PHASE

MINING & PROCESSING OPERATIONS

4

Scorpion Zinc Mine
Rosh Pinah
Karas
Namibia
2019 © paulgodard.com

ACKNOWLEDGEMENTS

This Best Practice Guide was developed through extensive engagement with government and industry, along with expertise from consultants and specialists who availed their time to make this publication possible. The following organisations contributed substantially to the development of the Best Practice Guide, and without their expertise, this publication would not be possible.

MINISTRY OF MINES AND ENERGY
The Ministry of Mines and Energy provided indispensable input, in terms of government expectations for bi-annual reports, as well as for permit and licence obligations throughout the mining life cycle.

MINISTRY OF ENVIRONMENT AND TOURISM
The Ministry of Environment and tourism provided input about streamlining government expectations for bi-annual reporting with industry standards.

NATIONAL RADIATION PROTECTION AUTHORITY (NRPA)
The Ministry of Health and Social Services' National Radiation Protection Authority (NRPA) provided input regarding all matters relating to the regulation, licencing and permitting of all uranium sources throughout the mining life cycle.

MINISTRY OF AGRICULTURE, WATER AND FORESTRY
The Ministry of Agriculture, Water and Forestry provided input on permit obligations during the mining life cycle phases

NAMIBIAN CHAMBER OF MINES
One of the publication's joint initiative partners and key stakeholders, is the Namibian Chamber of Mines (CoM).

The CoM is an industry body that aims to effectively promote, encourage, protect, foster and contribute to the growth of responsible exploration and mining in Namibia, to the benefit of the country and all stakeholders.

NAMIBIAN CHAMBER OF ENVIRONMENT
Another of the publication's joint initiative partners and key stakeholders, is the Namibian Chamber of Environment (NCE).

One of the core NCE objectives is to promote best environmental practices, including habitat rehabilitation, and to support efforts to prevent and reduce environmental degradation and pollution. This project aligns to several of the NCE core objectives.

OTJIKOTO GOLD MINE
Case studies supplied:
- Corporate social responsibility
- Rehabilitation

DUNDEE PRECIOUS METALS TSUMEB
Case studies supplied:
- Air quality monitoring

TREKKOPJE MINE
Case studies supplied:
- Securing a mine's water supply
- Restoration trials

SKORPION ZINC
Case studies supplied:
- Water management

ACKNOWLEDGEMENTS

DEBMARINE NAMIBIA
Case studies supplied:
- Environmental monitoring

NAMPOWER – NAMIBIA NATURE FOUNDATION STRATEGIC PARTNERSHIP
Case studies supplied:
- Powerline monitoring

NAMIBIAN URANIUM ASSOCIATION
Case studies supplied:
- Namibia's uranium SEA

HUSAB MINE
Case studies supplied:
- Water quality monitoring
- Tailings management

NAMDEB
Case studies supplied:
- Biodiversity monitoring
- Concurrent rehabilitation
- Heritage

RÖSSING URANIUM
Case studies supplied:
- Hazardous Waste Management
- Tailings Management
- Air Quality

ENVIRONMENTAL COMPLIANCE CONSULTANCY
Authors of this publication
Contact details:
+264 81 669 7608
info@eccenvironmental.com

UTOPIA CONSULTING - communications solutions for sustainable business | Dr Paul Godard assigned photographer of the publication

Desalination Plant - Orano
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

FOREWORD

The first two decades of the 21st century have starkly revealed our unprecedented impact on the natural world. The level of impact threatens our very existence. Climate change, biodiversity loss and pollution are at the top of the list. No longer can we do business as usual, with sectors being isolated from one another, and business focusing only on the financial bottom line. We need a new approach that is more holistic, inclusive and responsible. In short, we need a "profit, people and planet" triple bottom line approach whereby companies generate profit for shareholders and national revenue while simultaneously improving people's lives and safeguarding the planet from climate change, biodiversity loss and pollution. This new holistic and responsible approach to business will not necessarily reduce profit but can certainly enhance opportunities, attract discerning investors, increase sector resilience and social acceptance, reduce risk and reputation damage, and leave a nett positive legacy.

This Best Practice Guide applies the new triple bottom line approach to the Namibian mining sector to ensure a lasting legacy for mining companies, the country and her people. From the outset this initiative embraced transparent governance and a collaborative approach which involved the Namibian government – the Ministry of Mines and Energy and the Ministry of Environment and Tourism; the private sector – the Chamber of Mines and its member mining companies; and the environmental civil society sector – represented by the Namibian Chamber of Environment.

Namibia is rich in a variety of mineral deposits such as zinc, gold, uranium and diamonds, some of which are considered world-class. The Namibian Government recognises the importance of prospecting and mining to social and economic development, as expressed in various national development plans. Equally important is Namibia's commitment to ensuring a safe and healthy environment. The Best Practice Guide for mining in Namibia highlights leading practices in social, economic and environmental aspects at all stages of the mining life cycle, namely Exploration, Projects and Construction, Operations, and Mine Closure and Completion. Further, this Best Practice Guide brings together all the regulatory requirements for the mining sector from all government agencies into one reference document, with links to download forms, submit reports, etc. The Guide is available in electronic format, and we would encourage all mining companies to ensure that it is available to their staff, management, boards of directors and investors.

The Namibian mining industry strives to play an active role in sustainable development by implementing world class environmental practices in their operations. Through the implementation of these practices, exploration and mining companies can maintain a good relationship with regulators, lawmakers, investors and the communities in which they operate. This guide is ultimately aimed at assisting the Namibian mining industry to implement their "planet, people and profit" approach as they develop Namibia's mineral resources, by delivering practical mining solutions that are benchmarked against best practices and striving for ever more ambitious legacy impacts.

Finally, the mining sector has taken the lead in Namibia by being the first economic sector to develop such a Best Practice Guide. It is our wish that other sectors follow suit and that, sector by sector, we implement a "planet, people and profit" philosophy and programme of action across Namibia.

Tom Alweendo, MP
Minister of Mines and Energy

MINISTRY OF ENVIRONMENT AND TOURISM
REPUBLIC OF NAMIBIA
2019 11 19
OFFICE OF THE MINISTER
PRIVATE BAG 13346, WINDHOEK

Pohamba Shifeta, MP
Minister of Environment and Tourism

CONTENTS

PART ONE
INTRODUCTION **1**
Scope and purpose of this guide 1
1.1 Compliance 2
1.2 Types of mining activities 2
1.3 Mining operations and land ownership in Namibia 4

PART TWO
ENVIRONMENTAL MANAGEMENT DURING THE OPERATIONAL PHASE **5**
Key environmental management tasks 5
2.1 Risk Management in Operations 6
2.2 Community Relations during the Operational Phase 6
2.3 Heritage 12
2.4 Biodiversity Management 17
2.5 Non-mineral waste management 31
2.6 Hazardous substances 32
2.7 Managing acid mine drainage 39
2.8 Air quality 43
2.9 Water management 52

PART THREE
MINERAL WASTE MANAGEMENT **60**
Introduction 60
3.1 Challenges 60
3.2 Tailings management 62
Key principles 62
Types of tailings storage facilities 65
3.3 Waste rock dumps 79
Key principles 79

PART FOUR
MONITORING REQUIREMENTS DURING THE OPERATIONAL PHASE **81**
The importance of monitoring 81
4.1 Water monitoring 82
4.2 Mineral waste monitoring 88
4.3 Air quality monitoring 88

PART FIVE
BEST PRACTICE STANDARDS FOR MINING **101**
Introduction 101
5.1 Standards for mining 102

PART SIX
BEST STANDARDS FOR PROCESSING OPERATIONS **106**
The need for standards 106
6.1 Mining operations and processing of base metals 106
6.2 Mining operations and processing of precious metals 106

PART SEVEN
REPORTING GUIDELINES **111**
The need for reporting 111
7.1 Reporting from the mining companies to the State 111
Reporting to the Mining Commissioner 111
Reporting to the Environmental Commissioner 112
Reporting to the Labour Commissioner 111
Reporting to the National Radiation Protection Authority 112
Reporting to the Department of Water Affairs 113
7.2 Reporting from the State to mining companies 113
7.3 Reporting and auditing requirements in protected areas 113

PART EIGHT
TRANSITION TO THE NEXT PHASE **114**

PART 9 | REFERENCES **115**

TABLES

1	Recommended community related management activities to be undertaken during the operational phase of the mining life cycle (International Council on Mining and Metals)	7
2	General standards for waste/effluent water discharge	51
3	The standards/guidelines derived from the WHO, EU and South African standards	91
4	Best practice standards for open pit operations	103
5	Best practice standards for underground operations	105
6	Best practice guidelines applicable to base metal processing	107
7	A summary of best practices applicable for the mining and processing of rare metals in Namibia	
8	Best practice standards for the processing of gold in Namibia	109
9	Reporting to the Mining Commissioner	112

FIGURES

1	Four mine phases	1
2	Potential impacts of the operational phase of the mining life cycle	5
3	Tri-linear plot to determine the best cover to use under different climatic regimes in order to prevent AMD	40
4	Shows three purposes that monitoring serves	82

DEFINITIONS AND ABBREVIATIONS

AAQMS	Ambient Air Quality Monitoring Station
AMD	Acid Mine Drainage
CO	Carbon Monoxide
CoM	Chamber of Mines
CSI	Corporate Social Involvement
DEA	Department of Environmental Affairs
DNP	Dorop National Park
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPL	Exclusive Prospecting Licence
ETP	Effluent Treatment Plant
EU	European Union
GCL	Geosynthetic Clay Liner
IFC	International Finance Corporation
LLDPE	Linear Low-Density Polyethylene
LoM	Life of Mine
MAWF	Ministry of Agriculture, Water and Forestry
MET	Ministry of Environment and Tourism
ML	Mining Licence
MME	Ministry of Mines and Energy
MoHSS	Ministry of Health and Social Services
MSBP	Millennium Seed Bank Project
MSDS	Material Safety Data Sheet
NBRI	National Botanical Research Institute
NCE	Namibian Chamber of Environment
NCRST	National Commission on Research Science and Technology
NEPL	Non-Exclusive Prospecting Licence
NNNP	Namib Naukluft National Park
NO_2	Nitrogen Dioxide
NRPA	National Radiation Protection Authority
O_3	Ozone
OHS	Occupational Health and Safety
PA	Protected Areas
Pb	Lead
RBS	Risk-Based Solutions
REDs	Regional Electricity Distributors
RL	Reconnaissance Licence
RMP	Radiation Management Plan
RO	Reverse Osmosis
SANS	South African National Standards
SHEQ	Safety, Health, Environment and Quality
SO_2	Sulphur Dioxide
TSP	Total Suspended Particles
WB	World Bank
WHO	World Health Organization

PART ONE

INTRODUCTION

SCOPE AND PURPOSE OF THIS GUIDE

Mining and processing activities—the operational phase of the mining life cycle—encompass extraction, processing and selling of the ore and is a complex phase that requires a great deal of planning and management, in order to be profitable. Strategy is the pillar of the operational phase, which in turn determines the success of a mine. During this phase, investment is aimed at the optimal return for shareholders, and as a result, resource expansion, production rates and cut-off grades are key factors, in addition to productivity, safety, and the management of environmental and social impacts.

Leading practices during the operational phase include: community relations management, heritage and biodiversity management, waste management (mineral and non-mineral, and hazardous substances), acid mine drainage, air quality, water management, monitoring requirements, and applicable "Leading Standards". The content serves as guidelines for the Namibian mining sector, offering mining companies and interested stakeholders practical examples for leading sustainable activities during the operational phase of the mining life cycle, thereby demonstrating that commitment to sustainable development objectives is a central theme.

The different phases of the mining life cycle can vary in duration, but it is quite common to see the phase of mining and processing—the operational phase—as the longest of the phases. FIGURE 1 shows the mining phases, illustrating the approximate duration of each phase.

[FIGURE 1]
Four mine phases

Emphasis on sustainability and environmentally responsible and safe operations is increasing globally and these have become sound practices that enable a mining company to build a good reputation during the operational phase. Compliance, in addition, is non-negotiable. If commitments to sustainability and compliance are not incorporated into daily operations and management, or adhered to, a mining company can expect high risk costs of environmental clean-ups, disputes, and lawsuits, etc. Moreover, the reputation of a mining company can be tarnished to an unrepairable extent.

1.1 COMPLIANCE

Mining companies should operate in compliance with all applicable Namibian laws, regulations and other legal requirements at all times. To conduct mining operations, a mining company should be in possession of a valid Mining Licence (ML), as stipulated in the Minerals (Prospecting and Mining) Act, No. 33 of 1992, including all the necessary conditions laid out in the ML and the Environmental Clearance Certificate, as the Environmental Management Act, No. 7 of 2007 requires. The latter highlights certain activities permitted and formalised by management measures stipulated in an obligatory Environmental Management Plan (EMP). Management of these measures implies an environmental management system (EMS), environmental monitoring and reporting programs, and environmental auditing and enforcement.

In addition to the legal requirements highlighted above, a mining company is obliged to have all implied permits, licences and agreements in place. Requirements relate to the removal and exporting of mineral samples, the drilling of water supply boreholes, abstraction and discharge of water, clearing of vegetation, waste management and the handling of radioactive substances. Other requirements relate to labour, finance and procurement. The management of a legal and compliance register assists with the upkeep of these obligations.

If there are any deviations from the law, corrective steps should be taken to rectify non-compliance.

1.2 TYPES OF MINING ACTIVITIES

Mining activities can generally be divided into two categories: surface mining and underground mining.

The term surface mining describes several methods of mining mineral deposits from the surface, which involves land clearance and the removal of vegetation, top soil, and overburden above the mineral deposit. Topography and the physical characteristics of the deposit influence the choice of the surface mining method and can include contour mining, strip mining, quarrying, dredging, and hydraulic mining. As a result, surface mining can result in a single deep open pit, multiple open pits, or a series of shallow satellite pits, of which some are progressively backfilled with overburden or waste.

Underground mining allows for a more selective mining approach. Underground mining methods are typically employed for deep deposits and where there are restrictions to surface land use. Extraction is through a series of vertical ramps, shafts and horizontal drifts, and the ratio of waste rock to the ore generated is lower in relation to that of surface mining activities. From an environmental standpoint, underground mining is a friendlier approach, as it has a smaller environmental footprint than an open pit mine with comparable capacity. Since underground mining is more selective, less waste is mined. Environmental impacts that typically accompany underground mining operations include the release of compounds into the water and air.

In many cases the open pit approach is preferred over an underground approach for mining, because of its economic advantages. To some extent, it is also safer and easier to operate. Disadvantages include aspects such as extensive accessory works and infrastructure, a high waste-to-ore ratio, and a large footprint due to the placement of overburden and waste rock. Furthermore, a mine with an open pit requires heavy machinery and equipment, more personnel, and an extensive network of infrastructure and service support. The footprint of an underground mine is normally small when compared to an open pit mine, but the spatial scale of operations is limited and confined. Accessory works, service support and infrastructure are normally smaller; vital ancillary services include the removal of groundwater and the provision of ventilation and light; machinery and equipment are smaller and specialised, and as a result are relatively expensive.

Both surface and underground mining activities are undertaken in Namibia, although open pit activities dominate. Open pit mines include Rössing, Husab and Langer Heinrich (all uranium mines located in the central Namib Desert near Swakopmund); Navachab and Otjikoto (both gold mines, the former near Karibib and the latter near Otjiwarongo); Tschudi (a copper mine near Tsumeb) and Skorpion, a zinc mine in the central south of the country. The Rosh Pinah Lead-Zinc Mine near Skorpion is currently the only operational underground mine in Namibia. Other underground mines such as Tsumeb, Berg Aukas, Kombat, Otjihase, and Matchless are either closed or currently not in operation. Other mining activities include the mining of diamonds between Oranjemund and Lüderitz (shallow but extensive beach mining and inshore and offshore marine mining) in the southwestern corner of Namibia; salt mining along the central coast; the mining of dimension stone in the central Namib Desert and around Karibib; cement production near Otjiwarongo and Otavi; and the smelting of copper ore at Tsumeb. Processing methods and on-site activities used by the different mines in Namibia vary widely.

1.3 MINING OPERATIONS AND LAND OWNERSHIP IN NAMIBIA

This section is written with the assumption that consultations and compensation contracts have been reached between the various parties and the necessary legal requirements have been obtained and are in place. It is strongly recommended that both the land owner and the mining company refer to the relevant sections of this Best Practice Guide (Exploration, Section 1.3), prior to, and during, mining operations, for clarity related to mining and land ownership.

Scorpion Zinc Mine
Rosh Pinah
Karas
Namibia
2019 © paulgodard.com

PART TWO

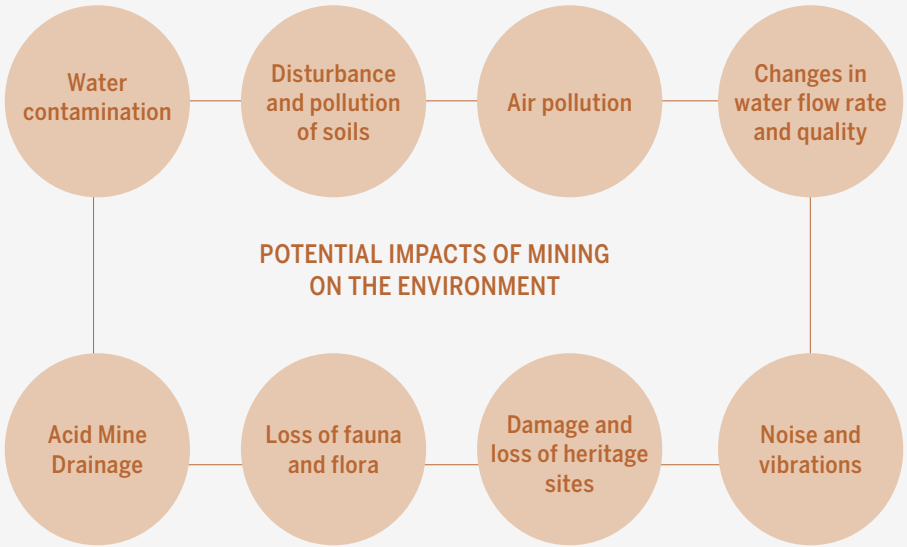
ENVIRONMENTAL MANAGEMENT DURING THE OPERATIONAL PHASE

KEY ENVIRONMENTAL MANAGEMENT TASKS

Not only is it the longest in duration, but the operational phase of the mining life cycle is often also the most challenging in terms of environmental impacts and sustainability—and underlines the importance of good planning during the projects and construction phase, as well as the implementation of good practices of monitoring and mitigation during the operational phase. Different management systems and tools such as EMS must be implemented, all legislative and regulatory requirements must be adhered to, and the management measures of an EMP must be incorporated into operational activities (Toovey, 2011).

The EMP must stipulate various actions, like monitoring and mitigation, to manage the different environmental impacts of the operational activities of a mine. Some of the most common impacts are illustrated in FIGURE 4.

[FIGURE 2]
Potential impacts of the operational phase of the mining life cycle



2.1 RISK MANAGEMENT IN OPERATIONS

There are several risks associated with the mining industry, and these risks may also differ over time during the mining life cycle. Mining and processing activities necessitate the integration of risk management in all business operations, and the implementation of an effective risk management program becomes inevitable, in order to identify, assess and manage all risks—it is recommended that you read the section on risk management, which is covered in the overarching chapter of this Best Practice Guide.

Risk assessment is a continuous process, of which fundamental work has to be initiated and conducted during the projects and construction phase (i.e. during the inception stages). Moreover, it means that risk management measures need to be in place when the operational phase commences. For this reason, it is also advisable to read the section on risk management in the projects and construction chapter of this Best Practice Guide.

During the operational phase, risk management becomes a continuous and iterative activity and requires a holistic and robust approach for integration into business decision-making. It is also recommended to assign risk management to a responsible person(s), to establish a business-wide risk register, and to train the workforce on the application and updating of the risk register.

2.2 COMMUNITY RELATIONS DURING THE OPERATIONAL PHASE

Community engagement is an ongoing process, preferably already started in the exploration phase, continuing during the projects and construction phase, and increasingly maturing during the operational phase. As a result, the emphasis shifts from information sharing and basic communication, towards the building of relations, the commencement of directive communication campaigns and community-related activities, the establishment of sustainable principles, and a definite drive to ensure that no dependency is created and that stakeholders are left behind in a better position than before.

One of the main objectives of community engagement during the operational phase of a mining company is to establish a prominent role as socio-economic catalyst. More intensive management of community relations, communication, and several new interventions, become necessary. TABLE 1 illustrates some of the recommended community engagement and development activities to be undertaken during this phase.

TABLE 1 | Recommended community related management activities to be undertaken during the operational phase of the mining life cycle (International Council on Mining and Metals)

DESCRIPTION	Opportunities for the implementation of long-term community development initiatives focusing on locally identified development needs
RECOMMENDED COMMUNITY ENGAGEMENT AND DEVELOPMENT ACTIVITIES TO BE UNDERTAKEN	• External support from experts as required • Qualified staff on board • Adequate budget for community engagement • Managing funds for Corporate Social Responsibility projects • Program for stakeholder engagement • Functional grievance mechanism in place • Constant collection of updated data • Additional studies as required • Full-scale evaluation and monitoring program in place • Consistent reporting of internal and external challenges and progress • Up-to-date stakeholder records and analysis • Agreements with communities

Throughout the mining industry, it can be noted that when communities benefit significantly from mining operations, they vouch for the operations and take a keen interest in seeing the mine succeed. By contributing to the development of the community, mining companies can realise several benefits, such as:

- Reputation: Properly engaging and developing the community enhances a mine's reputation amongst stakeholders
- Resources: Access to mineral resources (ore bodies) in remote areas can improve
- Local workforce: Building skills within the local communities reduces the dependence of companies on expatriates
- Employees: Employee retention can improve
- Reduced closure costs and liabilities: As a result of better management of the social risks and community expectations, the closure and liabilities costs of the mine can be significantly reduced
- Approval processes can help to resolve disputes: The approval process is generally smoother if a mining company has better relations with its stakeholders.

Like many other mines in Namibia, the Otjikoto gold mine has strong relationships with the local community in which it operates. An example of the work the mine has done with regards to community engagement, is outlined in the case study below:

Otjikoto mine, B2Gold
Namibia
Otavi
Otjozondjupa
Namibia
2019 © paulgodard.com

CASE STUDY

COMMUNITY ENGAGEMENT

OTJIKOTO GOLD MINE
owned and operated by B2Gold

LOCATION:
Otjikoto gold mine is situated approximately 300km from the capital city of Windhoek, in a sparsely populated area near Otjiwarongo in the Otjozondjupa region of Namibia.

BRIEF DESCRIPTION:
Otjikoto gold mine is an open pit gold mine.

DESCRIPTION OF THE CASE STUDY:
The mine has taken a holistic view in terms of contributing to the society and environment within which it is situated, demonstrating that a successfully run mining operation can be beneficial to the country beyond the contribution of taxes and royalties. Prior to the construction of the mine, the holding company, B2Gold, committed to the goal of leaving Namibians better off as a result of a mining operation. The organisation set out to understand and align itself with government development objectives for environmental management and social upliftment in particular.

From the outset, the corporate social involvement (CSI) activities of the company were designed to be fair and transparent. Following the stakeholder needs analysis, B2Gold Namibia chose to focus on four development areas, namely: health, education, livelihoods, and conservation. A CSI Steering Committee was established, which assesses all projects based on a fixed set of criteria. One of these is that projects must be outcome-orientated and have clearly articulated and achievable, measurable goals. Projects are voted on by the committee, and the successful projects are recommended to the CSI Board. The board then evaluates these projects and they are either accepted, rejected, or sent back to the committee for additional information.

Adjacent to the mining operation, a 15 000-hectare nature reserve has been established. The reserve, which forms part of the B2Gold land package, was previously heavily overgrazed by domestic livestock and is now being systematically rehabilitated to its natural state. The reserve also includes an extensive education centre where school learners attend a wide variety of complementary learning classes (free of charge), which supports the government's school curriculum, with an added focus on the environment,

Otjikoto mine, B2Gold
Namibia
Otavi
Otjozondjupa
Namibia
2019 © paulgodard.com

conservation, sustainable utilisation of biological resources, recycling, responsible living, and alternative energies. B2Gold hopes to inspire a lifelong appreciation for the environment. To date, approximately 4,000 pupils have visited the education centre.

A special focus has also been given to physics, to improve the understanding of applied physics in Namibia. In partnership with the Colorado State University (USA), a practical and fun-based approach to teaching basic physics has been introduced through their "Little Shop of Physics" program. This has positively and significantly impacted the academic achievements of the pupils.

In support of the Ministry of Environment and Tourism (MET) and the School of Veterinary Medicine based at the University of Namibia, the Otjikoto Nature Reserve has invited the Veterinary School to establish a research laboratory on site, and leverage the available facilities and support.

KEY LEARNING AND SUCCESS FACTORS:
- Early commitment to CSI (before project development)
- Develop a fair and transparent system for reviewing and deciding on investments
- Investment framework based on the results of a stakeholders' needs assessment
- Alignment with national (government) development objectives
- Partnerships with development organisations, and
- Partnerships with other like-minded private sector organisations.

Namdeb
Oranjemund
Karas
Namibia
2019 © paulgodard.com

2.3 HERITAGE

Operational activities—regardless of all the proactive work done during the earlier phases of the mining life cycle—may still have an impact on heritage. The approach to be taken when there are known or easily identifiable heritage objects on site, is outlined in the Overarching Chapter of this Best Practice Guide. If further heritage sites are discovered during the exploration phase, projects and construction phase, or operational phase, an attempt should be made to preserve the artefacts found.

It is worth noting that disobeying the National Heritage Act No. 27 of 2004, by relocating or disturbing the position of a protected object / artefact can lead to a fine of up to N$100,000. It remains a priority to maintain existing, and to implement additional management measures about heritage, as stipulated in the EMP. Awareness about the history, archaeology, ethnicity, culture, norms, and religions within the project area is advantageous, because in doing so, any possible conflicts between the local people, neighbours, and the proponent are minimised. Furthermore, it shows commitment to the respect of public opinion and precautionary principles.

During mining operations at Namdeb, a significant heritage finding was made. The case study below shows how diamond mining led to the discovery, conservation and management of artefacts from a 500-year-old shipwreck near Oranjemund, Namibia.

CASE STUDY

NAMDEB DIAMOND CORPORATION (PTY) LTD

is owned and operated by Namdeb Holdings (Pty) Ltd

LOCATION:

Namdeb Diamond Corporation (Pty) Ltd holds mining licences along the south-western coast of Namibia in the Tsau //Khaeb (Sperrgebiet) National Park. ML 43 is the southernmost licence and extends from the Orange River mouth to some 100 km north of it. Open cast mining below sea level is done by using stripped overburden material to construct a seawall to hold back the sea, so that the mining site is dewatered, in order to access the diamondiferous gravel. After stripping, the exposed gravel ore is loaded and hauled to the closest treatment plant. Industrial trans-vacuum machines are used to suck up any remaining gravel in the bedrock areas. Once all ore has been recovered, the seawalls are no longer maintained, and the sites are rapidly swallowed by the sea, leaving only remnants of mining in the form of ponds along the coastline.

BRIEF DESCRIPTION:

During diamond mining operations, artefacts of immense cultural, scientific and intrinsic value were discovered.

KEY ISSUE(S) ADDRESSED:

The discovery made during mining was one of the biggest heritage finds in Namibia and is of great significance. This case study aims to highlight how mining helped unearth this discovery.

DESCRIPTION OF THE CASE STUDY:

On the 1st of April 2008, whilst bulldozing a mining site situated approximately 20km north of the Orange River mouth, Namdeb employee Kapaandu Shatika discovered several half-sphere copper ingots, and therefore stopped his dozer. Namdeb soon found more artefacts in the form of two canons, elephant tusks, pieces of timber, and coins. The area of the find was approximately 7m below sea level, clearly suggesting that these would be artefacts from an old shipwreck. The initial steps taken by Namdeb included halting the mining operation, cordoning off the site, and requesting the full-time assistance of an archaeological specialist. The specialist immediately realised the significance of the find and called for the assistance of a maritime archaeologist. Since Namdeb's mining sites are protected under the Diamond Act, the site was under constant security surveillance. Despite the huge costs involved, Namdeb continued to keep the seawall intact, to ensure that all the necessary steps for the excavation and rescue of the shipwreck could take place. Prior to the 2008 discovery, ad hoc reports of elephant tusks found in ML43 were made. In October 2007, a piece with two parallel openings to operate a block and tackle was found (Alves, 2011). However, it was only when the artefacts of 2008 were found, that the pieces of the puzzle slowly but surely fell into place.

It was reported during the initial excavation that 5 438 artefacts of immense cultural, scientific and intrinsic value were discovered, recovered and subjected to preliminary conservation procedures. These artefacts include 2 159 gold coins, 1 845 copper ingots, 109 silver coins, 67 elephant tusks, 14 cannon balls, 8 bronze cannons, 5 anchors, 3 astrolabes, 3 navigation compasses and part of a compass, as well as tin tableware, copper cooking utensils, swords and chains. The copper alone weighs about 20 tons, and there are also 3.5 tons of tin ingots. Among other items, several wrought iron cannons, swords, muskets and a box of sword blades were found (Noli 2008; Noli & Werz, 2008).

Namdeb initially availed a prefab workshop facility for short-term temporary storage of the collection. A survey was executed by Namdeb's professional surveyors under the maritime archaeologist's supervision, thus allowing for the documentation of minute details of the find, inclusive of hundreds of photographs, video footage and a geodesic survey of the site using a laser scan aligned to international standards (Alves, 2011). After the initial excavation, the site was covered with a 1-meter thick layer of sand and rocks.

On the 22nd of August 2008, a team of Namibian government and international specialists came to the site to discuss the way forward. The temporary storage facility was visited, and it was agreed that a more suitable building was needed, to mitigate the exposure of the artefacts to the elements. Namdeb therefore availed a proper brick workshop, which was refurbished and fitted for use as a museum storage facility in the medium term and until such time as an appropriate museum could be built. A common set of objectives was agreed upon by all of the stakeholders.

A second rescue excavation was led by international specialists—in particular, Portuguese specialists—and the Namibian government, with support from Namdeb, and took place from the 5th of September 2008 to the 10th of October 2008. It focused on the excavation and dismantling of two unique fractions of the ship's hull, the elements of which were still structurally connected. Plates were inserted along the planks to make sure they did not fracture when being moved. The planks were labelled, covered in plastic film and taken to a freshwater conservation pool provided by Namdeb, and a distribution map was drawn up (Alves, 2011). The main reason for having these wooden artefacts under water, was to remove the salt and to prevent cracking during drying. Sodium carbonate

is used on iron artefacts to lower the rust released. This second excavation included an archaeo-graphic record of full-scale drawings and mosaic photography of the four faces of each piece of the two sets of fragments (Alves, 2011). The work was carried out by the Portuguese team in a house donated by Namdeb, and the company's cartography and topography facilities were used to assist.

Initially it was thought that the ship was of Spanish origin, due to the vast number of Spanish gold coins found. However, the presence of some Portuguese coins allowed a rather precise dating, as these coins were minted during the reign of King João III in the period 1525 – 1538, after which they were recalled, melted down and never reissued. During this time, the Portuguese East India Company was sailing from Europe to India, and hence around Africa. The archives of the Portuguese East India Company show that 21 ships were lost on the way to India between 1525 and 1600, but only one anywhere near Namibia: The Bom Jesus, which sailed in 1533 and was lost near the turn of the Cape of Good Hope. It is therefore believed that the artefacts belong to this Portuguese trading ship which was part of a trading ship fleet sent from Portugal to India in 1533. The discovery of the Bom Jesus shipwreck is of tremendous importance because it provides insight into a complete suite of merchandise with which a European trade vessel was loaded at the start of the blossoming trade with India. There are no comparable finds known from this period.

Of interest is the copper, lead and tin ingots, and a provenance study has been carried out since 2014. Most of the 1845 copper ingots show the trademark of the Fugger Company from Augsburg, Germany. Historical accounts testify to massive copper and silver production of the Fugger Company in the area of Neusohl in the Slovak Ore Mountains. Geochemical analyses of 60 copper ingots clearly link the copper to the mines in the Sklowak Ore Mountains, and it was also found that lead was added deliberately to the copper to extract silver by the Liquation Process. This technological innovation is one of the numerous hallmarks of the Renaissance period and the "Age of Discovery". Lead isotope abundance ratios point to an origin from lead deposits in Cracow-Silesia. The ore districts of Neusohl and Cracow-Silesia were intensively connected to mining and metal production during the post-medieval period (Hauptmann et al., 2016). In 2018, the lead and tin ingots were sampled, and the first geochemical analyses point to an origin in the northern Pennines of England for the lead. The analysis of the tin is ongoing. Throughout the study, Namdeb has been rendering logistical support and provides access to the site, thus contributing to research and new knowledge about the complexity of world trade in the 16th century.

In conclusion, Namdeb has provided machinery, equipment and personnel resources to support the excavation and rescue operation of the shipwreck, as well as the conservation efforts of the shipwreck collection during all phases of the project. Consequently, the company was honoured in 2015 with the African World Heritage Fund Award for the company's commitment and exemplary contribution to the conservation and management of the Bom Jesus shipwreck. Namdeb continues to support the ongoing research, has updated its Chance Find Policy and Procedures, and continues to educate its workforce on the potential finds of cultural artefacts and the process to follow in such a case. The unique type of Namdeb's mining operations in ML43 has led to the discovery of an extraordinary 500-year-old shipwreck, probably the oldest discovered wreck in sub-Saharan Africa (Alves 2011). The ship links three continents and the protection of a diamond mining area has ensured that it has not been destroyed by treasure hunters, but is being studied today by scientists (Noli, 2008, Noli & Werz, 2008), and has become a proud part of Namibia's cultural heritage.

REFERENCES:

Alves, F.J.S. (2011): *The 16th century Portuguese shipwreck of Oranjemund, Namibia*. Report on the missions carried out by the Portuguese team in 2008 and 2009.
Hauptmann, A., Schneider, G.I.C. & Bartels, C. (2016): *The Shipwreck of Bom Jesus, AD 1533: Fugger Copper in*
Namibia. Journal of African Archaeology, 14 (2).
Noli, D. (2008): *Shipwreck Excavation Report*, unpublished. Noli, D. & Werz, B. (2008): Preliminary report on the U60 shipwreck, unpublished. Oranjemund, Namibia.

2.4 BIODIVERSITY MANAGEMENT

Each phase of the mining life cycle has the potential to affect biodiversity, both directly and indirectly. Direct or primary impacts can result from any activity that involves land clearance and earthworks including road construction and preparation for construction, overburden stripping, impoundment of water or discharges of water, or the air (such as dusts or emissions). Direct impacts are usually readily identifiable and can easily be managed through the mitigation hierarchy and measures stipulated by the EMP. Indirect or secondary impacts can result from knock-on changes induced by construction activities and create delayed and collective impacts. They are habitually harder to identify immediately and to manage proactively.

It remains a high priority to maintain existing, and to implement additional, management measures, as stipulated in the EMP, during the operational phase and to widen the focus of biodiversity management from site level to the landscape level. Good biodiversity management, normally aligned to fully employed EMS, is also important for preventing eventually increased rehabilitation and closure costs; for avoiding demanding social pressure and unrealistic expectations from stakeholders; for allowing the social licence to operate; and for avoiding restricted access to finance.

This Best Practice Guide aims to ensure the establishment of biodiversity management as a leading practice during the operational phase. Continued monitoring activities, application of research findings, implementation of rehabilitation interventions, and attainment of the highest biodiversity management standards are some of the key elements required for making informed decisions.

SOME OF THE BENEFITS ASSOCIATED WITH A GOOD BIODIVERSITY MANAGEMENT PRACTICE INCLUDE (DEPARTMENT OF RESOURCES, ENERGY AND TOURISM , 2011):

- Procedures for the monitoring of the nearshore subtidal environment
- Better relationships with regulatory authorities, often resulting in shorter permitting cycles
- Reduced liabilities and risks
- Better relationships with stakeholders
- Increased employee motivation and loyalty

Like many other mining operations in Namibia, Namdeb has demonstrated best practice in biodiversity monitoring. An example of the work Namdeb has done is outlined in the case study below:

During the operational phase, there are several opportunities for biodiversity enhancement and protection. For a new mining project, the potential environmental impacts have been identified during the impact assessment process, and addressed by management measures stipulated in the EMP. For existing mining operations, where biodiversity has not been considered prior to the commencement of production, de facto interventions are necessary. Some of the principle guidelines include:

- Consider effects beyond the obvious interfaces such as land clearance. Consider also impacts such as discharges into waterbodies and the downstream effects that can be associated with such effects. Restriction of water as an ecological driver may only show its detrimental effects later, for example
- Consider the interface between society and the environment. Society may have very different views and expectations in terms of biodiversity, and it is essential to align these expectations to the priorities of a mine
- Consider effects beyond the boundaries of the mine site. Dust, noise and vibrations, for example, may affect biodiversity offsite, while incidents such as spillage of hazardous waste on the routes on which the chemicals are transported, have important implications for neighbours and more distant stakeholders
- Ensure that ancillary equipment such as export infrastructure and powerlines are considered in biodiversity management too. An elevated water pipeline, for example, can restrict the migration of animals. A powerline may cause regular incidents of bird kills and be visually intrusive.

Leading practice involves managing, monitoring and mitigating all biodiversity risks and the management of impacts with the necessary insight. The case study below provides some guidelines on how this should be done.

NAMDEB DIAMOND CORPORATION (PTY) LTD
is owned and operated by Namdeb Holdings (Pty) Ltd

LOCATION:
Namdeb Diamond Corporation (Pty) Ltd holds mining licences along the south-western coast of Namibia in the Tsau //Khaeb (Sperrgebiet) National Park. ML 43 is the southernmost licence and extends from the Orange River mouth to some 100 km north of it.

DESCRIPTION OF THE CASE STUDY:
Namdeb's Pocket Beach areas project was initiated to target the sandy beach deposits in the Bogenfels (ML 44) and Mining Area 1 (ML 43) licence areas. A pocket beach is a sandy embayment, containing diamonds, between two rocky headlands. The project consisted of two phases, which stretched between Chameis and the Bogenfels Arch, a significant landmark and tourist attraction along the west coast of Namibia. The scope for the biodiversity monitoring work for this case study is focused on the Pocket Beach's Phase 2 project (site 11 and 12 –see map) which commenced production in mid-2007 and mining was completed in 2011.

Resources were dedicated for biodiversity monitoring before mining commenced. Key issues that were addressed included obtaining baseline and subsequent biodiversity monitoring data. The project's team set a vision for no visible signs of mining 5 years after mining. This has set the tone for the biodiversity and rehabilitation work that followed in the areas. The mining methodology was very unique, since it was the first time that Namdeb used a cut-off wall in conjunction with the seawall and dredge.

The Pocket Beach areas are located in the Tsau //Khaeb (Sperrgebiet) National park, where access has been restricted for more than 100 years because of diamond security regulations. In addition to the Bogenfels Arch, the area is considered sensitive, due to its significance for being in the Succulent Karoo Biome, one of the biodiversity hotspots of the world. The scenic landscapes and presence of fossils, archaeological, historical and cultural sites, seabirds and seal colonies, make it an asset to Namibia for conservation and future tourism. The climate is arid with coastal fog and strong southerly and south-westerly winds throughout the year. Winter and summer rains are possible.

Dedicated environmental resources, a reputable team of specialists, a Marine Scientific Advisory Committee, and an Annual Stakeholders Forum Meeting, assist with setting a high standard for rehabilitation and the reintroduction of biodiversity into the area. The approach to biodiversity restoration was developed through extensive research, in partnership with the National Botanical Research Institute (NBRI), the Millennium Seed Bank Project (MSBP) at Kew Gardens in the United Kingdom, and the Gobabeb Training and Research Centre—the oldest of its kind in Namibia. This was done in consultation with the future end land user - the MET.

There was continuous monitoring of the physical changes to the area (accretion, high water line, pond perimeter and bathymetry of the remaining pond, physical parameters of the pond, and the use of satellite images of the area).

OTHER BIODIVERSITY MONITORING INCLUDED:

- Procedures for the monitoring of the nearshore subtidal environment
- Sandy beaches including the flagship species *Tylos granulatus*
- Rocky intertidal monitoring
- Monitoring of the survival rate of plants re-introduced back into the -5m beach area
- *Salsola nollothensis* re-vegetation at the beach area, brown hyena monitoring, fish and bird species in and around the remaining pond

Salsola nollothensis seeds were collected and their germination potential assessed. Seedlings were transplanted back into the area. Re-establishment/survival of transplanted Salsola plants in the vicinity of the remaining pond was used as an indicator to evaluate the success of biodiversity monitoring and the major conclusions were:

- The rehabilitation program following the diamond mining was essentially successful
- In some areas, the zones for planting should be more clearly established to avoid planting in the beach zone
- Accurate zonation of the dune system would suggest the planting of distinct species in different zones to result in the restoration of the natural plant communities
- There is little visual impact due to mining in the region
- The ponds resulting in the beach zone following mining can form a natural part of the system and no active rehabilitation is necessary
- Spontaneous restoration may result in the establishment of plant communities in the pond over time. There is only circumstantial evidence of this occurring at present

Sperrgebiet NP - Atlas Bay Luderitz
Karas
Namibia
2019 © paulgodard.com

AUTHORS:

NAMPOWER / NAMIBIA NATURE FOUNDATION

Strategic Partnership

BRIEF DESCRIPTION:

The NamPower/Namibia Nature Foundation Strategic Partnership was launched in 2008, with a mission to address wildlife and electricity supply interactions in Namibia, in the interests of promoting sustainable development. The project is generously funded by the European Investment Bank. The project's objectives are to:

- Monitor, report and manage electricity and wildlife interactions
- Conduct research and incorporate wildlife mitigation into existing electricity supply networks, and into the planning of future networks
- Promote awareness, education, communication and collaboration about the risks that the electricity supply poses to wildlife, and wildlife to the electricity supply.

To include local partners in this monitoring as part of their environmental programmes, three uranium mines in the Erongo region have been included. This case study aims at showcasing generic procedures and guidelines for the monitoring of electricity generation and supply structures and their interactions with wildlife.

KEY ISSUE(S) ADDRESSED:

The management and mitigation of impacts on wildlife are based on the following dedicated guidelines and procedures with regard to:

- Powerline survey methods
- Incident recording
- Incident reporting

DESCRIPTION OF THE CASE STUDY:

A. Dedicated powerline monitoring surveys

Permission and permits

The permission of the relevant electricity supply utility, e.g. NamPower or the Regional Electricity Distributors (REDs) is required for working on any powerline servitude in Namibia. Before any survey can take place on a NamPower powerline, the control room at head office should be notified of the start and end time of the survey. This allows the control room to take cognisance of potential threats to the party conducting the survey.

BEST PRACTICE FOR MONITORING OF POWERLINES AND ENERGY PRODUCING STRUCTURES ON MINES

Additionally, open communication from the survey team allows proactive interaction if problems do arise while the powerline is being surveyed.

The permission of the land owner is also required. In the case of mines, the mine is the owner; however, for any other powerline, various owners may be involved, including municipalities, the MET (in which case a free entry permit is required), conservancies, and/or farmers.

At present a research authorisation permit from the National Commission on Research, Science and Technology (NCRST) is not required for normal powerline monitoring; however, the carcass remains should be left on site. (A NCRST permit would be required should any carcass remains be collected, removed from the site, and/or transported.)

Training

An induction for access to NamPower lines is required for working on any NamPower powerline servitude, for which a certificate is issued by NamPower; this training should be repeated every year.

The NamPower/Namibia Nature Foundation Strategic Partnership is available to conduct additional basic on-site training in wildlife and powerline monitoring; the programme includes a general introduction to common types of wildlife and power supply interactions in Namibia, mitigation measures to avoid powerline incidents, methods for monitoring and feedback on results of monitoring to date, and bird identification. The impacts of wildlife on electricity generation and supply structures are also addressed. As part of the above training, a powerline survey form is discussed and made available. Note that there are separate forms for dedicated powerline surveys, and for records that are obtained on an incidental basis (see below).

Powerline survey methods

Survey frequency

Surveys should be undertaken on a monthly basis for at least two years. Thereafter the frequency could be reduced to a quarterly basis, unless wildlife impacts are found to be significant (in which case monitoring should continue, and mitigation should be investigated for identified problem areas).

Survey equipment

Vehicle, NP/NNF Partnership survey form (see above) and pencil, camera, GPS, bird field guide, binoculars, and gloves (for handling carcass remains).

Survey method

Surveys should be timed for as early as possible in the day, to avoid windy and hot conditions. Note the following aspects, as per the above survey forms: weather conditions, habitat type, vegetation type, tower design(s) and voltage, other infrastructure in the area; live birds and nesting behaviour on or near powerline structures; signs of scavenging activity.

Conduct the survey along the powerline route. Walking is regarded as the best method for spotting carcass remains; alternatively, drive very slowly (<20 km/hr) or use a combination of driving and spot checks with walking. Preferably two persons should walk parallel to each other, a few metres apart. Avoid walking directly beneath the powerlines, although it is important to stay within the dedicated servitude of the powerline that is being inspected.

Incident recording

When carcass remains are spotted (sometimes only feathers or bones), record the following details as per the survey form:

- GPS position and time (if no GPS is available, refer to the numbers of the towers on either side of the incident)
- Photograph the incident as follows:
  - A general view showing the carcass, tower/powerline and surrounding landscape
  - Each mortality/injury: from above and beneath; detail of head including beak if possible
  - The nearest electricity pole/tower and its number
- Identify the carcass, if possible; if the species is unknown, record it as such
- State/freshness of carcass
- Position of carcass in relation to the towers and to the centre line of the powerline(s)
- Mitigation devices fitted to the powerline, and whether these devices are present at the site of the incident
- Any pertinent habitat details (e.g. proximity to a water body)

Reporting

Both the survey reports and incidental reports should be kept on file as required by each mine. Photographs relevant to each survey should be referenced with the survey, incident number and date, and kept in the same folder as the form.

The sharing of the above data would be appreciated by the NamPower/Namibia Nature Foundation Strategic Partnership for inclusion in a countrywide database, which is being built up as a basis for making informed recommendations for the application of targeted mitigation measures. The incidents are also mapped and made available on the Environmental Information Service (EIS; www.the-eis.com, Birds and powerlines tool).The data should be evaluated regularly, and the survey methods/frequency adapted accordingly. Monitoring of the effectiveness of any mitigation measures should be included in the analyses of data. Regular feedback to survey participants is recommended, to maintain motivation.

CASE STUDY

BEST PRACTICE FOR MONITORING OF POWERLINES AND ENERGY PRODUCING STRUCTURES ON MINES

B. Incidental records

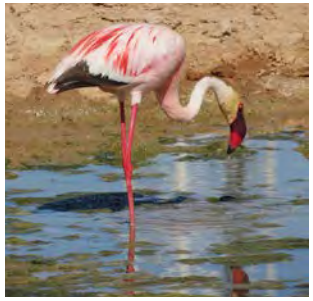
Records that are obtained on an incidental basis (i.e. not as part of a dedicated survey covering a section of powerline) may be recorded on a separate form. The details required are self-explanatory; in particular, the carcass remains should be photographed as indicated above. The form is downloadable from the Partnership website: http://www.nnf.org.na/index.php/projects.html#nampower-nnf-strategic-partnership.

Renewable energy

Guidelines for the monitoring (and assessment) of renewable energy structures, including both wind and solar energy, are well developed. The comprehensive best practice guidelines below are recommended for monitoring such developments in Namibia (downloadable from http://www.birdlife.org.za/media-and-resources/birdlife-south-africa-scientific-publications):

Jenkins AR, Ralston-Paton S, Smit-Robinson H. 2017. *Birds and Solar Energy: Best practice guidelines for assessing and monitoring the impact of solar power generating facilities on birds in southern Africa*. BirdLife South Africa, South Africa.

Jenkins AR, Van Rooyen CS, Smallie JJ, Harrison JA, Diamond M, Smit-Robinson HA, Ralston-Paton S. 2015. *Birds and Wind-Energy Best Practice Guidelines: Best practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in Southern Africa and the Endangered Wildlife Trust*. South Africa.



TOP LEFT: The team from Orano Mining Namibia investigates an incident on a powerline on the mine (L to R): Richard Gurirab, Helmut Ochurub and Kaarina Nkandi, with Mike Scott (photo: Ann Scott)

TOP: Lesser Flamingo (Vulnerable in Namibia and Globally Near Threatened) is an intra-African migrant and prone to collisions on powerlines (photo: Ilka Schröer)

LEFT: Ludwig's Bustard (Endangered in Namibia and Globally Endangered) is a partial migrant and prone to powerline collisions (photo: Ann Scott)

Namdeb
Oranjemund
Karas
Namibia
2019 © paulgodard.com

Different mining methods present different opportunities for biodiversity management. Underground mines typically have a smaller environmental footprint as compared to surface mines. Open pits gradually widen and deepen, leading to a steady increase in the total surface area of disturbance. The mineral waste dumps and tailings depository facilities of open pit mines are also increasing, creating an ever-growing footprint. In these environments, the management of water becomes a multidimensional topic—creating challenges for the management of surface drainage, restriction of water as an ecological driver, and the prevention of water contamination. Other related impacts include the accidental release of chemicals, emissions into the air (dust and particulates, and heavy metals and sulphur dioxide from pyro-metallurgical processes such as smelting), seepage from low grade stockpiles into surface and groundwater, and slag disposal from pyro-metallurgical processes, which contains toxic metals. Namibia is the world's leading nation in seabed mining, and such an activity has its own special dimensions when it comes to environmental impacts, including the actual seabed as well as the water column above it.

Debmarine has demonstrated innovative methods in biodiversity monitoring. Their example is outlined in the case study below:

MINING LICENCE AREA 47

Commonly referred to as the Atlantic 1 marine diamond mining licence area, Mining Licence Area 47 is situated off the southern coast of Namibia. The Atlantic 1 marine diamond recovery operation is home to Debmarine Namibia, a joint venture Company, owned in equal shares by the Government of the Republic of Namibia and De Beers Group. Debmarine Namibia is a wholly-owned subsidiary of Namdeb Holdings (Pty) Ltd.

BRIEF DESCRIPTION:

The licence area is approximately 6 000 km^2 in extent, however, diamonds are only recovered from a small portion of this area. The licence area lies approximately 8 km offshore and stretches from Oranjemund in the south to Chameis Bay in the North. Debmarine Namibia utilises specialised vessels to recover gem-quality diamonds at water depths of between 90 and 150 metres. The diamond-bearing sediments are located in patchy deposits typically located at a depth of less than a metre beneath the sea floor. The gravel and sediment that is removed, is treated in the processing plants on-board the vessels, where the diamonds are extracted and the remaining sediment — over 99% — is discharged and settles back to the seabed. No chemicals are used in the diamond recovery process. Each vessel is a single, unique and totally integrated mine. Sediments are recovered and treated on-board with no stockpiling of sediments for later treatment. Access to the resource by the vessels is only constrained by the time taken for a vessel to move from one area to another (~24 hours) and resource planning flexibility. No permanent infrastructure is placed in the mining licence area.

Exploration and resource delineation is undertaken by low-energy, geophysical acoustic survey methods (bathymetry, side scan sonar and seismics) to map the sea floor. This is then followed up by sampling, undertaken with a special purpose-built exploration and sampling vessel, the SSN.A fleet of six diamond recovery vessels operate in Atlantic 1, comprising five drill-vessels and one vessel that operates a seabed crawler. The vessels are manned by a highly skilled and technically experienced crew who work in rotating teams, on-board the vessels for 28 days on and 28 days off. The crew are transported to and from the vessels and head office in Windhoek via helicopter and fixed-wing aircraft from the Company's logistics base at Oranjemund Airport. Debmarine Namibia employs over 900 people, the majority of whom are seagoing.

KEY ISSUE(S) ADDRESSED:

Ensuring the sustainability of marine diamond recovery operations requires a unique approach and a reliance on independent marine scientific research and monitoring, to assess sedimentary and ecological changes and rates of recovery. Debmarine Namibia has implemented a comprehensive environmental monitoring programme employing various techniques to understand the pre-mining seabed environment and to monitor post-mining impact and recovery. These techniques include:

- Collection of seabed samples using a Van Veen grab sampler to assess sediment grain size composition, sediment chemistry, and the biomass and abundance of macrofauna species living in the sediments, in the pre- and post-mining environments.
- Use of seabed video footage collected by manned and unmanned submersibles to assess changes in fauna on adjacent hard substrata (Jago Project).
- Analysis of high-resolution geophysics to assess mining impact and re-sedimentation, including chirp seismic, backscatter, side scan sonar and bathymetric data.

DESCRIPTION OF THE CASE STUDY:

Debmarine Namibia's production targets are based on a Life of Mine (LoM) Plan, with a planning window until the end of the profitable resource, which is reviewed and updated on an annual basis. The company produces around 1.4 million carats per annum.

The De Beers Group, including Debmarine Namibia, has been studying the impacts of marine diamond recovery and the subsequent recovery of the seabed, since 1994. The extensive environmental monitoring programme includes the gathering and analysis of sediment samples, benthic macrofauna, geophysical survey data and photographic records, on an annual basis to achieve the following objectives:

- Obtain pre-mining baseline information on the seabed habitat and macrofaunal communities living in the top 30 cm of the seabed. These animals are usually sessile, with a long generation time, which means that the benthic community structure reflects the environmental conditions in a particular area, integrated over a period of time.
- Investigate the relationship of benthic community structure with water depth, sediment type, geographic position, and other factors.
- Assess and monitor the rate of recovery of seabed habitat and macrofaunal communities following mining disturbance. Current monitoring studies indicate that seabed recovery occurs naturally at a rate dependent on sediment supply from adjacent areas. The rate can vary from 2 to 3 years in areas of abundant sediment supply, such as close to the Orange River mouth, while in areas of slower sediment infill, recovery can take between 3 and 10 years. In rocky terrain, where sediment supply is reduced, recovery can take more than 10 years. There is no direct overlap between commercial fishing grounds, or known fish spawning, feeding or nursing areas and the Atlantic 1 license area.

There are currently 93 environmental monitoring stations across the Atlantic 1 mining licence area. The environmental monitoring programme forms part of the approved Environmental Management Program, the Biodiversity Action Plan, and the Closure Plan for the Atlantic 1 mining licence area. The company's overarching closure and rehabilitation objective is to leave a post-mining environment that has returned to a state where ecological function has returned to a state equivalent to comparable undisturbed sites. This is defined as being at least 80% similar in terms of species composition, abundance and biomass measured over a period of at least 3 consecutive years.

CASE STUDY

Debmarine Namibia has a complement of four full-time Environmental staff, and compliance to environmental objectives is managed within the framework of an ISO14001 certified Environmental Management System. Over N$ 15 million is spent annually on the environmental monitoring programme, which is conducted by independent marine scientists and evaluated by an independent advisory committee of academics and scientists in the region. The success of the environmental monitoring programme is measured by the sampling rates and quality achieved during the sampling campaigns, the expansion of biodiversity knowledge, and demonstration of recovery against the rehabilitation objective. Following analysis, Debmarine Namibia's benthic samples are shared with other local entities such as the University of Namibia and the Ministry of Fisheries and Marine Resources, to facilitate education, capacity-building and the training and development of local marine researchers within Namibia.

In 2012, a Marine Scientific Advisory Committee (MSAC) was established, comprising of recognised marine scientists from academia and industry and other key stakeholders. The committee advises on the monitoring of design and research techniques, reviews the results of the environmental monitoring programme to determine its effectiveness, and provides recommendations to Debmarine Namibia on marine environmental science related aspects.

SOME OF THE KEY CHALLENGES ASSOCIATED WITH ACHIEVING THE OBJECTIVES OF THE ENVIRONMENTAL MONITORING PROGRAMME ARE:

- Insufficient information on key drivers of natural variability;
- Inadequate understanding of the links between physical habitat recovery and that of the faunal communities; and
- Technical and cost constraints associated with the gathering of data in rocky substrates that cannot be sampled using traditional grab sampling methods.

Recognition of these challenges has resulted in new innovations being included in the programme. For example, additional data are now being collected on habitat quality (organic carbon and nitrogen in the sediment), structure (sediment thickness), and water quality (temperature, dissolved oxygen and turbidity). Debmarine Namibia also plans to expand the use of geophysical survey and visual techniques for biodiversity habitat mapping and to monitor recovery of benthic communities affected by mining.

Debmarine Namibia's ongoing surveys have made a substantial contribution to new biodiversity information and the monitoring programme continues to provide valuable information on the natural variability in benthic macrofaunal communities in the Atlantic 1 mining licence area, the impacts of diamond mining operations on the benthic environment, and post-mining recovery.

Some of the benthic macrofauna collected during the annual sampling survey.

A: *Lumbrineris heteropoda difficilis*
Distribution: South western and eastern coasts of Africa; widely distributed within the Indian Ocean

B: Masked Carb: *Nautilocorystes ocellata*
Distribution: Along the coastline of Namibia and South Africa

C: Burrowing mud shrimp: *Callianassa australis* | **D:** *Calocaris barnardi*
Distribution: Observed in the South West coast Africa (Namibia and South Africa)

E: *Lysianassa variegate* | **F:** *Phaxas decipiens*
Distribution: Observed in the South West coast Africa (Namibia and South Africa)

Drop camera images of the monitoring sites in the Atlantic 1 Mining Licence area.

Site: NA_AB Natural Variability / Control Site

Site: NA_A Natural Variability / Control Site

Site: SS/22/M Designated Impact Site

Site: SA_C Natural Variability / Control Site

2.5 NON-MINERAL WASTE MANAGEMENT

At any mine, a big variety of waste types and quantities are generated during the operational phase. In simple terms, a distinction is made between mineral and non-mineral waste and each type must be assessed and managed on its own merits. It is also important to review the waste management measures stipulated in the EMP regularly, as the quantities and disposal options may vary over time. In this section, the management of non-mineral waste is discussed; the management of mineral waste is discussed in Part Three of this document.

It is recommendable that an operator seeks the advise of the National Radiation Protection Authority (NRPA) on the management of waste that contains radioactive substances. For mines with uranium-bearing ores exceeding an ore grade threshold of 80 ppm, a site operation licence must be obtained. A licence holder is restricted by the provisions of the Atomic Energy and Radiation Act (No.5 of 2005) and conditions of the licence, including waste management. In consultation with the NRPA radiation safety rules and within a practice or for the use, handling, storage, transportation, or disposal of radiation sources or nuclear material produced or prepared need to be prepared by the licence holder. Furthermore, any generator of radioactive waste needs to be licensed and compliant to the Radiation Protection and Waste Disposal Regulations (No. 221 of 2011), in particular Regulation 58 – 74 (Disposal of Waste).

Non-mineral waste is produced in much smaller volumes to mineral waste but is a key indicator for measuring the ecological footprint of an operation. If not properly managed, non-mineral waste items can cause multiple negative environmental and social impacts. Negligent management of non-mineral waste items is visual and reflects badly on any business. Non-mineral waste items consist primarily of auxiliary materials that support mining operations, and include a very wide range of different types and quantities—tyres, oils and grease, batteries, empty containers, plastic and wood packaging, scrap metal, paper, building rubble, and waste items from processing, maintenance, workshops, laboratories, gardens, and other domestic rubbish.

The Pollution Control and Waste Management Bill is currently in draft form and should be finalised by parliament to become an Act. In the absence of national legislation, non-mineral waste management in Namibia is implied through by-laws under the auspices of several authorities (e.g. local and regional government, parks management, etc.). Mines are managing non-mineral waste through the obligations in their EMPs, and implementing self-regulatory best practices.

A best practice of non-mineral waste management is based on a separation and recycling system, preferably introduced already during the projects and construction phase of the mining life cycle. The early introduction of a waste separation and recycling practice has the potential to gain reputation and raise environmental awareness among employees. Clean-up campaigns, waste reduction efforts, and recycling challenges are initiatives with great participative rewards and can assist in building morale and boosting a company's reputation. The introduction of a waste separation and recycling practice implies the classification of non-mineral waste, e.g. industrial non-mineral waste (generated in workshops and processing plants); contaminated waste (e.g. industrial and hydrocarbon contaminated soil and sludge, radioactive items in the case of uranium mines, and chemical contaminated items in the case of metallurgic processing); hazardous non-contaminated waste (hazardous items coming from workshops and processing plants, which should be disposed of at a certified hazardous waste site); and non-hazardous, non-contaminated waste (packaging, redundant and discarded items, and household rubbish, etc.).

Recyclable items include wood, paper and cardboard, plastic from packaging and empty containers, scrap metal, oil (in practice at the uranium mines), and electronic waste. More complicated to recycle are items such as used grease, tyres, conveyor belts, batteries, and empty lubricant containers. Items that have little to no potential for recycling include redundant chemicals and chemical waste, building rubble, kitchen remains, sanitary and medical waste, and contaminated containers. A proper waste separation and recycling practice entails clear signage for segregation, designated dump areas, scheduled routines for waste removal and disposal, and a strong awareness campaign about waste. Furthermore, employees should be encouraged to avoid, reduce and recycle waste, including the compression of bulky waste items.

2.6 HAZARDOUS SUBSTANCES

Most mines store significant quantities of various chemicals, fuels, oils and greases, including used chemicals, oils and greases. Many of these are hazardous substances, i.e. materials in the form of a solid, liquid or gas; vapour, dust or particulates, fumes, mist, solvents, and aerosol, etc., that contains ingredients which may cause environmental damage or degradation of the surrounding area, and could cause health and/or safety risks to persons coming into contact with these substances, when not handled correctly. These substances are grouped by the Hazardous Substances Ordinance 14 of 1974 and all hazardous substances must be controlled and assessed according to the Ordinance.

Most mines implement a site-specific Code of Practice or Management Procedure for the control of hazardous substances—for purchasing, handling, storage, application and disposal. Best practice is to keep a hazardous substances register, which identifies the name of a substance; contains a material safety data sheet (MSDS) for each of the substances; and stipulates procedures for handling and managing the risks of each substance. The register is maintained and audited accurately.

The ordering or purchasing of a hazardous substance involves an assessment of the substance prior to its ordering and purchasing; consultative research on finding an alternative non-hazardous substance; communication and training about the substance to be ordered or purchased; obtaining a factual and correct MSDS for the substance; purchasing of minimum quantities to limit the risk; emergency procedures; and solutions for disposal of the empty containers and accidental spills and waste generated.

Transportation needs to be compliant with the prescribed containment and packaging guidelines (for example of dangerous goods legislation) and requirements as indicated in the MSDS. Some substances may be transported and delivered in bulk (e.g. acid, ammonium, hydrocarbons, etc.) and stored as such in an enclosed system. Other bulk substances include process reagents (collectors, frothers, alkalis, flocculants, coagulants, solvents and modifiers) or blasting components (ammonia nitrate and other nitrogen compounds) and are stored in isolated containers or designated areas. Substances such as industrial chemicals and flammable materials are stored in areas suitable for the specific type of material and in such a way that it does not pose a safety, health or environmental risk. These areas are secure and appropriately equipped (with access control, bunds, spill kits, etc.). Training and awareness on the handling or use of a hazardous substance needs to be done, according to the understanding of the safety and environmental requirements as indicated in the MSDS of the specific product. Spill management procedures and disposal procedures need to be in place too.

All hazardous substances no longer required, and their empty containers, have to be identified for disposal. Disposal needs to be done in compliance with the MSDS requirements. No hazardous substance or empty containers of a hazardous substance may be discarded in a general garbage bin or enter surface drainage or sewage systems for disposal, emphasising the importance of preventative measures such as bunds, designated areas and correct management procedures. All damaged and redundant hazardous substances have to be returned to suppliers and empty containers have to be returned to suppliers with whom an agreement is in place, or disposed at a certified hazardous waste site.

RÖSSING URANIUM LIMITED

is operated by China National Nuclear Corporation (CNNC) also the majority shareholder. The mine has a production capacity of 4500 tonnes of uranium oxide per year with latest annual production of 2479 tonnes in 2018. The current life of mine ends in 2025. In 2018, Rössing mined 19.8 million tonnes of rock (21 per cent less than in 2017) of which 8.0 million tonnes were uranium-bearing rock (17.8 per cent less than in 2017) and 11.5 million tonnes were waste rock. This presents a waste-to-ore strip ratio of 1.48 which is significantly lower than 2017 at 1.57.

LOCATION:

The mine is located 12 km from the town of Arandis, which lies 70 km inland from the coastal town of Swakopmund in Namibia's Erongo Region. Walvis Bay, Namibia's only deep-water harbour is located 30 km south of Swakopmund. The mining operation is located in a hyper-arid environment. Insolation at Rössing Uranium is high, and as a result, daytime temperatures ranges are wide, especially during May and September, when the difference between minimum and maximum temperatures exceeds 20°C daily. The lowest temperature is normally recorded during August, but frost is rare. The highest temperature is normally recorded in the last summer, particularly in March. The mine site encompasses a mining licence and accessory works areas of about 180 km2, of which 25 km2 is used for mining, waste disposal and processing.

BRIEF DESCRIPTION:

Rössing is one of the longest-operating uranium mines in the world. The uranium-bearing ore is mined through drilling, blasting, loading and hauling from the Open pit (which current dimensions of approximately 3 km by 1.5 km, and 390 m depth).

The ore is delivered to the Primary crushers and then passes through a further series of crushers (secondary, tertiary and quaternary crushers), reduction process ends with further grinding in rod mills before extraction of the uranium can be done to produce (recover) our product, uranium oxide.

Once milled (grinded) to the desired size of D80 of 1 mm (80% pass through 1 mm) extraction commences through leaching with Sulphuric Acid and various Oxidants. The intricate process further involves material passing through the cyclones, rotoscoops and thickeners before a "pregnant solution" is extracted (the barren solution is transferred to the tailing storage facility (TSF).

The recovery process starts off with solvent extraction using Ammonium Hydroxide and precipitated with Ammonia gas. The precipitated is filtered and subjected to calcination before the final product "uranium oxide" is drummed.

The 42 years mine operation is characterised by significant footprint of about 2500 hectares, which is mostly occupied by tailings storage facility (650 ha), waste rock dumps (747 ha) and open pit (457 ha), the remaining hectares is occupied by other infrastructures such roads, reservoirs and plant area amongst others. The TSF is surrounded by dewatering wells systems and telemetry seepage control systems.

KEY ISSUE(S) ADDRESSED:

Rössing Uranium Ltd (RUL) waste management plan requires the business unit to inspect external facilities receiving and disposing of its hazardous waste. As a result, Rössing Uranium conducted audits to all its waste receivers and improvement opportunities were identified especially with respect to licensing and best practices. RUL continues to work with external stakeholders in an effort to establish offsite, regional or national facilities able to receive hazardous waste in a coordinated fashion amongst all stakeholders. The waste segregation strategy and its awareness is very effective in ensuring separation of domestic and hazardous waste.

DESCRIPTION OF THE CASE STUDY:

Rössing Uranium mine is operated by CNNC also the majority shareholder. The mine is having a production capacity of 4500 tonnes of uranium oxide per year with latest annual production of 2110 tonnes in 2017. The current life of mine ends in 2025. In 2017, we mined 25.2 million tonnes of rock (3 per cent more than 2016) of which 9.6 million tonnes were uranium-bearing ore (20 per cent more than 2016) and 15.6 million tonnes were waste rock. This presents a waste-to-ore strip ratio of 1.63 which is significantly lower than 2016 at 2.07.

For the past 42 years that Rössing has been in operation, a total of 70 historical and current waste dumps have been identified and assessed in terms of remediation requirements. A contaminated site register is in place together with a geographical map indicating the size and location of each dump site which is maintained by the surveyors as per regulatory requirements.

Rössing operates Mining and Processing facilities including maintenance workshops and administrative areas. All areas produce different types of hazardous waste streams of varying volumes according to activity levels. The hazardous waste management is supported by an onsite integrated waste management contractor that manages and coordinate disposal.

All items (i.e. paint containers, used oil and grease) used in the Processing plant areas are regarded as potentially radioactive contaminated materials therefore cannot be recycled. Redundant materials are regarded as radioactive contaminated when they have a fixed or non-fixed surface contamination of alpha or beta exceeding 0.4 Bq/cm^2. The radioactive contaminated wastes are retained on site and disposed of at the Tailings Storage Facility. This practice excludes all hydrocarbons and chemical-related waste. Currently all radioactive hydrocarbons are retained on site awaiting assessments for safe disposal methods.

An internal operational Non-Mineral Waste Management Plan and a "Non-Mineral Waste Management Procedure are in place to ensure sound hazardous waste management through minimization of waste generation and safe handling, treatment and safe disposal of waste. The procedure addresses the safe handling requirements of the different types of hazardous wastes generated at Rössing during the operational phase and how it can be disposed of safely.

To avoid the spread of radioactive contamination, waste is placed in white luggerbins and gets buried at the Tailings Storage Facility where there is a dedicated site which has been identified and demarcated as a "Waste Disposal Area" by the TSF Operations Plan. TSF is a controlled area where the dumping of waste is scheduled regularly and done in a controlled manner.

Recyclable non-radioactive hazardous waste such as used oil, gets placed in 210L sealed drums that should be cleaned and clearly labelled before they are transported to the oil storage yard for temporally storage. After this process, the oil drums goes offsite for recycling. Other hazardous wastes treated in the same manner are the redundant chemicals and fluorescent tubes that are disposed of offsite at licensed facilities. In the absence of licensed facility in the close proximity of the mine, hazardous waste is retained on site at the old temporally oil yard until sufficient quantities are available for bulk transportation and disposed of offsite at licenced facilities in municipal areas.

In the absence of a clear legislative framework for waste and hazardous material management in Namibia, Rössing uses international standards such as ISO 14001, best practices and as well as appropriate South African standards.

Rössing sets specific targets for hazardous waste management where the progress is monitored and reported on an annual basis. Performance effectiveness is measured against the following performance indicators:

CASE STUDY

HAZARDOUS WASTE MANAGEMENT

THE ADVANTAGES OF INCORPORATING HAZARDOUS WASTE MANAGEMENT INTO THE OPERATIONAL PLAN ARE AS FOLLOWS:

- Eliminate or minimize hazardous waste generation
- Maximize re-use of hazardous waste products in a safe and effective manner
- Maximize recycling of hazardous wastes
- Minimize the adverse effects of hazardous waste disposal on the environment

- Number of non-conformances recorded.
- Increase in number of recycled/re-used waste.
- Reduction in hazardous waste generated.
- Incidents of pollution

The hazardous waste management practices are monitored through regular inspections, internal compliance audits (1st party assurance audits), ISO 14001:2015 annual audits. The compliance to the standards will be assessed as set out in the Rössing Environmental E2 protocols.

Rössing is facing challenges in relation to hazardous waste management due to the lack of a licensed and well managed disposal site in the region and limited expertise in hazardous waste management at national level.

In conclusion the hazardous waste management at Rössing is effective as there was no major environmental incidents reported that had a negative impact on the environment. Emerging challenges identified through our Internal Performance Standards are being addressed at regional industry level and there is good progress. The need for a licenced facility is becoming greater considering the cumulative impacts emanating from the growing mining industry in the country. This should be a key focus for the national agenda.

Tsumeb smelter - Dundee Precious Metals Tsumeb
Tsumeb
Oshikoto
Namibia
2019 © paulgodard.com

2.7 MANAGING ACID MINE DRAINAGE

Apart from water contamination as a result of spills or seepage, Acid Mine Drainage (AMD) is a major environmental threat associated with metallic and coal mines. AMD is caused when sulphuric acid forms as a result of the exposure of sulphide minerals to air and water. Other minerals in surrounding rock can dissolve in the sulphuric acid and if uncontrolled, AMD has the ability to run off into streams and rivers, and seep into groundwater. The resulting impacts can be detrimental, mainly because AMD causes the water to drop to a pH lower than 4 in some instances, making survival of aquatic plants and animals impossible. The AMD potential of a mine is thus a decisive part of an environmental assessment to determine whether the project is environmentally acceptable or not.

AMD can be released from any part of the mine where sulphide minerals are exposed, such as leach pads, tunnels and channels, tailings, waste rock dumps and open pits. The treatment of AMD is typically accomplished by either using active or passive treatment, where active treatment is commonly used for operational mines and passive treatment is more prominent in abandoned and closed mines.

THERE ARE DIFFERENT APPROACHES TAKEN WHEN DEALING WITH AMD, THE MOST POPULAR APPROACHES BEING THE FOLLOWING:

- Neutralise the acid
- Prevent exposure of the mineral to water and oxygen
- Avoid/prevent bacteria from catalysing the reaction

A common method for managing AMD is through the reclamation of contaminated land by adding alkaline materials or lime, in order to neutralise the acidity. Other methods include the planting of vegetation, adding uncontaminated topsoil, and the modification of slopes, in order to reduce infiltration of surface water and to stabilise the soil. Direct treatment of contaminated water requires treatment plants, the adding of neutralising material, or through creating artificial wetlands, where microbial action can be used to create oxygen-free conditions to stop the formation of sulfuric acid.

Abandoned mines need to be filled to reduce the formation of AMD, this can include filling a mine with alkaline material to avoid the formation of acidic water.

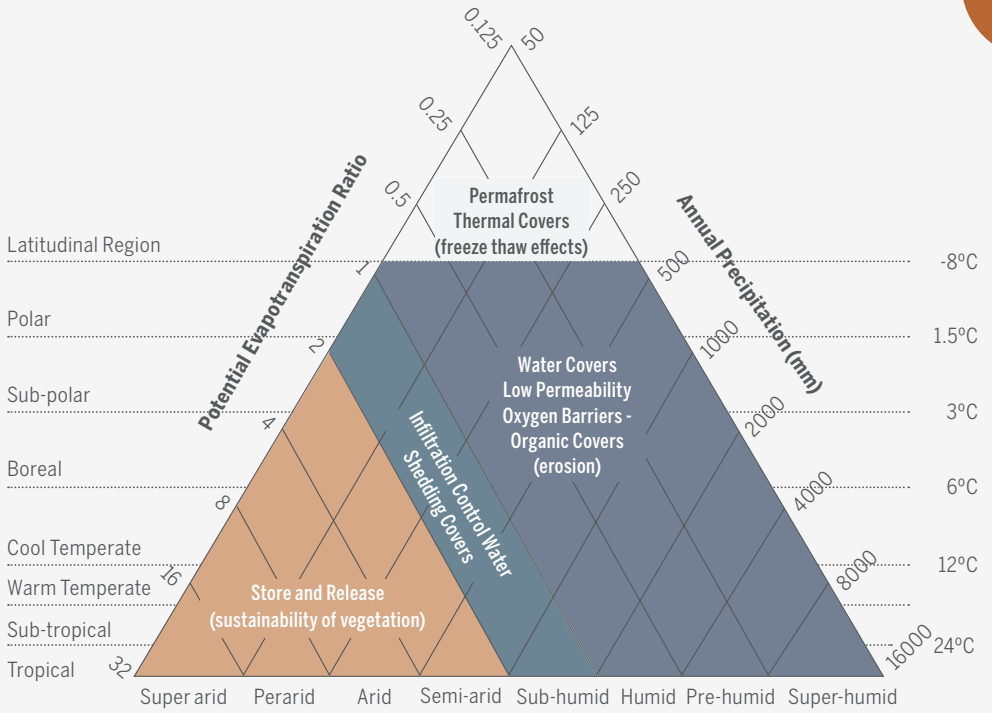
Relocation and isolation of contaminated waste that has the potential to lead to AMD if it comes in contact with water, is necessary. Leading practice involves moving the waste to above the water table and covering it with an impermeable layer to keep out surface water.

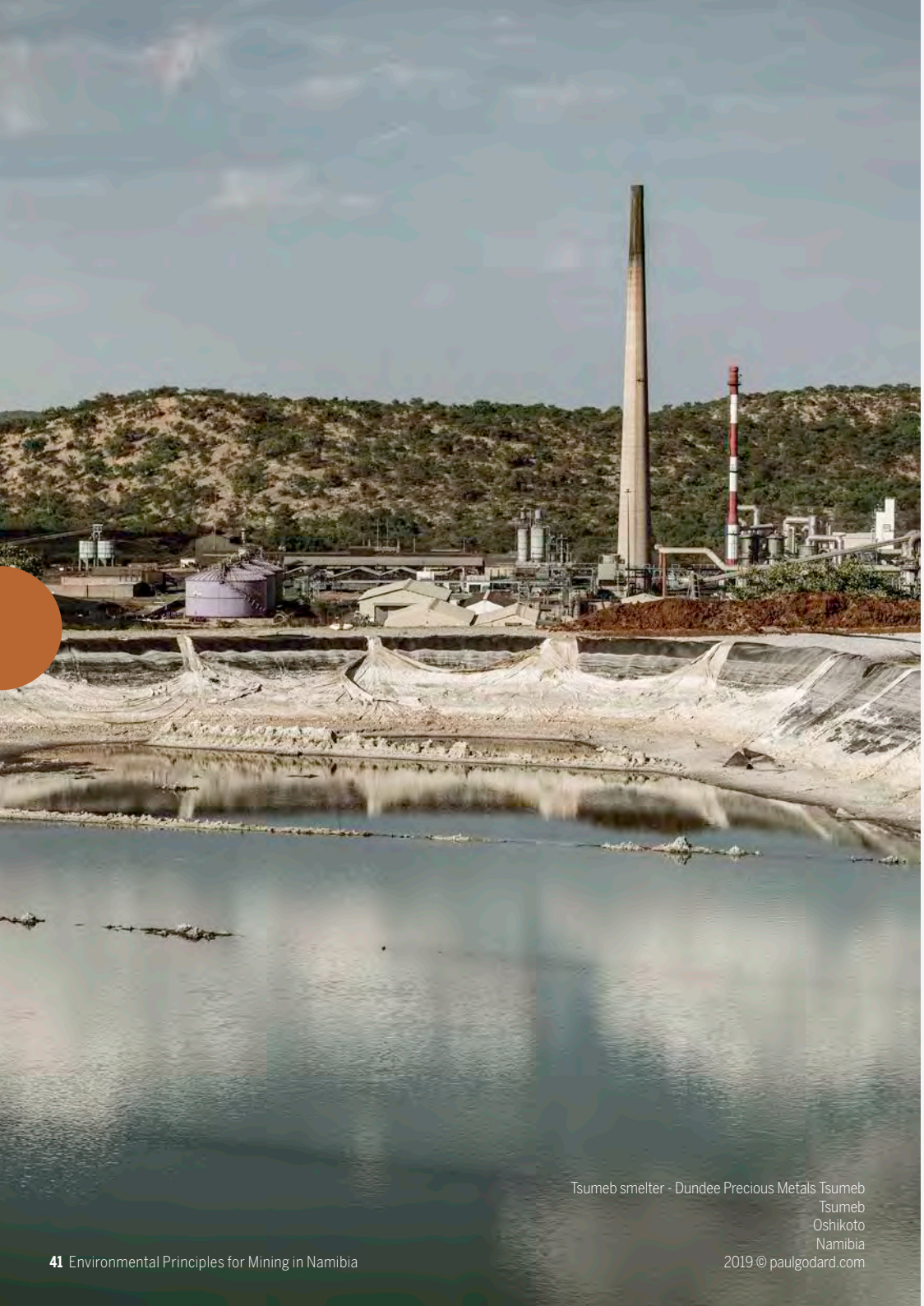
To ensure that water does not flow through AMD-forming materials, surface water channels should be diverted from the mine site. Prior to using this method, accurate hydrogeological and hydrological studies should be conducted—the lack of proper studies often leads to the failure of this method.

Bacteria control can also be applied, as certain bacteria act as a catalyst in the formation of AMD—to control these bacteria, bactericides can be used.

Contaminated soil needs to be removed to areas where it can be treated and monitored. Dry covers can be placed on acid-forming materials with the aim of stabilising mine waste to prevent water and wind erosion.

[FIGURE 3] Tri-linear plot to determine the best cover to use under different climatic regimes in order to prevent AMD





Tsumeb smelter - Dundee Precious Metals Tsumeb
Tsumeb
Oshikoto
Namibia
2019 © paulgodard.com

The key factors that need to be considered during the design of a soil cover, include the climatic regime of the site, the texture and reactivity of the mine waste material, the durability of the economically feasible cover material, along with their hydrogeological and geotechnical properties, and the long-term effects of erosion, evolution and weathering of the cover system.

There are various cover designs used and typically two covers are required. Leading practice requires the first layer to have low permeability and suitable materials for the first layer are clays (especially bentonite). Clay can however be prone to breaking during the dry seasons—a suitable alternative can be a thick layer of organic matter. The low permeability layer should then be followed by a drainage layer. This layer prevents the capillary migration of metals and safeguards the dump from human influence, erosion, and freezing (SCIELO, 2014). Over the years, dry covers interact with human activity, climate, animals, vegetation and hydrology. The tri-linear plot in FIGURE 5 provides guidance on which cover types are suitable for which climate.

As can be seen in FIGURE 5, the use of soil covers for the prevention of AMD has certain limitations and considerations.

THE USE OF DRY COVERS FOR THE PREVENTION OF ACID MINE DRAINAGE IS OUTLINED BELOW:

Considerations:

- Reactivity of waste
- Climate – freezing, thawing, wetting and drying
- Topography
- Erosion and surface water flow
- Final land use
- Hydrogeological setting
- Construction quality and maintenance
- The availability of cover materials

Limitations:

- When subjected to climatic conditions, the permeability of the barriers can increase with time
- Soil covers do not stop infiltration in all instances and may not stop acid mine drainage
- Oxygen barriers are particularly sensitive to holes caused by animal activity, etc.
- Soil covers have long-term maintenance and monitoring requirements and are prone to erosion
- Soil covers may be sensitive to vehicle, human and animal activity

2.8 AIR QUALITY

The operations phase of the mining life cycle presents the most significant air quality and emissions issues, and during this phase, an ongoing management plan is highly beneficial. As a minimum, an air quality management plan is essential for dealing with issues that can potentially have an adverse impact on operations. In addition to dust, an air quality plan needs to incorporate the management of emissions (release of pollutants and particulates) and fumes as well. It is important to ensure that the management plan can be applied daily by the environmental manager, senior management and site operators. Operations that generate excessive noise and vibration need to incorporate these impacts in their management plans too.

Dust generation at Namibian mines is quite common, due to aridity. Therefore, all mines have to manage dust as the minimum requirement of an air quality management plan. The activities with the most potential for dust generation at a mine site are drilling, blasting, loading, hauling and excavation, and screening, crushing and processing. Given the arid to semi-arid conditions in most of Namibia, dust emanating from tailings facilities is a common problem.

MANAGING DUST DURING DRILLING

Blast hole drilling during operations has the potential to generate a significant amount of dust, particularly during dry conditions. Leading practice involves using measures to minimise dust generation as much as practically possible. These measures include:

- All drills must be fitted with dust extraction systems or water injection to control dust during the drilling of the hole
- Cleaning filtration devices and replacing filters on a regular basis to prevent dust build-up
- If dust is discharged through ducting, position the ducting in a way that avoids dust from blowing back on operators or other people working in the vicinity
- Control dust during the crushing of samples

MANAGING DUST DURING BLASTING

Dust stemming from blasting events can be managed when blasting events are planned in close consideration of climatic factors such as wind speed and direction.

MANAGING DUST DURING LOADING, HAULING AND EXCAVATION

Excessive levels of dust are generated during the loading and hauling or the excavation of ore and waste. Measures to control dust generation include the following:

- Spraying water on haul roads and blasted stockpiles
- Installation of water sprayers at dump pockets
- Using dust controlling agents other than water or using less water, such as Micromass Xtreme, Soil Sement and / or EK 35

MANAGING DUST DURING SCREENING, CRUSHING AND PROCESSING

Dust needs to be adequately managed at each mill, grinder or crusher. This involves fitting dust control appliances at the primary crusher feed hopper—the same needs to be done for the secondary and tertiary crushers. Dust build up and spillage needs to be monitored and removed when necessary. Dust management can be assisted by having dust extraction on transfer points:

- Dust extraction at crushers, conveyor tipping points and screens
- Fine ore stockpiles should be enclosed, otherwise they can be a major dust source
- Conveyors between stockpiles and crushers that are exposed to wind, should be at least partially enclosed, to reduce dust emission

MANAGING DUST FROM TAILINGS STORAGE FACILITIES

Wind-blown dust from dry materials deposited at tailings storage facilities is a typical challenge at many of the mines in Namibia. Situations differ from mine to mine (e.g. in terms of prevailing wind direction, surrounding topography, type of material, deposition method, etc.), and at many of the mines air quality monitoring focuses specifically on this issue. Several site-specific studies have been done on the different management approaches such as wind rows, covers of mineral waste, dust suppression methods, irrigated vegetation, etc. The Geological Survey has also done studies on this particular issue at Oamites and Rosh Pinah.

RÖSSING URANIUM LIMITED

is operated by China National Nuclear Corporation (CNNC) also the majority shareholder. The mine has a production capacity of 4500 tonnes of uranium oxide per year with latest annual production of 2479 tonnes in 2018. The current life of mine ends in 2025. In 2018, Rössing mined 19.8 million tonnes of rock (21 per cent less than in 2017) of which 8.0 million tonnes were uranium-bearing rock (17.8 per cent less than in 2017) and 11.5 million tonnes were waste rock. This presents a waste-to-ore strip ratio of 1.48 which is significantly lower than 2017 at 1.57.

LOCATION:

The mine is located 12 km from the town of Arandis, which lies 70 km inland from the coastal town of Swakopmund in Namibia's Erongo Region. Walvis Bay, Namibia's only deep-water harbour is located 30 km south of Swakopmund. The mining operation is located in a hyper-arid environment. Insolation at Rössing Uranium is high, and as a result, daytime temperatures ranges are wide, especially during May and September, when the difference between minimum and maximum temperatures exceeds 20°C daily. The lowest temperature is normally recorded during August, but frost is rare. The highest temperature is normally recorded in the last summer, particularly in March. The mine site encompasses a mining licence and accessory works areas of about 180 km2, of which 25 km2 is used for mining, waste disposal and processing.

BRIEF DESCRIPTION:

Rössing is one of the longest-operating uranium mines in the world. The uranium-bearing ore is mined through drilling, blasting, loading and hauling from the Open pit (which current dimensions of approximately 3 km by 1.5 km, and 390 m depth).

The ore is delivered to the Primary crushers and then passes through a further series of crushers (secondary, tertiary and quaternary crushers), reduction process ends with further grinding in rod mills before extraction of the uranium can be done to produce (recover) our product, uranium oxide.

CASE STUDY
AIR QUALITY MONITORING

Once milled (grinded) to the desired size of D80 of 1 mm (80% pass through 1 mm) extraction commences through leaching with Sulphuric Acid and various Oxidants. The intricate process further involves material passing through the cyclones, rotoscoops and thickeners before a "pregnant solution" is extracted (the barren solution is transferred to the tailing storage facility (TSF). The recovery process starts off with solvent extraction using Ammonium Hydroxide and precipitated with Ammonia gas. The precipitated is filtered and subjected to calcination before the final product "uranium oxide" is drummed.

The 42 years mine operation is characterised by significant footprint of about 2500 hectares, which is mostly occupied by tailings storage facility (650 ha), waste rock dumps (747 ha) and open pit (457 ha), the remaining hectares is occupied by other infrastructures such roads, reservoirs and plant area amongst others. The TSF is surrounded by dewatering wells systems and telemetry seepage control systems.

KEY ISSUE(S) ADDRESSED:

Rössing Uranium Ltd (RUL) has a very good understanding of the air quality through the air inventory assessment studies and supported by long term monitoring, the impacts are well managed. There is continous research on understanding the air quality related aspects and their management. The site has good long term baseline data that is being used by the regional air quality studies and is statistically very reliable. The cooperation with surrounding mines has been useful in understanding and sharing experiences on air quality monitoring equipments to ensure comparability and learning in the space of air quality. The comparison of equipment and introduction of same equipments procurement has benefited the companies in the uranium mining sector through Namibia Uranium Association (NUA). Cost sharing on equipment maintenance, calibrations and most importantly data comparison and contribution to the regional studies in the Erongo region through the SEMP coordinated by the Geological Survey of Namibia at Ministry of Mine and Energy has brought and kept the industry players together.

DESCRIPTION OF THE CASE STUDY:

Rössing Uranium mine is operated by CNNC also the majority shareholder. The mine is having a production capacity of 4500 tonnes of uranium oxide per year with latest annual production of 2110 tonnes in 2017. The current life of mine ends in 2025. In 2017, we mined 25.2 million tonnes of rock (3 per cent more than 2016) of which 9.6 million tonnes were uranium-bearing ore (20 per cent more than 2016) and 15.6 million tonnes were waste rock. This presents a waste-to-ore strip ratio of 1.63 which is significantly lower than 2016 at 2.07.

AIR-QUALITY MONITORING

Rössing Uranium Ltd (RUL) employs a comprehensive air quality monitoring network comprised of:

- Ambient air quality monitoring system with which two types of dust are measured: firstly, a very fine inhalable dust invisible to the naked eye that is comprised of particulate matter less than 10 micron (known as PM10), measure continuously every 10 minutes using PM10 Monitoring stations and secondly, fallout dust, which is visible on the ground and comprised of lager particles, including PM10 and measured using dust fallout buckets placed at various locations on the mining lease areas.
- Periodical stacks monitoring which measures the air emissions emanating from point sources which are mainly stacks from the Final Product Recovery plant and bag houses. The emission surveys are conducted periodically by external consultants/experts but RUL is currently undertaking a project to install continous monitors on our major stacks in addition to the monitoring currently in place.
- Blast and ground vibration monitoring stations on site and at Arandis. Environmental Noise is monitored at six (6) stations that are scattered around the mine.
- Multi-verticals are used to collect and measure the amount of material eroded from the tailings storage facility and therefore measures the effectiveness of the dust control measures in place.
- Meteorological data is vital to air quality data interpretation and analysis. These are used in the determination of dilution and dispersion of atmospheric contaminants. Climatic data measurements are therefore maintained through four weather stations on site.

The air quality monitoring network at RUL provides data that is sufficiently reliable and long term data is available. The air quality monitoring provides useful information for planning and designs for any new capital projects that may impact air quality. The monitoring also helps to analyse the cumulative effects of combined activities through modelling and guides the operations to ensure minimal dust generation through the introduction of effective dust control measures such as; dust suppression and other controls.

At Rössing Uranium Ltd (RUL) dust is generated during blasting, loading and dumping of ore and waste, as well as during crushing and conveying ore. Therefore, the air quality pollution is a concern with respect to occupational exposure. Ambient air quality inventory assessment studies conducted by air quality specialists enables RUL to design the fit for purpose air quality monitoring network. The ambient environment includes the general public, visitors to RUL, the residents of Arandis as well as the fauna and flora surrounding the mine which may be affected by radiation, dust and gases emanating from the mine and its related activities.

In order to manage the air/dust emission from the mine, a dust monitoring program has been set up. The environmental dust monitoring and subsequent management started in 1980's and this was to introduce the internal dust control measures and monitor the effectiveness thereof.

Initially, the ambient dust level off the mine impoundment was measured with 3 high volume samplers at the three locations around the mine. Two of these were located down the prevailing wind directions from the tailings storage facility – at Arandis airport and at Namib Lodge (i.e. to the west and east respectively). The third sampler was located at Arandis, the site of the nearest residential population. This was then reduced to only one high volume sampler in the year 2000 with a focus on the occupational exposure.

With the life of mine extension project, an environmental impact assessment was done. A recommendation was made to expand the ambient dust monitoring and set up a comprehensive dust management program. Therefore, in 2012 a dust management program was put in place to optimise RUL's performance with regards to dust emissions, monitoring and control measures.

DUST EMISSIONS

Our mining activities, such as the blasting, drilling, loading and hauling of ore on unpaved roads are typically the major sources of dust emissions. An emission inventory listing of all sources of air pollutants within a defined region that provides information on the types of emission sources in the area, their location and the amount of air pollution emit has been compiled. It is an essential tool for planning as well for managing the air quality. For Rössing, the air quality hazard assessment was initially conducted during a series of workshops in March 1993. During the workshop the nature of the airborne emissions, the mechanisms which result in the release of the airborne contaminants and the control systems to limit this release were identified and understood. Air emission inventories for all sources of pollutants were identified and compiled. For a detailed report of the assessment see Report 151977/5/volume2: Risk Base Assessment to define Rössing Environmental Control Threshold (1997).

THE AGENTS THAT INFLUENCE AIR QUALITY WERE IDENTIFIED AS BEING:

- radiation - radon (Rn222) and airborne radio-nuclides
- dust (total and respirable) - silica (free crystalline silica), manganese, pyrite, ammonium, radionuclides (U238, U234, Th230, Ra226), heavy metals
- gases - sulphur dioxide, sulphuric acid mist, nitrous oxides, ammonia, carbon monoxide, carbon dioxide and odour

CERTIFICATION AND LEGISLATION

RUL is certified to ISO 14001:2015 and therefore audited regularly. The Rossing Environmental Performance Standard – E12 Air Quality Protection is required to set ambient air quality internal criteria in cases where there are no sufficient national standards. There is an Atmospheric Pollution Prevention Ordinance 11 of 1976 but not sufficient standards for ambient air quality in Namibia therefore, an internal air quality criteria has been developed voluntarily to guide the operations. The internal air quality criteria use limits and guidelines adopted from nearest countries such as the Air Quality Act of South Africa (NEM: AQA Act No. 39 of 2004) as well as the WHO guidelines. The focus of air quality management therefore is to monitor receptor-based impacts.

MONITORING TECHNIQUES

PM 10 is monitored using a Met-One E-Sampler.
A Met-One E-sampler Real Time PM10 Particulate monitor was first set-up at the Arandis Valve House in 2010 to monitor PM10 dust particulate. In 2011, a second PM10 monitor was erected on the southwest boundary of the mine to monitor dust pollution that is emitted from the mine. The third PM10 Particulate is erected at the Communications Management Centre (CMC) and the fourth at the Tailings Storage Facility to monitor dust on site. These monitors measure the PM10 dust on a continuous basis. The levels measured in the last years showed that PM10 dust concentrations at all stations were below the adopted World Health Organisation standard of 0.075 mg/m3.

DUST DEPOSITION BUCKETS (DUST FALLOUT):

Dust deposition buckets are erected at six different positions around the mine site. This system uses the international standard of collecting and analysing for dust "ASTM 1982 Standard Method for Collection and Analysis for Dust Fall" (Settle-able Particulates"). The method collects dust deposition of a size above 5µm. The samples are collected monthly and the dust deposition rates are expressed in units of mg/m²/day. Values measured during the past years at the six stations were well below the adopted South African dust-control regulation.

MULTI-VERTICAL SAMPLERS:

A multi-vertical sampler consists of a 4.5m angle-iron mast holding a 24-bottle sample stack. The bottles have an open slot of a known area, which traps the airborne dust. The weight of this trapped dust is then used to compute the dust losses and to calculate the different heights at which various particle sizes are being transported. The multi-vertical samplers are located at the perimeter of the tailings storage facility, to provide an indication of the quantity eroded and the down-wind erosion areas, as well as the volumes of material leaving the facility during the Bergwinds events, usually from April to September.

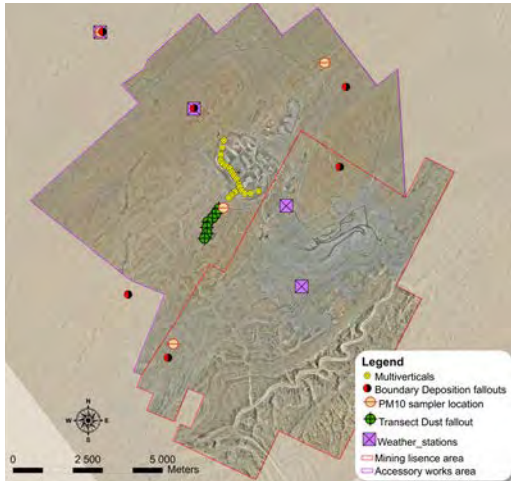
WEATHER STATIONS

Meteorological data is collected in order to characterise the ambient environment, as well as for the determination of dilution and dispersion of atmospheric contaminants. There are currently four weather stations in operation, located at Point Bill, Open pit and at the tailings storage facility on site and at the Valve House in Arandis.

DUST CONTROL MEASURES

Dust at Rössing is managed in various ways. Water is used to suppress dust on gravel roads. In addition, calcium lignosulphonate, a chemical binder, is sprayed onto some road surfaces. The impacts of blast dust are reduced by considering wind direction, prior to blast events, in order to limit dispersal and deposition. In addition, the blast areas are soaked with water before blasting. Dust control at the crushers is achieved through preventative maintenance and frequent wash downs. In addition there are dust extraction systems in place. At the tailings storage facility, windrows were created to break prevalent air flow over the paddies.

In conclusion, RUL is aware that sustainable growth which is required as an effective response to climate change and other environmental aspects. As a significant uranium producer and consumer of energy, we are committed to reduce greenhouse gas (GHG) emissions and all impacts. The study addressed the background of mining and ownership as well as detailed emphasis effectiveness of air quality monitoring and techniques. Multiple layers of monitoring and control are required to effectively manage the impacts related to air quality control and management.



[FIGURE] Air quality monitoring network at Rössing Uranium mine

TABLE 2 | General standards for waste/effluent water discharge

DETERMINANTS	MAXIMUM ALLOWABLE LEVELS
Arsenic	0,5 mg/l as As
Biological Oxygen Demand (BOD)	no value given
Boron	1,0 mg/l as B
Chemical Oxygen Demand (COD)	75 mg/l as O
Chlorine, residual	0,1 mg/l as Cl_2
Chromium, hexavalent	50 µg/l as Cr(VI)
Chromium, total	500 µg/l as Cr
Copper	1,0 mg/l as Cu
Cyanide	500 µg/l as CN
Oxygen, dissolved (DO)	at least 75% saturation
Detergents, Surfactants, Tensides	0,5 mg/l as MBAS
Fats, Oil & Grease (FOG)	2,5 mg/l (gravimetric method)
Fluoride	1,0 mg/l as F
Free & Saline Ammonia	10 mg/l as N
Lead	1,0 mg/l as Pb
Oxygen, Absorbed (OA)	10 mg/l as O
pH	5.5 – 9,5
Phenolic Compounds	100 µg/l as phenol
Phosphate	1.0 mg/l as P
Radioactivity	below ambient water quality of the recipient water body
Sodium	not more than 90 mg/l Na more than influent
Sulphide	1.0 mg/l as S
Temperature	35°C
Total Dissolved Solids (TDS)	not more than 500 mg/l more than influent
Total Suspended Solids (TSS)	25 mg/l
Typical faecal Coli.	no typical coli should be counted per 100 ml
Uranium	15-500 mg/l as U
Zinc	5.0 mg/l as Zn

2.9 WATER MANAGEMENT

It is required that all mine water in Namibia is adequately monitored and analysed, to ensure compliance with regulatory standards, according to the obligatory industrial and domestic effluent discharge exemption permit under sections 21(5) and 22(2) and 110 of the Water Act (Act 54 of 1956) and Parts 11 – 13 of the Water Resources Management Act, No. 11 of 2013. TABLE 2 indicates the general standards for Article 21 Permits (effluents).

DETERMINANTS	UNIT	FORMAT	95 PERCENTILE REQUIREMENTS	
PHYSICAL REQUIREMENTS				
Temperature	°C		Not more than 100C higher than the recipient water body	
Turbidity	NTU		< 5	< 12
pH			6.5-9.5	6.5-9.5
Colour	mg/litre Pt		< 10	< 15
Smell			No offensive smell	
Electric conductivity 25 °C	mS/m		< 75 mS/m above the intake potable water quality	
Total Dissolved Solids	mg/litre		< 500 mg/litre above the intake potable water quality	
Total Suspended Solids	mg/litre		< 25	< 100
Dissolved oxygen	% saturation		>75	>75
Radioactivity	units		below ambient water quality of the recipient water body	
ORGANIC REQUIREMENTS				
Biological Oxygen Demand	mg/litre	BOD	< 10	< 30
Chemical Oxygen Demand	mg/litre	COD	< 45	< 100
Detergents (soap)	mg/litre		< 0.2	< 3
Fat, oil & grease, individual	mg/litre	FOG	nil	< 2.5
Phenolic compounds	µg/litre	as phenol	< 0.01	< 0.10
Aldehyde	µg/litre		< 50	< 100
Absorbable Organic Halogen	µg/litre	AOX	< 50	< 100

Groundwater is usually monitored from borehole samples, also beyond the mining licence area for comparing water quality encountered on site to the ambient water quality in the wider environment, and identifying potential impacts on downstream users. The monitoring schedule includes sites monitored for natural water quality and any seepage from tailings impoundments, process solutions, leachates from landfill sites and waste rock dumps, as well as effluent samples from sewage plants or septic tanks.

Permit conditions usually require that monitoring and analysis of water quality parameters (physical, microbiological and inorganic) should be conducted at least every six months. A potable water control system should also be in place to ensure that the quality of water meets the drinking water standard in terms of the Water Act, No. 54 of 1956.

WATER CONTROL TECHNIQUES

The release of waste water into the environment can lead to detrimental environmental impacts on water users downstream.

Different combinations of strategies can be applied, and the selection of strategies is site-specific. Variables to be considered are the layout of the mine infrastructure, topography, climate, and hydrological characteristics. Interception and diversion of surface water is a

TO PREVENT THIS RELEASE, VARIOUS CONTROL TECHNIQUES CAN BE USED TO AID IN REDUCING THE POTENTIAL OF WATER CONTAMINATION AND REDUCE THE AMOUNT OF WATER REQUIRING TREATMENT. THE TECHNIQUES INCLUDE:

- Diverting and intercepting surface water—this can be achieved by building upstream dams to capture water and to reduce contamination potential from tailings, exposed ore or waste rock
- Capturing drainage water from precipitation at the mine site—this can be done using pipes and liners and directing water to a suitable storage facility, e.g. tailings or seepage dams to prevent potentially contaminated water from entering the groundwater or flowing off-site
- Recycling water used for processing ore, to reduce the volume of water requiring treatment
- Allowing water to evaporate in ponds, to reduce the volume of contaminated water to be discharged. Obviously, this option is less favourable in a dry country like Namibia
- Installing liners and covers on waste rock and ore piles, to reduce the potential for contact with precipitation and contamination of ground water
- Capturing seepage water from mineral waste sites in trenches or boreholes for re-use in the processing plant

more prominent concern in environments with high rates of precipitation, whereas more emphasis is placed on water recycling in arid regions with very little water availability. Re-use of water, ideally to achieve zero discharge, is the best solution for Namibia. optimising the water balance can result in major cost savings and environmental benefits, as shown in the following case study by Skorpion Zinc.

WATER TREATMENT

Water treatment technologies can be classified mainly as passive or active treatment. Active treatment requires the input of chemicals and energy. Passive technologies use natural processes such as plant systems, gravity and micro-organisms (Fraser institute , 2012). The level of pollution determines the treatment technology that will be used, and the technology used is also dependent on the water quality requirements.

Active water treatment

Active water treatment is the most popular and effective water treatment at mines. It involves using energy, chemicals, infrastructure and labour to produce clean water, whilst leaving the smallest possible environmental footprint in the shortest time. The chemistry of the effluents at a mine can be predicted using software prior to construction, at which point the best fit water treatment technology is determined. The addition of lime, caustic soda or limestone is often required to raise the pH of acidic mine water. Active treatment of mine water is typically associated with high disposal and maintenance costs, and mines are continuously trying to figure out ways to recycle sludge (Fraser institute , 2012).

Passive water treatment

Passive water treatment takes advantage of geochemical and natural biological processes to remove contaminants without additional chemical and physical inputs. Passive water treatment is usually combined with water monitoring programs. These processes include:

- Bacteria-controlled metal precipitation
- Filtration through sediments and soils
- Reactive barriers, also referred to as a permeable reactive treatment zones
- Uptake of contaminants by plants

Due to the relatively lower operational and maintenance costs associated with the passive treatment of mine water, its use is becoming increasingly popular in the mining industry. However, the biggest challenge with this treatment method is treating highly acidic mine water. This treatment method is especially popular after mine closure. The most common passive water treatment system is constructed wetlands, which act as purification systems that remove contaminants before they are transported to fresh water environments or into a water re-use system. Passive water treatment systems require constant maintenance to remain effective.

SKORPION ZINC

Skorpion Zinc is part of Vedanta Zinc International (VZI), a grouping of zinc assets located in Namibia, South Africa, and Ireland. VZI is owned by India-based Vedanta Limited, a listed subsidiary of Vedanta Resources plc.

LOCATION:

Skorpion Zinc Mine and Refinery is situated about 25 km north of Rosh Pinah town in Southern Namibia. The mine and refinery site lies just inside the Sperrgebiet National Park.

BRIEF DESCRIPTION:

The Skorpion circuit was commissioned in early 2003 and was the first mine-to-metal operation to commercially apply a purely hydrometallurgical process route, to exploit a zinc oxide ore-body. The Skorpion Zinc process comprises of atmospheric leaching, solvent extraction, electro-winning and final casting of the metal into sizable ingots. The existing Skorpion circuit has a production capacity of 150ktpa of Zn from an open pit oxide mine.

KEY ISSUE(S) ADDRESSED:

Skorpion Zinc is committed to minimising water use and recycling water, with the ultimate goal of a **Zero Discharge Philosophy**. Skorpion Zinc refinery has a closed loop system, with all water recycled back into the system. This case study discusses how Skorpion Zinc managed to reduce overall water consumption and the challenges faced. Also discussed are the challenges regarding domestic effluent and the method employed to deal with these challenges. Skorpion Zinc is ISO 14001:2015 certified and compiles to the International Finance Corporation (IFC) Standards.

DESCRIPTION OF THE CASE STUDY:

The metal production for the financial year (2017/18) was 84,215t against a target of 91,443t, indicating a respectable 92.1% achievement. The metal production deficit being mainly due to the ore shortage and lower mining grade. A 92% achievement is the best recorded in the last four years. This is against a back-drop of reduced grade from the pit, ore availability challenges and complexities in the refinery.

Skorpion Zinc Refinery has a water-use design capacity 7,957 m^3/day and is currently using between 6,000 – 7,000 m^3/day. Skorpion Zinc is supplied with water by NamWater, which pumps water from the Orange River 43.7 km south of the refinery at an elevation of approximately 600m.

In line with Skorpion Zinc's Water Management Policy and the drive to conduct business responsibly, Skorpion Zinc assessed the challenges it has faced with solution balance in the refinery. A careful review of the Solution Balance was undertaken, and corrective actions implemented to reduce the water consumption to levels below design capacity. Further water conservation projects were identified through reduction, recycling and monitoring of progress against water consumption reduction targets.

SKORPION ZINC WATER MANAGEMENT PROCESS:

The Skorpion Zinc Water Management Process can be divided into two (2) categories. The one category concerns Process Water Management and the other Domestic Water Management. The two will be dealt with separately below.

PROCESS WATER MANAGEMENT:

As alluded to above, Skorpion Zinc refinery has a closed loop system (Zero Discharge Philosophy), with all water recycled back into the system. Skorpion Zinc Refinery has a water use design capacity of 7,957 m^3 per day as illustrated in the table below. Over the years, the aim has been to reduce water consumption well below the design capacity. This target was realised through the identification and implementation of various projects, as discussed below.

SKORPION ZINC WATER CONSUMPTION

	Water-Use Design Capacity (m^3)
Total Water to Refinery	7957
Thick Floc	306
Filter Floc	162
Acid Plant	1882
Residue belt filters lubrication	432
Cooling Towers	749
Zn Dust	48
Reverse Osmosis Plant	2688
Gland Seal Water	613
Zn Dust and Others	1075

The Reverse Osmosis (RO) plant is the highest consumer of raw water, with an average consumption of 2,688 cubes making up approximately 35% of the raw water to the refinery. Demineralised water from the RO plant is used in Solvent Extraction and Electro-winning. The RO plant is followed by the Acid Plant Cooling Towers which uses an average of 1,884 cubes per day, constituting approximately 27% of total daily water consumption. Gland Seal Water—water used for residue belt filter lubrication—and Floc make-up goes to one holding tank that constitutes about 17% of total water consumption of the refinery. Most reduction efforts were centered on these three process units, as they amount to almost 80% of the water consumption.

Reverse Osmosis Plant and Acid Plant

An opportunity to re-use the treated water from the Effluent Treatment Plant (ETP) circuit was exploited. In the ETP, pH is increased to 9.5 with the addition of lime, to precipitate all metals. The treated water is of lower quality than raw water. A decision was made to install a containerised Reverse Osmosis (RO) plant to treat this solution. As the quality of this treated solution is slightly better than that of raw water, this solution is best utilised at the main RO plant, this reduced raw water consumption by more than 300m³/day.

Cooling Tower Blow-downs and Reverse Osmosis Plant Brine

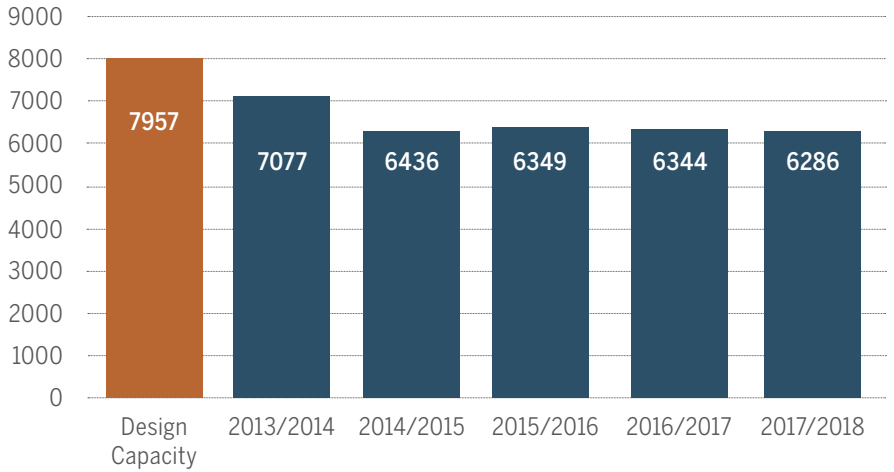
The cooling tower blow downs and RO plant brine was found to be of relatively good quality. This water source was found suitable for flocculent make-up, RBF lubrication water and dust suppression. However, the brine was found marginal for gland seal water because of the high amount of chlorides that could increase corrosion rates of the cast iron pumps in the refinery. To reduce the impact of the high chlorides, the recycle water is blended on a 50/50% ratio with raw water before it is fed to the flocculent make-up plant, gland seal distribution tank and the Belt Filter Lubrication, which otherwise would have been fed using raw water. A recycle water tank was constructed to accommodate surges and to blend the water to the various users above. This change resulted in a saving of more than 400 m³/day of raw water.

Other initiatives in place that resulted in a further reduction in water consumption are:

- cooling tower chemical dosing optimisation (anti-scalant and biocides)
- optimisation of unit operations to reduce raw water usage
- decreasing raw water usage while process units are not running, especially during maintenance shuts

The above initiatives brought about a significant reduction in water consumption as indicated in the figure below. The refinery is currently operating well below water-use design capacity.

DAILY AVERAGE WATER CONSUMPTION (M³)



DAILY WATER CONSUMPTION AT SKORPION ZINC

DOMESTIC WATER MANAGEMENT:

Domestic water is treated via a Sewage Trickling Filter Plant in compliance with Namibian legislation as well as IFC requirements. The effluent is treated up to a standard fit for animal consumption. In an attempt to divert birds away from the process solution in our holding tanks, an artificial wetland referred to as the Bird Pond (as illustrated in the figures below) was constructed. The treated sewage water is recycled by feeding it into the bird pond in lieu of raw/fresh water. The quality of the water is monitored on a monthly basis through laboratory analysis. The bird pond resembles a natural habitat and as a result the birds are naturally attracted to it, thereby diverting them way from the holding tanks.

CONCLUSION:

Skorpion Zinc operates on a **Zero Discharge Philosophy**. All its process and domestic effluent/water is either recycled or re-used. Skorpion Zinc aims to operate below its refinery water-use design capacity—a target that has been achieved for the past 5 years by implementing water reduction initiatives. Domestic effluent is treated and is recycled into an artificial wetland (Bird Pond), aimed at diverting birds away from its processes. Although Skorpion has attained significant success with regards to water management, the mine continues to explore other avenues for further water reduction.

Scorpion Zinc Mine
Rosh Pinah
Karas
Namibia
2019 © paulgodard.com

Scorpion Zinc Mine
Rosh Pinah
Karas
Namibia
2019 © paulgodard.com

PART THREE

MINERAL WASTE MANAGEMENT

INTRODUCTION

Mineral waste includes waste rock, overburden, tailings and ore remains from mineral processing (e.g. ripios and spent heap leach materials). This waste further includes: rock masses disturbed by block caving, rejects from ore beneficiation or concentration, mineral residues, refinery discards and sludge, smelter and other furnace slags and ashes, water treatment sludge, dredging materials, and soils contaminated by mineral waste.

Although the volumes of mineral waste from open pit mines, as a rule, are more than the volumes originating from underground mines, all mines are faced with the management of mineral waste—in particular because of the significant footprint size of tailings storage facilities and waste rock dumps.

During the operations phase of the mining life cycle, overburden and waste rock are stripped and dumped in allocated areas, followed by the first disposal of tailings from the processing plant, shortly thereafter. The deposition is done in accordance with the initial LoM Plan and the EMP. Moreover, it means that mineral waste management measures need to be in place when the operational phase commences and must be regularly reviewed for continuous improvement thereafter. The type and quantities of mineral waste items will differ from mine to mine. As a rule of thumb, waste rock and tailings are generated in the biggest quantities and their repositories are responsible for the biggest part of a mine's footprint size.

3.1 CHALLENGES

Each mine manages the disposal of waste rock and tailings as two waste streams, guided by the LoM Plan, the EMP and, in many cases, an internal mineral waste management plan. Management of the waste streams are further guided by an EMS with a particular focus on the management of geotechnical (potential failure, stability, slope steepness, erodibility, etc.) and geochemical risks (radioactivity, in the case of uranium mines, AMD and the seepage of residuals such as nitrates, etc.). For the efficient implementation of a mineral waste management plan, and best practice, the assignment of clear accountabilities and responsibilities is essential.

Stability of mineral waste repositories is a priority, and the risk of failure needs to be eliminated. Compliance to all relevant safety standards is non-negotiable. A conceptual geotechnical understanding must be developed for potential modes of failure for mineral waste repositories. All geotechnical factors governing their stability, factors pertaining specifically to the mine site, and directives for the planning, design, construction and operation of the repositories (also the legal and regulatory requirements), have to be part of such a study and the recommendations have to be honoured. In some cases, it could be advantageous to segregate mineral waste types before deposition, so that material with the same geochemical and geotechnical features can be placed together. Full geotechnical reviews have to be done regularly.

AN EFFICIENT SYSTEM FOR MANAGING MINERAL WASTE NECESSITATES:

- Characterisation of mineral waste (in terms of the environmental conditions of the mine site, e.g. climate, and site-specific surroundings of the waste repositories) need to be understood
- Physical characteristics (mineralogy) of the mineral waste, as well as the materials that will be exposed, covered or disturbed by mineral waste, need to be identified and understood
- Chemical composition and characteristics of the mineral waste, as well as the materials that will be exposed, covered or disturbed by mineral waste, need to be identified and understood
- All possible hazards of the mineral waste, as well as the materials that will be exposed, covered or disturbed by mineral waste, need to be identified and understood through regular reviews of a maintained risk register
- Reliable estimates of potential water and air quality impacts, direct exposure hazards, erosion potential and geotechnical hazards need to be made
- The AMD potential of mineral waste repositories needs to be identified and understood
- Emergency plans and contingency measures for response to unplanned conditions or unexpected impacts have to be in place
- A detailed mineral waste inventory is necessary. The inventory may contain information such as a description of geochemical and geotechnical characteristics, mass, volume, surface area and storage location; details about the material production and placement, techniques used and dates of disposal; maps and/or photographs showing the location of disposal, repository boundaries, drainage features, permanent test plots and sampling locations, and boreholes.

The mineral waste inventory needs to be accurately maintained and synchronized with a Geographic Information System for the mine site, to enable appropriate calculations, modelling and planning, as well as easy reporting on land use disturbance and footprint size.

3.2 TAILINGS MANAGEMENT

Tailings storage facilities can pose several environmental challenges. Among these are surface seepage from the impoundment, resulting in an extensive seepage control program and monitoring system in the case of unlined storage facilities; windblown accumulation of precipitates, resulting in an extensive monitoring system and interventions to suppress dust formation; and radioactive release pathways (in the case of tailings of operations dealing with radioactive materials) which implies a cover layer at completion. Tailings material, furthermore, is susceptible to wind and water erosion and could be dispersed into the surroundings.

KEY PRINCIPLES

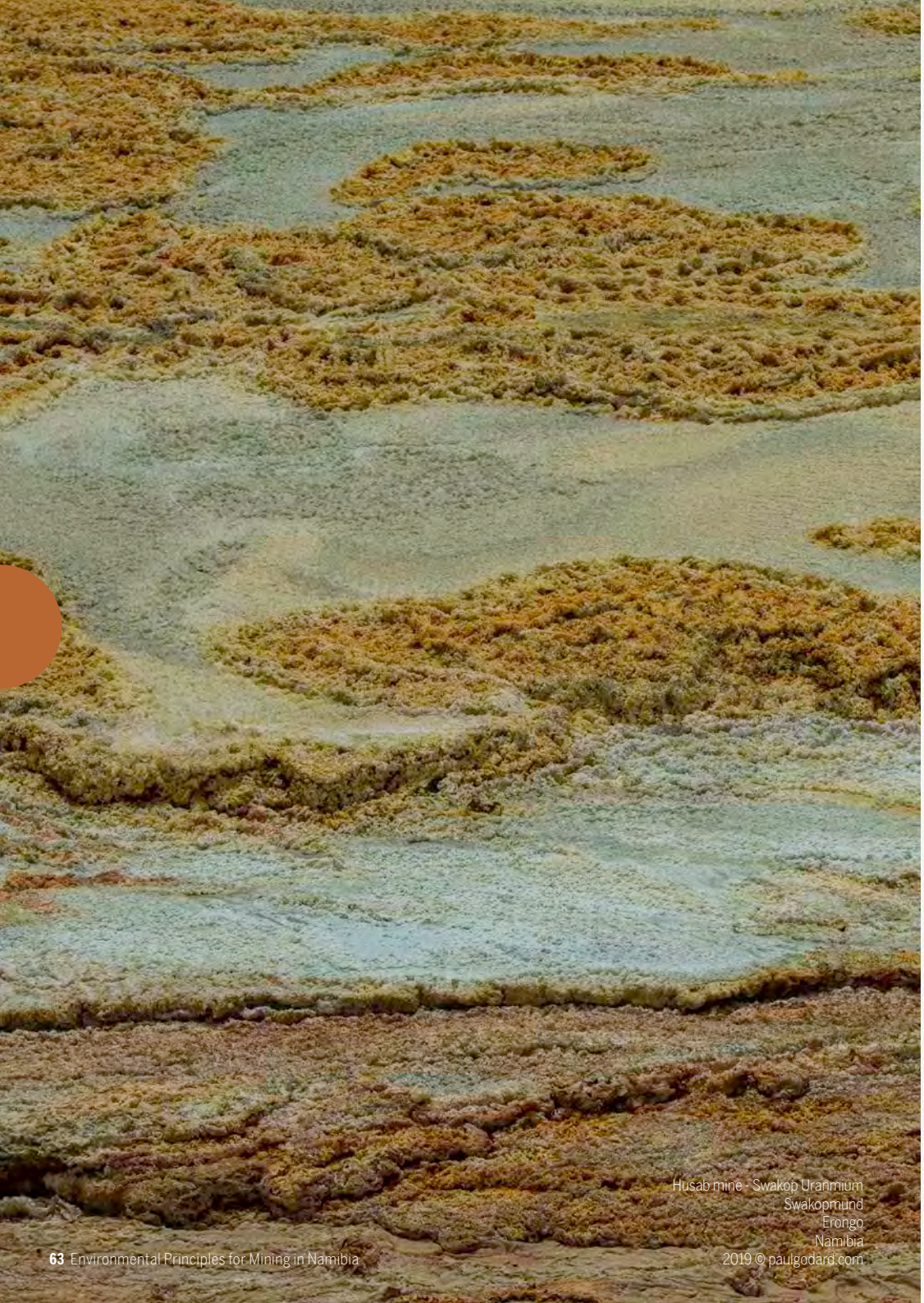
A primary driver to the design and location of mineral waste facilities at any mine site, is the placement of tailings storage facilities. Failure to adequately manage tailings can tarnish the reputation of a company, even resulting in the loss of a social licence to operate, and can lead to increased costs during mine closure and clean-up, and also result in disasters from tailings dam failures.

All tailings structures need to be operationally stable, able to be rehabilitated, and retain long-term integrity. To ensure this, a risk-based approach should be used to manage tailings. A risk-based approach should also be used to consider all relevant economic, environmental and social aspects during all stages of tailings management, in order to minimise short- and long-term impacts.

A tailings storage facility at an operational mine should be managed on the basis of a management plan (operation manual) and mineral waste management plan, which have been approved and evaluated by a competent authority.

A tailings storage facility at an operational mine should be managed on the basis of a management plan (operation manual) and mineral waste management plan, which have been approved and evaluated by a competent authority. Tailings management is also closely associated with a water management plan and the LoM Plan. The following should be contained in the operation manual:

- A description of the monitoring programs, accompanied by operational procedures and reporting arrangements
- A description of the tailings delivery system around and to the facility
- Standard procedure for reporting non-compliance and failures
- Parameters to assess the suitability and effectiveness of the operational manual
- An in-house emergency plan
- Actions to be applied in the event of non-compliance



Husab mine - Swakop Uranmium
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

POSSIBLE RECYCLING AND REUSE OPTIONS FOR TAILINGS ARE LISTED BELOW:

- Clay rich tailings can be used for the manufacturing of bricks, as is done in Uis.
- Cu-rich tailings as extenders for paints
- Tailings rich in Fe can be mixed with fly ash and sewage sludge as lightweight ceramics
- Mn-rich tailings can be used in agro-forestry, cast resin products, building and construction materials and glass ceramics
- Sand rich tailings can be combined with cement and used as backfill in underground mines
- Phosphate rich tailings can be used for the extraction of phosphoric acid

Continuous research into strategic issues and improvements in the management of tailings, is essential. This includes geotechnical risk assessments, dam failure studies, closure requirements and groundwater studies (including seepage modelling and the management of potential pollution plumes). Knowledge-sharing and benchmarking against leading practices are important directives.

A key principle is to have mechanisms in place to reduce the production of tailings and maximise its potential re-use. Reducing tailings production is cost-effective, aside from leaving a smaller footprint size behind. Although tailings are a waste product of a mine, and are deposited in a repository, which becomes a permanent landform of a mine site, not all types of tailings are non-recyclable. However, some tailings have the potential to be re-processed to recover other value minerals. In Namibia, the Klein Aub tailings dam contains considerable amounts of Platinum group metals, and the tailings of the Oamites Mine have been investigated for their uranium content.

To minimise environmental impacts, tailings storage facilities can be encapsulated and/or lined. Furthermore, filter drainage systems and a leakage collection system with seepage cut-off trenches around the toe of an impoundment, can capture seepage. In addition, monitoring boreholes are used for the early detection of possible seepage.

Remediation of tailings impoundments is a complex process, often constituting the largest single component of overall decommissioning costs at a mine. For decommissioning, retaining structures at a tailings storage facility need to isolate waste for a reasonably long period of time, and the structures have to restrict the release rate of pollutants from the containment to the surroundings, meaning that long-term monitoring and maintenance is minimised. Stakeholder engagement is also important for successful planning, management and closure of tailings storage facilities.

TYPES OF TAILINGS STORAGE FACILITIES

Three types of tailings storage facilities are typically used, namely upstream ring deposit facilities, centreline tailings dams, and downstream tailings dams. Tailings can also be backfilled into mined-out open pits (e.g. at Langer Heinrich Mine) or underground mining voids. Mines situated on plains usually build ring deposit facilities (e.g. at Husab Mine and Rosh Pinah Zinc).

Upstream ring deposit facilities

The upstream method requires the least fill material and is the most popular method for raised tailings dams. It also has the lowest initial construction cost. Slurry from the processing plant is conveyed or pumped to the facility, in many cases with run-off or waste water from the processing plant. This method, which was used during the 1970s and 1980s at Rössing Uranium Limited, implies high water consumption. To implement a more water-wise method, the processing circuit at Rössing has been changed to allow water stored on the tailings facility to be recovered, thereby offsetting freshwater intake. A paddock deposit system was also introduced to eliminate the tailings pond permanently, and to reduce the wetted perimeter. A conveyor belt system replaced the pipe system, which required even less water and resulted in even bigger water savings. Currently, the tailings storage facility at Rössing is still operated this way, making it the largest feature of the mine at about 750 ha in surface cover and about 100 m above the surroundings. It is one of the largest uranium tailings in the world and by far the largest located in an arid landscape.

Upstream ring deposit facilities are the most common method of failing, with the key failure mode of upstream embankments being a static/transient load-induced liquefaction.

The tailings storage facility at the Rosh Pinah Zinc Mine is also operated as a ring deposit facility, and is managed by a South African company, which provides an array of mining-related services in accordance with a code of practice. The company provides monthly inspections and an annual report. The tailings dam at Rosh Pinah is a ring deposit facility and created by means of wall construction (illustrated in FIGURE 6). As the tailing material contains no clay, very little moisture is retained, and it is free-draining. The facility is surrounded by several piezometers for monitoring water table levels, to see if there are any leaks into the surrounding area.

Centreline tailings dams

The centreline tailings dam is a combination of the upstream and downstream methods, to reduce the volume of construction material placed in the downstream shell of the embankment. The centreline tailings dam is the most effective of the tailings storage facilities.

Downstream tailings dams

The downstream design aims to reduce the risks associated with the upstream method, especially in the event of possible earthquakes. The drainage zones and impervious cores installed when using the downstream method, also enable the impoundment to hold a significant volume of water directly against the upstream face of the embankment.

Valley-fill dams

Another form of tailings impoundment is using natural depressions for tailings storage facilities, in which case the sides of the valley serve to contain the tailings. An advantage of valley-fill impoundments is that it provides relief from the wind erosion of tailings material (U.S. Environmental Protection Agency, 1994). Valley-fill impoundments have several design variations, with the cross-valley design being the most frequently used, as it requires the least fill material and is thus favoured for economic reasons. A disadvantage of this method is that the depth of the storage is limited, which can result in an increase of the reclamation, environmental mitigation and closure costs.

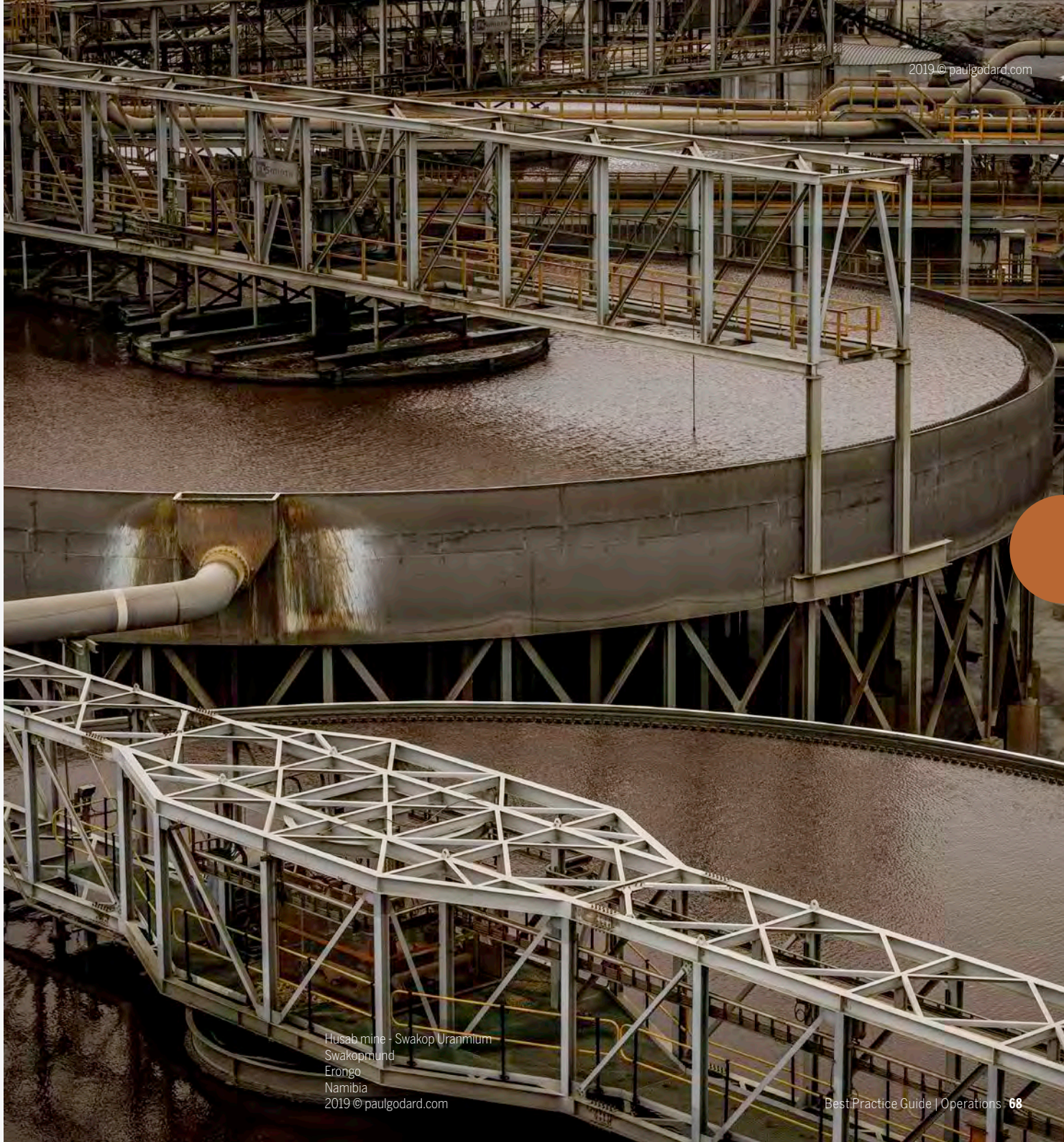
Backfilling

At Langer Heinrich Uranium, the tailings storage facilities are placed in the mined-out voids, inside the paleo valley where the ore body is located. Tailings are deposited as a series of in-pit tailings disposal facilities, all of them below the surface and as high-density facilities, partly with embankment construction. The open voids are first made safe and secure, to prevent contamination through seepage before disposal commences. A disadvantage of this approach is that the first tailings storage facility could not be placed inside a mined-out void and was constructed as a temporary facility. Another disadvantage is that the capacity of the open voids are limited, which means that multiple disposal facilities have to be created.

Using the suitable open voids as in-pit tailings disposal facilities, on the other hand, means major cost-savings as “substitute” backfilling of the open voids, while making the tailings disposal facilities safe and secure at the same time.

Tailings storage facilities at uranium mines are responsible for four radioactive release pathways: from radon, airborne radionuclides in dust, water-borne radionuclides and direct radiation. Furthermore is tailings material susceptible to wind and water erosion and can be dispersed into the surroundings over time. As a result of these risks, site-specific management measures are required, in addition to monitoring and research. Specific requirements include long terms geotechnical stability, controlled access and the minimizing of water and wind erosion, seepage, radiation and radon emanation. The key objectives are to ensure that these facilities retain and isolate radioactive waste for a long period of time; that the release of pollutants from the containments is restricted; and to minimize possible public exposure. This entails reducing the direct gamma radiation from the facilities to background levels, reducing the emanation from the facilities to the surroundings, and to prevent contamination of groundwater through erosion, seepage or run-off.

The importance of the management of radioactive tailings is illustrated by the case study submitted by Husab Mine, the youngest and biggest of Namibia’s uranium mines:



Husab mine - Swakop Uranium
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

HUSAB MINE

is owned and operated by Swakop Uranium, representing a partnership between the Republic of Namibia and the People's Republic of China. Taurus Minerals Ltd owns 90% of the shares and 10% are owned by a Namibian company—Epangelo Mining Company.

LOCATION:

Husab Mine is situated in the northernmost part of the Namib Naukluft National Park (NNNP), about 12 km southwest of the town of Arandis. It is in a sensitive and unique biodiversity environment, whereby main *Welwitschia mirabilis* fields are situated around the mine site. The mine is located upstream from both the Khan and Swakop Rivers.

BRIEF DESCRIPTION:

Drilling activities, as part of the exploration phase, commenced in 2005. The construction of some of the mining infrastructure commenced in October 2012 and mining started in March 2014. Overburden from the mine pit is deposited on waste rock dumps east of the open pits, with a drainage channel located to the east. Commissioning of the processing plant started in December 2016. Tonnage to be mined per annum depends on the business plan for that period. However, the processing plant name plate design production is estimated between 5,000 and 6,000 tons of uranium oxide per annum. It is worth noting that the mine operates its one acid plant. Additionally, the mine generates its own electricity with the steam from the acid plant via a water turbine. Currently, desalinated water is pumped via a 65-km-long pipeline, and travels through the NNNP and Dorob National Park (DNP) from the Swakopmund NamWater reservoir. Drainage systems were established to provide water to downstream receptors during rainfall/flood events.

KEY ISSUE(S) ADDRESSED:

It is important to know the contents of the tailings, to determine if pollution takes place or if clean-up measures are required for noted spillages. The tailings associated with the Husab Mine are acidic, and therefore need to be treated through neutralisation. Issues considered by Husab Mine regarding tailings, include:

General design options

- Old design (dry tailings)
- New design (wet tailings deposits)
- The tailings storage facility area is approximately 420 ha in size and located to the south of the processing plant operations

Information on the Lining System

- 1.0mm thick Linear Low-Density Polyethylene (LLDPE) geomembrane liner has been specified, with an ultra-violet-stabilised upper white surface that reflects sunlight
- Geomembrane liner is placed upon a 0.3 m thick protection layer of selected material derived from the tailings basin area
- Additional protection is ensured by the inclusion of a needle-punched geotextile immediately above the geomembrane
- Use of Geosynthetic Clay Liner (GCL) beneath the geomembrane provides further hydraulic containment
- To prevent wind damage, the exposed geomembrane in the base of the storage facility is held in place by 1 tonne aggregate bags, on a 20 m grid

Closure Commitments

- The tailings storage facility is designed to have a 2 m thick layer of waste rock and an outer cover of 0.5 m durable rip-rap (2.5 m thick cladding of graded rock and rip-rap)
- The design allows for no exposure of tailings surface material for a 1000-year period
- Swakop Uranium is committed to monitoring potential seepage/pollution for up to 200 years

Monitoring

Intensive water and air quality networks to determine potential pollution sources

Daily monitoring and reporting covers the following aspects (shift and daily)

- Seepage sump station levels and pump status
- Decant pumps flow rates and volume totaliser readings
- Decant pond levels
- De-position valves in operation and on standby in the different zones
- Leakages observed on slurry and other substance pipelines
- Ambient minimum and maximum temperature
- pH on seepage and decant return water
- De-positioning hours
- Decant pumps running hours
- Rainfall

Husab mine - Swakop Uranmium
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

Safety, Health, Environment and Quality (SHEQ) Management

To keep senior management, operations management, designers, and SHEQ personnel well informed about the status of the facility, reports are being distributed on a monthly or events-based basis. Design and operations management teams are updated, and quarterly reviews are scheduled, to inform and discuss the operational status, to provide statistics and to determine the way forward. In addition, the SHEQ management of the facility is fully integrated into the Husab Mine policies and programs. Safe operating procedures, and a site-specific baseline risk assessment with control measures, have been developed to minimise and control risks.

DESCRIPTION OF THE CASE STUDY:

History and current status

Since commissioning in December 2016:

- A total of 6,528,145 dry metric tons of final tailings against a budget of 8,153,810 tons has successfully been distributed to the storage facility
- 5,616,292 cube/m of decant water has been recovered for reuse in the main process
- Planned civil construction to raise the causeway to the decant facilities has been completed according to specifications and within financial budget
- After initial difficult challenges, the Husab tailings storage facility is currently in an excellent operational condition and ready to progress to the next phase, where its wall raising will be a key focus area

Performance reviews of the tailings storage facility of the Husab mine are carried out on a quarterly basis by design engineers who conduct site visits and monitor performance. Monitoring of the facility is conducted daily by the operational contractor and Swakop Uranium team, whereby daily pH readings and water samples are taken and analysed for chemical/metal content.

For long-term post-closure sustainability, Husab mine has adapted to requirements and standards for tailings storage facilities, as established by the US EPA, as called for by the Uranium Mill Tailings Radiation Control Act (UMTRCA), 1978 (USA), and as part of the design process. The mine also has an emergency response plan for managing large failures and, if required, a cut-off trench will be constructed to pump seepage water back into the storage facility.

CONCLUSIONS:

One underlining challenge experienced by Husab, is understanding the changes in risk profile from the design to the operational phase. The mine has experienced some shortcomings in managing this aspect effectively, which subsequently led to some issues. The facility is currently managed based on the 'no water, no problem' golden rule. Accordingly, Husab strives to achieve environmental sustainability by keeping abreast with ever-changing technologies, maintaining standard requirements, and regular monitoring and reviewing of its operational activities.

RÖSSING URANIUM LIMITED

is operated by China National Nuclear Corporation (CNNC) also the majority shareholder. The mine has a production capacity of 4500 tonnes of uranium oxide per year with latest annual production of 2479 tonnes in 2018. The current life of mine ends in 2025. In 2018, Rössing mined 19.8 million tonnes of rock (21 per cent less than in 2017) of which 8.0 million tonnes were uranium-bearing rock (17.8 per cent less than in 2017) and 11.5 million tonnes were waste rock. This presents a waste-to-ore strip ratio of 1.48 which is significantly lower than 2017 at 1.57.

LOCATION:

The mine is located 12 km from the town of Arandis, which lies 70 km inland from the coastal town of Swakopmund in Namibia's Erongo Region. Walvis Bay, Namibia's only deep-water harbour is located 30 km south of Swakopmund. The mining operation is located in a hyper-arid environment. Insolation at Rössing Uranium is high, and as a result, daytime temperatures ranges are wide, especially during May and September, when the difference between minimum and maximum temperatures exceeds 20°C daily. The lowest temperature is normally recorded during August, but frost is rare. The highest temperature is normally recorded in the last summer, particularly in March. The mine site encompasses a mining licence and accessory works areas of about 180 km2, of which 25 km2 is used for mining, waste disposal and processing.

BRIEF DESCRIPTION:

Rössing is one of the longest-operating uranium mines in the world. The uranium-bearing ore is mined through drilling, blasting, loading and hauling from the Open pit (which current dimensions of approximately 3 km by 1.5 km, and 390 m depth).

The ore is delivered to the Primary crushers and then passes through a further series of crushers (secondary, tertiary and quaternary crushers), reduction process ends with further grinding in rod mills before extraction of the uranium can be done to produce (recover) our product, uranium oxide.

Once milled (grinded) to the desired size of D80 of 1 mm (80% pass through 1 mm) extraction commences through leaching with Sulphuric Acid and various Oxidants. The intricate process further involves material passing through the cyclones, rotoscoops and thickeners before a "pregnant solution" is extracted (the barren solution is transferred to the tailing storage facility (TSF).

The recovery process starts off with solvent extraction using Ammonium Hydroxide and precipitated with Ammonia gas. The precipitated is filtered and subjected to calcination before the final product "uranium oxide" is drummed.

The 42 years mine operation is characterised by significant footprint of about 2500 hectares, which is mostly occupied by tailings storage facility (650 ha), waste rock dumps (747 ha) and open pit (457 ha), the remaining hectares is occupied by other infrastructures such roads, reservoirs and plant area amongst others. The TSF is surrounded by dewatering wells systems and telemetry seepage control systems.

KEY ISSUE(S) ADDRESSED:

Impacts and Aspects associated with safe storage (or disposal) of tailings is one of the most challenging issues for mining operations which generate gangue. At Rössing Uranium mine, the design criteria and operations of the Tailings Storage Facility (TSF) is based on

- safety and
- environmental impact

Rössing through its HSE policy is committed to excellence in health, safety, environment and communities' management, while maintaining and adhering to its commitment to the local regulations as documented in the Namibian Legislation.

Rössing requirement for the TSF is to meet the D5 safety standard which addresses the "Management of Tailings and Water Storage Facilities". The standard covers all development phases from planning, design through construction, operation, closure and, post-closure where applicable. Along with the Management of tailings and water storage facilities Group procedure, it covers the requirements for management of risk associated with tailings and water storage facilities.

The TSF is also operated according to the Rössing Environmental Standards considering; 1) Water usage and quality management, 2) Air quality protection, Chemically reactive mineral waste control, 3) Land disturbance control and rehabilitation and; 5) Hazardous materials and non-mineral waste control minimisation.

Rössing operates under ISO 14001:2015 certifications, audits are independently carried out by Bureau Veritas as surveillance and recertification on alternating years.

Internal (site based) audits are also conducted periodically to ensure that the business complies with Rössing standards.

The Tailings Storage Facility is operated with a valid "Domestic and Industrial Effluent disposal Exemption" Permit, as statutory by Namibian Law & Legislation, specifically the Water Resources Management Act (No 24 of 2004) & Water Act of 1956 (Act No 54). Through the change tailings deposition, dewatering well and seepage recovery systems the fresh water consumption was reduced from 9.7 million m3 per year (1981) to 2.88 million m3 per year (2018).

Daily operations at the TSF are guided by the "Tailings Operating Manual" which is frequently reviewed and updated. The document also includes as appendices:

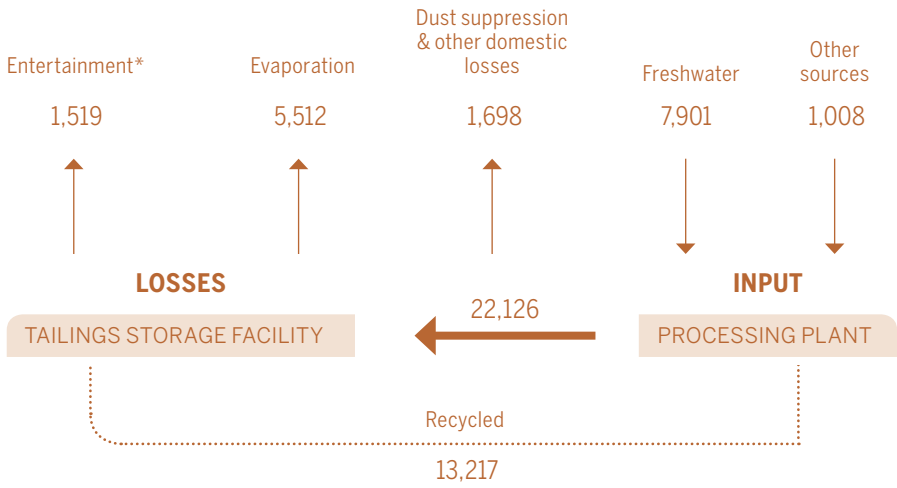
- Design Criteria and basis of Design
- TSF Operator Guidelines
- Emergency Response Plan
- Forms and Log sheets
- Tailings Storage Facility History
- Tailings Storage Facility Construction Drawings
- Mechanical Specifications for the Tailings delivery System
- Domestic and Industrial Effluent Discharge Exemption Permit
- Rio Tinto Design Review Board Charter
- Tailings Dam Traffic Safety Rules

DESCRIPTION OF THE CASE STUDY:

Uranium was discovered in the Namib Desert in 1928, but it was not until intensive exploration in the late 1950s that much interest was shown in the area. After discovering numerous uranium occurrences, Rio Tinto secured the rights to the low-grade Rössing deposit in 1966. Ten years later, in 1976, Rössing Uranium, Namibia's first commercial mine, started with production. CNNC owns the majority of shares (69 per cent) in Rössing Uranium Limited.

The mine has a production capacity of 4500 tonnes of uranium oxide per year with latest annual production of 2479 tonnes in 2018. The current life of mine ends in 2025. In 2018, we mined 19.8 million tonnes of rock (21 per cent less than in 2017) of which 8.0 million tonnes were uranium-bearing rock (17.8 per cent less than in 2017) and 11.5 million tonnes were waste rock. This presents a waste-to-ore strip ratio of 1.48 which is significantly lower than 2017 at 1.57.

Water recycling Rössing (cubic metres per day), 2018



Commissioned in 1976, all tailings were pumped into a single paddock TSF using 2 pumps. In order to confine tailings, the 1st lined earth embankments were constructed in 1980 and in the same year, groundwater dewatering systems installed. In 1984, the Plant was modified to accept process water from the TSF and multiple paddock deposition strategy was introduced in 1985 to reduce water losses and increase re-use of process water. Various capital projects have been implemented since, which optimized seepage recovery for re-use.

The TSF is the source of two types of potential contaminants to the Environment, namely seepage (which is processed water driven) and dust fallout (which is wind driven). Monitoring of the Tailings Storage Facility (TSF) is a 24 hour operation which is divided into 8 hour shifts, continous and well resourced. The civil engineer oversees the operation and monitoring of the tailing storage facility. The TSF has a piezometer monitoring system where the activity of water in the TSF itself is monitored i.e. pore pressure.

The processing plant produces two tailings streams; sandy coarse tailings and fine tailing. The coarse tailings are conveyed and the fine tailings are pumped via a pipeline to the Station X (aka Paddy X) mixing station on the TSF. The two tailings streams are mixed at Station X and pumped to and deposited in the operating paddock. The tailings are pumped to the paddocks via 450 mm diameter rubber or HDPE-lined steel pipes. Two pipe systems are available for operation; System 1 and System 2. One system is always in operation while the other is on standby. The TSF uses a multiple paddock system with only one paddy active at any given moment. The discharge point for disposal is rotated around the periphery of the active paddy, with embankment walls raised as deposition progresses.

There is an operating manual, which contains specific guidelines on construction of paddocks, operating of a paddock and for the civil engineer (CE) to audit the operation teams. Added to the manual is the deposition plan which is a paddock schedule of where and when to deposit and move paddocks. The recently implemented D5 Standard and procedures on management of tailings and water storage facilities are used as these outline mandatory requirements for managing the TSF especially managing critical risk associated with the Rössing TSF. A risk register is kept to list, class and manage all risks present. The Rössing TSF also has an appointed Engineer of Records/Design Engineer (EoR) who is an added technical support.

Most performance reviews are bi-annually, independent reviews which can be operational or technical. Should the need arise for the reviews to be annually the EoR and Independent review panel will be contacted.

This is done by inspecting the physical structure for damage, cracks, and wet areas. Reporting and investigating the findings to put control measures in place to better manage the physical structure. RUL uses mechanical and chemical methods to control wind erosion on the TSF. The mechanical solution is primarily with windrows; however, certain areas are also covered with rock. The chemical method is the use of lignosulphonate polymers on the in-active paddies and access roads.

TSF collapse: If seepage within the TSF is not monitored and regulated (abstracted), elevated phreatic surface within the TSF can lead to cumulative increase in excess pore pressure which can endanger slope stability of a Tailings Storage Facility. Rössing has numerous abstraction wells on and around the TSF and monitors phreatic surfaces in several piezometers. Piezocone testing (CPTU) is also carried out frequently on the dam. A numerical model on both dry & wet day TSF collapse has been develop, showing flow scenarios, with it a rescue plan.

Groundwater contamination: In addition to the seepage extraction systems on the TSF, a wide array of dewatering boreholes and trenches are strategically (based on local hydrogeology) placed within preferential flow paths to curb seepage. A comprehensive groundwater quality monitoring programme is in place, sample are collected and analysis done by an independent accredited laboratory.

Rössing has an active closure plan document, in which various actions are listed for the TSF post closure. Operations on the TSF are guided by an operational manual, which covers all aspects of the dam. Responsible persons are appointed to various tasks & a civil engineer is appointed to oversee the operations. Monitoring & abstraction equipment are installed at strategically selected locations.

Seepage recovery begins on the active paddy were ponding processed water is recovered via decamp pumping. Infiltrated processed water as seepage is recovered on the dam through various recovery systems (wells and sumps), pumping continuous beyond the TSF with abstraction from a dewatering wellfield which is drilled downstream within fractured rock. Further downstream, along the preferential flow path from the TSF, cut-off trenches are installed for seepage recovery. Water quality is monitored to understand the seepage and groundwater interaction.

The mine is ISO 14001:2015 certified and also complies with the internal Health, Safety and Environmental Standards, scheduled audit are carried out to verify compliance.

Human resources are divided into 2 groups; day shift team and the shifts team. The day shift team is responsible for the construction of the running paddock and the preparing the paddock for next deposition. The shift team is responsible for operating the section including the running paddock, recovery and movement of processed solution. The TSF does have machinery mainly used on day shift for the construction and operation maintenance. There are monitoring systems i.e. piezometers distrusted around the TSF to monitor the stability of the unit, borehole/trench system to recover and monitor movement of seepage. Annually finances are allocated for small scale work that has to be performed but for large scale work capital is requested with proper justification.

- Performance on the TSF is driven by several indicators which include; The availability of discharge points (open ends) and systems for deposition,
- Recovery of processed solution for reuse in the processing plant, and
- Preparation of the next paddock for deposition.

Phreatic levels in the TSF are monitored with piezometers (with telemetry systems), installed at strategic locations as identified through CPTU Test.

Deviance from planned & documented procedure to actual operations on the ground can be experienced. Therefore, ongoing training (refresher) and skills development is required for consistency in operating and maintaining the TSF.

With the correct understanding of the nature of the Tailings, the history of the Deposition and Geotechnical properties of the deposited material, it is possible to maintain the sound stability of the TSF and use it to its fullest potential. The management of tailings requires a team of competent Technical Management, and a competent team downstream with not only labor power but also ability to appreciate the risks involved.

3.3 WASTE ROCK DUMPS

In many cases, the footprint size of waste rock dumps is the largest feature of open pit mines. Waste rock dumps may include overburden and low-grade stockpiles, but mostly contain material rejected for processing. As a result, this type of mineral waste varies in size from coarse, angular fragments and large boulders of more than 1 m in diameter, to gravel-sized particles and sand.

In rare cases, in the case of open pit mines that were in production for long periods, it happened that some foreign materials were also accidentally dumped in the waste rock dumps. Nowadays, waste rock dumps are managed with great care and accuracy, closely coupled to the obligations contained in the EMP and LoM plan. For this reason, a detailed mineral waste inventory is maintained—to keep a record of the characteristics, volume, location, and date of disposal. The mineral waste inventory includes information about the material production, techniques used, maps and photographs, as well as a description of repository boundaries, drainage features and the location of test plots, sampling points and boreholes. It is advantageous to have the inventory synchronised with a Geographic Information System.

Waste rock dumps can have multiple negative environmental impacts. Among these are alterations to surface drainage systems, depletion and fragmentation of habitats, and destroying of migratory routes. Waste rock dumps have the most intrusive and visible impacts (sometimes also because of colour differences), and because of their presence, it is difficult to return the entire landscape to as close to an original state as practical. They may also pose threats to surface drainage and groundwater resources (e.g. seepage), safety and stability. In the case of uranium mines, they also have a radiation potential and emit radon.

KEY PRINCIPLES

Waste rock dumps should only be placed within permitted areas. The management and placement of waste rock dumps need to be closely coupled to a LoM plan, guided by operational manuals such as the EMP and, in some cases, an internal mineral waste management plan. Waste rock dumps need to be designed, constructed and operated by considering the following factors:

- Steep slopes need to be avoided, as they may result in instability, increase the potential for erosion, and require re-shaping as part of closure commitments. Avoidance of steep slopes minimises the erosion potential and likelihood of injury to humans and wildlife, also throughout the closure and post-closure periods
- Access to waste rock dumps has to be controlled and minimised during the operational phase, and prevented after closure. It is advantageous to have the waste rock dumps located in an isolated area, or close to access roads after completion, for example
- Surface water, groundwater, and the biophysical environment have to be protected against exposure to hazardous waterborne chemicals, i.e. water quality parameters, as close as possible to the range of natural variability, have to be ensured. To avoid AMD, the buffering capacity and the presence of residuals and solutes in the mineral waste should be known, and management measures implemented accordingly. A good understanding of the local climate is essential to be able to plan for unusual rainfall events and floods, and to plan for potential wind and water erosion. Run-off and eroded material from waste rock dump surfaces have to be minimised.
- Acidic and/or radioactive seepage needs to be captured and re-directed to collection points. For this purpose, cut-off trenches might be necessary at the toe of waste rock dumps
- Waste rock dumps at uranium mines have to warrant protection against radiation, to ensure that doses to the workforce and public do not exceed the limits and constraints recommended by the NRPA, International Atomic Energy Agency and the International Commission on Radiological Protection
- To minimise rehabilitation liabilities, waste rock dumps need be contoured to minimise their visual impacts as artificial landforms, to blend into the surrounding landscapes, and to enable (active and passive) re-vegetation

To avoid double handling and to minimise hauling costs, to secure scheduling flexibility and to stay within parameters of the geotechnical design, the placement of waste rock dumps is a compromise between environmental and economic factors. Considerations include the mechanical competency of the mineral waste, the distance between the source and the dumps, stability of the foundation surface, topography, surface and groundwater drainage characteristics, wind and water erosion potential, and suitability for closure commitments (such as re-contouring and blending into the surroundings). In some cases, waste rock is temporarily placed for backfilling of an open void later, but it is more efficient if in-pit dumping can be done immediately.

PART FOUR

MONITORING REQUIREMENTS DURING THE OPERATIONAL PHASE

THE IMPORTANCE OF MONITORING

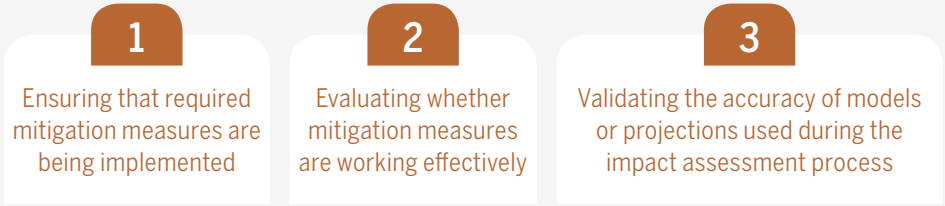
Monitoring aims to determine whether the impacts resulting from operational activities meet the appropriate criteria set out in the EMP. Therefore, monitoring activities provide information that indicates if the measures to manage and mitigate the effects are on track with stated objectives, to evaluate performance against set criteria and appropriate indicators, and to check whether operational activities are in line with the legislative framework. Hence, monitoring is a crucial component for leading practice in mining.

An approach commonly considered for assessing mine impacts and recovery is the "before-after control-impacts" (Quinn & Keough, 2002). This refers to the conducting of measurements prior to and after change that is likely to cause impact(s), and controlling the impact(s). The aspects to be monitored might have been identified and assessed during the environmental impact assessments (EIAs), during the planning processes of the projects and construction phase, or by gathering baseline information during the various stages of the operational phase (for example to be compliant and to ensure compliance with evolving legislative conditions). For this reason, monitoring activities are used to ensure that required measures are implemented; to evaluate the progress of mining activity towards environmental protection by an implemented EMS; and to validate the efficiency of cross-sectional applied strategies, tools and techniques over time. Monitoring is also done in respect of responsible natural resource management in Namibia, in support of baseline information and data collection processes, to strengthen public participation, to assist with operational decision-making, and as a result of follow-up requirements. FIGURE 7 highlights the purpose of monitoring.

In the past, technical reporting required by the state was largely confined to mining and employment statistics. Since the early 1990s, environmental performance became more prominent as a result of the new Minerals (Prospecting and Mining) Act, No. 33 of 1992, as well as a voluntary adherence of mines to Namibia's Environmental Assessment Policy for Sustainable Development and Environmental Conservation (1994).

Environmental auditing of mines requires ongoing monitoring and inspection by regulatory bodies or independent authorities, to ensure compliance with existing national and international requirements and standards. Mines are often associated with international groups, and acquire certification and compliance with international recognised certification such as ISO standards: 14001 and 18000. Audits are an important aspect, and are part and parcel of monitoring and certification. They may be conducted both internally

[FIGURE 4]
Shows three purposes that monitoring serves



and externally, and are used to gauge the company's performance and compliance against regulatory frameworks, adapted management systems and applied standards. Subsequently, audits are used to demonstrate performance against criteria and indicators, and to reassure continuous improvement. If gaps and/or inadequacies are discovered during the auditing process, they enable the auditee to improve the monitoring programs.

The Environmental Management Act, No. 7 of 2007 empowers the Environmental Commissioner to undertake inspections on mine sites to monitor compliance with the Act and against the conditions specified in the Environmental Clearance Certificate. The Environmental Commissioner has the power to confiscate or withdraw the certificate and reinstate it once the holder of the Environmental Clearance Certificate has rectified his/her non-compliance. In practice, the MET will first issue a compliance order and give the mine some time to rectify the deficiency.

Environmental monitoring and auditing includes, amongst other things, water, air quality, and mineral waste.

4.1 WATER MONITORING

Water plays a key role at any mining operation and managing water is fundamentally part of many operational activities at a mine. Each situation has its own unique water characteristics, but in essence, all mines incorporate environmental concerns and regulations into their water monitoring programs, in order to manage water consumption and effluent, and to avoid water pollution.

All mines in Namibia are obliged to adequately monitor and analyse water in compliance with the industrial and domestic effluent discharge exemption permit under section 21(5) and 22(2) of the Water Act (Act 54 of 1956).
Water usage at mines has the potential to affect the quantity and quality of surface and groundwater downstream. One of the tools needed, in order to achieve the aim of surface and groundwater protection, is an effective water quality monitoring program, which includes water quality sampling and analysis (including surface water, groundwater, sewage effluent, and leachates); monitoring of pH and flow volumes of seepage points; monitoring of water table elevations, and potable water quality monitoring.

The principal source(s) of potential water pollution at any mine needs to be identified, as well as the incidental sources of pollution such as accidental spillage of process solutions, chemicals or hydrocarbons; leachates from waste rock dumps and landfill sites; sewage effluent; and workshop wash-downs. The objective of a water monitoring program is to detect changes in water quality, identify the source(s) of the contaminant(s) and assess their impact on human health or the environment. Remedial actions need to be taken, based on the results of monitoring data evaluation. Ultimately, a water monitoring program should be designed to cover remedial actions and achieve sustainable water management.

At Rössing Uranium Limited, one of the oldest operational mines in Namibia, hydro-chemical data have been collected within the mining grant since the start of operations in 1976. About 150 sites have been monitored for groundwater composition, at varying intervals (mostly monthly or quarterly) initially, later reduced after an evaluation of long-term trends and the composition of a water balance for the mine.

Data obtained from a water monitoring program is evaluated and reported, internally as well as externally. The water monitoring program needs to be audited periodically and corrective and improvement actions need to be taken, if necessary. A water monitoring program includes:

- A description of all monitoring mechanisms in place, namely sampling frequency, sampling locations, checklists and compliance parameters such as pore pressure, drainage system functionality, groundwater level, slope stability, dam movement and surface water diversion
- Full implementation of the EMP's waste and water management plans
- Generation of baseline/background data (preferably before the operational phase)
- Identifying the sources of pollution and potential extent—which constitutes legal consequences linked with the risks of contamination. This may include a public health risk assessment if groundwater resources used by third parties are at risk of contamination, e.g. by toxic or radioactive elements
- Monitoring of water usage (including downstream and upstream)
- Verification and calibration of various prediction and assessment models
- Identification, design and monitoring of appropriate water treatment technology
- Controlling unit processes such as process plants and water treatment plants
- Auditing and evaluating the success of implemented management actions against adopted standards such as ISO 14001 standards
- Assessing compliance with set standards and legislation
- The importance of water monitoring is illustrated by the case study submitted by Husab Mine, the youngest and biggest of Namibia's uranium mines:

Tsumeb smelter - Dundee Precious Metals Tsumeb
Tsumeb
Oshikoto
Namibia
2019 © paulgodard.com

HUSAB MINE'S WATER MONITORING PROGRAM

HUSAB MINE

is owned and operated by Swakop Uranium, representing a partnership between the Republic of Namibia and the People's Republic of China. Taurus Minerals Ltd owns 90% of the shares and 10% are owned by a Namibian company—Epangelo Mining Company.

LOCATION:

Husab Mine is situated in the northernmost part of the Namib Naukluft National Park (NNNP), about 12 km southwest of the town of Arandis. It is in a sensitive and unique biodiversity environment, whereby main *Welwitschia mirabilis* fields are situated around the mine site. The mine is located upstream from both the Khan and Swakop Rivers.

BRIEF DESCRIPTION:

Drilling activities as part of the exploration phase commenced in 2005. The construction of some of the mining infrastructure commenced in October 2012 and mining started in March 2014. Commissioning of the processing plant started in December 2016. Tonnage to be mined per annum depends on the business plan for that period. However, the processing plant name plate design production is estimated between 5,000 and 6,000 tons of uranium oxide per annum. It is worth noting that the mine operates its one acid plant. Additionally, the mine generates it's on electricity with the steam from the acid plant via a water turbine. Currently, desalinated water is pumped via a 65-km-long pipeline, travelling through the NNNP and Dorob National Park (DNP), from the Swakopmund NamWater reservoir. Drainage systems were established to provide water to downstream receptors during rainfall/flood events.

KEY ISSUE(S) ADDRESSED:

Husab mine boasts a comprehensive environmental monitoring network, supported by appropriate baseline data. Water monitoring at Husab has the following objectives:

- Compliance monitoring
- Water level measurements
- Monthly groundwater quality monitoring
- Surface water monitoring (*ad hoc* activity)

In compliance with legal requirements, a borehole monitoring network comprising of 70 boreholes was established for monitoring groundwater levels and quality. Groundwater levels are important, especially in a dry country such as Namibia, in particular when abstraction of groundwater from rivers takes place. Results are reported quarterly and bi-annually. Monitoring activities include assessment of rest water levels and quality, and are inclusive of the following parameters: EC, pH, Eh, temperature and metals and ions. A Grundfos submersible pump for purging and sampling is used. Water sampling is only done when the boreholes have recovered from purging. For quality control, a blank sample is collected for every 10 samples from randomly selected boreholes. In addition, ad hoc activity includes the monitoring of surface water when it has rained.

Monitoring for quarterly reporting

Comprises of 15 monitoring sites

Monitoring for bi-annual monitoring sites

A total of 35 monitoring boreholes have been selected for bi-annual reporting and parameters measured remain the same

Monitoring of radionuclides is done on both bi-annual and quarterly bases

The following radionuclides series are monitored:

- Th-232 series: 232Th, 228Ra
- U-238 series: 238u; 234U;230Th; 226Ra, 210Pb; 210Po
- U-235 series: 235U

For groundwater quality monitoring, early pollution detection is conducted prior to each sampling campaign. Equipment is therefore calibrated before the commencement of the monitoring activities.

DESCRIPTION OF THE CASE STUDY:

Potential groundwater and surface water quality, and quantity impacts, are a concern during the life cycle of the Husab Mine and, as such, should be closely monitored. As per the commitments in the Environmental Management Plan (EMP), both the quantity and quality of surface and groundwater should not be adversely affected by mining activities and should remain consistent with baseline conditions.

Additionally, the data obtained assists with a better understanding of the surrounding environment and functioning of the bigger landscape, especially because water is an important ecological driver in the central Namib Desert. The mine adheres to requirements/objectives from ISO14001, NOSA, SEMP indicators and EMP commitments, based on best practice (such as that of the IFC and ICCM). Additionally, all legal requirements need

to be complied with. The mine's budget is determined annually, based on the following year's needs. This takes into cognizance additional monitoring facilities and equipment requirements, as well as possible worst-case scenarios.

CONCLUSIONS:

Husab Mine is still gathering baseline data for all groundwater monitoring boreholes. Once there is sufficient data available, thresholds can be established. Currently a lower and an upper threshold have been determined for existing boreholes, based on the recommendations of specialists. Husab mine considers equipment maintenance, and the storage, handling and control of equipment, as vitally important for ensuring accurate monitoring. This is also in line with best practice and the manufacturer's specifications. Furthermore, an inventory review is conducted following each sampling campaign, and defects are reported.

Husab mine - Swakop Uranmium
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

4.2 MINERAL WASTE MONITORING

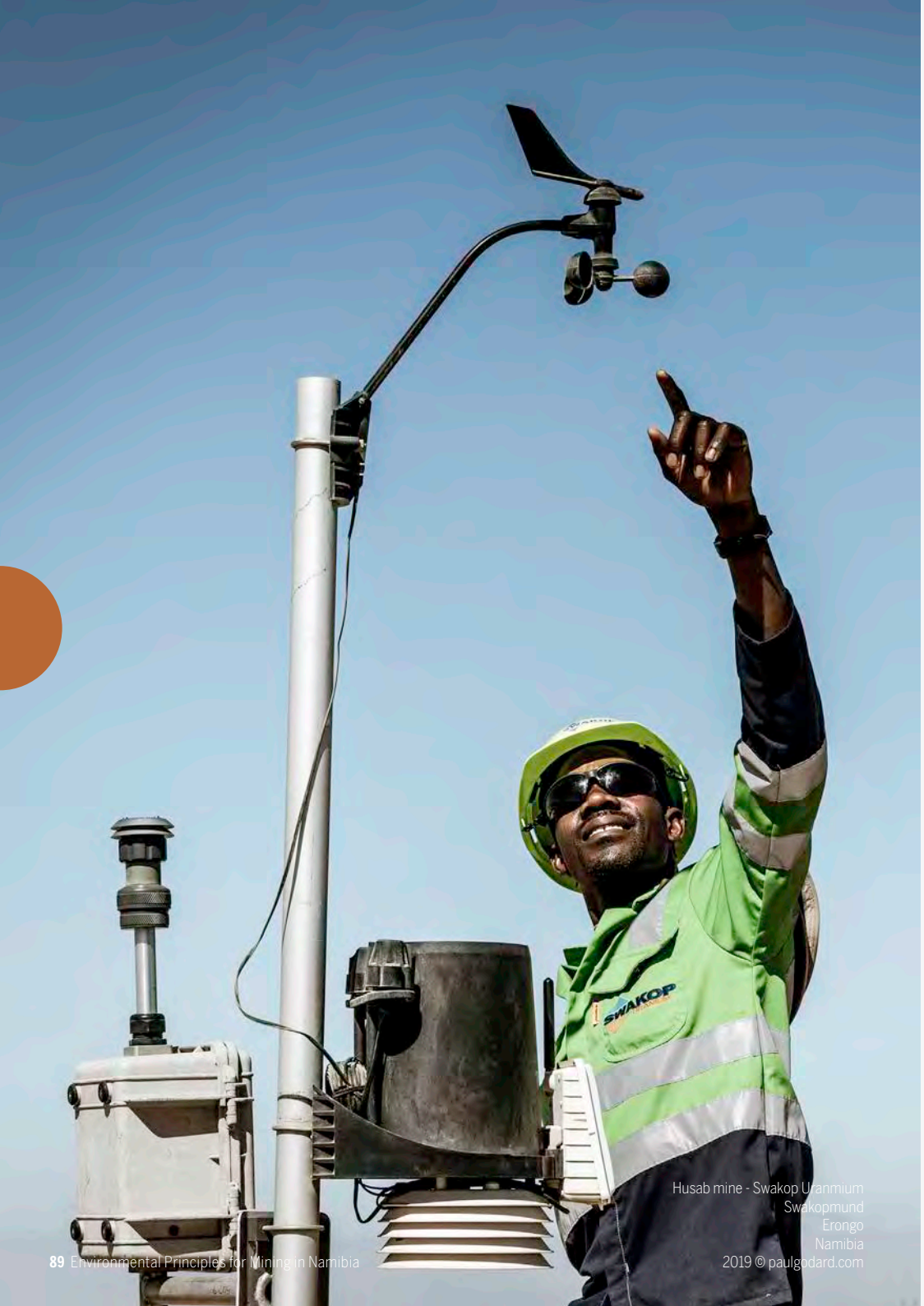
The characteristics of mineral waste will differ depending on the type of material being mined, the geology of the mine and the processing technology used. All mineral materials that have little or no economic value are deemed mineral waste. Most mine wastes are benign, but mining companies are required to manage their mineral waste and to deal with the large volumes of waste produced, in order to protect the environment in which they operate. As part of mine approval and the projects and construction phase of the mining life cycle, waste management plans and strategies are developed. Waste strategies for addressing problematic waste, long-term stabilisation of waste, and the rehabilitation of waste dumps as part of mine closure, should be included in these plans. Most of a mine's mineral waste is produced during the operational phase of the mining life cycle. Read also Part 3 of this Best Practice Guide.

Environmental impacts posed by mineral waste will vary with the type of mining activities. Waste rock and tailings that contain large amounts of sulphide, can release AMD when exposed to water and air, for example. Hence, every mine is expected to have its own approach for the prediction, control, monitoring and treatment of mineral waste. The usual approach to managing mineral waste is to contain and collect the waste from the point of generation to treatment, and to dispose it in an environmentally friendly manner.

Ongoing monitoring and data collection on mineral waste is essential, in order to secure the geotechnical integrity and geochemical stability of mineral waste landforms. Monitoring typically includes regular visual inspections of infrastructure and water management systems, for signs of excessive surface erosion and shallow or deep-seated failure on the outer slopes of mineral waste repositories, water pressure and/or water levels in embankments and within the mineral waste repository. More in-depth rigorous monitoring may include slope movement sensors, periodic topographic surveys and piezometer measurements.

4.3 AIR QUALITY MONITORING

The operational phase of the mining life cycle is a major contributor of particulate emissions. Particulate matter is categorized by size, and as such, have potential impacts on the receiving environment and human health. Particulate matter less than 10 µm and 2.5 µm in aerodynamic diameter (PM_{10} and $PM_{2.5}$) respectively, and Total Suspended Particulates (TSP) such as dust fall, are associated with health and nuisance impacts. Other pollutants that are also monitored, include sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene.



Husab mine - Swakop Uranmium
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

The most widely referenced international criteria are those published by the World Bank, (WB) World Health Organization (WHO), and the European Union (EU). Additionally, the South African legislation (Air Quality Act, No. 39 of 2004) stipulates ambient air quality standards for the mining sector, which can be regarded as representative indicators for Namibia, because of the similarity in social, environmental and economic features. Short intervals between measurements (10 minutes) are most useful in understanding and determining the source of emissions. The South African standards include a margin of tolerance (i.e. frequency of exceedances), and leading practices at Namibian mines are guided by these thresholds. It is worth noting that the minimum standards for South Africa may be adopted by the mining sector in Namibia, but these are voluntary commitments and are not legally enforceable. Therefore, the standards used must meet the ultimate objective of air quality improvement and management at various phases of the mining life cycle.

The WB Handbook of 1998 stipulates that ambient air quality standards ought to be set once an agreement has been reached on the environmental quality objectives that are targeted, and costs are addressed, which a society is willing to accept, to meet the set objectives. Initially, ambient air quality standards were aimed at protecting human health, but lately ambient air quality standards incorporate the protection of ecosystems in some countries.

During the 1990s the WHO stated that no safe thresholds could be determined for particulate exposures and responded by reproducing linear dose-response relationships for PM_{10} and $PM_{2.5}$ concentrations (World Health Organization, 2017). These guidelines would serve as a tool of explicit objectives for air quality managers and policymakers when tasked with setting national air quality standards. Given that air pollution levels in developing countries (site specific) frequently far exceed the recommended WHO air quality guidelines, the interim target levels proposed are more than the air quality guidelines, to promote steady progress towards meeting the WHO air quality guidelines. The EU air quality criteria standards were designed primarily to safeguard human health. The current standards were developed with due regard to environmental conditions, the economic and social development of various regions, and the importance of a phased approach to attaining compliance. TABLE 3 provides a summary of the various standards and guidelines for air quality.

TABLE 3 | The standards/guidelines derived from the WHO, EU and South African standards

POLLUTANT	AVERAGING PERIOD	WHO GUIDELINES (µg/m³)	EU DIRECTIVES (µg/m³)	SOUTH AFRICA STANDARDS NAAQS (µg/m³)
Particulate matter (PM_{10})	1 year	70 (IT-1) 50 (IT-2) 30 (IT-3) 20 (guideline)	40 (n)	50 (l) (f) 40 (m) (f)
	24 hours	150 (IT-1) 100 (IT-2) 75 (IT-3) 50 (guideline)	50 (o)	120 (l) 75 (m)
Particulate matter ($PM_{2.5}$)	1 year	35 (IT-1) 25 (IT-2) 15 (IT-3) 10 (guideline)	25 (u)	25 (q)(r) 20 (q)(s) 15 (q)(t)
	24 hours	75 (IT-1) 50 (IT-2) 37.5 (IT-3) 25 (guideline)	-	65 (q)(r) 40 (q)(s) 25 (q)(t)
Sulphur dioxide (SO_2)	1 year	-	20 (d)	50
	24 hours	125 (IT-1) 50 (IT-2) (a) 20 (guideline)	125 (c)	125 (f)
	1 hour	-	350 (b)	350 (g)
	10 minutes	500 (guideline)	-	500 (h)
Carbon monoxide (CO)	1 hour	30 000 (guideline)	10 000	30 000 (g)
Nitrogen dioxide (NO_2)	1 year	40 (guideline)	40 (i)	40
	1 hour	200 (guideline)	200 (j)	200 (g)

NOTES:

(a) intermediate goal based on controlling motor vehicle emissions; industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvement.

(b) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 24 times per calendar year).

(c) EC Directive 2008/50/(http://ec.europa.eu/environment/air/quality/standards.htm). Limit to protect health, to be complied with by 1 January 2005 (not to be exceeded more than 3 times per calendar year).

(d) EC First Daughter Directive, 1999/30/EC (http://rod.eionet.europa.eu/instruments/517). Limited value to protect ecosystems. Applicable two years from entry into force of the Air Quality Framework Directive 96/62/EC.

(e) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). 99th percentile of 1-hour daily maximum concentrations, averaged over 3 years.

(f) 4 permissible frequencies of exceedance per year

(g) 88 permissible frequencies of exceedance per year

(h) 526 permissible frequencies of exceedance per year

(i) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Annual limit value for the protection of human health. Limit value entered into force 1 January 2010.

(j) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Not to be exceeded more than 18 times per year. Limit value entered into force 1 January 2010.

(k) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). 98th percentile, averaged over 3 years.

(l) Applicable immediately to 31 December 2014.

(m) Applicable from 1 January 2015.

(n) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Limit value entered into force 1 January 2005.

(o) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Not to be exceeded more than 35 times per calendar year. Limit value entered into force 1 January 2010.

(p) US National Ambient Air Quality Standards (www.epa.gov/air/criteria.html). Not to be exceeded more than once per year on average over three years.

(q) Proposed draft $PM_{2.5}$ regulations as published in the Government Gazette (no. 34493) on the 5th of August 2011.

(r) Applicable immediately to 31 December 2015.

(s) Applicable 1 January 2016 to 31 December 2029.

(t) Applicable 1 January 2030.

(u) EC Directive 2008/50/EC (http://ec.europa.eu/environment/air/quality/standards.htm). Target value entered into force 1 January .2010 and limit value enters into force 1 January 2015.

A recent study in the Erongo Region (Airshed, 2019) determined guidelines to provide the necessary performance indicators for the region as part of an Air Quality Management Plan.

The study found that, based on measured data to date, the South African National Ambient Air Quality Standards (SA NAAQSs) for PM_{10} seems to be the appropriate limit for the region and the WHO Interim-Target 3 (WHO-IT3) limit for $PM_{2.5}$ and recommends that the SA NAAQS limit for PM_{10} and the WHO-IT3 for $PM_{2.5}$ is adopted. Recommendations of the study include Dust Management Plans for all operational sites; annual reporting of dust fall levels and PM_{10} concentrations to the authorities; dust suppression at construction sites (as well as annual reporting on dust mitigation measures); update and improvement of the current emissions inventory; establishing a monitoring regime to enhance source apportionment of PM concentrations and sodium content; and continuation with PM_{10} and meteorological monitoring.

Namibia's uranium mines, operational and those on care and maintenance, are all located in the central Namib Desert. The mines have an extensive air quality monitoring program in place, which are very similar to each other. All of the mines are located near or in areas with sensitive third parties such as tourists, farms, other mines, the Namib Naukluft Park and urban areas (Arandis, Swakopmund and Walvis Bay). The monitoring is required to determine whether permitted levels are exceeded, of concern, or remain within legal limits, and to provide necessary recommendations and implement mitigation measures to reduce unwanted emissions. Guidelines used are from an air quality specialist company from South Africa.

Contributors to possible emissions on the uranium mines are derived from vehicle entrainment, mining activities, including drilling and blasting, loading and hauling, burning of explosive-related materials etc.; equipment maintenance, construction-related activities, processing activities (i.e. crushing, material handling points, reagent storage points, windblown dust—from mineral waste repositories such as tailings storage facilities); from the Final Product Recovery stacks; and general vehicle emissions. Currently dust suppressions activities / projects are in place to limit exposure. Air quality monitoring entails the measuring of fall-out dust (or Total Suspended Particles), PM_{10} and $PM_{2.5}$ monitoring, chemical analysis of emissions (including stack emissions), radio-nuclide analysis, and passive sampling monitoring. In addition, noise and vibration are also monitored. At each of the mine sites there is more than one weather station which provide continuous meteorological data.
Air quality trends are interpreted against the relevant background/baseline studies for the central Namib Desert and potential dispersal is modelled accordingly. Regular reporting—weekly, monthly and annually—is done to identify trends and make comparisons.

The main pollutants of concern identified in a recent study in the Erongo Region were particulate matter (dust) and radon, with the radionuclide content within the dust being important for the radiation dose assessment update (Airshed, 2019). The study put a particular focus on the atmospheric exposure pathway (the exposure dose resulting from the inhalation of ambient atmospheric radon and its decay products, and the exposure dose due to the inhalation of ambient atmospheric dust that contains radioactive elements) and associated public exposure dose. All sources of air pollution in the region were addressed, pollutants identified and quantified (where possible), and the significance thereof determined.

Part of the study was to conduct dispersion modelling to identify the main contributing sources to the measured PM_{10} and $PM_{2.5}$ concentrations over a year period. The sources identified and quantified in the emissions inventory included: regional roads; windblown dust from mine tailings storage facilities, waste rock dumps and stockpiles; mining and quarrying operations; and point sources. Two primary natural sources / events have been identified – windblown dust during East-wind conditions, and sea salts from the ocean.

Vehicle entrainment from roads was identified as the main contributing modelled source to PM_{10} and $PM_{2.5}$ emissions, followed by mining and quarry operations. From the simulation mining and quarrying operations were indicated as the main contributing sources of PM_{10} concentrations at the central receptors, while the contribution from roads dominated at all other receptors in the region. Mining and quarrying operations was simulated as the main contributing source group of $PM_{2.5}$ concentrations at Arandis only while roads were indicated as the main contribution source for most of the other receptors.

As part of the study the real-time ambient atmospheric radon concentration were measured. At Walvis Bay the maximum radon concentration recorded was 110.5 Bq/m^3, at Swakopmund it was 99.5 Bq/m^3 and at a point between Arandis and the Rössing Uranium Mine it was 266 Bq/m^3. Based on the long-term average radon concentrations determined in the study, the annual average public exposure dose contributions from the inhalation of radon and its decay products, amount to 0.1 mSv/a at Walvis Bay, 0.2 mSv/a at Swakopmund, and 0.4 mSv/a at the monitoring location in-between Arandis and Rössing. Moreover the public exposure doses are far smaller than the world-wide average public exposures due to radon – i.e. 1.095 mSv/a – as suggested by the United Nations Scientific Committee on the Effects of Atomic Radiation (United Nations, 2000)). The study furthermore confirms that the exposure dose due to the inhalation of radioactive dust in ambient air in the inhabited areas in the Erongo Region does not constitute a public health risk.

Dundee Precious Metals Tsumeb also has a state-of-the-art air quality monitoring system in place as illustrated in the case study below:

Tsumeb smelter - Dundee Precious Metals Tsumeb
Tsumeb
Oshikoto
Namibia
2019 © paulgodard.com

TSUMEB SMELTER

The Tsumeb Smelter is owned and operated by Dundee Precious Metals Tsumeb, a subsidiary of the Canadian-based Dundee Precious Metals. The smelter is registered as a processing factory (not a mine) and produces blister copper (98.5% Cu) and sulphuric acid as its two main products. The parent company, Dundee Precious Metals Inc., is an international gold mining company engaged in the acquisition, exploration, development, mining and processing of precious metals.

LOCATION:

The Tsumeb Smelter is located about 2km north-east of the town of Tsumeb in the Oshikoto Region of Namibia and approximately 430 km north-east of the Namibian capital city, Windhoek.

BRIEF DESCRIPTION:

The Tsumeb Smelter and associated infrastructure had gone through various transformations over the years, which include recessions and change of ownership. The current smelter is one of a few in the world that can treat complex copper concentrates.

The smelter consists of a primary smelting furnace, being the Ausmelt Furnace, two Peirce Smith Converters, bag houses and cooling towers, a slag milling plant, two high-voltage distribution sub-stations, a material handling facility, two oxygen plants, a fume extraction system, and a sulphuric acid plant. The arsenic-bearing waste is disposed at an onsite hazardous waste disposal facility, which is an engineered and approved waste landfill.

KEY ISSUE(S) ADDRESSED:

Since 2010, Dundee Precious Metals Tsumeb has made significant investments to address occupational health and safety (OHS) concerns, including industrial hygiene, as well as environmental issues associated with historic and current operations. The key investments included a sulphuric acid plant, which has significantly reduced sulphur dioxide (SO_2) emissions to the atmosphere and improved local ambient air quality. There were also engineering improvements to reduce fugitive emissions, including the installation of new bag houses to capture process dust, construction of a secure hazardous waste disposal facility for arsenic-bearing waste, as well as improved monitoring and medical surveillance for the employees.

CHALLENGES:

- Managing the influence and impact of legacy dumps on environmental dust
- Control of SO_2 emissions during plant upset conditions due to external factors like power interruptions

HIGHLIGHTS:

- Dundee Precious Metals Tsumeb uses state-of-the-art Environment Protection Agency (EPA) referenced air quality equipment to monitor sulphur dioxide (SO_2), arsenic (measured as PM_{10}), as well as two particulate fractions (PM_{10} and $PM_{2.5}$)
- Dundee Precious Metals Tsumeb currently runs a network of five (5) ambient air quality monitoring stations within the town of Tsumeb and along the smelter boundary. Three of the stations are in residential areas referred to as the community stations, and two along the boundaries of the smelter
- The monitoring sites all meet the requirements as outlined in the US EPA's *"Quality Assurance Handbook for Air Pollution Measurement Systems"* and *"SANS 1929"*, a South African National Standard covering data and quality assurance requirements for Air Quality Monitoring Systems
- In addition, Dundee Precious Metals Tsumeb also has 17 dust fall-out deposition buckets

DESCRIPTION OF THE CASE STUDY:

Air quality pollutants of concern at Dundee Precious Metals Tsumeb emanating from the copper smelting processes are SO_2, arsenic dust, PM_{10} and $PM_{2.5}$. These pollutants have potential negative impacts if not closely controlled and monitored. For instance SO_2 could have the following impacts:

- Inhibits photosynthesis by disrupting the photosynthesis mechanism negatively affecting the growth in some plant species
- Reacting with rain, a weak sulphuric acid is formed, which is the main component of acid rain
- Irritant to the respiratory system in humans and can temporarily aggravate the symptoms of asthma

Four distinct monitoring programs are in place to monitor and manage ambient air quality—the Ambient Air Quality Monitoring (AAQM); meteorological monitoring; dust fallout monitoring; and the monitoring of community complaints when there are exceedances of SO_2 felt in the community.

Each AAQM is equipped with a SO_2 analyser, a TEOM (PM_{10}) monitor, Partisol 2025i PM_{10} sampler and meteorological station. In addition, two of the community stations at the Stadium and the Dundee Precious Metals Tsumeb Information Centre are equipped with the BAM $PM_{2.5}$ monitors. Meteorological data is critical when assessing air quality data – due to its profound influence on contaminant dispersion and concentration. The SO_2, PM_{10} and $PM_{2.5}$ monitors automatically collect, analyse, and report measurements on an hourly basis. Datasets are verified by an external party continuously and prepared for reporting. The Partisol 2025i PM_{10} filter samplers are scheduled to sample for 24 hours every 144 hours, that is, every 6th day. All five station instruments are programmed to sample simultaneously at midnight for comparison purposes. Filter-based dust samples (PM_{10}) are collected manually and shipped to a SANS Accredited Testing Laboratory for arsenic analysis and a full metal suite.

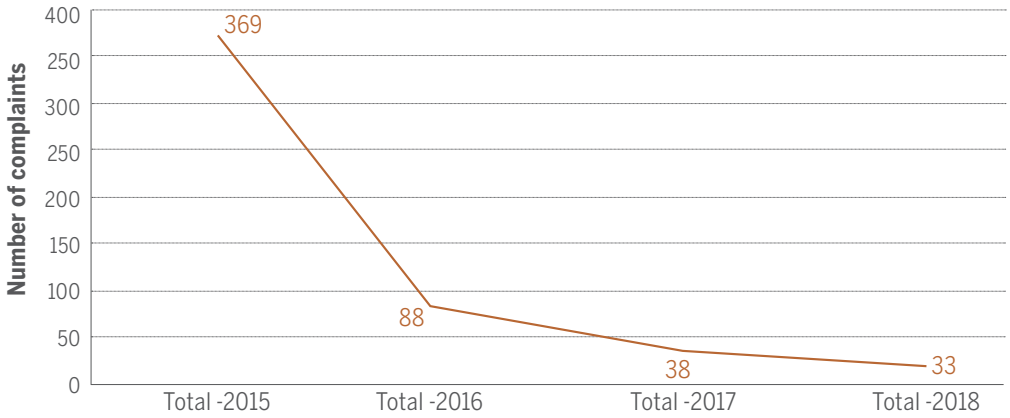
The real-time daily profiles of the SO_2 and PM_{10} and $PM_{2.5}$ concentrations and meteorological data for each station are accessible via a web-based application. A warning system linked to the monitoring system, sends alerts out to Dundee Precious Metals Tsumeb operations, teams and other relevant managers when SO_2 levels are above the SANS limits. Both the web-based application and warning system are managed by third party for quality control and assurance.

Dundee Precious Metals Tsumeb continuously monitors seventeen (17) dust fallout sites that are strategically located around the town of Tsumeb and the smelter vicinity. The windblown dust fallout at Dundee Precious Metals Tsumeb is monitored based on the American Society of Testing and Materials' standard method for collection and analysis of dust fallout (ASTM D1739:1970). Dust fallout samples are collected monthly after a 30 ± 3 days' exposure period.

At the emission source, the following control systems are in place:

- The Sulphuric Acid Plant was installed in 2015 to capture SO_2, and convert it to Sulphuric Acid. Sulphuric Acid (H2SO4), is sold to uranium and copper mines, where it is used in the extraction process. The installation of the Sulphuric Plant acid plant has a positive impact on the ambient air quality for the community, as demonstrated by the declining number of complaints in the figures below:

COMMUNITY COMPLAINTS as a result of SO_2 - Total per year, 2015 to 2018 YTD



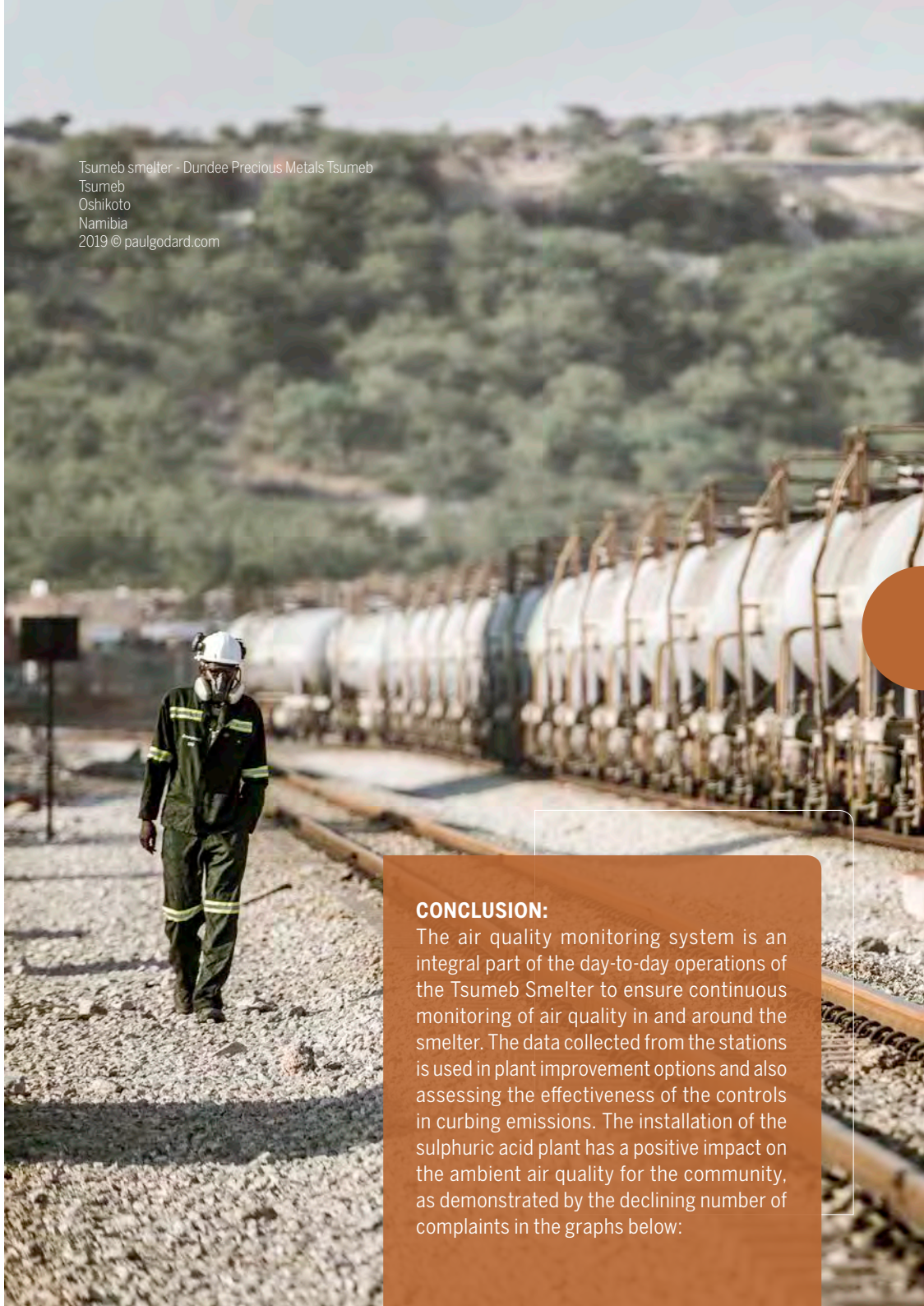
Number of SO_2 exceedances of the SA 24 hr limit of 125ug/m³

- Fume hoods extraction system: The copper converters are fitted with tight sealing water cooled primary hooding as well as secondary hooding to minimise the fugitive gas containing SO_2 into the atmosphere.
- Baghouses and scrubber system is in place and acts as a gas cleaning system to remove particulate matters before gas is consumed by sulphuric acid or released into the atmosphere through the stacks.

Dundee Precious Metals Tsumeb's air quality monitoring is embedded as an integral part of the business, with a significant budget allocation. Air quality monitoring and dust control is a key performance indicator with above 90% data availability. An air quality environmental officer oversees the day-to-day operations of the air quality monitoring stations with the ongoing support of the external independent party, who is also responsible for calibration, gathering, processing and validation of the air quality data.

AREAS FOR IMPROVEMENT:

Modelling and forecasting capacity will be an essential complement to the air quality monitoring network, as it will maximise the value of the data collected. Dundee Precious Metals Tsumeb is looking into dispersion models based on air quality monitoring data and meteorological data. A monitoring network cannot monitor every area of Tsumeb, but with modelling, reliable predictions can be made. Models will predict the direction of the pollutant plume and enable Dundee Precious Metals Tsumeb to respond appropriately and efficiently.


Tsumeb smelter - Dundee Precious Metals Tsumeb
Tsumeb
Oshikoto
Namibia
2019 © paulgodard.com

CONCLUSION:
The air quality monitoring system is an integral part of the day-to-day operations of the Tsumeb Smelter to ensure continuous monitoring of air quality in and around the smelter. The data collected from the stations is used in plant improvement options and also assessing the effectiveness of the controls in curbing emissions. The installation of the sulphuric acid plant has a positive impact on the ambient air quality for the community, as demonstrated by the declining number of complaints in the graphs below:

PART FIVE

BEST PRACTICE STANDARDS FOR MINING

INTRODUCTION

The production cycle of mining activities is comprised of two basic operational units, namely drilling and blasting, and loading and hauling. Ore then enters the crushing and grinding stage before it is delivered to the processing plant. Mining activities have the potential to negatively impact the environment and, as such, business operations must comply with all applicable legislation and environmental guidelines that advocate best practices.

Drilling and Blasting

Drilling and blasting play a significant role in open pit mines, which is crucial in the downstream stages. For open-pit mining, blast holes of 75 to 380 mm in diameter are formed by rotary or percussion drills for the placement of explosives when consolidated rocks are to be removed. Explosive charges are then inserted and detonated to reduce the overburden or ore to a size range suitable for excavation. Primary auxiliary accessories for operations include those providing slope stability, power supply, pumping, maintenance, waste disposal, and the supply of material to the production phases (AZO Mining, 2014; Abbaspour, Dredenstedt, Badroddin, & Maghaminik, 2018).

On the other hand, underground mines' production cycles are unlike that of the surface mines. Although equipment may be scaled down in size, smaller drill holes are used, and trucks are sometimes replaced with shuttle cars and conveyor belts. Additionally, certain auxiliary accessories are often required, including; roof support, ventilation and air-conditioning, power supply, lighting, communications, and delivery of compressed air and water supplies to the working sections, etc. (Abbaspour, Dredenstedt, Badroddin, & Maghaminik, 2018).

Loading and Hauling

The process of loading and hauling is a complementary service that contributes to the efficiency of the mining process. It is an essential part of estimating a productive mining process and must be considered when taking into account matters of machinery and equipment utilised, against outsourcing waste movements and haulage, to better predict any mining project's efficiency. Therefore, the Auxiliary for loading and hauling (i.e. excavators, haul trucks, etc.) are critical technologies for mining operations, and are the units around which most mining operations are designed and planned for operational activities (The RAND Corporation, 2001).

The decision between open pit and underground mining is not solely governed by the depth of the deposit, but rather by a host of factors including, but not limited to, economics, ore grade, deposit geometry, and topography, etc. Irrespective of the type of mining methods used, it is essential that mining companies adhere to sound environmental standards to prevent environmental degradation.

Trekkopje mine - Orano
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

5.1 STANDARDS FOR MINING

Open pit mining is a method of ore extraction used for mining shallow ore bodies. This method often provides higher recovery, improved grade control, flexibility, and a safer working environment when compared to underground mining. Environmental concerns associated with open pit mining are attributed to the generation of large volumes of waste rock, the permanence of a huge open pit and associated infrastructure such as a road network, powerlines and other structures, and the creation of dust and noise. All these environmental impacts need to be addressed in the operational EMP, implying that management measures are in place to curb the impacts.

Drilling and blasting, and loading and hauling require proper planning and scheduling. TABLE 4 and TABLE 5 propose some best practice standards for these activities.

TABLE 4 | Best practice standards for open pit operations

ACTIVITY, POSSIBLE ASSOCIATED IMPACTS, AND LEADING PRACTICE STANDARDS

Activity	Possible Impacts	Leading Practices
Blast hole drilling	• Dust generated could have negative impact on worker's health and surrounding fauna and flora • Lack of guidelines for re-fuelling and chemical handling may result in surface and ground water contamination • Excessive noise generated by the drill rigs • Lack of disposal guidelines for used oil and drill pipe lubricants may result in surface and ground water contamination	• Drills should be fitted with dust collector units that should be monitored during shift inspections • Use of appropriate fuel and chemical storage and handling equipment • Develop and implement spill clean-up plans • Remain within specified occupational health and safety noise limits • Implement used oil collection plans and recycling programs • Train personnel to use appropriate lubricants, avoiding overuse
Blasting	• Air emissions • Vibration and noise • Fly rock • Soil, surface and ground water contamination • Public safety • Workers' health and safety	• Blast designs should always minimise air emissions and noise, and control fly rock and vibration • Blasthole liners and emulsion explosives should be used in wet holes • Blast areas should be restricted to authorised personnel only
Post-blast inspections	• Misfires could have a negative impact on workers' safety if not dealt with correctly • Lack of guidelines for handling unexploded explosives, like emulsion during post-blast inspections could affect surface and ground water	• Only individuals that hold blasting tickets should be allowed to enter blast areas and conduct post-blasting inspections • The Mine Health and Safety Regulations in Namibia, 10th Draft
Loading and Hauling Operation	• Dust generated could have negative impacts on workers' health and surrounding fauna and flora • Lack of guidelines for re-fuelling and chemical handling may result in surface and groundwater contamination • Excessive noise generated by load and haul equipment • Improper disposal of used oil lubricants may result in surface and groundwater contamination	• Drills should be fitted with dust collector units that should be monitored during shift inspections • Use of appropriate fuel and chemical storage and handling equipment • Develop and implement spill clean-up plans • Remain within specified occupational health and safety noise limits • Implement used oil collection plans and recycling programs • Train personnel to use appropriate lubricants, avoiding overuse

TABLE 5 | Best practice standards for underground operations

ACTIVITY, POSSIBLE ASSOCIATED IMPACTS, AND LEADING PRACTICE STANDARDS

Activity	Possible Impacts	Leading Practices
Blast hole drilling	• Dust generated could have negative impacts on workers' health • Lack of guidelines for re-fuelling and chemical handling may result in groundwater contamination	• Drills should be fitted with dust collector units that should be monitored during shift inspections • Use of appropriate fuel and chemical storage and handling equipment • Develop and implement spill clean-up plans • Train personnel to use appropriate lubricants, avoiding overuse
Blasting	• Air emissions • Ground water contamination • Vibration and noise	• Blast designs should always minimise air emissions and noise, and control fly rock and vibration • Blasthole liners and emulsion explosives should be used in wet holes • Blast areas should be restricted to authorized personnel only • Remain within specified occupational health and safety noise limits

PART SIX

BEST STANDARDS FOR PROCESSING OPERATIONS

THE NEED FOR STANDARDS

Mining companies must aim to actively mitigate potential environmental impacts of their processing activities to ensure compliance, commitment towards sustainable development principles, and the implementation of best practices. Effective prevention, reduction, management and mitigation of undesirable environmental impacts lies in implementing sound scientific and technological approaches—resulting in leading practices and setting standards appropriate to Namibian conditions.

Curbing of environmental impacts implies an EMS, environmental monitoring and reporting programs, environmental auditing and enforcement. In an effort to frequently review environmental performance and to make continuous improvements, several Namibian mines are ISO 14001 certified.

The severity of environmental impacts varies from mine to mine, mineral ore, the toxicity of waste from ore stockpiles, waste rocks and processing tailings. Furthermore, environmental impacts from processing are closely associated with geology, location and terrain cover, climate and hydrology.

6.1 MINING OPERATIONS AND PROCESSING OF BASE METALS

In order to ensure sound environmental practices in all aspects of processing, several leading international practices along with leading practices at Namibian mines have been used to set "Leading Standards" for the mining of base metals, as illustrated in TABLE 6.

6.2 MINING OPERATIONS AND PROCESSING OF PRECIOUS METALS

The processing of precious metals such as gold, silver and platinum, includes the processes of roasting and leaching; stripping and regeneration; refinery and furnace for the separation of minerals from the impurities. Some gold ores are pre-treated before they go into the leaching stage, while others are leached directly (Toovey, 2011). The release of toxic substances such as cyanide and mercury are often associated with the processing of precious metals. Currently gold mine operations in Namibia are undertaken by the Navachab and Otjikoto gold mines. The best practices standards for the processing of precious metals are summarized in TABLE 8, with special attention to gold.

NB! Always respect and make sure that you carry out your activities within the conditions of the ML. Contravention or failure to comply will lead to refusal of the renewal application.

TABLE 6 | - Best practice guidelines applicable to base metal processing

MINERAL PROCESSING ACTIVITY, POSSIBLE ASSOCIATED IMPACTS, AND BEST STANDARDS

Processing Activity	Possible Impacts	Leading Practices
Processing of zinc	• Visual and aesthetic impacts • Slags as a by-product of smelting may release metals to the environment • Erosion of mineralised waste drainage causing concentration of metals in stream sediments • Acid seepage from tailings impacts on stream habitat and groundwater • Degradation of surface and groundwater quality because of the oxidation and dissolution of metal-bearing minerals • Acid mine drainage containing pyrite (iron sulphide) contaminate groundwater • Atmospheric emissions: » Increase airborne dust and other emissions, such as sulphur dioxide and nitrogen oxides[1], flue dust from smelters and refineries • Erosion and sedimentation due to tailing pond instability due to the action of wind and water • Waste generation i.e., slag • Environmental degradation	• Seepage can be prevented or reduced by constructing tailing dams with impermeable barriers, i.e., clay is placed at the bottom of the impoundment • Use of reclamation methods to facilitate runoff and prevent infiltration of surface water • Treatments and stabilisation of metal-bearing soils • Prevention and treatment of contaminated water • Reduce the energy consumption • Use renewable energy instead of fossil fuels • Mining operations should be fenced off • Trespassing warning sings must be installed • Disturbed area should be revegetated. [1] Flue dust are fine particles of metal or alloy emitted with the gases of a smelter or metallurgical furnace.
Processing of lead	• Water resources contamination • Soil contamination • Waste generation » Waste rock, wastewater	• Wastewater to be treated before disposal • Establish monitoring boreholes • Quarterly monitoring and bi-annual monitoring of water sources • Have permissible barriers to prevent seepage and leachate of waste into the ground • Progressive rehabilitation of waste rock stockpile throughout the mine life cycle • Use of cleaner production techniques • Use waste as raw material • Reduce waste production through process re-engineering • Water must be treated at an acceptable quality before disposal
Processing of copper	• Seepage from heap leaching acid mine drainage: » can decrease water quality » can inhibit plant growth during mine reclamation	• Make use of drippers not sprinklers • Use engineered and lined pads, drainage system • Make use of locally available acid plant sources (e.g. the Dundee Tsumeb Smelter acid plant to minimise acid Import)

TABLE 8 | Best practice standards for the processing of gold in Namibia

ACTIVITY, POSSIBLE ASSOCIATED IMPACTS, AND LEADING PRACTICE STANDARDS

Activity	PROCESSING OF GOLD
Possible Impacts	• Contamination of surface and groundwater • Intensive water uses and depletion of water • Erosion, siltation, land subsidence • Alter runoff and drainage • Loss of biodiversity • Air pollution and pollution bearing dust, i.e. carbon oxides; sulphur oxides; nitrogen oxides; and methane • Bioaccumulation of metals such as lead, arsenic, mercury and cadmium • Land use patterns for animals is affected • Cyanide contamination can cause death in animal species • AMD tailings leachate
Leading Practices	• Reduce water use • Recycle and reuse water at other stages of processing, i.e. milling processes and dust reduction by spraying • Reduce waste generation and storage • Maintaining biodiversity by the rehabilitating (revegetation) and culturing of endangered plant species • Use of cleaner energy technologies, i.e. solar • Reduction in energy consumption at mines can reduce greenhouse gas emissions

Otjikoto mine, B2Gold
Namibia
Otavi
Otjozondjupa
Namibia
2019 © paulgodard.com

PART SEVEN

REPORTING GUIDELINES

THE NEED FOR REPORTING

Reporting is an important mechanism for authorities to ensure compliance from mining companies to the conditions outlined in the Environmental Clearance Certificate, the EMP and any other additional requirements such as permits and licences. Namibian reporting requirements for exploration and mining companies are outlined in the Minerals (Prospecting and Mining) Act, No. 33 of 1992.

Reports submitted to the state cover essential aspects of the operational activities, such as chemical reagent storage and use; (mineral) waste generation, handling and disposal; consumption of commodities such as water and energy; land disturbance; training, assurance and risk; and compliance in general. Mines belonging to global companies also do internal reporting on various aspects determined by their parent companies; some also do annual reporting to the public—to give stakeholders an overview of activities, including interaction with society, the economy and the environment. In the case of uranium mines, reporting has to be done to the NRPA as well. All mines are also required to do scheduled reporting on personnel and workforce matters to the Employment Equity Commission.

Once mining companies submit reports to the authorities, it is expected that the relevant state departments confirm the receipt of the reports and provide the necessary feedback. This two-way process of reporting ensures mutual transparency, honesty and accountability, and enhances integrity.

7.1 REPORTING FROM THE MINING COMPANIES TO THE STATE

Reporting to the mining commissioner

Mining companies are required to submit reports to the Mining Commissioner (i.e. the Directorate of Mines) as outlined in TABLE 9. The reporting period is dependent on the type of mineral licence of the proponent. Illustrated in the toolkit appendix is a reporting template, to provide guidance.

Reporting to the Labour Commissioner

Mines are required to report to the Employment Equity Commission for compliance verification in respect of labour-related acts, including affirmative action employment.

TABLE 9 | Reporting to the Mining Commissioner

TYPE OF LICENCE	REPORTING PERIOD
Non-Exclusive Prospecting Licence (NEPL)	• Upon request from the Commissioner
Reconnaissance Licence (RL)	• Within 60 days after the end of the currency of the RL
Exclusive Prospecting Licence (EPL)	• Quarterly • Annually • Within 60 days after the end of the currency of the EPL
Mineral Deposit Retention Licence (MDRL)	• Within 60 days after the end of the currency of such MDRL • Annually
Mining Licence (ML)	• Quarterly • Annually (60 days before the 31st of December)

Reporting to the Environmental Commissioner

Mining companies submit (also voluntarily) annual environmental reports to various state departments (i.e. the Directorate of Environmental Affairs, the Directorate of Mines, and the Directorate of Water Resource Management). However, these annual reports on environmental performance are not prescriptive in format or content for reporting. It is best practice to have a reporting format in place.

Reporting to the National Radiation Protection Authority

The Atomic Energy and Radiation Protection Act, No. 5 of 2005 deals with radiation protection, including protection on mines, as well as the permitting, auditing and safeguarding of facilities that are used in the handling and final disposal of radioactive materials in Namibia. Regulation of radiation exposure falls under the jurisdiction of the NRPA situated at the Ministry of Health and Social Services (MoHSS). The Act stipulates that the import into, or export from Namibia, or transport, storage, possession or disposal of any radiation source or nuclear material need to be registered, authorized, and subsequent licenced by the NRPA. A licence holder is restricted by the provisions of the Act and conditions of the licence; must keep records and compile reports related to radiation protection or required safety standards, and prepare radiation safety rules for the use, handling, storage, transportation, or disposal of radiation sources, waste or produced or prepared nuclear material. Export of uranium and worker exposures need to be reported to the NRPA twice per year. Furthermore the transport, storage and/or possession of radioactive materials is subject to permission by and reporting to the NRPA.

Reporting to the Department of Water Affairs

In compliance with conditions stipulated in the water permits issued by the Department of Water Affairs at the Ministry of Agriculture, Water and Forestry (MAWF), annual reports about water abstraction; disposal and management of effluent; and vegetation monitoring, are submitted to the head office in Windhoek.

7.2 REPORTING FROM THE STATE TO MINING COMPANIES

Among mines there is an expectation to receive written feedback from state departments when reports are submitted. This feedback should entail a written notice from the respective state department, verifying that the report(s) has been received. This verification should be sent 7 days after receiving the report(s). An example of this notification is illustrated in the toolkit appendix. In addition a feedback report, stating the level of satisfaction with the status of a project, has to be sent back to mining companies 60 days after receiving the report. An example of this is also illustrated in the toolkit appendix.

7.3 REPORTING AND AUDITING REQUIREMENTS IN PROTECTED AREAS

The following requirements apply when carrying out operational activities in a protected area in Namibia, in accordance with the Minerals Policy of Namibia of 2000, and the Mining and Prospecting in Protected Areas (PA) policy of 2018:

- The Mining Commissioner at the Directorate of Mines and the Environmental Commissioner at the Directorate of Environmental Affairs shall be provided with a report every 6 months. The two directorates may, at liberty, conduct inspections at any time, to monitor compliance, and to verify whether mining companies meet the conditions set out in documents such as the EMP and other permits and licences
- In addition to inspections conducted by various state departments, a technical committee will be established to conduct inspections on mines situated in protected areas. This committee will include members from the Ministry of Environment and Tourism (MET), the Ministry of Mines and Energy (MME), and other ministries such as the Ministry of Fisheries and Marine Resources
- The MET and MME shall conduct an annual audit on MLs and EPLs located in protected areas. An independent expert may also be commissioned to conduct the audit at the licensee's cost

NB! A mineral licence holder failing to report to the Mining Commissioner, in a reasonable period, shall be guilty of offence and be liable to pay N$50,000 and / or face imprisonment.

PART EIGHT

TRANSITION TO THE NEXT PHASE

INTRODUCTION

Namibia has a long history of legacy sites of mines that have not been adequately closed. It is essential that planning for mine closure starts during the operational phase of the mining life cycle and is not postponed until the site must enter the closure and completion phase. The Chamber of Mines (CoM) has developed a Namibian Mine Closure Framework (NMCF) that highlights the minimum requirements for mine closure planning.

MINING COMPANIES SHOULD BE FAMILIAR WITH THE NMCF AND COMPLY WITH THE GUIDELINES STIPULATED THEREIN, AS IT INFORMS LICENCE HOLDERS OF BASIC SOCIAL AND ENVIRONMENTAL OBLIGATIONS. AS A MINIMUM, THE FOLLOWING REQUIREMENTS HAVE TO BE MET:

- Compliance to all legislative and regulatory frameworks
- Consultation with stakeholders to develop a closure plan that will be beneficial to economic, social and environmental spheres
- Development of closure action plans and adherence to conditions derived from stakeholder consultations
- Implementation of the closure plan should reflect sound financial resources to achieve the closure solutions defined
- Relinquishment and post-closure monitoring

The Namibian Mine Closure Framework merely provides guidance, and should be read together with all other relevant Namibian legislative requirements. Ultimately, closure planning should not only reflect compliance, but promote sustainable solutions for after the operational phase. Premature mine closure can be caused as a result of changing market conditions, or force de majeure; therefore, precautionary planning should be made during the operational phase.

REFERENCES

U.S. Environmental Protection Agency. (1994). *Design and evaluation of tailings dams* . Washington : BiTech Publishers Ltd. .

Abbaspour, H., Dredenstedt, C., Badroddin, M., & Maghaminik, A. (2018). *Optimized design of drilling and blasting*
operations in open pit minesunder technical and economic uncertainties by system dynamic-modelling. International
Journal of Mining Science and Technology, 28, 839-848. Retrieved January 21, 2019, from https://reader.elsevier.com
/reader/sd/pii/S2095268616302695?token=87C086C60F643E2249C631F-24C068F1FD411B1F45F503F5BF1B0B22
BF8ABEFD2E25F1EFE7BDC9E7E28B9D91DF85F1B13

Airshed. (2019). *Advanced air quality management for the strategic environmental management plan for the uranium and other industried in Erongo Region*. Ministry of Mines and Energy. Ministry of Mines and Energy.

Amira International Limited. (2016, September 14). *slideshare* . Retrieved from Waste generation: reduce, reuse and recycle and the role of collaboration : https://www.slideshare.net/R3Mineral/waste-generation-reduce-reuse-recycle
-and-the-role-of-collaboration

AZO Mining. (2014, April 24). *AZO Mining*. Retrieved January 21, 2019, from Development Drilling - Mining Fundamentals: https://www.azomining.com/Article.aspx?ArticleID=1157

Condorchem envitech. (2012, March 19). *Smart ideas for wastewater & air treatment*. Retrieved from Wastewater Treatment and Zero Liquid Discharge in Mining: https://blog-en.condorchem.com/wastewater-treatment-in-mining-industry/#.WzyBtdIza00

Department of Resources, Energy and Tourism . (2011). *A Guide To Leading Practice Sustainable Development in Mining*. Canberra .

Fraser institute . (2012). *How is water managed and treated in mining?* Retrieved from miningfacts.org: http://www.miningfacts.org/Environment/How-is-water-managed-and-treated-in-mining/

Hudson, T. L., Fox, F. D., & Plumlee, G. S. (1999). *Metal Mining and the Environment*. Virginia: American Geological Institute.
INAP: the international network for acid prevention . (n.d.). GARD guide .

International Council on Mining & Metals. (2012). *Good Practice Guidance for Mining and Biodiversity*.
International Council on Mining and Metals . (n.d.). Community Development Toolkit .

Mansfeld, C. (2006). *Environmental Impacts of Prospecting and Mining in Namibian National Parks: Implications for Legislative Compliance*. University of Stellenbosch, Department of Geography and Environmental Studies. South Africa: University of Stellenbosch.

New Pacific Metals Corp. (2018, March). *Types of Mineral Exploration* . Retrieved from New Pacific Metals Corp.: https://newpacificmetals.com/mining-101/types-of-mineral-exploration

Quinn, G. P., & Keough, M. J. (2002). *Experimental Design and Data Analysis for Biologist.* New York: Cambridge University Press. Retrieved January 21, 2019, from https://www2.ib.unicamp.br/profs/fsantos/apostilas/Quinn%20&%20Keough.pdf

Risk-Based Solutions (RBS). (2018). *Draft Environmental Social Impact Assessment (ESIA) and Environmental Social Management Plan (ESMP)*. Walvis Basin, North-central Namibia: Tullow Namibia Limited. Retrieved June 08, 2018, from http://www.rbs.com.na/tullow-namibia-cormorant-1-Well-Draft-ESIA-and-ESMP-Report-24-March-2018.pdf

SCIELO. (2014, July). *Techniques to correct and prevent acid mine drainage: A review*. Retrieved from SCIELO: http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0012-73532014000400009

The RAND Corporation. (2001). *New Forces at Work in Mining: Industry Views of Critical Technologies*. The RAND Corporation. Retrieved January 21, 2019, from https://www.rand.org/content/dam/rand/pubs/monograph_reports/MR1324/MR1324.ch3.pdf

Toovey, L. (2011, October 24). *The Life Cycle of a Gold Mine: Operating the Mine*. Retrieved July 02, 2018, from Investing News Network: https://investingnews.com/daily/resource-investing/precious-metals-investing/gold-investing/the-life-cycle-of-a-gold-mine-operating-the-mine/

United Nations. (2000). *United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to the General Assembly*. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). New York: United Nations.

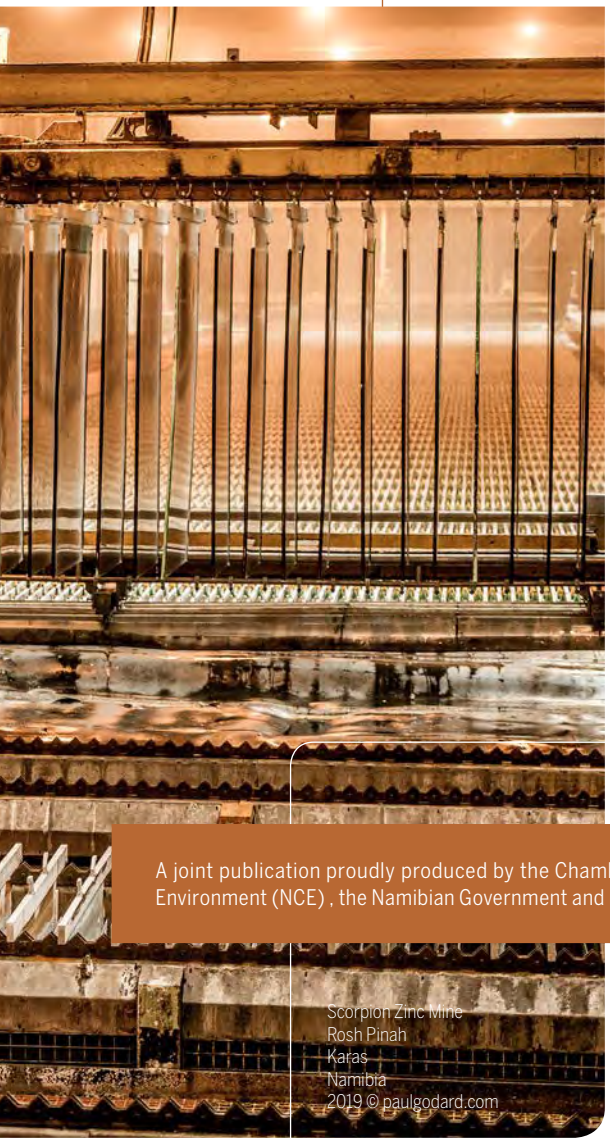
World Health Organization. (2017). *Evolution of WHO air quality guidlines: Past present and future*. UN City: World Health Organization. Retrieved November 08, 2018, from http://www.euro.who.int/__data/assets/pdf_file/0019/331660/Evolution-air-quality.pdf

Husab mine - Swakop Uranium
Swakopmund
Erongo
Namibia
2019 © paulgodard.com

ISBN: 978-99916-967-8-2

TU
RI
PAM
WE

Communication Design for Sustainability
www.turipamwe.com



Scorpion Zinc Mine
Rosh Pinah
Karas
Namibia
2019 © paulgodard.com

Chamber of Mines
OF NAMIBIA

NCE
Namibian Chamber of Environment

Ministry of Mines & Energy

Republic of Namibia
Ministry of Environment & Tourism

A joint publication proudly produced by the Chamber of Mines (CoM), Namibian Chamber of Environment (NCE) , the Namibian Government and members of the Namibian mining industry.

ECC
ENVIRONMENTAL
COMPLIANCE CONSULTANCY

Authors of this publication
Contact details:
+264 81 669 7608
info@eccenvironmental.com
www.eccenvironmental.com