BSR

Source; **Research Findings**

The results show that 7 Adit last discharged about 10% in January 2003. South effluent discharged over 50% of 60,000 m^3 in January 2003, thereafter wastewater discharge declined to levels below 45%. The 2004 discharge was lower than the 2003 levels in most cases, an indication that the earlier was performing better than the latter. Dam Stream started of at a high discharge of over 50% of 100,000 m^3 in 2003 that continued to decline to levels above 40%. In 2004, it started at a lower level than 50% then continued to decline to about 40%. This shows that wastewater discharge continued to decline over time hence the effluent EMP controlled the level of discharge into the streams.

The water samples that were taken from the surface streams and boreholes showed the concentration of pollutants in water at and near the study area, Table 4.3, in surface water for the points in Figure 3.1, page 28.

Table 4.3: The Pollutant Concentrations of Surface Water (ppm) at TNM and BSR.

	Arsenic		pH		Sulphate		Nickel		Copper		Cobalt		Oil/Grease	
	03	04	03	04	03	04	03	04	03	04	03	04	03	04
Dam Stream	<0.005	0.005	8.2	7.3	1035 (995)	418 (388)	<0.1	<0.1	0.02	0.02	0.1	0.1	6 (5.8)	2
Downstream Burnside	<0.005	0.005	8	7.8	319 (297)	393 (361)	0.3	0.4	0.03	0.12	<0.1	0.1	6 (5.8)	2
Pote	0.005	0.005	7.4	7.2	56	65	0.1	0.1	0.01	0.02	0.1	0.1	2 (0.6)	2
South Effluent	0.005	0.005	7.8	7.8	604 (550)	320 (284)	3.2 (2.3)	1.2 (0.7)	0.03	0.03	<0.1	0.1	4 (1.6)	3
TNM Cons Slurry	0.005	0.005	8.1	7.8	1066 (1013)	207 (187)	<0.1	<0.1	0.03	0.01	0.01	0.01	2 (0.6)	2

Source: Research Findings

The concentration level of the majority of the parameters were within the permissible limits for ZIMWA, World Health Organisation (WHO), Appendix 2, and set targets which shared the same values except for sulphate, nickel and grease/ oil. The problem pollutants were put to a statistical test at 0.05 lower confidence limit (LCL) to cater for the measurement error and determine whether they exceeded set targets. The LCL results in brackets on Table 4.3 reveal that some of the parameters shifted to a lower band. Only one parameter, greases/oil on South Effluent changed from green to the permissible blue in 2003.

Table 4.4: Effluent EMP and the Targets

Year	Result	Proportion	LCL	UCL
03	28/35	0.8	0.63	0.90
04	31/35	0.88	0.81	0.95

LCL -Lower Confidence Limit   UCL= Upper Confidence Limit

Source: Research Findings

The results in Table 4.4 show that the effluent EMP met the target in 80% of the cases in 2003 whereas in 2004 it met it in 88% of the cases. The score for 2003 was within the LCL and ULC of 63% and 90% respectively. As for 2004, it was between 81% and 95%. It can thus be concluded that the EMP performed better in 2004 than in 2003, which suggests that there was continual improvement as the level of pollutant concentrations declined.

Although the concentration levels in problem pollutants remained beyond the permissible limits, the results show that EMP was continually improving wastewater conditions. Most of the pollutants changed from a higher band to a lower one in 2004 including nickel that remained in red but changed to a lower value. Sulphate which was in the red, the highest level of pollutant, in 2003 in all streams except Pote in blue, declined to the yellow band in 2004. Grease/oil declined from green in 2003 in most of the streams to the permissible blue in 2004. The concentration levels in Pote River were below the set targets in all the parameters throughout. The decline in greases/oil concentrations was attributed the effectiveness of the oil management programme, section 4.3.3, that reduced the amount of the hydrocarbons in wastewater.

The questionnaire and interview surveys, Appendices 3 and 4, found that the EMP improved environmental conditions. All the farmers, 100%, confirmed that wastewater from the streams did not affect their livestock and crops. The farmers said they did not know any cases of livestock that got ill or died from drinking water from the effluent streams, the nearest source of water to them. The health institutions in the area, MOH, DNR and responsible authority, BDRC, concurred that they had not received cases of illnesses or death of either people or animals from using water from the effluent streams. The EMP thus was able to contain some of the harmful pollutants, except the unknown long-term effects that are yet to be investigated.

The level of pollutants in ground water at and near the study area is shown on Table 4.5. The values in brackets were calculated at 0.05 lower confidence limit to cater for measurement error.

Table 4.5: Level of Contaminants in Ground Water (in ppm) at and Near TNM and BSR

Point	Alkalinity		Arsenic		pH		Sulphate		Nickel		Copper		Cobalt		Oil/Grease	
	03	04	03	04	03	04	03	04	03	04	03	04	03	04	03	04
Savva	241	203	<0.005	<0.005	7.7	6.8	203	135	0.16	0.2	0.02	0.05	0.1	0.1	26 (18.7)	2
Training School	207	377	<0.005	<0.005	7.5	7.2	117	59	0.13	0.1	0.09	0.01	0.1	0.1	6.5 (5.2)	2
Coach House	11	91	0.009	<0.005	7.3	7.4	274 (241)	242	<0.1	0.1	<0.01	0.01	0.1	0.1	4 (1.6)	2
Taylor	268	184	<0.005	<0.005	7.7	7.3	19	16	<0.1	0.1	0.04	0.03	0.1	0.1	2 (0.56)	2
Insingizi	168	171	<0.005	<0.005	7.8	7.5	76	90	<0.1	0.1	0.02	0.02	<0.1	0.1	4 (1.6)	2
Chihuri	97	92	<0.005	<0.005	6.6	7.3	900 (864)	218	0.26	0.1	0.07	0.01	0.1	0.1	4 (1.6)	2

Source: Survey Results

The results show that the majority of the pollutants were within the normal band except sulphate and grease/oil that affected some of the boreholes in 2003 but were contained in 2004. When the LCL was calculated at Coach House sulphate moved from green to blue while the same occurred to grease/oil at Coach House, Insingizi and Chihuri Boreholes in 2003 in brackets, Table 4.5. However sulphate at Chihuri and grease/oil at Savva were beyond limits in 2003 both went down sharply to within permissible limits. Taylor borehole that was far away from the study area had pollutants within permissible ranges which implies that the contaminants were contained or got diluted before getting to the sampling points.

The study revealed that Effluent EMP contained the problem pollutants and reduced them significantly. The reduction in sulphate at Chihuri Borehole could be attributed to zero effluent discharge in BSR Main Drain that used to drain through the area. The oil management programme, section 4.3.3, alluded to earlier also contained grease/oil from contaminating ground water sources. At 0.05 confidence level, the effluent EMP met its target by between 77% and 97% in 2003. In 2004, the EMP on ground water contained all the pollutants within the permissible range; it achieved 100% effectiveness.

Overall, the study reveals that the effluent EMP contained the major pollutants. The surface streams showed that there was continual improvement in reducing contaminants and the volume of discharge. The EMP also contained pollutants in groundwater. The success of the effluent EMP was attributed to the oil management programme, zero effluent discharge and wastewater treatment programmes that were introduced in 2003.

4.3.2. Sulphur Dioxide EMP

The study found that SO_2 was mainly discharged at the smelter from processing a sulphidic ore and in small quantities at the boiler from coal combustion. Large volumes of the gas were emitted at the smelter during charging and leach blow processes, Table 4.5. The heat that was introduced into the smelter liberated the gas from the sulphidic ore at smelting which then found its way out through the stacks or any openings/vents into the atmosphere. The leach blow process, section 1.6.2.3, that was meant to reduce the volume of sulphur from the leach alloy, produced large volumes of SO_2 that were emitted into the surroundings. Two stacks and a precipitator that had induction fans were set up to disperse the gas into the upper atmosphere so that it did not affect the immediate environment.

4.3.2.1. Target and Objective

The research found that the target for the SO_2 EMP was to achieve emissions that were below 30mg/m^3. The objective was to comply with the requirements of the Atmospheric Pollution and Prevention Act (Control of Emissions S. I. 141, 2000). The target was specific and measurable however it did not specify the time period in the statement. The objective did not spell out what it intended to comply with in the legislation.

4.3.2.2. SO_2 MPIs

The research revealed that management provided resources for the rehabilitation and maintenance of the precipitator for it to draw the gas out through the stacks. This was in response to recommendations made by a consultancy firm, Environtech Consultancy Services, hired in October 2003 to study the emission of the gas and make recommendations on how to contain it. The precipitator however frequently broke down therefore did not effectively perform to expected standards. The consultancy firm also recommended that the stacks could be raised and constant monitoring was necessary to determine levels of concentration for planning purposes. The firm however did not suggest any measures that could contain contamination at source in line with the concept of cleaner production recommended by (Hart 2001) as the best EM practice in modern industry. The mining company did not raise the stacks because the consultancy firm suggested it as an option. It was also found that the company bought a gas analyser for measuring and monitoring the concentration of SO_2 emitted from its operations, at source and in the neighbourhood in order to develop management plans.

4.3.2.3. SO_2 OPIs

The study found that the major operations in practice at TNM and BSR were repairing the precipitator, maintenance of the smelter and constant monitoring of the emissions of the gas. The precipitator was repaired but frequently broke down thereby raising gas concentrations. It was revealed that the programme was affected by the shortage of spare parts. The study found that the furnace was maintained every Tuesday to enhance performance and reduce emission into the environment. It was however affected by the poor performance of the precipitator.

A gas analyser was used to monitor levels of the emissions on a weekly basis. Management provided transport for the monitoring exercise that was carried out by the Environment Department at the company. The research revealed that the company obtained a licence to emit the gas and other fumes into the atmosphere in compliance with the Atmospheric Pollution Regulations, General Notice 56 of 2001 (GOZ 2001), since nickel processing was a classified process. The licence did not help reduce pollution levels because it did not specify the pollution levels nor did it make it mandatory for the company to pay for measures to reduce pollution as required by The Polluter Pays Principle (PPP) (Dommen, 2004).

4.3.2.4. SO_2 ECIs

The study found that the environment was expected to achieve SO_2 concentrations that were below the WHO recommended levels of 30mg/m^3 at the workplace. The stacks had to disperse the gas in the upper atmosphere beyond the chimney height of 40 metres above ground surface. The results for SO_2 at source and other workplaces nearby are on Table 4.6.

Table 4.6: Sulphur Dioxide Levels (mg/m^3) at the Workplace

Location	Charging	Leach Blow
Smelter Furnace 1	1032	1965
Smelter Furnace 2	579	1304
Smelter Furnace 3	328	88
Converters	93	4000
Smelter Workshop	0	0
Smelter Offices	3	3
Dryer	0.13	0
Boilers	0.5	0
Refinery Offices	1.3	0
Tankhouse	0	0

Source: Survey Results

The results show that there was high SO_2 concentration at source, the smelter and converters that were adjacent to each other. The highest values during the charging process were recorded at the smelter while the highest during leach blow process were recorded at the converters. However the leach blow process generated higher concentrations. The results also show that at the values decreased with height at the smelter. The concentrations at these two places were beyond the target of 30mg/m^3 by a wide margin - the lowest values 88mg/m^3 and 93 mg/m^3 were too far from the target to call for the application of statistics to verify the differences from the target. The other places smelter offices, workshop, dryer, refinery offices and tankhouse recorded very low concentrations yet the furthest, the tankhouse was less than a kilometre from the smelter. The smelter workshop, dyer and smelter offices were just 50 metres away from the sources.

The results reveal that SO_2 was generated at charging when ore is fed into the smelter and heated by the charge that was introduced. The gas was liberated from the ore and escaped into the atmosphere. At the converter, the leach blow process was meant to reduce the sulphur levels in the sulphidic ore by blowing compressed air into the matte in converters, Section 1.6.2.3. The gas was thus liberated in large quantities depicted on Table 4.6. At the smelter, some of the gas escaped the control systems and found its way into the atmosphere. The precipitator failed to draw the gas out thus it tended to be high at the base of the smelter when the ore was fed in. The concentration level of the gas in the nearby places was determined by the wind direction. High values were recorded when it blew in their direction while some of the places such as the tankhouse and refinery were upwind of the smelter and the converter (Figure 3.2 page 28) thus were rarely affected.

The study found that the gas spread to the nearby areas shown on Table 4.7. The values in brackets have been changed to 0.05 LCL to determine whether there were significant differences between the target and the measured values.

Table 4.7 SO_2 Concentration (mg/m^3) in the Neighbourhood

Location	First Measurement	Second Measurement
Concentrator	0	0
General Offices	38 (29)	41 (32)
Clinic	3	10
Post Office	43 (33)	48 (39)
Beerhall	7	3
H2O Treatment Plant	0	0
Pote	0	0
Bowker	0	0
Sewage Ponds	0	0
Coach House	0	0
Insingizi	0	0

Source: Survey Results

The research found that on windy days, during the leach blow process, the gas was blown downwards from the chimneys and enveloped the nearby residential area. The higher values above the recommended target were recorded at the Post Office and the general offices. The Post Office had a mean of 46mg/m^3 that changed to 36mg/m^3 and the general offices had mean of 40mg/m^3 that changed to 31mg/m^3 when the LCL at 0.05 confidence level was applied. The levels were slightly above the target. The charging process did not affect the points in Table 4.7. The other places in the table had lower values than the target at leach blow and zero values at charging.

The post office was almost 500m away from the source of the emissions while general offices were almost a kilometre away but in the prevailing wind direction at the time of the study hence they recorded high values. It was observed that the gas was blown by wind from the smelter/converter and from the top of the stacks then descended onto the village and the general offices that were downwind. The study found that the gas did not affect the village and the surrounding areas during the charging process. During this process lower values were emitted and the gas tended to dissipate before it got to the post office and the general offices.

The other sampling points near the workplace that included the concentrator, water treatment plant, clinic and beerhall recorded low or zero values which was attributed to the influence of the wind direction on the spread of the gas. The results showed that all the sampling points beyond the company boundaries - Bowker, Pote, Coach House Inn, Sewage Ponds and Insingizi - recorded zero concentrations throughout the study period, March and April. The implications are that during the time of the study and weather conditions that prevailed, did not promote the spread of the gas to these areas and that they were some distance away from the source of the gas.

The questionnaire survey, Section 3.2.3, revealed that emissions affected employees both at work and home; it caused them to cough and sneeze. The researcher found the gas irritating during the study and made him cough and sneeze. Residents of the nearby village were exposed to risky health conditions since the readings were always above the WHO recommended level of $30mg/m^3$. Trojan Clinic confirmed that 60 families were relocated to a residential area upwind of the smelter to avoid the irritating effects of the offensive gas. The families had persistently visited the clinic complaining about an increase in asthmatic attack from bronchial irritation caused by the gas. The situation is confirmed by Gibbons (2001) and Wells *et al* (1994) who contend that excessive exposure to SO_2 leads to breathing difficulties to people suffering from respiratory infections such as asthma, bronchitis and emphysema.

According to the survey results, all the farmers interviewed (100%) indicated that the gas made it difficult for them to breathe, they coughed at home and in the fields and it damaged their cotton crop. The responsible authority, BRDC, confirmed that farmers had raised concern that the gas affected them but had not investigated the issue to verify the sentiments. Although Sinkala (2001) and Lack and Lambart (2001) allude to the point raised by the farmers that SO_2 damages vegetation and crops, the zero values that were recorded at the farm could not validate the sentiment. In addition, the crop the farmers cited was not in the fields to verify the concern that was raised. Nonetheless, there was need to continuously monitor the emissions for purposes of taking appropriate action.

The study revealed that SO_2 management at BSR could not disperse all the gas into the upper atmosphere beyond stack height. Some of the gas escaped and raised the level of atmospheric SO_2 concentrations at and near the workplace. The precipitator and the stacks were not efficient, contrary to expectations, the level of SO_2 concentration was higher near the source and above the target and recommended levels. In the weather conditions that prevailed at the time of the study, all the sampling points beyond the company premises recorded zero levels. On the whole the SO_2 management programme was yet to produce the desired results.

4.3.3. Oil EMP

The research revealed that the oil management programme was designed to manage oil that was discharged from scoop trams, drilling rigs, generators and other machinery that used oil. This section focuses on the underground oil EMP at the Diesel Workshop, other satellite workshops and ramps from level 23 to 29. Oil spillage occurred when hoses burst on machines, the machines were serviced and oil was transferred from one container into the machines. The EMP entailed bunding walls, oil separation, servicing of machinery and rehabilitation of the contaminated soils. This section is meant to determine the performance indicators of the oil management programme and evaluate EMP's performance in reducing environmental pollution.

4.3.3.1. Target and Objective

The study found that the target of the Oil EMP was zero oil spillage to the environment. The objective was to reduce oil spillage at source. The target was measurable but did not embody the time frame; it was shown in another column. The same applied to the objective, it also did not encompass a time frame though it was specific, result oriented and measurable. The research findings revealed that the objective was hard to achieve but some progress was made as shown in the environmental conditions.

4.3.3.2. Oil Management Performance Indicators (MPIs)

The research revealed that management put in place some measures to ensure that oil was handled according to policy expectations. Oil handling procedures were put in place at all the points where oil was dealt with. The procedures spelt out how oil was transferred from one source to another and stored to avoid spillage. The Diesel Workshop foreman, a senior person in that department, was assigned the responsibility to ensure that the procedures were followed. The findings revealed that the procedures reminded the workers of what they had to do (ISO, 2002, Natoli 1995) when handling oil. Nonconformance to the laid down procedures attracted a heavy fine on the workers who did not comply. The employees concerned therefore took the implementation of the EMP as an obligation thus implemented it as per company specifications.

The study showed that the company set up some infrastructure for the management of oil in form of bundwalls, oil traps, stainless steel trays and an oil farm. The walls were created around the area where oil was used so that it did not escape into the environment during transfer from one point to another. The sloppy floors directed the spilled oil into a container that was put below at one end of the wall. It was found that stainless steel trays were provided for use when draining oil from machinery when servicing and oil traps for oil separation were set up at levels 25/3, 25/0, 27/5 and 29/0. The trays collected most of the oil that was drained from the machines at service points and minimal spillage occurred when the oil was transferred into drums. The oil traps collected oil that spilled at the workshops and on the ramps.

4.3.3.3. Oil (OPIs)

The study revealed that the major operations were servicing machinery periodically, separating oil from water and rehabilitating contaminated soils in the oil farm. A service schedule to combat oil loss at source for seven scoop trams, one tractor, one scalar and four rigs used in the underground section was as outlined below:

- Two-hour maintenance of every scoop tram and rig was done every day.
- Diesel plant fitter, auto electrician and tyre fitters did a standard work procedure on each scoop tram and rig daily.
- The foreman did a random inspection of one or two machines daily to check that adequate maintenance was rendered to them.

The machines got routine attention as shown by the following schedule 125hours, 250 hours, 500 hours, 750 hours and 1000 hours. Every machine got a major service after working for 1000 hours. The routine was clear to and was followed by all the employees in the workshop. There was however no mechanism in place to contain spillage along ramps and at the workplace so that it was contained at source, the best way of handling pollutants (Hart, 2001).

The study showed that the effort outlined above had to achieve a 50% decline in the amount of oil that was used in the underground section, but the trends were as shown on Figure 4.5.

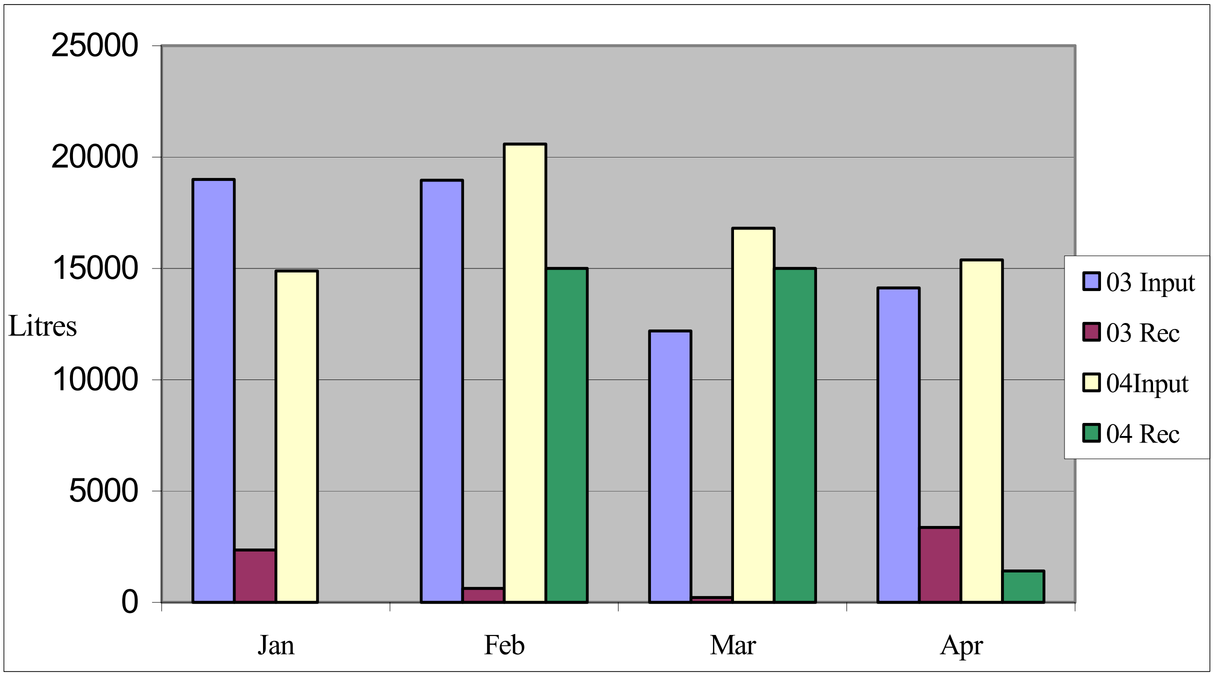

Figure 4.5: Oil Consumption and Recovery in Underground at TNM Rec - Recovered

Source: **Research Findings**

The trends revealed that oil input in the section was declining in 2004 except for February when it rose above the rest. Generally input was higher in 2004 than in 2003 by 3.5% which suggests that consumption rate was on the rise instead of a fall. The rise in oil consumption was attributed to a rise in the amount of ore that was mined from 90,000 to 96,000 tonnes per month. The study found that the amount of oil consumption began to decline in March 2004 when the control measures were adjusted to suit the new workload that was introduced.

The study showed that oil from the trays was drained into drums soon after it was collected while containers on the bund walls were emptied when full. A series of drainage tunnels and pipes from the diesel workshops and the ramps drained spilled oil into the ponds that were at a lower level. Oil contaminated surfaces were flushed with water so that the oil was drained to the ponds along the tunnels and pipes by gravity. In the ponds, the lighter oil floated and drained at a higher outlet into a collection drum while the heavier water drained through a lower outlet into the drainage system enroute to the 7Adit pond at the surface for recycling. The drums were emptied at irregular intervals that made it difficult to follow trends in oil recovery per given period.

The findings, Figure 4.5, show that the rate of oil recovery was erratic for the two years under study: some months recovered high levels while others did not recover anything at all. The implications are that the recovered oil was let to accumulate in drums at the collection points before it was collected and recorded and/or the collection was becoming more regular. The results also show that a mean of 3004.5 litres per month were recovered in 2003 and that of 7850 litres per month in 2004. The research found that 67, 454 litres of oil were recovered as from January 2003 to April 2004 and this amounts to 24% of the total oil that was put in this section. The percentage of oil that was recovered implies that the volume of oil that could have been discharged into the environment was greatly reduced by the oil EMP. Oil concentrations in water that was recycled and discharged into the environment, section 4.3.1.4, was thus reduced.

The study revealed that separation of oil from water was done in the oil traps or ponds alluded to earlier in Section 4.3.3 and the results are shown on Table 4. 8. The results showed that it was possible to recover oil from wastewater thereby reducing contamination of water sources from oil spillage, though it was done at TNM and BSR by what Starkey and Welford (1998) regard as an end of pipe approach.

Table 4.8: Oil Separation from Wastewater

Sampling Point	Inflow (g/l)	Outflow (g/l)	Difference	% Effectiveness
25/3 Level Pond	90.494	0.872	89.622	99.03
25/0 Level Pond	10.24	0.108	10.1392	99.16
27/5 Level Pond	2.2	0.034	2.166	98.45

Source: **Research Findings**

The results showed that 99% of the oil that entered the oil pond was separated from wastewater. This indicates that less than 1%, a negligible value, of the oil escaped the oil separation system and found its way out of the mine or into the ground water system. The oil separation system was very effective in reducing the level of oil pollutants in water sources. However the separation method was not able to cater for the contamination that occurred as the wastewater moved along the tunnels to the collection ponds.

The study found that oil contaminated soils were taken to the Oil Farm for rehabilitation by biodegradation of hydrocarbons in the soil under aerobic conditions. The level of contaminants in the soil was expected to change with the passage of time, Figure 4.6. It was however found out that records on the progress of the soil rehabilitation programme were not put in place hence it was difficult to assess progress with the passage of time.

4.3.3.4. Oil ECIs

The research found that the oil EMP was expected to achieve zero oil emission to the environment. However, the conditions underground showed that soils on the ramp and water in the drains contained some oil. The machines were still emitting some oil to the environment as they worked and on their way to the workshops for repair or service. The study revealed that water collected from level 23 ramp had 3.6g/l of oil. The inflows on Table 4.7 reflect that water from the ramps and workshops was contaminated; level 25/3 had 90g/l, level 25/0 had 10g/l and level 27/5 had 2.2g/l of oil. A sample that was taken from 7 Adit pump which distributed water from underground for recycling indicated that the water that left the underground had 0.018 g/l, 0.32g/l lower than the three ponds cited above. This shows that control of emissions at source was not achieved since the hoses continued to burst and oil was spilled on the ramps and at the workplace. However the water that left the underground working area had minimal contamination

The results on Figure 4.6 show the condition of soils from the ramps and from the Oil Farm that had been rehabilitated since 2003. The soils were from two ramps, 25 and 27 levels, and were meant to determine the level of oil contamination on the ramps where machines moved on their way to and from the workshops for repair. The soils from the farm were meant to show the progress that had taken place in soil rehabilitation.

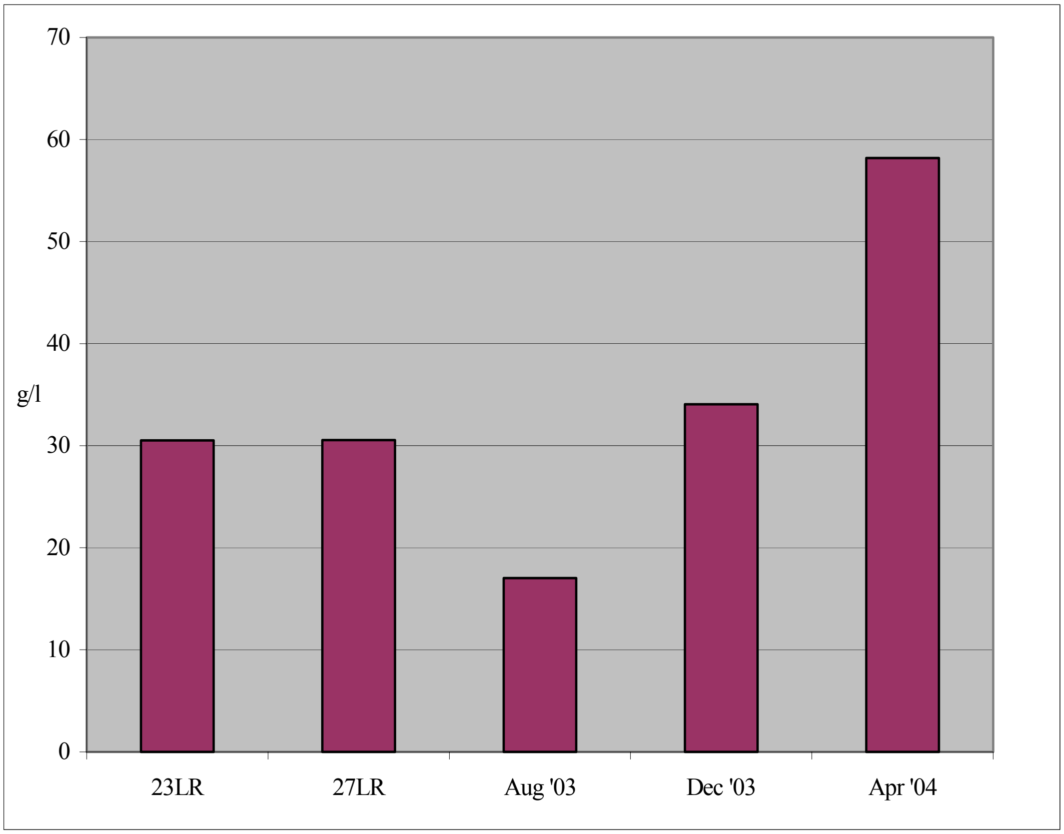

Figure 4.6: Results of Soil Condition on the Ramps and in the Oil Farm.

Source: Research Results LR - level ramp

Soils from the ramps showed that contamination levels of 30g of oil per litre were experienced on levels 25/0 and 27/0 where the soils were collected. The level of oil concentration for soil samples from the two ramps was almost the same. The implication is that oil spillage occurred on the ramps and zero oil spillage to the environment was yet to be achieved. The results showed that oil concentration in the soils from the Oil Farm declined with increasing age. The soils that were put earlier, August 2003, had the least amount of oil and that put recently in April 2004 had the highest level of oil contaminants. The results reveal that soil rehabilitation occurred in the Oil Farm under aerobic conditions but the duration it would take to be fully rehabilitated for plants to colonise was yet to be determined.

The study showed that the oil EMP was able to reduce the amount of oil that was being discharged into the environment. The programme was yet to achieve its target of reducing oil spillage into the environment at source. The management strategies that were put in place to control the oil scored some success in reducing environmental pollution.

4.3.4 Dust EMP

The research focussed on total atmospheric and respirable dust generated at the concentrator and the smelter from crushing and drying respectively. At the concentrator, dust was produced when ore was crushed into smaller particles in the primary, secondary and tertiary crushers for minerals to be liberated from rock waste, Sections 1.6.2.2, and 1.6.2.3. At the smelter, dust was generated when concentrates were dried at the drying shed and when they were fed into the smelter. Scrubbers, agglomerators and precipitators were used to control the emissions.

4.3.4.1. Target and Objective

The study revealed that the target for the dust EMP was to maintain the emissions within the $5mg/m^3$ for total atmospheric dust and $2mg/m^3$ for respirable dust. The objective was to reduce dust that was generated and also to ensure that the levels generated were below the maximum action limit level. The target was quantifiable and achievable however it did not specify the time frame it could be achieved. The objective did not specify the time frame and the action limit it referred to thus was not specific

4.3.4.2.Dust MPIs

The research showed that management put in place a dust EMP and provided the required support to ensure that the desired results were achieved. Spare parts for the dust collection units were secured, though there often was a shortage, and fitted to ensure that the units reduced environmental pollution from dust emission. However, there were frequent breakdowns that affected the functioning and efficiency of the dust control units. The study revealed that management failed to cope with the demand for spare parts and maintenance of the units resulting in the poor performance. It was also found that management provided and maintained a calibrator for measuring dust concentration in the atmosphere. The dust calibrator was sent to South Africa once a year for calibration to ensure that the measurements that were done were accurate and met international specifications.

4.3.4.3. Dust OPIs

The research found that dust particles on the conveyor belts were sprayed with water to promote cohesion of particles so that they were not easily blown away by wind at the concentrator. Scrubbers that were used had induction fans to draw dust particles from the crushers at the concentrator and from the dryer drum at the smelter. An agglomerator and a precipitator were used to recover dust for recycling at the smelter.

Dust recovery was done at smelter and the amount of recycled dust is on Table 4.9. The concentrator did not have mechanisms in place to measure the volume of recycled dust.

Table 4.9: Recovered Dust at the Smelter (tonnes)

Month	03 Total Input	04Total Input	03 Rec.	04 Rec.	03 %	04 %
January	8,801	13,055	255	605	2.8	4.6
February	7,407	13,274	199	651	2.7	5.2
March	11,906	9,162	526	431	4.4	4.7
April	15,541	13,522	620	699	4	5.2

Source: **Research Findings** Rec - recommended

The research findings reveal that the target for dust recovery was 3% of the total concentrate input. In 2003, dust recovery started of slightly below target then improved later to levels above the target. In 2004, dust recovery was above the target throughout the study period, which suggests that the recovery performance had improved. There was also a reduction in the amount of dust that was emitted into the atmosphere when the amount of dust that was recovered increased. The improved performance was attributed to the audit system, Section 4.2.1, which put pressure on the employees to check on dust emission levels to avoid a nonconformance charge.

The study reveals that a dust-monitoring programme was put in place to measure the level of dust concentration once a week. The ventilation officer was responsible for the exercise and his section was audited just like any other at the company. The dust measurements provided a source of data for planning and devising strategies to combat emissions that got beyond the recommended standards.

4.3.4.4. Dust ECIs

The environmental conditions showed the total atmospheric and respirable dust for the two sections studied at the concentrator and the smelter.

4.3.4.4.1. Total Dust Levels

The research revealed that atmospheric air at and near the source of dust was expected to have less than 5mg/m^3 of dust. The results for the concentrator are shown on Table 4.10.

Figure 4.10: Concentrator Total Dust Levels (mg/m^3)

	03	03 LCL	04	04 LCL	Recommended
January	5.79	5.39	5.52	5.13	5
February	4.97	4.52	5.53	5.13	5
March	4.05	3.66	5.65	5.35	5
April	6.76	6.25	5.61	5.13	5

Source: **Research Findings** LCL- lower confidence level

The LCL was applied at 0.05 confidence level to determine whether the values met the standard of 5mg/m^3. The results of the calculations show that the levels remained above target levels in all the values that were expected to be served by the LCL. The table shows that, only 2 out of 4 months – February and March - in 2003 were able to achieve the set target at the concentrator whereas in 2004 the levels were above the target throughout. The other two months for 2003 were above the recommended levels but below the year's average. Although the 2004 averages were above the target, the concentration levels were below 6mg/m^3 in all the four months under study.

The slight decline in dust emission was attributed to the constant water spraying on the dry ore particles and repair of the control units. However it was found that the target could not be achieved because of frequent break down of the dust collection units during the study period. The breakdowns took too long to be attended to due to a shortage of spare parts alluded to in dust EMP implying that the management indicators did not perform to expectation. The OPIs and the ECIs were thus affected and performed below the set targets.

Table 4.11, shows the performance of the dust EMP in controlling total dust levels at the smelter. The LCL 0.05 confidence level of proportions was calculated on the values that slightly exceeded the targets in order to cater for measurement error.

Table 4.11: Smelter Total Dust Emissions (mg/m^3)

Month	03	03LCL	04	04LCL	Recommended
January	6.5	5.3	6.3	5	5
February	6.9	5.6	6.7	5.5	5
March	6.4	5.1	5.7	4.5	5
April	6.8	5.6	6.2	5	5

Source: **Research Findings** LCL - lower confidence level

When the LCL was calculated, the results show that 2003 values remained above the target. However the 2004 levels show that 3 out of the 4 months changed to levels below the targets. Thus there was some continual improvement in the dust management in 2004 which is attributed to the EMP. The increase in dust recovery, Table 4.8, had an impact on the total dust levels. The findings reveal that the 2004 concentration levels were above the recommended standard but were below the 2003 levels. However no clear trend could be discerned. The emerging explanation was that the increase in the amount of dust that was recovered in 2004, Table 4.8, was attributed to the slight decline in the average dust levels in that year for this section.

The research findings show that the performance of dust management at the smelter and the concentrator was above the recommended standard in both 2003 and 2004. However, the emissions at the concentrator were lower than at the smelter. The survey also showed that 100% of the workers who responded to questionnaires indicated that the dusty working environment irritated them at the workplace but did not do so at home. The clinic confirmed that there were complains about dust pollution from the employees at the workplace but felt that the impact of the dust management programme in reducing health risks was yet to be realised. The survey also revealed that 100% of the farmers at Bowker, Figure 4.3, indicated that dust from the concentrator and smelter did not affect them and their crops.

4.3.4.4.2. Respirable Dust Conditions

The respirable dust level concentration at the concentrator is shown on Table 4.12. The 0.05 confidence LCL was used to calculate the whether the values measurements had exceeded beyond any doubt. The results are shown on the same table for the two years under study.

Table 4.12: Concentrator Respirable Dust (mg/m^3).

Month	03	03 LCL	03 Ave	04	04 LCL	Recommended
Jan	3.33	2.65	3.28	2.95	2.65	2
Feb	3.57	2.6	3.28	2.95	2.63	2
Mar	3.11	2.63	3.28	2.86	2.63	2
Apr	3.21	2.53	3.28	2.76	2.5	2

Source: **Research Findings** LCL - lower confidence level

When the LCLs were calculated, the results show that all the levels in the two years remained above the target level of 2mg/m^3. The results show that 2003 levels were higher than the 2004 levels, an average of 3.28 exceeded the recommended level of 2.00 mg/m^3 by 64%. The 2003 levels were above the set target throughout the year. In 2004 the levels were below the 2003 average but above set target of 2mg/m^3. The slight improvement was attributed to continual monitoring and control of emissions. The frequent breakdown of the dust control devices alluded to earlier were the cause of the high levels. It was also found out that all the workers were compelled to put on some protective clothes for them to work in the dusty conditions.

The results for respirable dust concentration levels at the smelter are shown on Table 4.13. The data were subjected to LCL at 0.05 and the results are shown on the same table below.

Figure 4.13: Smelter Respirable Dust (mg/m^3)

Month	03	03 LCL	03 Ave	04	04 LCL	Recommended
January	3.25	2.95	3.42	2.46	2.2	2
February	3.75	3.37	3.42	2.36	2.98	2
March	3.52	3.24	3.42	2.95	2.62	2
April	3.55	3.2	3.42	2.72	2.5	2

Source: **Research Findings** **LCL** - lower confidence limit

A mean of 3.42mg/m^3, realised in 2003 was above the recommended standard by 71%. In 2004 the levels fell below the 2003 average by 30%, which shows that that the performance of the dust EMP had improved. However, the dusty conditions remained above the set standard therefore called for use of protective clothing to protect the workers from the effects of dust as confirmed by Eisenriech (1981) that causes pneumoconiosis.

On the whole, the dust management programme reduced the level of dust concentration both in total and respirable dust levels in 2004 but above the target even when the LCL of the proportions was calculated at 0.05 confidence level. The MPIs performed below expectation thereby affecting the overall performance of the programme. At the smelter, dust recycling contributed to the reduction of dust emissions whereas at the concentrator there were no mechanisms in place to measure the amount of dust that was recovered. The dust management programme reduced concentration levels but was yet to meet the set targets.

4.4. Conclusion

The findings presented and discussed above show that the EMS at TNM and BSR was integrated into the mainstream business activities of the company. The company put in place critical EMS components that enhanced EMS performance in general and the EMPs in particular. The effluent and oil EMPs were controlling emission and were on the continual improvement path. The dust EMP was operational, reduced emissions but was yet to meet the set targets. SO_2 management was yet to achieve set targets; emissions at source were far beyond the recommended targets. Recycling, treatment of waste and monitoring were active operations at TNM and BSR while the environmental conditions showed continual improvement. On the whole EMS at TNM and BSR was active and reduced the impact of the company's activities on the environment.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

The study reveals that trends and the position of EM can be discerned at TNM and BSR
TNM and BSR made some achievements in EMS implementation but there is need for improvement in other areas. This chapter focuses on conclusions and recommendations on the findings of the study.

5.2. Conclusions

Major EMS components played a pivotal role in EM at TNM and BSR. The environmental policy, planning and resource allocation commit management and employees to EM and enhance performance. Training raises awareness among employees and facilitated communication throughout the company hierarchy so that every category of workers had a part to play in EM. The workers were adequately prepared to tackle emergencies and eventualities that occurred at the mining area. The documentation system at TNM and BSR captured data that were critical for the implementation of the EMPs and the documents were easily accessible. The EMS however left out some of key stakeholders, farmers and the responsible authority, in EMS implementation.

There was an effective effluent management programme at TNM and BSR that achieved zero discharge in three out of five effluent streams. The two streams that were still flowing had a decline in the volume of discharge and pollutants from the mining operations. Sulphate, nickel and oil/grease were the major pollutants for both surface and ground water but were attended to. Management played its part by providing the necessary equipment and infrastructure to enhance effective implementation of the EMP. The success of the effluent EMP was attributed to the major operations that were put in place in form of recycling, monitoring and water treatment. Wastewater discharged from TNM and BSR was safe for livestock and irrigation use; it had little pollutants and farmers did not complain.

The SO_2 management programme was yet to achieve the desired results. The level of gas concentration at source was beyond the set target of 30mg/m^3 by three times as much. In the immediate surroundings the values declined. The precipitator and two stacks were yet to cope with dispersing the gas into the upper atmosphere at least beyond the stack height; higher concentrations were found at and near the source. The rehabilitation of the precipitator had little impact, the gas was blown out through the stacks but came down during windy days. The gas irritated workers at the workplace and those who resided in the nearby village downwind of the smelter.

Underground machines were still emitting some oil onto the ramps and the working area, which implied that the oil management programme was yet to achieve its objective of zero spillage to the environment. Oil separation, though an end of pipe approach to managing pollutants, it was effective in reducing pollutant concentration in water and soil at TNM and BSR. Oil separation, oil trays and bund walls were effective in oil recovery as they enabled the mining company to recover almost a quarter of the oil that was put into the underground hydraulic system. The oil farm showed signs of rehabilitating oil-contaminated soils through aerobic biodegradation of hydrocarbons. The water that eventually left the underground had little quantities of oil particles.

Dust management was always above the recommended 5mg/m^3 targets for atmospheric and 2mg/m^3 for respirable dust during the study period. The management programme was able to keep concentrations below 7 mg/m^3 and 3.5mg/m^3 at the concentrator and the smelter for total atmospheric and respirable dust. Poor performance of the dust management programme was attributed to the frequent breakdown of the dust control units. Dust emissions irritated workers at the workplace but did not do so at home. The farmers downwind were not affected by dust emissions from the mine operations,

The EMS at TNM and BSR was very active in trying to contain pollutants and reducing discharge into the environment. Management devoted resources and strived to see the management programmes achieve the desired results.

5.2. Recommendations

In order to improve the performance of an EMS, there is need to reinforce the strengths and improve on the shortcomings. These recommendations are meant to improve EMS implementation at TMN and BSR and at other mines.

BNC needs to define the key stakeholders on the environmental policy statement. The key stakeholders, local farmers and the responsible authority, Bindura Rural District Council need to be involved in the implementation of the BNC EMS since they are directly affected by the company's operations. *Random surveillance checks on the implementation of the EMPs at TNM and BSR are needed to ensure effective implementation of EMPs*. It was found that workers tended to put more effort when preparing for an audit yet that was supposed to be the routine.

The objectives of the EMPs at TNM and BSR need to be specific and indicate time frame in the statement. The objectives that refer to pieces of legislation have to specify what components of the statutory instruments are to be complied with. *The time when a target is to be achieved needs to be part of the target/objective* to maintain the focus of EM and to assess progress in EM.

BNC and other mines need to reconsider zero effluent discharge in effluent management for the sake of the water users downstream. In the case of BNC, there are thousands of water users downstream of South Effluent and Dam streams who will face water problems if the streams were to run dry. Rather, *there is need for continuous monitoring and to neutralise the problem pollutants* so that the discharge is safe for downstream users. *There is need for BNC to drill monitoring borehalls near waste rock dumps to check on acid mine drainage then plan to combat it*. *The EMA needs to specify the maximum concentration levels to be adhered to in order for a company to get or retain a licence to discharge* so that the polluter bears the full cost of polluting the water resources (Dommen, 2001)

There is need to put oil leak detection measures on the scoop trams and drilling rigs so that oil leaks are detected before the environment is messed with oil. *BNC needs to involve suppliers of the hydraulic hoses in research on oil spillage*. Technical aspects such as lifespan and durability of the hoses could be determined when the mining company and the suppliers work together in a bid to contain spillage at source. *There is also need for the Diesel Workshop personnel at TNM to regularise the collection of oil recovered* say on a monthly basis so that oil recovery trends can be followed for assessing progress and planning for corrective action.

BNC needs to continue monitoring the level of concentration of SO_2 at source and in the neighbourhood at TNM and BSR so as to be able to verify the sentiments raised by stakeholders that the gas was affecting them. *BNC could consider desulphurising the emissions as confirmed by Kamal (2000) for effective management of SO_2*. In doing so, the emissions are contained at source and the performance of the EMP would be as recommended by Brown and Laurenson (1995) beyond the application to pollute.

There is need to cover the conveyor belts that transport dry crushed ore particles and concentrates so that dust is not blown away by wind. *The drop point at the stockpile needs to be covered by an adjustable chute whose height can be changed with the changing height of the ore. There is also need to introduce targets for dust recovery at the concentrator and to maintain the dust recovery equipment.* The dust emission trends would then be followed and the suitable corrective measure determined.

5.3. Conclusion

The research reveals that there is an active EMS at TNM and BSR. The four major EMPs that have been studied show that effluent and oil management achieved marked progress. SO_2 and dust programmes were yet to achieve the set targets. *It is recommended that key stakeholders need to be involved in EMS, the zero effluent discharge policy needs to be revisited* for the sake of downstream water users. There is also *need to consider technical components as key variables when managing oil at source*. *There is need to consider desulphurising to contain SO_2 at source and to cover the conveyor belts and maintain the scrubbers* so as to control dust emission. On the whole, the research shows that it is possible to develop and implement effective EMPs at mines in Zimbabwe. All the parties involved in the mining activities need to be committed to the EMS implementation process for the desired ends to be realised.

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Appendix 1: BNC Environmental Policy

APPENDIX 2

ZINWA/WHO/BNC Water Quality Standards

	Blue	Green	Yellow	Red
Arsenic	</= 0.05	</= 0.1	</= 0.15	</=0.3
Cobalt	*	*	*	</=2.0
Copper	</= 1.0	</=2.0	</= 3.0	</=5.0
Grease/Oil	</= 2.5	</=5.0	</= 7.5	</=10
Nickel	</= 0.3	</=0.6	</= 0.9	</=1.5
PH	6 - 9	6-9	6 - 9	</=10
Sulphate	</= 250	</=300	</=400	</=500

* Not Prescribed

APPENDIX 3a

Questionnaire: Underground/Concentrator/ Smelter

Note: You are kindly asked to complete the following questions for a research project for a master's programme in Environmental Policy and Planning. The data collected is for academic purposes only and will be treated with strictest confidence. You are asked **not to write** your name on the questionnaire.

1. Age in years: below 25 ☐ 26 - 35 ☐ 36 - 45 ☐ over 25 ☐

2. Education: Primary ☐ Secondary ☐ Tertiary ☐

3. How long have worked at this mine in this section?

Less than 5yrs ☐ 6 - 10 yrs ☐ 11 - 15 yrs ☐ Over 16 yrs ☐

4. Have you ever attended any EMS training sessions at this company? Yes ☐ No ☐

10. If the answer to 9 is yes how many training workshops did you attend since 2003?

5. Did the training workshops help you understand what EMS is all about? Yes ☐ No ☐

6. Do you take part in suggesting your training needs?

7. Do you have a/an effluent/dust/oil/SO_2 management system in your section?

8.What is the target for effluent/SO_2, oil/dust management programme in your section?

9. Are you affected by dust generated from your section at:

a) Work?

b) Home?

10. What are your comments on the effectiveness of dust management in your section since EMS was introduced?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Thank You!…………………………………………………………………………

APPENDIX 3b

EMS Questionnaire for Farmers

1 How long have you stayed at this farm?

1 yr ☐ 2yrs ☐ 3 yrs ☐ 4 yrs ☐ Over 4 yrs ☐

2 Has Trojan Nickel Mine and Bindura Smelter and Refinery introduced an Environmental Management System (EMS)? ☐ Yes ☐ No

3. Do you take part in suggesting how water and air pollution should be managed at TNM/BSR?

4. Since the introduction of an EMS at TNM/BSR was there any change in the level of :

a) Water pollution?

b) Dust emission?

5. Has the TNM and BSR operations affected your farming activities since 2003?

6. In what way have the operations cited above affected

a) Your crops since 2003?

b) Animals since 2003?

7. Are you affected by the emissions from TNM/BSR emissions;

a) At Home?

b. In the fields?

8. In what way does air pollution affect you?

9. What are your comments on the effectiveness of the EMS at TNM and BSR?

APPENDIX 4

INTERVIEW SCHEDULE

Effluent /SO_2/Oil/Dust Management

1. What are the methods used to manage effluent/SO_2/oil/dust in your section?
2. Are there any problems that you face when trying to manage dust? If there are what are they and how do you contain them?
3. How effective is effluent/SO_2/oil/dust management in your section? Are you able to meet your dust control target?
4. What contributes to the effectiveness or non-effectiveness of dust management in your section?
5. Do you get any compliments or complains from stakeholders about dust emission from your department?
6.Who are the key stakeholders at your company?
7 General comments on the effectiveness of the EMS in your section and at the company

APPENDIX 5

Checklist

Note: A tick is used for compliance and a cross for noncompliance

1. Environmental Policy
   - Stakeholder involvement
   - Legal requirements
   - Management commitment
   - Continual Improvement
   - Target and Objectives
   - Resource Provision
   - Specific Activity

2. Objectives
   - Quantifiable
   - Time framed
   - Clear and specific
   - Achievable
   - Environmental policy
   - Annual review

3. Training
   - -Programme/Concepts
   - -Frequency
   - -All workers/participants
   - -Other Stakeholders
   - -Duration
   - -Facilitators
   - -Venues

4. Resources
   - -Manpower
   - -Finance
   - -Time
   - -Technology

5. Planning
   - -Communication
     - -Channels/adequate
     - -Audits: internal/external
     - Programme/plan

6. Procedures
   - - Responsibilities
   - -Work Instructions

7. Emergency Requirements
   - Plan
   - Tests/Checks
   - Roles
   - Review

8. Documentation
   - Types of Records
     - Regular Recording

9. Corrective Action
   - Root Cause
   - Opportunities
   - Preventive Action
   - Continual Improvement