Air Quality Baseline Assessment for the Osino Gold Mine Project near Karibib in Namibia

Project done for **Environmental Compliance Consultancy (ECC)**

Project Compiled by:
Hanlie Liebenberg-Enslin

Report No: 20ECC02 | **Date:** August 2021

Address: 480 Smuts Drive, Halfway Gardens | Postal: P O Box 5260, Halfway House, 1685
Tel: +27 (0)11 805 1940 | Fax: +27 (0)11 805 7010
www.airshed.co.za

Report Details

Report Title	Air Quality Baseline Assessment for the Osino Gold Mine Project near Karibib in Namibia
Applicant	Deep Yellow Limited
Client	Environmental Compliance Consultancy (ECC)
Report Number	20ECC02
Report Version	Rev 1
Date	August 2021
Prepared by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg)
Assisted by	Rochelle Bornman MPhil. GIS and Remote Sensing (Cambridge)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighbourhood concerns to regional air pollution impacts as well as noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.
Copyright Warning	Unless otherwise noted, the copyright in all text and other matter (including the manner of presentation) is the exclusive property of Airshed Planning Professionals (Pty) Ltd. It is a criminal offence to reproduce and/or use, without written consent, any matter, technical procedure and/or technique contained in this document.

Revision Record

Version	**Date**	**Report Status**	**Summary Description of Revision(s)**
Rev 0	6 August 2021	Draft report	Submitted to client for review
Rev 1	18 August 2021	Final report	Updated mine layout

Abbreviations

ADMS	Air Dispersion Modelling System
AQG	Air Quality Guidelines
AQMP	Air Quality Management Plan
AQSRs	Air Quality Sensitive
ASTM	American Society for Testing and Materials standard method
CO	carbon monoxide
CO_2	carbon dioxide
EAADT	estimated annual average daily traffic
EC	European Community
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EQOs	Environmental Quality Objectives
FEL	front-end-loaders
GHG	greenhouse gas
GIIP	Good International Industry Practice
IFC	International Finance Corporation
IT	interim target
mamsl	mean sea level
NAAQS	National Ambient Air Quality Standards
NDCR	National Dust Control Regulations
NOx	oxides of nitrogen
NPI	Australian National Pollutant Inventory
PM	Particulate Matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 2.5 µm (thoracic particles)
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 10 µm (respirable particles)
PSD	particle size distribution
RA	Roads Authority
ROM	Run-of-Mine
SA	South African
SEA	Strategic Environmental Assessment
SEMP	Strategic Environmental Management Plan
SO_2	sulfur dioxide
TOC	Total Organic Compounds
TSF	tailings storage facility
TSP	Total Suspended Particulates
UK	United Kingdom
US	United States
VKT/day	vehicle kilometres travelled per day
VOCs	Volatile Organic Compounds
WBG	World Bank Group
WHO	World Health Organisation
WRDs	waste rock dumps

Units

°C	Degree Celsius
Gg CO_2-eq	Greenhouse gas carbon dioxide equivalent
K	Kelvin
km	kilometre
kPa	kilo pascal
m	metres
mm	millimetre
mg/m²/day	milligram per metre squared per day
t	ton
tpa	tons per annum
tpm	tons per month
µg/m³	microgram per cubic metre
%	percent

Glossary

Air pollution: means any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinders, solid particles of any kind, gases, fumes, aerosols and odorous substances.

Atmospheric emission: means any emission or entrainment process emanating from a point, non-point or mobile sources that result in air pollution.

Averaging period: This implies a period of time over which an average value is determined.

Dust: Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size.

Frequency of Exceedance: A frequency (number/time) related to a limit value representing the tolerated exceedance of that limit value, i.e. if exceedances of limit value are within the tolerances, then there is still compliance with the standard.

Particulate Matter (PM): These comprise a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. The former is called Total Suspended Particulates (TSP), whilst PM_{10} and $PM_{2.5}$ fall in the finer fraction referred to as Inhalable particulate matter.

TSP: Total suspended particulates refer to all airborne particles and may have particle sizes as large as 150 µm, depending on the ability of the air to carry such particles. Generally, suspended particles larger than 75 to 100 micrometre (µm) do not travel far and deposit close to the source of emission.

PM_{10}: Thoracic particulate matter is that fraction of inhalable coarse particulate matter that can penetrate the head airways and enter the airways of the lung. PM_{10} consists of particles with a mean aerodynamic diameter of 10 µm or smaller, and deposit efficiently along the airways. Particles larger than a mean size of 10 µm are generally not inhalable into the lungs. These PM_{10} particles are typically found near roadways and dusty industries.

$PM_{2.5}$: Respirable particulate fraction is that fraction of inhaled airborne particles that can penetrate beyond the terminal bronchioles into the gas-exchange region of the lungs. Also known as fine particulate matter, it consists of particles with a mean aerodynamic diameter equal to or less than 2.5 µm ($PM_{2.5}$) that can be inhaled deeply into the lungs. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

Point sources: are discrete, stationary, identifiable sources of emissions that release pollutants to the atmosphere (International Finance Corporation (IFC), 2007).

Vehicle entrainment: This is the lifting and dropping of particles by the rolling wheels leaving the road surface exposed to strong air current in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

Table of Contents

List of Tables

List of Figures

1 INTRODUCTION

Osino Resources Corp (Osino) plans to develop a new gold mine, called the Twin Hills Gold Project (the Project), outside of Karibib in the Erongo Region of Namibia. The Exclusive Prospecting Licence (EPL) for the Project covers an area of 6 577 km² and falls within the central and northern zones of Namibia's prospective Damara gold belt.

An air quality assessment is required as part of the Environmental Impact Assessment (EIA) for the Project, and this study covers the first phase (baseline) as part of the EIA. Airshed Planning Professionals (Pty) Ltd was appointed by Environmental Compliance Consultancy (ECC) to undertake an air quality baseline assessment for the proposed Osino Project. The aim of the investigation is to assess the current air quality within the vicinity of the proposed mine. To achieve this, a good understanding of the regional climate and local dispersion potential of the site is necessary and subsequently an understanding of existing sources of air pollution in the region and the resulting air quality.

The investigation followed the methodology required for a specialist baseline report.

1.1 Terms of Work

The baseline assessment includes a study of the receiving environment by referring to:

- A study of legal requirements pertaining to air quality – applicable international legal guidelines and limits and dust control regulations.
- Desktop review of all available project and associated data, including meteorological data, previous air quality assessments, EIAs and technical air quality data and modelled results.
- A study of atmospheric dispersion potential by referring to available on-site weather records for a period of at least one year (required for dispersion modelling), land use and topography data.
    - Details on the physical environment i.e. meteorology (atmospheric dispersion potential), land use and topography.
    - Identification of existing air pollution sources (other mines; industries; commercial operations, etc.).
    - Identification of air quality-sensitive receptors (AQSRs), including any nearby residential dwellings and proposed receptors (temporary or permanent workers accommodation site(s)) in the vicinity of the mine.
    - Any freely available ambient air quality data, specifically Particulate Matter (PM).
- Compilation of a baseline report, including:
    - summary and analysis of all available data (measured and modelled),
    - commentary on prevailing air pollution sources affecting the location,
    - summary of meteorological conditions (notably wind direction and speed, cloud cover, temperature, humidity, etc), and
    - results in tables and graphs compared to international ambient air quality guidelines and limits.

1.2 Project Description

The proposed mine will comprise of opencast mining operations, a processing plant, and a waste facility. Conventional mining methods such as drilling, blasting and excavation are used at two open pit areas: Twin Hills & Bulge and Clouds. Ore and waste will be removed with haul trucks and taken to the Run of Mine (RoM) stockpile area and waste rock dumps (WRDs), respectively. Ore will be crushed at a primary crusher where after it will undergo secondary crushing and milling at the processing plant. The waste from the processing plant will be sent to the tailings storage facility (TSF), which will be a co-disposal of waste rock and tailings material. The mine layout plan is provided in Figure 1.

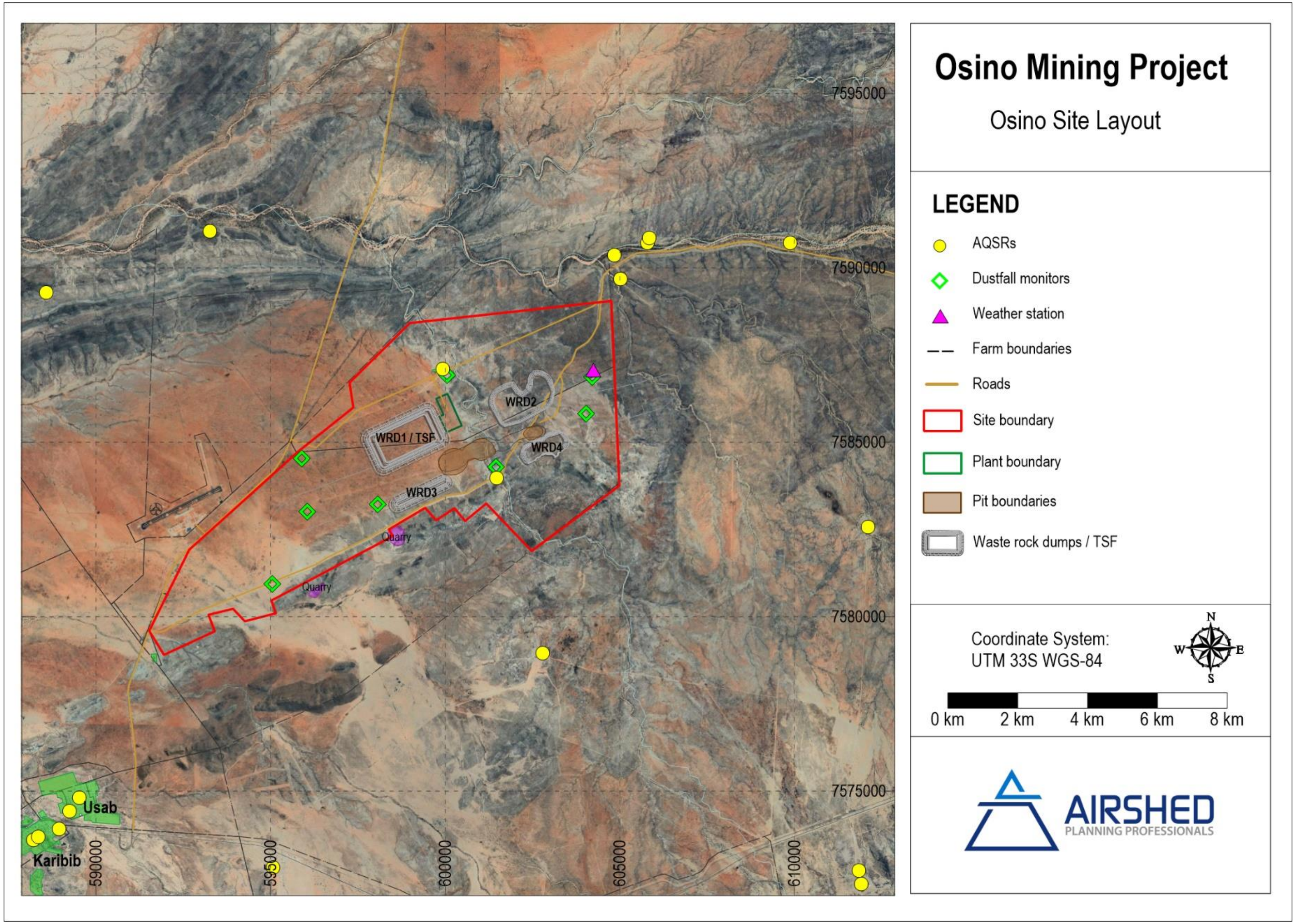

Figure 1: Osino Mine Project layout, monitoring network and identified air quality sensitive receptors

With the focus of this assessment on the baseline environment (pre-construction and pre-mining), the subsequent discussion is intended to provide an indication of the likely source activities associated with the different phases of the mine, and intended to guide planning around the monitoring network (i.e. which pollutants to focus on).

Air pollution associated with opencast mining activities include air emissions emitted during the construction-, operational-, closure- and post-closure phases.

The construction phase will include the establishment of required mining infrastructure and associated facilities such as workshops, maintenance areas, stores, wash bays, lay-down areas, batch plant, fuel handling and storage area, offices, change houses, etc. Activities that would result in air pollution during the construction phase are listed Table 1.

Table 1: Construction activities resulting in air pollution

Activity	Associated pollutants
Construction Phase	
Handling and storage area for construction materials (paints, solvents, oils, grease) and waste	particulate matter (PM)[(a)] and fumes (Volatile Organic Compounds [VOCs])
Power and water supply infrastructure	sulfur dioxide (SO_2); oxides of nitrogen (NOx); carbon monoxide (CO); carbon dioxide (CO_2)[(b)]; particulate matter (PM)
Drilling and blasting	SO_2; NOx; CO; PM, CO_2
Clearing and other earth moving activities	mostly PM, gaseous emissions from earth moving equipment (SO_2; NOx; CO; CO_2)
Stockpiling topsoil and sub-soil	mostly PM, gaseous emissions from front-end-loaders (FEL) (SO_2; NOx; CO; CO_2)
Foundation excavations	mostly PM, gaseous emissions from excavators (SO_2; NOx; CO; CO_2)
Opening and backfill of material (specific grade) from borrow pits	mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Establishing access roads (scraping and grading)	mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Digging of foundations and trenches	mostly PM, gaseous emissions from diggers (SO_2; NOx; CO; CO_2)
Delivery of materials – storage and handling of material such as sand, rock, cement, chemical additives, etc.	mostly PM, gaseous emissions from trucks (SO_2; NOx; CO; CO_2)
General building/construction activities including, amongst others: mixing of concrete; operation of construction vehicles and machinery; refuelling of machinery; civil, mechanical and electrical works; painting; grinding; welding; etc	mostly PM, gaseous emissions from construction vehicles and machinery (SO_2; NOx; CO; CO_2)

Notes: [(a)] Particulate matter (PM) comprises a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. Total Suspended Particulates (TSP) represents the coarse fraction >10μm, with particulate matter with an aerodynamic diameter of less than 10μm (PM_{10}) and particulate matter with an aerodynamic diameter of less than 2.5μm ($PM_{2.5}$) falling into the finer inhalable fraction. TSP is associated with dust fallout (nuisance dust) whereas PM_{10} and $PM_{2.5}$ are considered a health concern.

[(b)] CO_2 is a greenhouse gas (GHG).

The processing plant at the proposed Osino Project includes a number of processes (NPI, 2011(b)), which are illustrated in Figure 2 and described as follows:

- ***Comminution*** where the ore is reduced to fine particles through crushing and milling;
- ***Thickening*** reduces the water content of the concentrate slurry;
- ***Leaching (cyanidation)*** where the gold is separated from the waste stream by adding cyanide to the process slurry to promote the dissolution and complexing of the gold;
- ***Carbon-in-pulp (CIP)*** involves the removal of complex gold ions from solution by adsorption onto activated carbon – the Carbon Regeneration Kiln forms part of tis circuit (Figure 2);
- ***Elution*** is where the loaded carbon is washed in a hot water, caustic and cyanide solution to remove gold to the washing liquor;
- ***Electrowinning*** where an electric current is applied to the pregnant solution to precipitate gold onto steel wool cathodes;
- ***Roasting*** to convert any sulfides present to oxides (dissolution of sulfides is suppressed in the pre-aeration process prior to cyanidation); and
- ***Smelting*** where the crude gold is separated from the impurities (called slag) and the molten gold is poured into moulds.

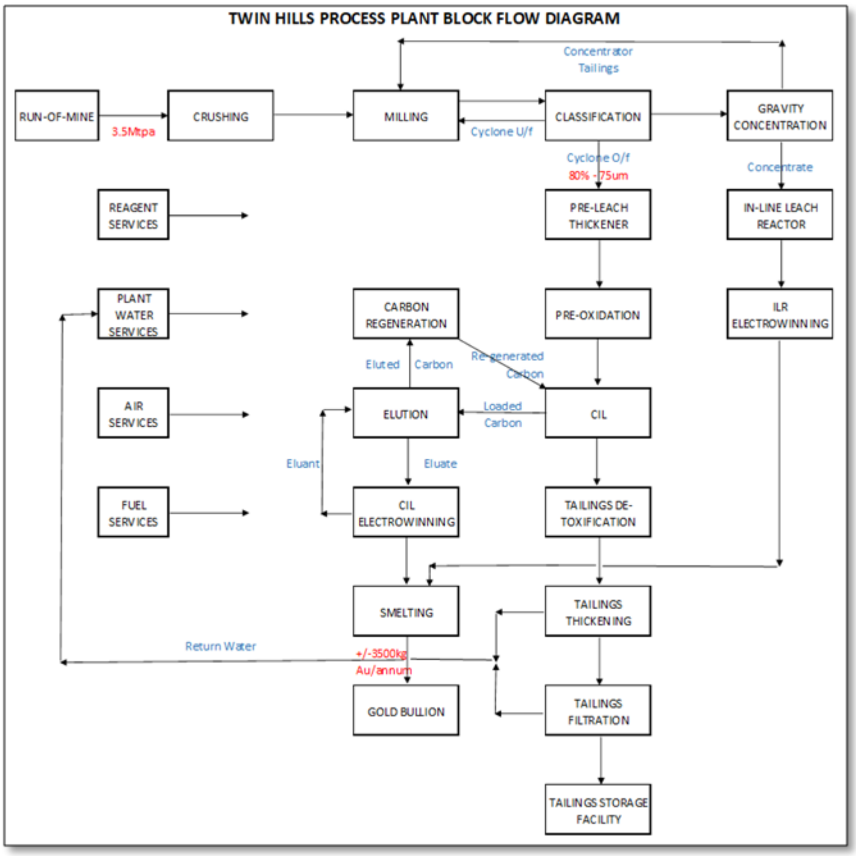

Figure 2: Twin Hills Process Plant Flowsheet sing plant (Moeller, 2021)

Support operations may include backup power generators, but this still needs to be confirmed.

Activities at Osino Gold Mine likely to result in pollutants to air are listed in Table 2.

Table 2: Operational activities resulting in air pollution

Activity		Associated pollutants
Operational Phase		
Open pit mining: drilling and blasting		PM, SO_2; NOx; CO; CO_2
Open pit: excavation of ore and waste rock		mostly PM, gaseous emissions from mining equipment (PM, SO_2; NOx; CO; CO_2)
Haulage of materials (ore and waste rock)		PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Waste rock dump(s) (WRDs)		PM from tipping and windblown dust, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
WRD/ TSF		PM from windblown dust
Processing of ore (crushing, screening, milling)		mostly PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2)
Processing Plant	comminution	PM, metals[(a)]
	leaching (cyanidation); elution; electrowinning	Acetone, ammonia (NH_3), carbon disulphide (CS_2), cyanide (HCN); hydrochloric acid (HCl); PM, Total Volatile Organic Compounds (TVOC)
	carbon regeneration kiln	CS_2, CO, HCN; HS, NOx, PM, SO_2
	roasting (diesel fuelled)	PM, metals[(a)(b)], NOx, SO_2, CO, TVOC, polycyclic aromatic hydrocarbons (PAH), toxic equivalent quantities (TEQ)
	smelting	PM, metals[(a)]; SO_2; SO_2, sulphuric acid (H_2SO_4), TVOC
Back-up diesel power generators		PM, metals[(a)(e)], NOx, SO_2, CO, TVOC, PAH, TEQ

Notes: [(a)] Metals include antimony, arsenic, beryllium, boron, cadmium, chromium(III), chromium(VI), cobalt, copper, fluoride, lead, manganese, mercury, nickel, selenium, zinc.

[(b)] All metals in [(b)] except antimony, boron, cobalt, fluoride, chromium(VI)Closure and post-closure activities typically include rehabilitation of the site infrastructure – demolition of infrastructure and vegetation of WRDs and WRD/TSF. These activities mainly result in PM emissions with gaseous emissions from equipment and trucks.

2 LEGAL OVERVIEW

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. Air quality guidelines and standards are based on benchmark concentrations that normally indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Benchmark concentrations could therefore be based on health effects, such as SO_2 or carcinogenic consequences, such as benzene.

Air quality guidelines and standards are normally given for specific averaging or exposure periods and are evaluated as the observed air concentration expressed as a fraction of a benchmark concentration. A standard, as opposed to a benchmark concentration only, is a set of instructions which include a limit value and may contain a set of conditions to meet this limit value. Standards are normally associated with a legal requirement as implemented by the country's relevant authority; however, organisations such as the World Bank Group (WBG) International Finance Corporation (IFC) and private companies also issue standards for internal compliance. The benchmark concentrations issued by the World Health Organisation (WHO), on the other hand, are not standards, but rather guidelines that may be considered for use as limit values in standards.

A common condition included in a standard is the allowable frequency of exceedances of the limit value. The frequency of exceedances recognises the potential for unexpected meteorological conditions coupled with emission variations that may result in outlier air concentrations and would normally be based on a percentile, typically the 99^{th} percentile.

Standards are normally issued for criteria pollutants, i.e. those most commonly emitted by industry including SO_2, NO_2, CO, PM_{10} and $PM_{2.5}$, but may also include secondary pollutants such as O_3. Some countries include other pollutants, specifically when these are considered to be problematic emissions.

In addition to ambient air quality standards or guidelines, emission limits aim to control the amount of pollution from a point source[1]. Emissions to air should be avoided or controlled according to Good International Industry Practice (GIIP) applicable to the specific industry sector (IFC, 2007).

Namibia does not have air quality guidelines or limits and reference is usually made to international ambient air quality guidelines and standards. The WHO is widely referenced, as well as countries in the region who have air quality standards. As part of the AQMP developed for the SEMP update, ambient guidelines for PM_{10} and $PM_{2.5}$ were determined to provide the necessary performance indicators for mines and industries within the Erongo Region. These guidelines are regarded applicable to the current study and discussed in one of the following sub sections.

2.1 Namibian Legislation

The Atmospheric Pollution Prevention Ordinance (No. 11 of 1976) deals with the following:

Part I	:	Appointment and powers of officers;
Part II	:	Control of noxious or offensive gases;
Part III	:	Atmospheric pollution by smoke;
Part IV	:	Dust control;
Part V	:	Pollution of the atmosphere by gases emitted by vehicles;
Part IV	:	General provisions; and
Schedule 2:		Scheduled processes.

[1] Point sources are discrete, stationary, identifiable sources of emissions that release pollutants to the atmosphere (IFC, 2007).

The Ordinance does not include any ambient air standards with which to comply, but opacity guidelines for smoke are provided under Part III. It is implied that the Director[2] provides air quality guidelines for consideration during the issuing of Registration Certificates, where Registration Certificates may be issued for "Scheduled Processes" which are processes resulting in noxious or offensive gases and typically pertain to point source emissions. To our knowledge no Registration Certificates have been issued in Namibia. However, an Environmental Clearance Certificate is required for any activity entailing a scheduled process as referred to in the Atmospheric Pollution Prevention Ordinance, 1976.

Also, the Ordinance defines a range of pollutants as noxious and offensive gases, but no ambient air quality guidelines or standards or emission limits are provided for Namibia.

Part II of the Ordinance pertains to the regulation of noxious or offensive gases. The Executive Committee may declare any area a *controlled area* for the purpose of this Ordinance by notice in the Official Gazette. Any scheduled process carried out in a *controlled area* must have a current registration certificate authorising that person to carry on that process in or on that premises.

The published Public and Environmental Health Act 1 of 2015 provides "a framework for a structured uniform public and environmental health system in Namibia; and to provide for incidental matters". The act identifies health nuisances, such as chimneys sending out smoke in quantities that can be offensive, injurious, or dangerous to health and liable to be dealt with.

2.1.1 Best Practice Guide for the Mining Sector in Namibia

A Best Practice Guide for the Mining Sector in Namibia was published in July 2020 (NCE, 2020). The document serves as a guiding framework during all mining phases to effectively assess aspects such as environmental and social impacts.

The report lists air quality as an environmental risk. It provides examples of sources and activities that would result in particulate and gaseous emissions and gives guidance on management and control of these source activities. Aspects relevant to the Osino Project can be summarised as follows:

- The benefits of the SEMP for industry are highlighted and the SEMP Environmental Quality Objectives (EQOs) require as a minimum management objective that "any change to the environment must be within acceptable limits, and that pro-active intervention will be triggered by the responsible party to avoid unwanted changes that breach a specific threshold." All mining companies within the region submit reports annually as part of the SEMP annual report which is available in the public domain.
- Section 3 provides requirements for Baseline Studies where air quality is listed as one of the most important aspects where background conditions of dust, gaseous and nuisance emissions and in some cases fumes and odours are required. Dust and gaseous emissions require immediate monitoring, as well as the establishment of a network of meteorological measuring points. Dust requires the monitoring of particulate matter (PM), in PM_{10}–format, but the monitoring program may require simultaneous measurement of TSP or $PM_{2.5}$ as well.
- Applicable ambient air quality guidelines are listed in Section 3 of the report. It states that Namibia does not have ambient air quality standards or guidelines and references the SEMP AQMP (Liebenberg-Enslin, et al., 2019) guidelines which were determined to provide the necessary performance indicators for the region. These are discussed in more detail under Section 2.4.
- Recommendations in Section 3 include: Dust Management Plans for all operational sites (mines, exploration sites and quarries); annual reporting of dust fall levels and PM_{10} concentrations to the authorities; dust suppression at

[2] *Director* means the Director of Health Services of the Administration, and, where applicable, includes any person who, in terms of any authority granted to him under section 2(2) or (3) of the Ordinance.

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.

- Section 4 indicates that once mines are operational, 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. All mines must, as a minimum requirement of an air quality management plan, manage dust.
- Requirements for air quality monitoring during the operational phase is provided under Section 4.3 and reference is made again to the SEMP guidelines as performance indicators for the region. All the uranium mines in Namibia are located in the Erongo Region and all these mines have extensive air quality monitoring programmes in place.
- Section 5 provides guidance on closure and maintenance where management and monitoring of erosion is one of the essential aspects.

2.2 International Criteria

Typically, when no local ambient air quality criteria exist, or are in the process of being developed, international criteria are referenced. This serves to provide an indication of the severity of the potential impacts from proposed activities. The most widely referenced international air quality criteria are those published by the WBG, the WHO, and the European Community (EC). The South African (SA) National Ambient Air Quality Standards (NAAQS) are also referenced since it is regarded representative indicators for Namibia due to the similar environmental and socio-economic characteristics between the two countries. The PM guidelines selected as part of the SEMP AQMP for the Erongo Region were based on these international guidelines and standards, and the following subsections provide the relevant background.

2.2.1 WHO Air Quality Guidelines

Air Quality Guidelines (AQGs) were published by the WHO in 1987 and revised in 1997. Since the completion of the second edition of the AQGs for Europe, which included new research from low-and middle-income countries where air pollution levels are at their highest, the WHO has undertaken to review the accumulated scientific evidence and to consider its implications for its AQGs. The result of this work is documented in *'Air Quality Guidelines – Global Update 2005'* in the form of revised guideline values for selected criteria air pollutants, which are applicable across all WHO regions (WHO, 2005).

Given that air pollution levels in developing countries frequently far exceed the recommended WHO AQGs, interim target (IT) levels were included in the update. These are in excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). There are two or three interim targets depending on the pollutant, starting at WHO interim target-1 (IT-1) as the most lenient and IT-2 or IT-3 as more stringent targets before reaching the AQGs. The SA NAAQS are, for instance, in line with IT-1 for SO_2 and IT-3 targets for PM_{10} and $PM_{2.5}$. It should be noted that the WHO permits a frequency of exceedance of 1% per year (4 days per year) for 24-hour average PM_{10} and $PM_{2.5}$ concentrations. In the absence of interim targets for NO_2, reference is made to the AQG value. These are provided in Table 3 for pollutants considered in this study.

2.2.2 SA National Ambient Air Quality Standards

NAAQSs for SA were determined based on international best practice for SO_2, NO_2, $PM_{2.5}$, PM_{10}, O_3, CO, Pb and benzene. These standards were published in the Government Gazette on 24 of December 2009 and included a margin of tolerance (i.e. frequency of exceedance) and with implementation timelines linked to it. SA NAAQSs for $PM_{2.5}$ were published on 29 July 2012. As mentioned previously, SA NAAQS closely follow WHO interim targets, which are targets for developing countries, for $PM_{2.5}$, PM_{10} and SO_2. The SA NAAQS for ambient NO_2 concentrations are equivalent to the WHO AQG. SA NAAQSs referred to in this study are also given in Table 3.

Table 3: International assessment criteria for criteria pollutants

Pollutant	Averaging Period	WHO Guideline Value (µg/m³)	South Africa NAAQS (µg/m³)
Sulfhur Dioxide (SO_2)	1-year	-	50
	24-hour	125 (IT1) 50 (IT2) (a) 20 (guideline)	125 (b)
	1-hour	-	350 (c)
	10-minute	500 (guideline)	500 (d)
Nitrogen Dioxide (NO_2)	1-year	40 (guideline)	40
	1-hour	200 (guideline)	200 (c)
Particulate Matter (PM_{10})	1-year	70 (IT1) 50 (IT2) 30 (IT3) 20 (guideline)	40 (e) (b)
	24-hour	150 (IT1) 100 (IT2) 75 (IT3) 50 (guideline)	75 (e)
Particulate Matter ($PM_{2.5}$)	1-year	35 (IT1) 25 (IT2) 15 (IT3) 10 (guideline)	25 (f) 20 (g) 15 (h)
	24-hour	75 (IT1) 50 (IT2) 37.5 (IT3) 25 (guideline)	65 (f) 40 (g) 25 (h)

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) 4 permissible frequencies of exceedance per year
(c) 88 permissible frequencies of exceedance per year
(d) 526 permissible frequencies of exceedance per year
(e) Applicable from 1 January 2015.
(f) Applicable immediately to 31 December 2015.
(g) Applicable 1 January 2016 to 31 December 2029.
(h) Applicable 1 January 2030.

2.2.3 Dustfall Limits

Air quality standards are not defined by all countries for dust deposition, although some countries may make reference to annual average dust fall thresholds above which a 'loss of amenity' may occur. In the southern African context, widespread dust deposition impacts occur as a result of windblown dust from mine tailings and natural sources, from mining operations and other fugitive dust sources.

South Africa has published the National Dust Control Regulations (NDCR) on the 1st of November 2013 (Government Gazette No. 36974). The purpose of the regulations is to prescribe general measures for the control of dust in all areas including residential and light commercial areas. Similarly, Botswana published dust deposition evaluation criteria (BOS 498:2013). According to these limits, an enterprise may submit a request to the authorities to operate within the Band 3 (action band) for a limited period, providing that this is essential in terms of the practical operation of the enterprise (for example the final removal of a tailings deposit) and provided that the best available control technology is applied for the duration. No margin of tolerance will be granted for operations that result in dustfall rates in the Band 4 (alert band). This four-band scale is presented in Table 4.

Table 4: Bands of dustfall rates

Band Number	Band Description	30 Day Average Dustfall Rate (mg/m^2-day)	Comment
1	Residential	Dustfall rate < 600	Permissible for residential and light commercial
2	Industrial	600 < Dustfall rate < 1 200	Permissible for heavy commercial and industrial
3	Action	1 200 < Dustfall rate < 2 400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	Alert	2 400 < Dustfall rate	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

2.3 International Conventions

The technical reference documents published in the IFC Environmental, Health and Safety (EHS) Guidelines provide general and industry specific examples of Good International Industry Practice (GIIP). The General EHS Guidelines are designed to be used together with the relevant Industry Sector EHS Guidelines (IFC, 2007).

The IFC EHS Guidelines provide a general approach to air quality management for a facility, including the following:

- Identifying possible risks and hazards associated with the project as early on as possible and understanding the magnitude of the risks, based on:
  - the nature of the project activities; and,
  - the potential consequences to workers, communities, or the environment if these hazards are not adequately managed or controlled.
- Preparing project- or activity-specific plans and procedures incorporating technical recommendations relevant to the project or facility;
- Prioritising the risk management strategies with the objective of achieving an overall reduction of risk to human health and the environment, focusing on the prevention of irreversible and / or significant impacts;
- When impact avoidance is not feasible, implementing engineering and management controls to reduce or minimise the possibility and magnitude of undesired consequence; and,

- Continuously improving performance through a combination of ongoing monitoring of facility performance and effective accountability.

Significant impacts to air quality should be prevented or minimised by ensuring that:

- Emissions to air do not result in pollutant concentrations exceeding the relevant ambient air quality guidelines or standards. These guidelines or standards can be national guidelines or standards or in their absence WHO AQGs or any other international recognised sources.
- Emissions do not contribute significantly to the relevant ambient air quality guidelines or standards. It is recommended that 25% of the applicable air quality standards are allowed to enable future development in a given airshed. Thus, any new development should not result in ground level concentrations exceeding 25% of the guideline value.
- The EHS recognises the use of dispersion models to assess potential ground level concentrations. The models used should be internationally recognised or comparable.

2.3.1 Degraded Airsheds or Ecological Sensitive Areas

The IFC provides further guidance on projects located in degraded airsheds (IFC, 2007), i.e. areas where the national/ WHO/ other recognised international Air Quality Guidelines are significantly exceeded or where the project is located next to areas regarded as ecological sensitive such as national parks. The Osino Project is not located in an ecologically sensitive area, and the airshed is not regarded to be degraded.

2.3.2 Fugitive Source Emissions

According to the IFC (IFC, 2007), fugitive source emissions refer to emissions that are distributed spatially over a wide area and confined to a specific discharge point. These sources have the potential to result in more significant ground level impacts per unit release than point sources. It is therefore necessary to assess this through ambient quality assessment and monitoring practices.

2.4 Recommended Guidelines and Objectives

The IFC references the WHO guidelines but indicates that any other internationally recognized criteria can be used such as the United States (US) Environmental Protection agency (EPA) or the EC. It was, however, found that merely adopting the WHO guidelines would result in exceedances of these guidelines in many areas due to the arid environment in the country, and specifically in Namibia. The WHO states that these AQG and interim targets should be used to guide standard-setting processes and should aim to achieve the lowest concentrations possible in the context of local constraints, capabilities, and public health priorities. These guidelines are also aimed at urban environments within developed countries (WHO, 2005). For this reason, the South African NAAQS are also referenced since these were developed after a thorough review of all international criteria and selected based on the socio, economic and ecological conditions of the country.

In the absence of guidelines on ambient air concentrations for Namibia, reference is made to the Air Quality Objectives (AQO) recommended as part of the SEMP AQMP (Liebenberg-Enslin, et al., 2019). These objectives are based on the WHO interim targets and SA NAAQSs (Table 5). The criteria were selected on the following basis:

- The WHO IT3 was selected for particulates since these limits are in line with the SA NAAQSs, and the latter are regarded feasible limits for the arid environment of Namibia.
- Even though $PM_{2.5}$ emissions are mainly associated with combustion sources and mainly a concern in urban environments, it is regarded good practice to include as health screening criteria given the acute adverse health

effects associated with this fine fraction. Also, studies found that desert dust with an aerodynamic diameter 2.5 µm cause premature mortality.

- For SO_2, there is no IT3, and the IT2 was selected since the WHO states: “This would be a reasonable and feasible goal for some developing countries (it could be achieved within a few years) which would lead to significant health improvements that, in turn, would justify further improvements (such as aiming for the AQG value)”.
- The WHO provides no interim targets for NOx. The AQGs are in line with the SA NAAQSs and therefore regarded as achievable limits.
- The Botswana and South African criteria for dust fallout are the same and with limited international criteria for dust fallout, these were regarded applicable.

The proposed evaluation criteria as set out in Table 5 are intended to be used as indicators during the baseline monitoring.

Table 5: Proposed evaluation criteria for the Osino Project

Pollutant	Averaging Period	Criteria	Reference
NO_2	1-hour average (µg/m³)	200[a]	WHO AQG & EC & SA NAAQS
	Annual average (µg/m³)	40	WHO AQG & EC & SA NAAQS
SO_2	1-hour average (µg/m³)	350[a]	EC Limit & SA NAAQS (no WHO guideline)
	24-hour average (µg/m³)	50[b]	WHO IT2 (seen as a per 40% of the SA and EC limits)
	Annual average (µg/m³)	50	SA NAAQS (no WHO guideline)
Particulate matter (PM_{10})	24-hour average (µg/m³)	75[b]	WHO IT3 & SA NAAQS (as per SEMP AQMP)
	Annual average (µg/m³)	40	SA NAAQS (as per SEMP AQMP)
Particulate matter ($PM_{2.5}$)	24-hour average (µg/m³)	37.5[b]	WHO IT3 (as per SEMP AQMP)
	Annual average (µg/m³)	15	WHO IT3 & SA NAAQS (as per SEMP AQMP)
Dustfall	30-day average (mg/m²/day)	600[c]	SA NDCR & Botswana residential limit
		1 200[c]	SA NDCR & Botswana industrial limit
		2 400	Botswana Alert Threshold

Notes: [a] Not to be exceeded more than 88 hours per year (SA)
[b] Not to be exceeded more than 4 times per year (SA)
[c] Not to be exceeded more than 3 times per year or 2 consecutive months

3 DESCRIPTION OF THE BASELINE ENVIRONMENT

3.1 Site Description

The proposed Osino Gold Mine Project is located just outside of Karibib (approximately 5 km), in the eastern part of the Erongo Region of Namibia. This region is characterised by low rainfall, extreme temperature ranges and unique climatic factors influencing the natural environment and biodiversity (Goudie, 2009). Episodic dust storms associated with strong easterly winds occur during the autumn and winter months, giving rise to dust emissions from natural and anthropogenic sources under conditions of high wind speeds (Ministry of Mines and Energy, 2010).

The Project covers an area with dimensions of about 25 km northeast-southwest and 11 km north-south. The terrain is hilly, with a ridge to the north and northwest, and a ridge on the southern side. The topography of the Project site is shown in Figure 3.

Air Quality Sensitive (AQSRs) primarily relate to where people reside. There are no villages or homesteads near the project, with the closest settlement – farmhouses – directly to the south of Twin Hills pit, and one at the proposed Processing Plant (this one is assumed to be relocated). The town of Karibib (and Usab suburb) is located about 3.5 km to the southwest from the site boundary. Other settlements in the vicinity include scattered homesteads to the north of the mine boundary, along the Khan River. All identified AQSRs are shown in Figure 1 providing the spatial context for the closest AQSRs. These will be included as sensitive receptors during the air quality impact assessment.

Main (national) roads in close proximity to the Osino Project are the B2 to the south of the project and the C33 to the west.

3.2 Atmospheric Dispersion Potential

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field.

A description of the wind field, temperature, precipitation, and atmospheric stability is provided in the following section. Osino operates a weather station on-site (21°49'2.17"S; 16°0'30.89"E) recording wind speed (km/hr), wind direction (degrees), temperature (°C), humidity (%), barometric pressure (Pa) and rainfall (mm). Weather data is available since 23 July 2020, when the station was installed. Data availability for the period is provided in Table 6.

Table 6: Data availability of meteorological parameters measured at the Osino Weather Station

Data Period	Wind Speed (m/s)	Wind Direction (deg)	Temperature (°C)	Humidity (%)	Barometric Pressure (Pa)
23 Jul 2020 – 22 Jul 2021	99%	99%	100%	100%	100%

Note: Data availability was assessed based on the period data was recorded for.

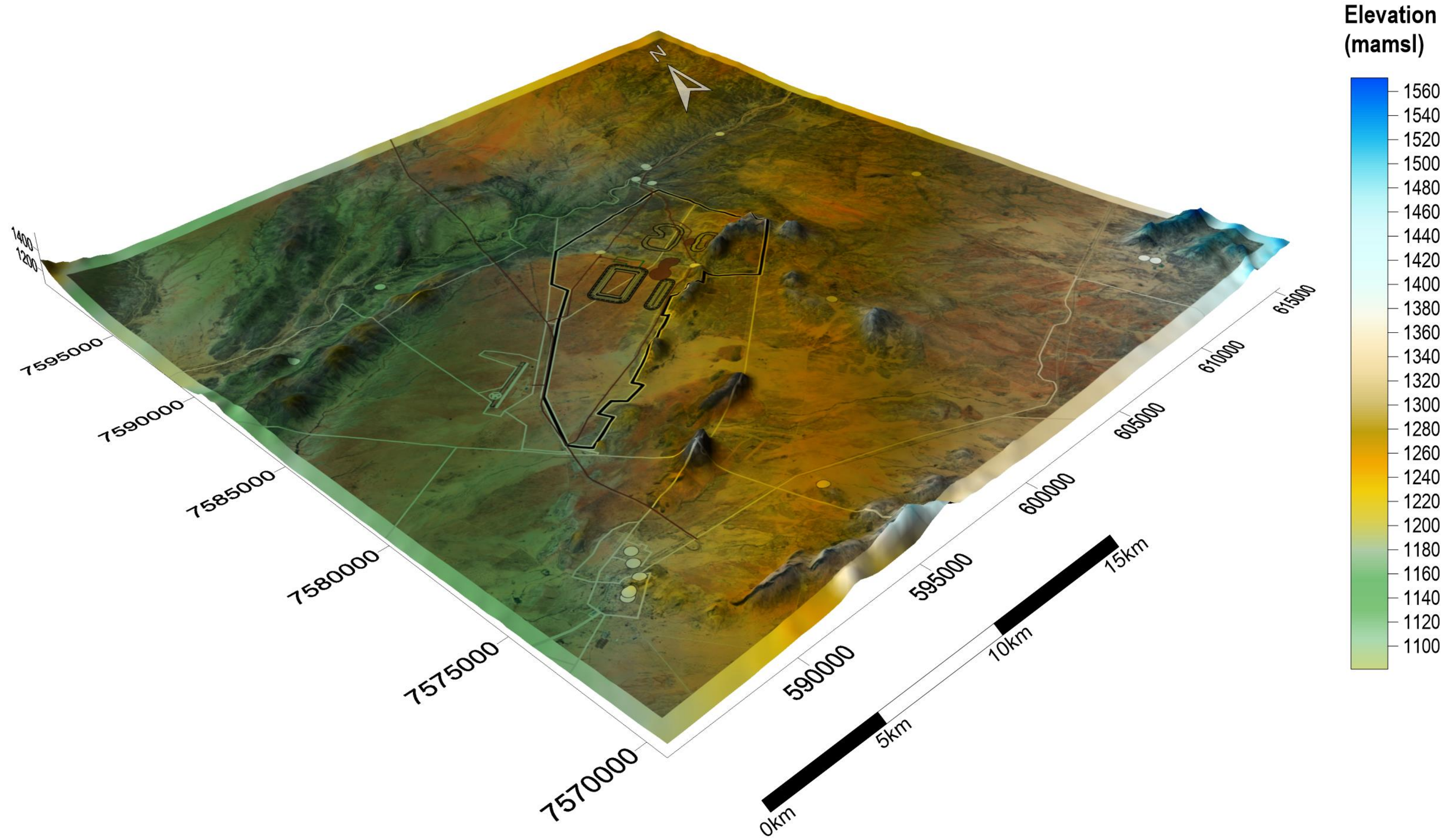

Figure 3: Topography of the proposed Osino Gold Mine Project

3.2.1 Surface Wind Field

The wind direction, and the variability in wind direction, determines the general path that air pollutants will follow, and the extent of crosswind spreading. Wind roses comprise 16 spokes, which represent the directions from which winds blew during the period. The colours used in the wind roses below, reflect the different categories of wind speeds; the red area, for example, representing winds between higher than 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred refers to periods during which the wind speed was below 1 m/s.

Period, daytime and night-time wind roses for the study area, based on the Osino meteorological data for 12-month period: 23 Jul 2020 to 22 Jul 2021 are depicted in Figure 4, with monthly wind roses for the same period shown in Figure 5.

The wind field is dominated by winds from the southwest and the east to south-east, with the strongest winds from the southwest. Calm conditions prevailed 7.5% of the time with a period average wind speed of 2.3 m/s. During the day, easterly winds prevailed with strong but less frequent winds from the southwest, and calm conditions for 3.7%. At night, the wind field shifted to more frequent south-westerly winds with winds at lower wind speeds less frequently from the east to southeast (Figure 4). The highest winds speed recoded during the 23 Jul 2020 to 22 Jul 2021 period was 8.9 m/s.

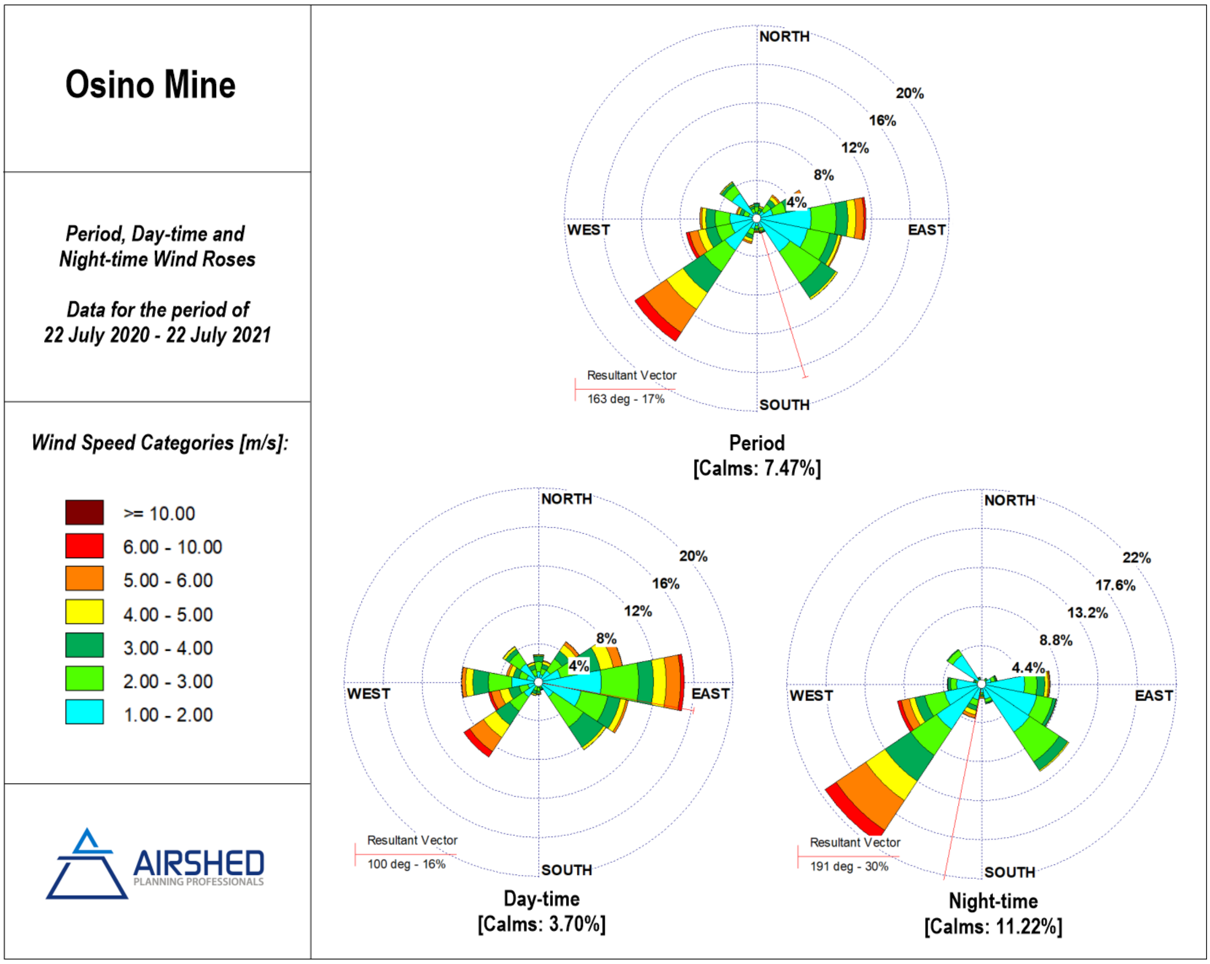

Figure 4: Period, day- and night-time wind roses based on Osino on-site weather data (22 July 2020 – 22 July 2021)

Monthly variation in the wind field is shown in Figure 5. During the summer months November to February, the south-westerly winds dominate with infrequent weak winds from the east. In March the wind field changes to dominant easterly winds and less frequent south-westerly winds. During April the wind field shifts slightly to the southeast, but with strong, although less frequent easterly winds are associated with the so called "East wind conditions". The south-easterly winds prevail during the months of May to July. In August winds from the northwest dominates followed by strong easterly winds, whereafter the wind field shifts to strong south-westerly winds and frequent, but weaker, easterly winds in September.

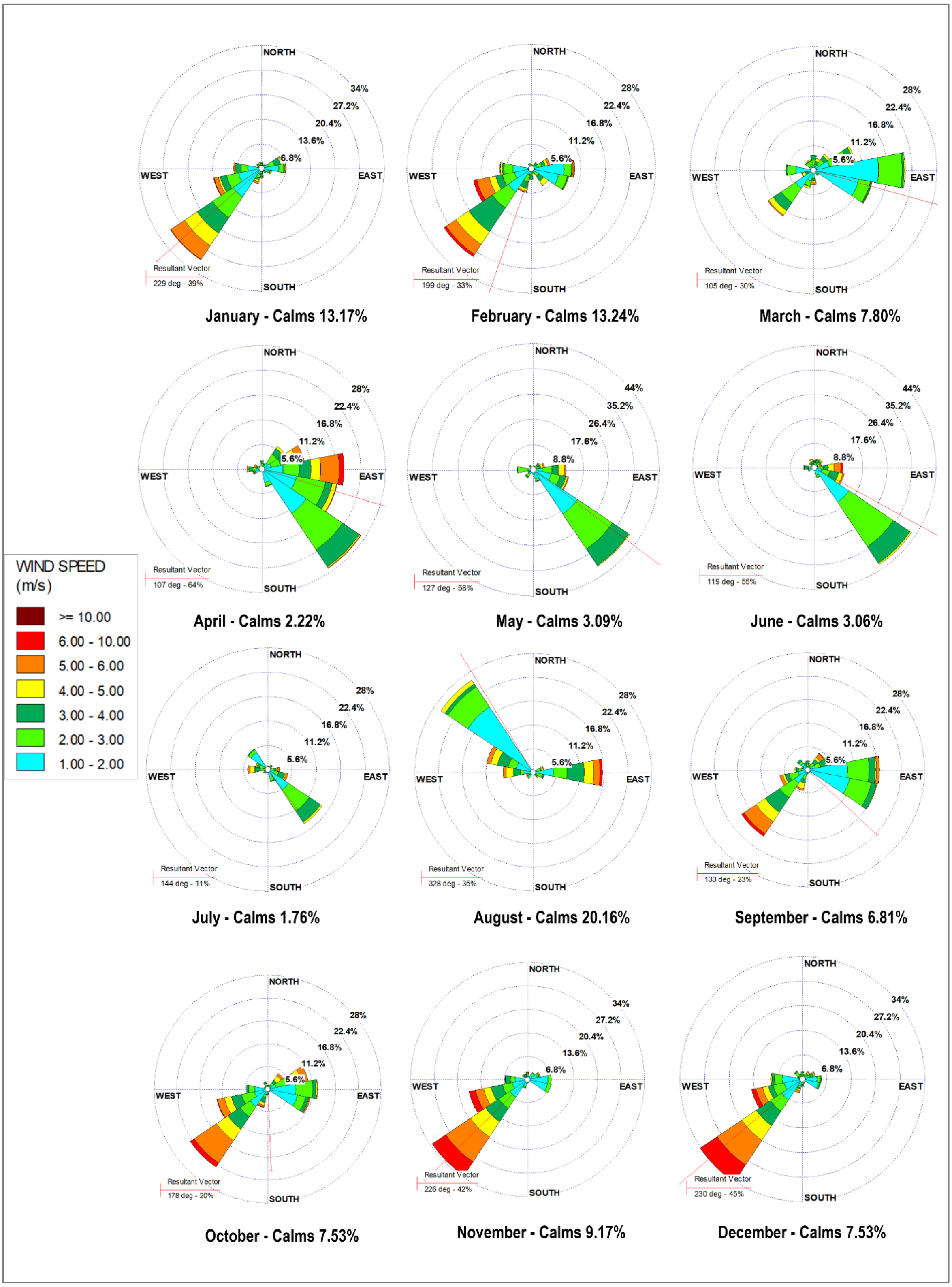

Figure 5: Monthly wind roses based on Osino on-site weather data (22 July 2020 – 22 July 2021)

According to the Beaufort wind force scale (https://www.metoffice.gov.uk/guide/weather/marine/beaufort-scale), wind speeds between 6-8 m/s equate to a moderate breeze, with wind speeds between 14-17 m/s near gale force winds. Based on the available data for the period Jul 2020 – Jul 2021, wind speeds fell mostly in the 1-2 m/s category with winds exceeding 8 m/s only for 0.05% (Figure 6). Winds exceeding 5 m/s occurred for 7.5% of the time, with a maximum wind speed of 8.9 m/s. The average wind speed over the period was 2.3 m/s. Calm conditions (wind speeds <1 m/s) occurred for 7.5% of the time (Figure 6). The likelihood for wind erosion to occur from open and exposed surfaces, with loose fine material, but taking into account that the natural surfaces are crusted, was estimated when the wind speed exceeds 10 m/s (Liebenberg-Enslin, et al., 2019), whereas the estimated wind speed threshold for gold tailings is 8.8 m/s (Liebenberg-Enslin, 2014). Wind speeds exceeding 10 m/s occurred for 0% over the period, and 0.01% of the time above 8.8 m/s.

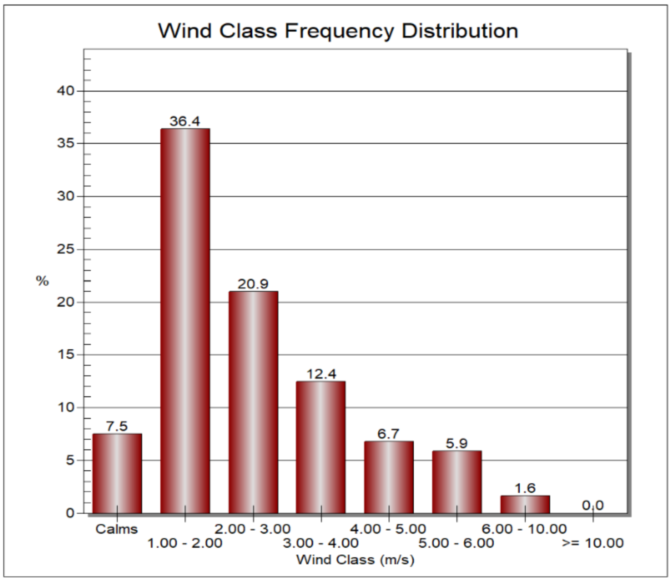

Figure 6: Wind speed categories based Osino meteorological data (Jul 2020 – Jul 2021)

3.2.2 Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume can rise), and determining the development of the mixing and inversion layers.

Minimum, average, and maximum temperatures for the study area are given as -3°C, 23°C and 42°C respectively, based on Osino weather data for the period Jul 2020 – Jul 2021 (Figure 7).

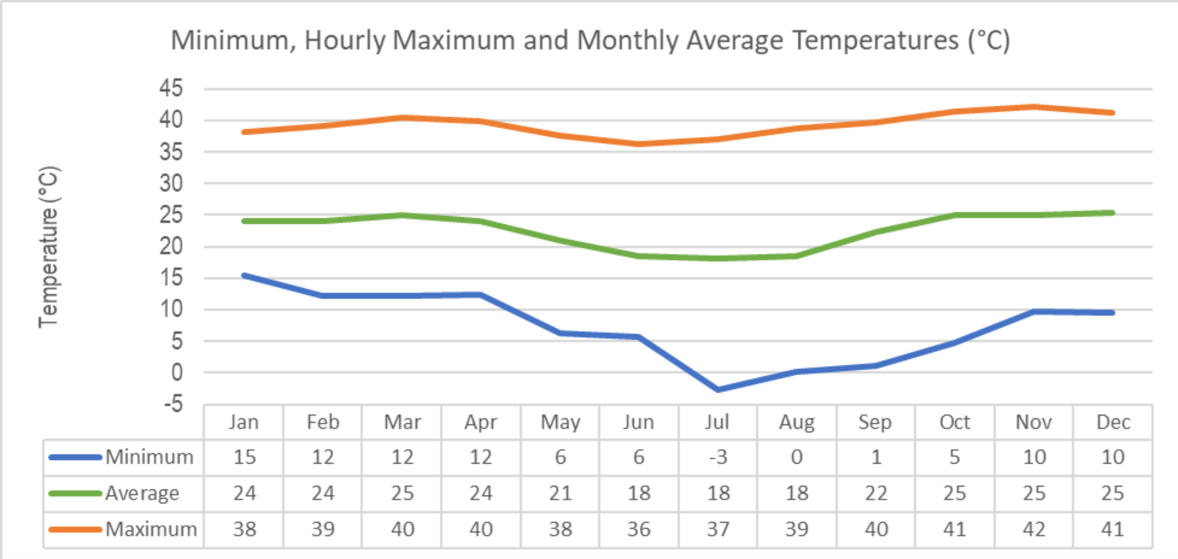

Figure 7: Daily minimum, average, and maximum temperatures based on Osino meteorological data (Jul 2020 – Jul 2021)

3.2.3 Precipitation

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation potentials. Monthly average rainfall figures obtained from the Osino weather station data are illustrated in Figure 8. Annual rainfall for July 2020 to June 2021 is 254 mm, with the highest rainfall of 115 mm in January 2021.

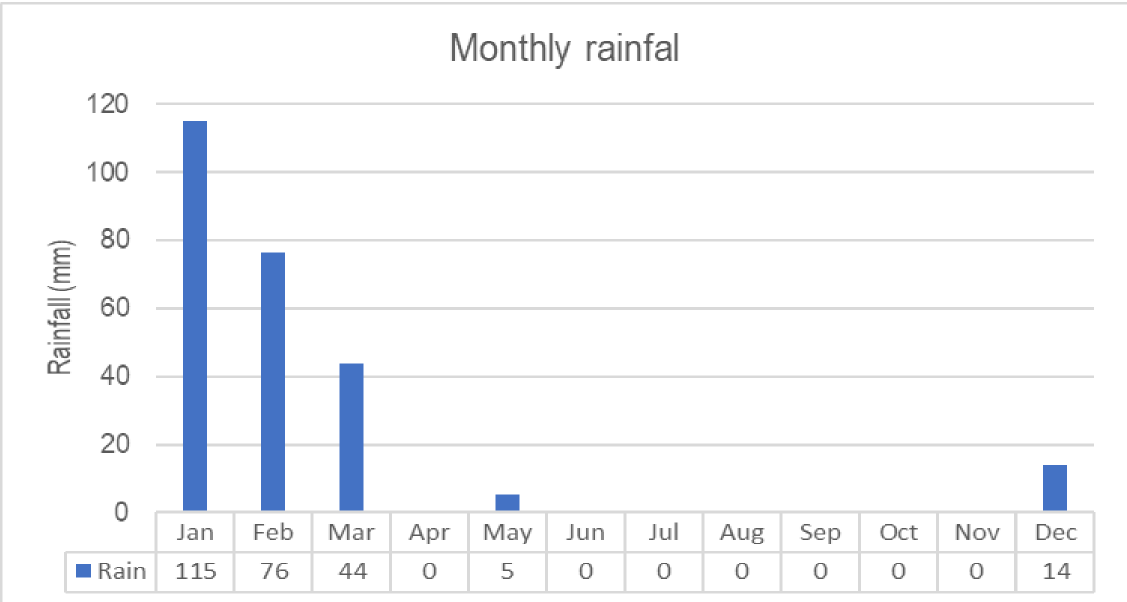

Figure 8: Average rainfall based on Osino meteorological data (Jul 2020 – Jul 2021)

3.2.4 Atmospheric Stability

The new generation air dispersion models differ from the models traditionally used in several aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters: the boundary layer depth and the Obukhov length, rather than in terms of the single parameter Pasquill Class. The Obukhov length (LMo) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004).

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the predominance of an unstable layer. In unstable conditions, ground level pollution is readily dispersed thereby reducing ground level concentrations. Elevated emissions, however, such as those released from a chimney, are returned more readily to ground level, leading to higher ground level concentrations.

Night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and less dilution potential. During windy and/or cloudy conditions, the atmosphere is normally neutral (which causes sound scattering in the presence of mechanical turbulence). For low level releases, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions.

Atmospheric stability is frequently categorised into one of six stability classes – these are briefly described in Table 7 with the percentage time each class occurred during the 12 months. For low level releases, such as mining operations, the highest ground level concentrations would occur during weak wind speeds and stable (night-time) atmospheric conditions (Category E), which relates to on average 7% of the time at the proposed Project site. However, windblown dust is likely to occur under high winds (neutral conditions – Category D) which accounted for 5% of the time, on average. Stack releases, such as from the power generators and smelter stacks, unstable conditions (Category C – 22%) can result in very high concentrations of poorly diluted emissions close to the stack. Neutral conditions disperse the plume equally in both the vertical and horizontal planes and the plume shape is referred to as coning. Stable conditions (Category E) prevent the plume from mixing vertically, although it can still spread horizontally and is called fanning (Tiwary & Colls, 2010).

Table 7: Atmospheric stability classes: Frequency of occurrence for the period July 2020 to July 2021

Designation	Stability Class	Atmospheric Condition	Frequency of occurrence
A	Very unstable	calm wind, clear skies, hot daytime conditions	12%
B	Moderately unstable	clear skies, daytime conditions	12%
C	Unstable	moderate wind, slightly overcast daytime conditions	22%
D	Neutral	high winds or cloudy days and nights	5%
E	Stable	moderate wind, slightly overcast night-time conditions	7%
F	Very stable	low winds, clear skies, cold night-time conditions	42%

3.3 Current Ambient Air Quality

3.3.1 Existing Sources of Atmospheric Emissions in the Area

The Osino Project falls within the eastern part of the Erongo Region. The main air pollution sources within the region, as identified during the 2019 air quality study as part of the SEMP AQMP (Liebenberg-Enslin, et al., 2019), include current mining and quarry operations, exploration activities, public roads (paved, unpaved and salt/treated), and natural exposed areas prone to wind erosion. In addition, there are several other sources emitting particulate matter (PM) such as small boilers and incinerators, commercial activities, charcoal packaging, construction activities (roads, buildings, etc.), and marine aerosols (sea salts and organic matter originating from the Atlantic Ocean).

The main pollutant of concern would be particulate matter (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved, unpaved, and treated surfaces), windblown dust, and mining and exploration activities. Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles and combustion sources, but these are expected to be at low concentrations due to the few combustion sources in the region.

3.3.1.1 Vehicle entrainment from roads

Particulate emissions from roads occur when the force of the wheels on the road surface grinds the surface material into finer particles which are then lifted by the rolling wheels and kept in suspension due to the turbulent wake behind the vehicle (U.S. EPA, 2011). Dust emissions from paved and unpaved roads varies linearly with the volume of traffic. In addition, a number of parameters influence the surface condition of a particular road, such as average vehicle speed, mean vehicle weight, silt content of road material, and road surface moisture, and these will thus impact on dust emissions (U.S. EPA, 2006).

The national road to the south (B2) of the Osino Project is a paved road and one of the main routes from Windhoek to Swakopmund, resulting in one of the road sections with the highest traffic in the region. During the SEMP AQMP, the emissions from these roads were quantified based on vehicle estimated annual average daily traffic (EAADT) figures, as provided by the Namibian Roads Authority (RA) for the year 2016. The vehicle kilometres travelled per day (VKT/day) on the paved B2 were calculated to be 224,722. Vehicle entrainment from the B2 was calculated to be a significant contributor at 29% to the regional paved road $PM_{2.5}$ and PM_{10} emissions. The C33, is a paved road connecting the Karibib Airport to the B2 and will be used to connect the mine to the B2. This road was not accounted for in the SEMP study but is assumed to have very low traffic counts[3].

Dispersion modelling was conducted to identify the main contributing sources to the measured PM_{10} and $PM_{2.5}$ concentrations. Modelled results indicated that vehicle entrainment from roads (paved, unpaved, and salt/treated surfaces) are the main contributing sources of PM_{10} and $PM_{2.5}$ emissions, but mostly affecting receptors close to the roads. Vehicle entrained emissions from the paved B2 are likely to be a significant background source of PM_{10} and $PM_{2.5}$ concentrations at the Osino Project.

3.3.1.2 Windblown dust

Windblown particulates from natural exposed surfaces, mine waste facilities, and product stockpiles can result in significant dust emissions with high particulate concentrations near the source locations, potentially affecting both the environment and human health.

Wind erosion is a complex process, including three different phases of particle entrainment, transport, and deposition. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the friction velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover

[3] This will be confirmed with the Traffic Specialist to include in the impact assessment phase.

influence the removal potential. For a natural environment such as the gravel plains of the Erongo Region, the threshold friction velocity was estimated to be 10 m/s and above due to the crusting effect of the soil surface.

In the quantification of windblown fugitive PM, use was made of the Airshed inhouse ADDAS model taking into account the particle size distribution (PSD); moisture content; particle density and friction threshold velocity. Windblown dust from natural exposed areas within the entire Erongo Region regarded to be prone to wind erosion (16,170 km²), resulted in high emissions ranging between 11 g/m²/year for $PM_{2.5}$ and 15 g/m²/year for PM_{10}. When reported as a soil (PM) loss per square metre (m²), the erosion losses seem reasonable when compared to other reported soil/PM_{10} losses due to wind erosion (Pi et al., 2018; Schepanski, 2018). The percentage hours where emission rates occurred ranged between 0.1% and 2.1%, which is in line with wind speeds exceeding 10 m/s. Wind speeds at the Osino weather station exceeded 10 m/s for 0% of the time over the 12 months of available data. Windblown dust from natural exposed surfaces at and around the Osino Project is regarded to be an insignificant source of particulate matter.

3.3.1.3 Mines and Exploration operations

Pollutants typically emitted from mining and quarrying activities are particulates, with smaller quantities associated with vehicle exhaust emissions. Mining and quarrying activities, especially open-cast mining methods, as well as exploration activities, emit pollutants near ground-level over (potentially) large areas. Source activities resulting in significant dust emissions include: drilling and blasting; materials handling (loading, unloading, and tipping); crushing and screening; windblown dust (from the sources as described above); access roads; and plant stack emissions.

Mines in proximity to the proposed Osino Project are Navachab Gold Mine located west-southwest of Karibib, approximately 20 km from Osino, and a number of marble quarries – Capra Hill, Dreamland and Savanna Marble.

Emissions quantified for the various mines in the region as part of the SEMP AQMP (Liebenberg-Enslin, et al., 2019), indicated vehicle entrained dust from on-site haul roads and access roads (combination of paved and unpaved road surfaces) to be the main contributing source to PM_{10} emissions. The largest source of $PM_{2.5}$ emissions was windblown dust mainly derived from the mining TSFs. Crushing and screening operations were identified as the third largest source of PM emissions followed by materials handling.

From the regional dispersion model, mining and quarry operations were the second highest dust sources. The impact range of these sources were a few kilometres from the mining operations, primarily within an east-west (or east-northeast and west-southwest) direction, not affecting the coastal towns but the nearby settlements.

3.3.1.4 Regional transportation of pollutants

Another source of air pollution is aerosols as a result of regional-scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia (http://www.fao.org/docrep/005/x9751e/x9751e06.htm). Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gasses being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held, et al., 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. Formenti et al., (2018) attributed the recording of black carbon at Henties Bay to contributions from biomass burning and even from the SA highveld's coal fired power stations.

Evaporation of sea spray are also sources of airborne particles, whereas pollen grains, mould spores and plant and insect parts all contribute to the atmospheric particulate load. Marine aerosols may include sea salt as well as organic matter (O'Dowd and De Leew, 2007). Sea salt is a major atmospheric aerosol component on a global scale, with a significant impact on PM concentrations (O'Dowd and De Leew, 2007; Athanasopoulou et al., 2008; Kelly et al., 2010; Karaguliun et al., 2015). Aside from the primary contribution from sea salt, recent interest is on its role in chemical reactions (with gaseous emission) and on climate change (O'Dowd and De Leew, 2007; Kelly *et al.*, 2010). One of the findings from the SEMP AQMP was the contribution from the ocean (westerly sector) to PM_{10} concentrations at Swakopmund and Walvis Bay. The contribution from sea salts in the PM_{10} filters was confirmed through chemical analyses (Liebenberg-Enslin, et al., 2019). How far these sea salts can be transported inland is not known.

3.3.2 Existing Ambient Air Pollutant Concentrations in the Project Area

There is a dustfall monitoring network in place at the Osino project, but no ambient PM (PM_{10} and $PM_{2.5}$) monitoring network.

PM concentrations measured as part of the SEMP AQMP monitoring network were limited to the coastal towns of Swakopmund, Walvis Bay and Henties Bay with a station in the central western part of the region on the farm Jakalswater. None of these locations are representative of the air quality in the Karibib region.

3.3.3 Dustfall monitoring data for the Osino Project

The dustfall monitoring network was initiated in June 2020 and comprises of eight (8) single dustfall units (Figure 1).

Dustfall deposition rates from the Osino monitoring network for the period June 2020 to June 2021 are presented in Figure 9. Dustfall rates are generally low for the sampling period and well within the dustfall limit of 600 mg/m²/day (adopted limit for residential areas) and 1 200 mg/m²/day (adopted limit for non-residential areas). Dustfall rates were the lowest during the months of June to September 2020 and might have been influenced by the regional lockdown due to COVID-19. It should be noted that no exchanges were made as a result of this in August, hence the reason for the combined Aug/Sep period. The highest dustfall was collected at AQ-02 during October 2020 (422 mg/m²/day) and March 2021 (520 mg/m²/day), followed by AQ-07 in January 2021 (502 mg/m²/day) and AQ-03 in April 2021 (403 mg/m²/day).

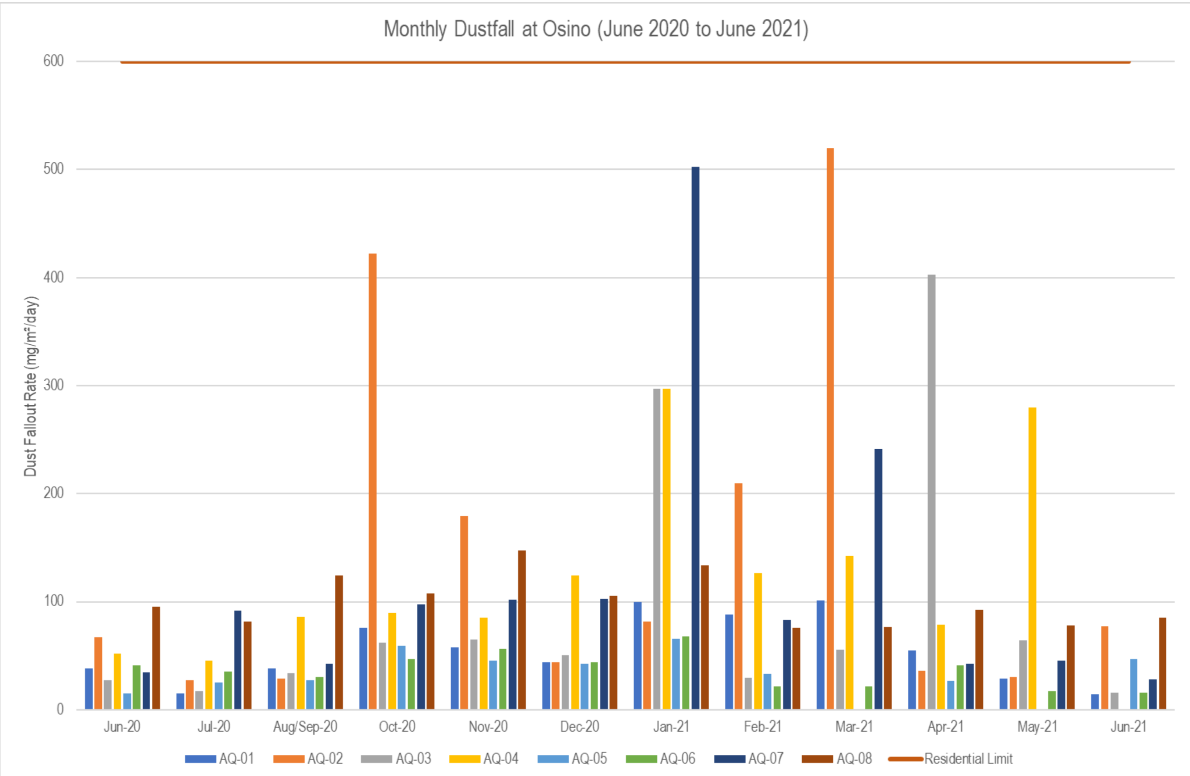

Figure 9: Dustfall rates for Osino Project monitoring (Jun 2020 – Jul 2021)

The dustfall rates show slight spatial and temporal variation across the site as shown in Figure 10. The dustfall rates are presented as a daily average over the 12-month period (June 2020 – June 2021), with no clear spatial trend visible. AQ-01, AQ-03, AQ-05 and AQ-06 had the lowest average dustfall over the period with the rest slightly higher.

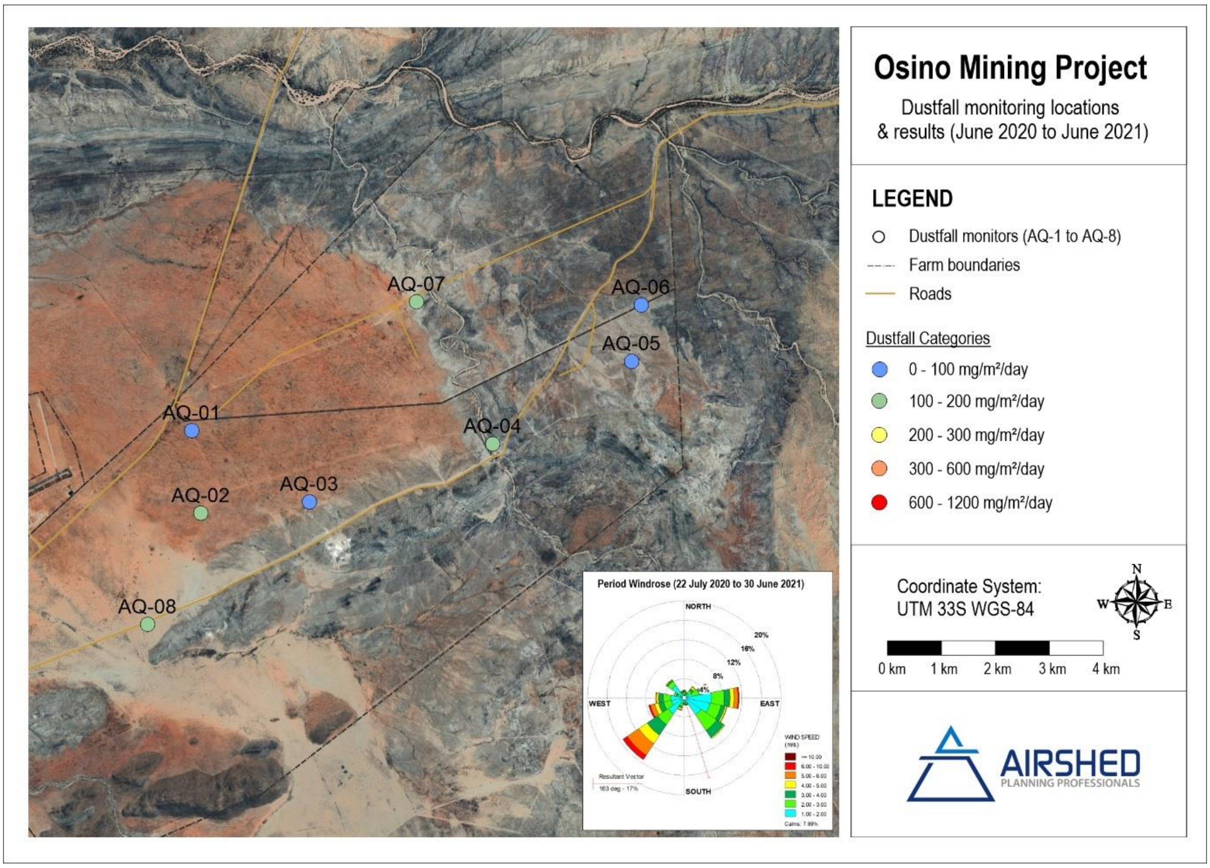

Figure 10: Spatial representation of the dustfall rates at Osino Project, with dustfall as a daily average over the period Jun 2020 – Jul 2021

4 FINDINGS AND RECOMMENDATIONS

An air quality baseline assessment was conducted to determine the current air quality in the area where the proposed Osino Project will be developed. The main concern is the potential air quality impacts from the proposed Project on the receiving environment and human health.

The main findings from the baseline assessment can be summarised as follows:

- The Osino Project is located approximately 5 km northeast of the town of Karibib, in the eastern part of the Erongo Region of Namibia.
- The Project covers an area with dimensions of about 25 km northeast-southwest and 11 km north-south.
- The terrain is hilly, with a ridge to the north and northwest, and a ridge on the southern side.
- There are no villages or homesteads near the project, with the closest settlement – farmhouses – directly to the south of Twin Hills pit, and one at the proposed Processing Plant (this one is assumed to be relocated). The town of Karibib (and Usab suburb) is located about 3.5 km to the southwest from the site boundary. Other settlements in the vicinity include scattered homesteads to the north of the mine boundary, along the Khan River.
- The on-site weather data available for the period 23 July 2020 – 22 July 2021. The wind field is dominated by winds from the southwest and the east to south-east, with the strongest winds from the southwest. During the day, easterly winds prevailed with strong but less frequent winds from the southwest, and at night the windfield shifted to the southwest. Calm conditions were recorded for 7.5% of the time with a period average wind speed of 2.3 m/s. Higher wind speeds occurred during the night, with the strongest winds recorded from the southwest. A maximum wind speed of 8.9 m/s were recorded.
- Monthly variation in the wind field showed more frequent south-westerly winds during the summer months and a shift to easterly winds in May, and then to the southeast during April to July – the so called “east-winds”. In August, winds from the northwest prevailed, whereafter it shifted to the southwest in September with a remaining easterly component. The winter months were dominated by high velocity north-easterly winds, also called
- Maximum, minimum, and mean temperatures were given as 42°C, -3°C and 23°C respectively from the Osino weather station for the period Jul 2020 – Jul 2021.
- Rainfall over the 12-month period totalled 254 mm, with the highest rainfall month January 2021 (115 mm).
- The main pollutant of concern in the region is particulate matter (TSP; PM_{10} and $PM_{2.5}$) resulting from vehicle entrainment on the roads (paved, unpaved and treated surfaces), windblown dust, and mining and exploration activities. Gaseous pollutants such as SO_2, NOx, CO and CO_2 would result from vehicles and combustion sources, but these are expected to be at low concentrations due to the few sources in the region.
- Sources of atmospheric emissions in the vicinity of the proposed Osino Project include:
    - Vehicle entrainment from roads: The national road to the south (B2) of the Osino Project is the main road between Windhoek and Swakopmund, and one of the roads in the region with the highest traffic counts. paved road with vehicle entrainment calculated to be a significant contributor to the regional paved road $PM_{2.5}$ and PM_{10} emissions. The C33, is a paved road connecting the Karibib Airport to the B2, and although no information was available for this road, it is expected to have very low traffic counts and low $PM_{2.5}$ and PM_{10} emissions.
    - Windblown dust: Windblown particulates from natural exposed surfaces, mine waste facilities, and product stockpiles can result in significant dust emissions with high particulate concentrations near the source

locations, potentially affecting both the environment and human health. Windblown dust from natural exposed surfaces in and at the Osino Project is only likely to result in particulate matter emissions under high wind speed conditions (>10 m/s), and since recorded wind speeds did not exceed 10 m/s, this source is likely to be of low significance.

  - Mines and Exploration operations: Pollutants typically emitted from mining and quarrying activities are particulates, with smaller quantities associated with vehicle exhaust emissions. Mining and quarrying activities, especially open-cast mining methods, emit pollutants near ground-level over (potentially) large areas. Mines in proximity to the proposed Osino Project are Navachab Gold Mine located west-southwest of Karibib, approximately 20 km from Osino, and a number of marble quarries – Capra Hill, Dreamland and Savanna Marble.
  - Regional transport of pollutants: regional-scale transport of mineral dust and ozone (due to vegetation burning) from the north of Namibia is a significant contributing source to background PM concentrations.

- A dustfall monitoring network comprising of eight (8) single dustfall units are in place at the Osino project, with dustfall data available for the period June 2020 to June 2021. Dustfall rates were generally low for the sampling period and well within the dustfall limit of 600 mg/m²/day (adopted limit for residential areas) and 1 200 mg/m²/day (adopted limit for non-residential areas). Dustfall rates were the lowest during the months of June to September 2020 and might have been influenced by the regional lockdown due to COVID-19. The highest dustfall of 520 mg/m²/day was recorded at AQ-02 in March 2021. The dustfall results show no clear spatial trend.

4.1 Way forward

Based on the activities associated with the proposed Osino Project (see Section 1.2), an air quality impact assessment is proposed to be conducted as part of the Environmental Impact Assessment (EIA). The scope of work will include the following tasks:

- The compilation of an emissions inventory including the identification and quantification of all emissions associated with the proposed mining, processing and smelting operations. Pollutants quantified should, as a minimum, include particulate matter (TSP, PM_{10} and $PM_{2.5}$) and gaseous emissions (SO_2, NO_2 and CO). Use should be made of engineering design parameters, design emission standards, emissions factors published by the US EPA and Australian National Pollutant Inventory (NPI).
- Dispersion modelling will be conducted using an international approved dispersion model such as the United Kingdom (UK) Air Dispersion Modelling System (ADMS).
- Impact assessment to be compiled by comparing ambient pollutant concentration levels to the relevant air quality limits/ guidelines as set out in Section 2.4, to assess the potential impact on the surrounding environment and human health.
- The identification of air quality management and mitigation measures based on the findings of the compliance and impact assessment.

5 REFERENCES

Cachier, H., 1992. Biomass burning sources. Volume 1.

Held, G. et al., 1996. *Air Pollution and its impacts on the South African Highveld,* Cleveland: Environmental Scientific Association.

IFC, 2007. *General Environmental, Health and Safety Guidelines.* s.l.:World Bank Group.

Liebenberg-Enslin, H., 2014. *A Functional Dependence Analysis o f Wind Erosion Modelling System Parameters to Determine a Practical Approach f or Wind Erosion Assessments,* Johannesburg: Faculty of Science, University of Johannesburg.

Liebenberg-Enslin, H. et al., 2019. *Advanced Air Quality Management for the Strategic Environmental Management Plan for the Uranium and Other Industries in the Erongo Region: Air Quality Management Plan Report,* s.l.: Ministry of Mines and Energy.

Moeller, W., 2021. *Osino Resources: Twin Hills Gold Project Preliminary Economic Assessment (PEA) - Mining Study. Report No. LYC/OSI/PEA/2021/018/01. 15 June 2021,* s.l.: Lycopodium Minerals Africa (Pty) Ltd.

NCE, 2020. *Best Practive Guide - Environmental Principles for Mining in Namibia,* Windhoek: Namibian Chamber of Environment.

NPI, 2011(b). *Emission estimation technique manual for Gold Processing ,* s.l.: Australian Government: Department of the Environment and Heritage.

Tiwary, A. & Colls, J., 2010. *Air pollution: measurement, monitoring and mitigation.* 3rd Edition ed. Oxon: Routledge.

U.S. EPA, 2006. *Compilation of Air Pollution Emission Factors (AP-42) - Unpaved Roads,* s.l.: U.S. Environmental Protection Agency.

U.S. EPA, 2011. *Compilation of Air Pollution Emission Factors (AP-42) - Paved Roads,* s.l.: U.S. Environmental Protection Agency.

WHO, 2005. *WHO air quality guidelines global update 2005: Report on a Working Group meeting,* Bonn, Germany: World Health Organization.