**APPENDIX G: AIR STUDY**

*Project done on behalf of*
*Metago Environmental Engineers (Pty) Ltd*

# AIR QUALITY IMPACT ASSESSMENT FOR CURRENT MINING OPERATIONS AND PROPOSED EXPANSION PROJECT AT LANGER HEINRICH URANIUM MINE, NAMIBIA

**Report No.: APP/09/MEE-03 Rev 2**

***August 2009***


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# REPORT DETAILS

| | |
|---|---|
| ***Reference*** | APP/09/MEE-03 |
| ***Status*** | FINAL Revision 2 |
| ***Report Title*** | Air Quality Impact Assessment for Current Mining Operations and Proposed Expansion Project at Langer Heinrich Uranium Mine, Namibia |
| ***Date Submitted*** | August 2009 |
| ***Client*** | Metago Environmental Engineers (Metago) |
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| ***Acknowledgements*** | The authors would like to express their sincere appreciation for the invaluable discussions and technical input from Brandon Stobart of Metago Environmental Engineers (Pty) Ltd, Jefta Ampueja, Charles Cleghorn and Werner Petrick of Langer Heinrich Uranium Mine for the meteorological and technical data they provided. |

# EXECUTIVE SUMMARY

## 1. INTRODUCTION

Airshed Planning Professionals (Pty) Ltd was appointed by Metago Environmental Engineers (Pty) Ltd to undertake an air quality impact assessment for the current and proposed mining activities at Langer Heinrich Uranium Mine. The mine is located approximately 90 km east of Swakopmund in the Namib Naukluft National Park, Erongo Region.

Langer Heinrich Uranium Mine comprises of open pit mining operations currently producing 3.7 million tonnes of uranium per annum (Mtpa). The mine proposed to increase production to between 5 Mtpa and 10 Mtpa. This requires the expansion of the current operations to include, amongst other processes, an additional crushing and screening plant, a heap leach pad, expansion of the current processing plant and additional road infrastructure. Several new pit locations will be explored during future operations.

The concern from an air quality perspective is the potential that exists for increased impacts on the surrounding environment and human health. Based on the current and proposed operations at Langer Heinrich Uranium Mine, particulates were regarded as the pollutant of concern. Gaseous emissions from on-site vehicles and equipment and from power generation (not continuous source) were regarded as negligible.

The air quality assessment comprised of a baseline and impact assessment study. The baseline study included the review of the site-specific atmospheric dispersion potential, relevant air quality guidelines/limits and existing ambient air quality in the region. The predicted air quality impact assessment comprised the establishment of an emissions inventory for the current, proposed construction and future operational phases. Subsequent dispersion simulations whereby ambient air pollutant concentrations and dust fallout rates were predicted followed by a comparison to health risk and compliance requirements. An air quality management plan including possible mitigation and management measures for significant sources was developed.

### 1.1 Terms of Reference

The terms of reference for the study comprised of two main components, *viz.*, the establishment of *baseline conditions* and a *predicted* air quality impact assessment. The terms of reference for the baseline assessment were as follows:

A ***baseline air quality characterisation***, which included the assessment of:

- The regional climate and site-specific atmospheric dispersion potential.
- Preparation of hourly average meteorological data for input to the dispersion model;
    - Preparation of raw meteorological data.
    - Formatting of meteorological data for input to the dispersion model.
    - Simulation of wind field, mixing depth and atmospheric stability.
- Extraction and processing of topographical data for input into the dispersion model.
- Identification of existing sources of emission and characterisation of ambient air quality within the region based on observational data recorded to date.
- Collation and analysis of all available monitoring data from existing mining operations in the

region and recorded data from site (if available).

- Identification of potentially sensitive receptors within the vicinity of the current and proposed mining operation that would be susceptible to air quality impacts;
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and standards, and dust-fall classifications with specific reference to the applicable international requirements such as the World Health Organisation, World Bank Group and European Community.

An ***air quality impact study***, which included*:*

- Quantification of all proposed sources of atmospheric emissions including (but not limited to) the following sources:
  - Opencast mining operations;
  - Haul roads from the mine to the processing plant,
  - Crushing and screening operations;
  - Vehicle entrainment on paved and unpaved roads;
  - Materials handling operations (i.e. tipping, loading and off-loading); and,
  - Wind erosion from exposed areas such as the waste rock dump, topsoil piles and tailings/slimes dam.
- Construction phase: This mainly pertained to the construction activities for the proposed expansion.
- Dispersion simulations of ground level PM10 concentrations and dust fallout for the proposed operations reflecting highest daily and annual average PM10 concentrations and dust deposition due to *routine* and *upset* emissions from the opencast mining operations. Atmospheric Dispersion Modelling System (ADMS) developed by the Cambridge Environmental Research Consultants (CERC) to be used for the study.

- Analysis of dispersion modelling results, which included:
  - Determination of zones of maximum incremental ground level impacts (concentrations and dust fallout from each source); and,
  - Determination of zones of maximum predicted cumulative ground level impacts (concentrations and dust fallout from all sources at the mine).
- Evaluation of potential for human health and environmental impacts.

- Preparation of predicted PM10 concentrations and dust fallout level model output files (for the current and proposed operations) that will be used by the Radiation Specialists to determine the potential impacts from radiation within the modelling domain.

A ***dust management plan*** for the mine*:*

- Development of a dust management plan for the mine, which included:
  - Estimation of emission control efficiencies required for each significant source;
  - Identification of suitable pollution abatement measures able to realise the required dust control efficiencies, and possible contingency measures;
  - Specification of source-based performance indicators, targets, and monitoring methods applicable for each source;
  - Recommendation of receptor-based performance indicators comprising of a monitoring network and targets;
  - Recommendations pertaining to record keeping, environmental reporting and

community liaison.

### 1.2 Project Assumptions and Limitations

Whereas with the current mining operations emissions and dispersion simulations were based on actual activities, proposed operations were based on design specifications. This usually infers limited data and calls for certain assumptions to be made. It is important to understand these constraints specifically when interpreting the simulated results. Data limitations and assumptions associated with this project are listed below:

- No long-term ambient monitored concentration data were available for the area. A dust fallout monitoring network and PM10/PM2.5 sampler have recently been installed at the mine with only data available on the dust fallout for the period April to May 2009. Dust fallout data from the multi-directional buckets could not be used for data were only reported for the east and west buckets.

- The impact assessment was limited to airborne particulates (including TSP and PM10). Although the current and proposed activities also emit gaseous pollutants from vehicle exhausts, the impact of these compounds are regarded to be low and was omitted from this study. Emissions emanating from the on-site power plant might be more significant but insufficient information was available at the time of the study and only the emissions were included.

- The dispersion model (ADMS) cannot compute real time mining processes, therefore average mining process throughputs were utilised. Thus even though the nature of the open pit mining operations (pit utilisation and roads) change over the life of mine, the current and proposed open pit mining areas were modelled to reflect the worst case condition (i.e. resulting in the highest impacts).

- Routine emissions for the current and proposed operations were simulated. Atmospheric releases occurring as a result of non-routine conditions were not accounted for. Blasting is seen as an intermittent source of emissions (non-routine) but was included in the routine simulations. The reason being that ambient air quality standards and guidelines for particulates are limited to 24-hour averages and cannot determine the significance of short-term releases such as blasting.

- The proposed expansion operations at Langer Heinrich Mine will include open pit operations to the east and west of the current operations. For the purpose of the current study, three future pit locations were selected to provide an indication of the variation in impact magnitude and spatial extent.

- The locations of the waste rock dumps for the proposed future mining operations were assumed to be near the open pit and the dimensions were based on the volume of the waste rock material.

- The mine layout plan used for the quantification of emissions and dispersion simulations reflected the worst-case design of the proposed expansion (i.e. largest footprint of the proposed tailings dam and proposed processing plant located further to the west). It also assumed all waste dumps, stockpiles and the tailings dams to be at the maximum size.

- A natural crusting of the outer layer of stockpiled material was observed during the site visit. This reduces the potential for wind erosion when undisturbed. No literature reference could be found on the control efficiency of this crust and for the purpose of this study it was assumed to be 30%. Crusting is a condition which occurs when wet soil dries, upon which the surface forms a hard crust. Crusting is a surface problem and it has been stated that with a crusting thickness

of about 1cm there is virtually no erosion and the threshold friction velocity becomes 1.5 m/s, which under normal conditions will not be exceeded. If crusting does not occur, the predicted particulate emission rates would be significantly underestimated and result in under-prediction of particulate air concentration and fallout.

- Radiation (radon and various radionuclides) associated with current and proposed future operations has not been covered as part of the air quality study and will be addressed by the Radiation Specialists. The predicted PM10 concentrations and dust fallout levels were used by the Radiation Specialists to determine the potential impacts from radiation within the modelling domain. For radon, separate dispersion simulations were conducted for use by the Radiation Specialists.

### 1.3 Evaluation Criteria

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. Ambient air quality guidelines and standards aim to protect public health therefore these are applied to off-site areas rather than on-site occupational impacts. Thus, the predicted impacts at the sensitive receptors identified were the main focus of the assessment

To date no ambient air quality guidelines or standards, or emission limits have been developed for Namibia. Reference was therefore made to international evaluation criteria as published by the World Bank Group, the World Health Organisation and the European Community. South Africa has recently revised their ambient air quality standards and these were also referenced.

## 2. BASELINE ASSESSMENT

Other than the current mining operations at Langer Heinrich Uranium Mine no anthropogenic sources of emissions exists in the immediate vicinity of the mine. Rössing Uranium Mine, the only other operational uranium mine is located ~46 km to the north-west with prospecting areas such as Valencia Uranium Mine (Valencia located ~49 km to the north), Bannerman Etango project and Extract Resources Rössing South project. The natural environment is arid with the potential of generating background dust specifically during strong winds. Unpaved roads in the region are likely to be the main background source of fugitive dust.

No residential areas are located near the mine with the Drillers Camp and Bloedkoppie Camp Site the only two potentially sensitive receptors with regards to human health. A contractor's camp will be in place for the duration of the construction activities that will last for approximately 12 months.

### 2.1 Dispersion Potential of the Site

On-site meteorological data for Langer Heinrich Uranium Mine were obtained for the years 2006 to 2008 and included hourly average wind speed, wind direction and temperature. Parameters not measured were estimated based on prognostic equations. The analysis of the meteorological data included a diurnal temperature profile, wind roses, and atmospheric stability classifications. This provided a general description of the local climate and served as input data into the dispersion model.

The prevailing winds were recorded to be from the west-northwest, west and west-southwest with the strongest winds from the east-northeast and northeast. The easterly winds started to prevail during

the autumn months and dominated during the winter months. Summer and spring months mainly reflected westerly flow.

### 2.2 Existing Air Quality in the Region

A dust fallout monitoring network currently exists at Langer Heinrich Uranium Mine with data available for the period April to May 2009. On average the recorded dust fallout at the mine site was high exceeding the German limits for industrial sites (650 mg/m²/day) at three locations during April and 4 locations during May. The SANS limit for industrial areas (1,200 mg/m²/day) was also exceeded at 2 sites during April and 4 sites during May. A PM10/PM2.5 sampler has also been installed but only recently became operational with insufficient data available for inclusion into the report.

Due to the limited monitored data, current operations at Langer Heinrich Uranium Mine were assessed through dispersion simulations. This provided a baseline for the mine but excluded background pollution (i.e. other sources in the region). All pollution generating sources at the mine were identified and emissions quantified. The establishment of an emissions inventory is necessary to provide the source and emissions data required as input to the dispersion simulations. Current sources of emissions included vehicle activity on the unpaved haul roads, wind erosion from waste rock dumps, storage piles and the tailings dam, materials transfer points, crushing and screening. In-pit operations accounted for included excavation of ore and waste rock, drilling and blasting and equipment movement within the pits (Pit A west and Pit D). Information on the power generation plant was limited, thus only the emission concentrations were reported on. Gaseous emissions from vehicles and equipment were regarded as insignificant and omitted from the study. The main sources of particulate emissions from the current operations were quantified to be as follows:

- Wind erosion was the main contributing source to PM10 and TSP emissions (83% for both).
- The second most significant source was unpaved roads with contributions of 13% and 14% to PM10 and TSP emissions, respectively.
- Blasting was predicted to be the third most significant source of PM10 and TSP (2% and 1.5% respectively).

The ADMS model developed by the Cambridge Environmental Research Consultants (CERC) was used in this study. ADMS is a Gaussian plume model regarded to be most accurate in near-field applications (less than 10 km). It is designed to predict pollution concentrations from continuous point, area, line, and volume sources. The model provides conservative values under unstable atmospheric conditions in that it predicts higher concentrations than the older models close to the source. Similar to other Gaussian plume models such as AERMOD, a disadvantage of the ADMS is that spatial varying wind fields, due to topography or other factors cannot be included. Also, the range of uncertainty of the model predictions could to be -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

The predicted daily PM10 concentrations indicated exceedances of the EC standard and WHO air quality guideline at the Drillers Camp. PM10 concentrations at Bloedkoppie were however within the required standards and guidelines. The number of days when the PM10 concentrations exceeded the EC standard (of 50 µg/m³) at the Drillers Camp was 16 days over the one year. Over an annual average no exceedances were predicted at any of the sensitive receptor sites and the significance of these impacts can be regarded as Moderate to Low.

Dust fallout levels were predicted to be well below the SANS residential dust fallout limit of 600 mg/m²/day at the sensitive receptors. Similarly the predicted dust deposition can be regarded as Moderate to Low.

## 3. IMPACT ASSESSMENT

For the proposed expansion operations a conservative approach was followed by assessing the 10 Mtpa production rate. Also, the maximum sizes of the waste dumps, stockpiles and tailings dams were used. Three pit locations were selected to provide an indication of the potential impacts associated with the varying mining locations. The three future scenarios were as follows:

- *Future Scenario 1: Future West Pit;*
- *Future Scenario 2: Future Centre Pit;* and,
- *Future Scenario 3: Future East Pit.*

Due to the expansion in infrastructure, the impacts from construction operations were also addressed.

### 3.1 Construction Phase

Activities associated with this phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has its own duration and potential for dust generation. Since no detailed construction plan was available a single emission factor for construction activities was applied to the heap leach pad, mine workshop, tailings dam and crusher area. The plant expansion will be at the existing processing plant and expected to have limited impacts since it is already a built-up area. Emissions from the construction operations were quantified as a single emission factor accounting for all associated activities during construction, thus the main impacting sources cannot be singled out. However based on the types of activities during construction it is likely that the vehicle activity on the unpaved roads and land clearing activities will be the main dust generation sources.

The predicted daily average PM10 ground level concentrations for the proposed construction activities in addition to the current operations exceeded the EC PM10 standard, the WHO daily air quality guideline and the all the interim targets, and the SA Standard at the sensitive receptors. The highest impacts were predicted at the Contractors Camp for this is located nearest to the dust generating activities. Over an annual average the WHO guideline was exceeded at all the receptors with the EC standard and proposed SA standard exceeded at the Contractors camp. The significance was regarded as Moderate mainly during to the limited duration of the construction operations (i.e. for 12 months). Predicted maximum dust fallout was also highest at the Contractors Camp with an exceedance of the German limit but not the SANS residential limit.

### 3.2 Future Operational Phase

As with the baseline operations, all future sources of dust emissions were identified and quantified. This included all materials transfer points, in-pit operations (i.e. excavations, drilling and blasting), all vehicle movement on unpaved haul roads, windblown dust from the waste dumps, stockpiles and tailings dams. The operations at the current and expanded processing plant were accounted for in addition to the new crushing and screening plant. The main sources of *emissions* were as follows:

*Future Scenario 1: West Pit*

- Wind erosion was predicted to be the main contributing source to PM10 and TSP emissions (63% and 62% respectively).
- The second most significant source of PM10 and TSP emissions were the unpaved roads (34% and 36% respectively).
- Blasting was predicted to be the third most significant source of PM10 and TSP (1% and 0.7% respectively).

*Future Scenario 2: Centre Pit*

- Wind erosion was the main contributing source to PM10 and TSP emissions (57% and 56% respectively).
- The second most significant source of was unpaved roads (41% for PM10 and 42% for TSP).
- Blasting activities remained to be third.

*Future Scenario 3: East Pit*

- Unpaved roads were predicted to be the most significant source of PM10 and TSP emissions (53% and 54%) respectively.
- The second most significant source of PM10 and TSP emissions was predicted to be wind erosion (45% and 44% respectively).

Concentrations for inhalable particulates (PM10) and dust-fall levels (TSP) were predicted using the same dispersion model (ADMS). Since the Contractors Camp will only exist for the duration of the construction activities, only Bloedkoppie and the Drillers Camp were addressed as part of the future scenarios assessment.

***Future Scenario 1: Proposed West Pit Mining Operations***

Emissions from the proposed *West Pit operations* exceeded the EC standard and WHO ambient guideline at the Drillers Camp. They also exceeded all the WHO IT-2 and IT-3 (at the Drillers Camp) and the proposed SA standard. The number of days the EC standard was exceeded at the Drillers Camp totalled 86 over the one year period and 44 days exceeding the proposed SA Standard. Predicted ground level concentrations over an annual average complied with all the relevant screening criteria at both sensitive receptor sites. The significance of the predicted concentrations was regarded as Moderate due to the fact that there are no permanent residents at Bloedkoppie and the Drillers Camp. Predicted maximum dust fallout levels did not exceed both the German limits and the SANS limit for residential areas both at Bloedkoppie and the Drillers Camp.

***Future Scenario 2: Proposed Centre Pit Mining Operations***

Future Centre Pit will require ROM material to be hauled over greater distances. The predicted PM10 daily concentrations exceeded all standards and guidelines at both sensitive receptor sites. Only Bloedkoppie complied with all the WHO interim targets. The number of days when the EC standard was exceeded at the Drillers Camp was 334 over the one year period, with 299 days exceeding the SA Standard. The annual average ground level concentrations were also predicted to exceed the EC standard, the WHO guideline and the SA Standard at the Drillers Camp. A Moderate significance rating was based on the non-permanent residency of either the Drillers Camp or the Bloedkoppie Camp site. Maximum dust fallout levels were also higher at the Drillers Camp, exceeding both the German and SANS limits for residential areas.

***Future Scenario 3: Proposed East Pit Mining Operations***

Proposed East Pit also involved the use of a lengthy haul road. Similar impacts as predicted for *Future Scenario 2* were predicted with higher impacts at both sensitive receptor areas. This resulted in non-compliance with all the screening criteria at the Drillers Camp. The frequency of exceedance increased to 355 and 343 days over the 1 year period at the Drillers Camp for the EC limit and SA Standard, respectively. Annual average predicted PM10 concentrations were also higher than for *Future Scenario 2*, resulting in exceedances of all the selected standards and guidelines at the Drillers Camp. Although the more stringent WHO air quality guideline was exceeded at Bloedkoppie, the EC standard and proposed SA standard were not exceeded. This scenario, even though resulting in higher impacts than the other scenarios also resulted in a Moderate significance rating. Dust fallout levels were also slightly higher than in Scenario 2, exceeding the residential criteria and the SANS industrial limit at the Drillers Camp.

## 4. CONCLUSIONS

- The main conclusion is that the proposed expansion operations will result in an increase in ground level PM10 concentrations and dust fallout levels at the various sensitive receptors. The significance of these impacts can be regarded as Moderate since these locations are not permanently inhabited, nor is it likely that people will stay at these locations for longer than a day.

- The modelling approach also followed a conservative approach to ensure that the worst-case scenarios are reflected in the assessment. Even though the pit operations will extend further east and west, the magnitude of the impacts are unlikely to be higher.

- Vehicle entrainment from the unpaved haul roads resulted in the highest predicted impacts at the sensitive receptors. The significance of dust generated from vehicle movement on unpaved roads increased during the future operations and where the pit locations are nearest to the sensitive receptors.

## 5. RECOMMENDATIONS

### 5.1 Target controls for the Main Sources

*Construction Phase*

- Construction of the tailings dam wall, mine workshop and heap leach pad, crusher area – 50% control efficiency through effective water sprays.
- Vehicle entrainment on temporary unpaved roads – 75% control efficiency through effective water sprays on haul roads.

*Current and Future operational phase*

- Vehicle entrainment on unpaved haul roads – 90% control efficiency through the application of chemical surfactants or surface paving.
- Vehicle entrainment on in-pit haul roads – these roads change depending on the area to be mined and hence it is not practical to apply chemicals. It is recommended that a minimum of 75% control efficiency is achieved through affective water sprays.

- Although emissions from blasting would be of significance during the current and future phases, the duration of blasting would be only for a couple of minutes per day. It is recommended that controlled blasting techniques be investigated since the visual reduction in dust emissions between a conventional blast and a controlled blast is significant.

*Closure Phase*

- It is expected that the natural crusting of stockpiled material will occur once these sources are not disturbed

**5.2 Suitable Mitigation Measures**

*Unpaved haul roads*

- It is recommended that water be used in combination with chemical surfactants to reduce the amount of water required to achieve control efficiencies in excess of 90% on the main haul roads at Langer Heinrich Uranium Mine. One of the main benefits of chemical stabilisation in conjunction with wet suppression is the management of water resources. A cost-effective chemical control programme should be developed evaluating the costs and benefits arising from various chemical stabilization practices on site specific roads.

*Material handling operations*

- The control efficiency of pure water suppression provide an effective control mechanism achieving on average 62% efficiency by doubling the moisture content. Again, the combination of water and chemicals provides the most feasible mitigation option.

**5.3 Monitoring Requirements**

*Key performance indicators* against which progress may be assessed form the basis for all effective environmental management practices.

Source based performance indicators include the following:

- No visible dust on unpaved roads when trucks/vehicles drive on the roads. It is recommended that dust fallout in the immediate vicinity of the road perimeter be less than 1,200 mg/m$^2$/day and less than 600 mg/m$^2$/day at the sensitive receptors.
- The absence of visible dust plume at all tipping points and outside the primary crusher would be the best indicator of effective control equipment in place. In addition the dust fallout in the immediate vicinity of the tipping and crushing sources should be less than 1,200 mg/m$^2$/day.
- From all activities associated with Langer Heinrich Uranium Mine, dust fallout levels should not exceed 600 mg/m$^2$/day at the sensitive receptor areas.

Receptor based performance indicators include the following:

- The current dust fallout network at Langer Heinrich Uranium Mine comprises of four directional dust buckets and six single buckets positioned at various areas close to the mining operations. Given that open pit mining operations changes location over time and that the proposed pit operations will stretch over an area of approximately 15 km (east-west) over the life of mine, it is recommended that the dust fallout network be expanded. A total of 10 single dust fallout buckets and 6 directional buckets should be implemented as indicated in Figure A.

One directional bucket should be placed at Bloedkoppie (not indicated on the map) and one at the Drillers Camp. Monitoring should be undertaken using the American Society for Testing and Materials standard test method for the collection and analysis of dustfall (ASTM D-1739) or any other method which can demonstrated to give equivalent results (SANS, 2004).

- A PM10/PM2.5 monitor was installed at the mine close to the processing plant due to the concern for health impacts. It is recommended that this station be moved to the Drillers Camp to ensure the mining and processing plant operations are in compliance with the relevant ambient air quality guidelines. The monitor should however be calibrated at least once a year and the data validated.

- The operation of the on-site meteorological station should be continued. The meteorological station must be calibrated at least once a year with regular span checks and data validation carried out to ensure the data reported are correct.

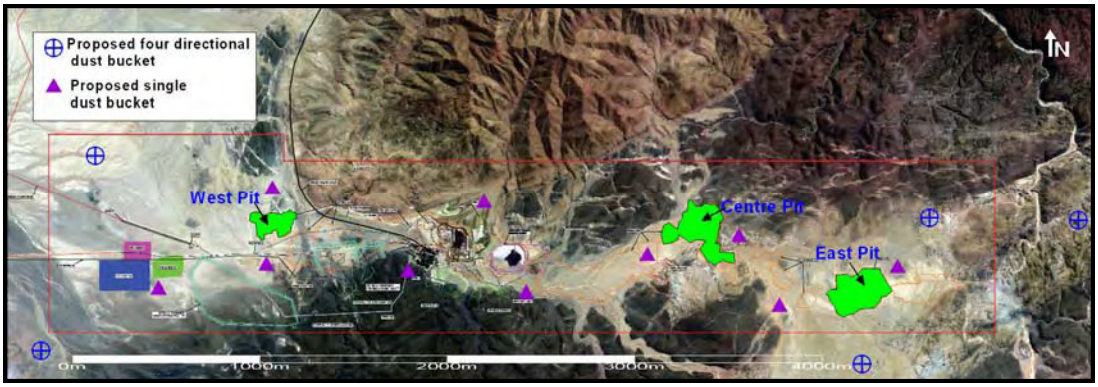


**Figure A: Proposed dust fallout network for future mining operations at Langer Heinrich Uranium Mine.**

### 5.4 Record-keeping and Environmental Reporting

It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during operations, with annual environmental audits being conducted. Annual environmental audits form part of the overall EMS at Langer Heinrich Uranium Mine. A budget should be drawn to provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans.

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## LIST OF ACRONYMS AND SYMBOLS

| | |
|---|---|
| **ADMS** | Atmospheric Dispersion Modelling Systen |
| **Airshed** | Airshed Planning Professionals (Pty) Ltd |
| **amsl** | above mean sea level |
| **APCS** | Air Pollution Control System |
| **APIA** | Air Pollution Impact Assessment |
| **APPA** | The Atmospheric Pollution Prevention Act (No.45 of 1965) |
| **ADMS** | Atmospheric Dispersion Modelling System |
| **C** | Carbon |
| **$CH_4$** | Methane |
| **CERC** | Cambridge Environmental Research Consultants |
| **CO** | Carbon Monoxide |
| **DEAT** | The Department of Environmental Affairs and Tourism. |
| **DME** | The Department of Minerals and Energy |
| **EMP** | Environmental Management Programme |
| **EHS** | Environmental, Health, and Safety Guidelines |
| **EU** | The European Union |
| **GDP** | Gross Domestic Product |
| **GIIP** | good international industry practice |
| **HSE** | UK Health and Safety Executives |
| **IFC** | International Finance Corporation |
| **MWth** | Megawatt thermal |
| **METAGO** | Metago Environmental Engineers (Pty) Ltd |
| **$m^3$** | Cubic metre |
| **NEMAQA** | South Africa National Environment Management Air Quality Act (No. 39 of 2004) |
| **$NO_x$** | Oxides of Nitrogen |
| **PM10** | Particulate Matter with an aerodynamic diameter of less than 10μ |
| **PM2.5** | Particulate Matter with an aerodynamic diameter of less than 2.5μ |
| **PPM** | Parts per Million |
| **ROM** | Run Of Mine |
| **SA** | South Africa |
| **SANS** | South African National Standards |
| **SEPA** | Scottish Environmental Protection Agency |
| **$SO_2$** | Sulphur Dioxide |
| **tpd** | Tons Per Day |
| **TSP** | Total Suspended Particles |
| **μ** | Microns |
| **μg** | Micrograms |
| **US-EPA** | United States Environmental Protection Agency |
| **WB** | The World Bank Group |
| **WHO** | The World Health Organisation |

# AIR QUALITY IMPACT ASSESSMENT FOR CURRENT MINING OPERATIONS AND PROPOSED EXPANSION PROJECT AT LANGER HEINRICH URANIUM MINE, NAMIBIA

## 1 INTRODUCTION

Airshed Planning Professionals (Pty) Ltd was appointed by Metago Environmental Engineers (Pty) Ltd to undertake an air quality impact assessment for the current and proposed mining activities at Langer Heinrich Uranium Mine. The mine site is located approximately 90 km east of Swakopmund in the Namib Naukluft National Park central Erongo Region (Figure 1-1 and Figure 1-2).

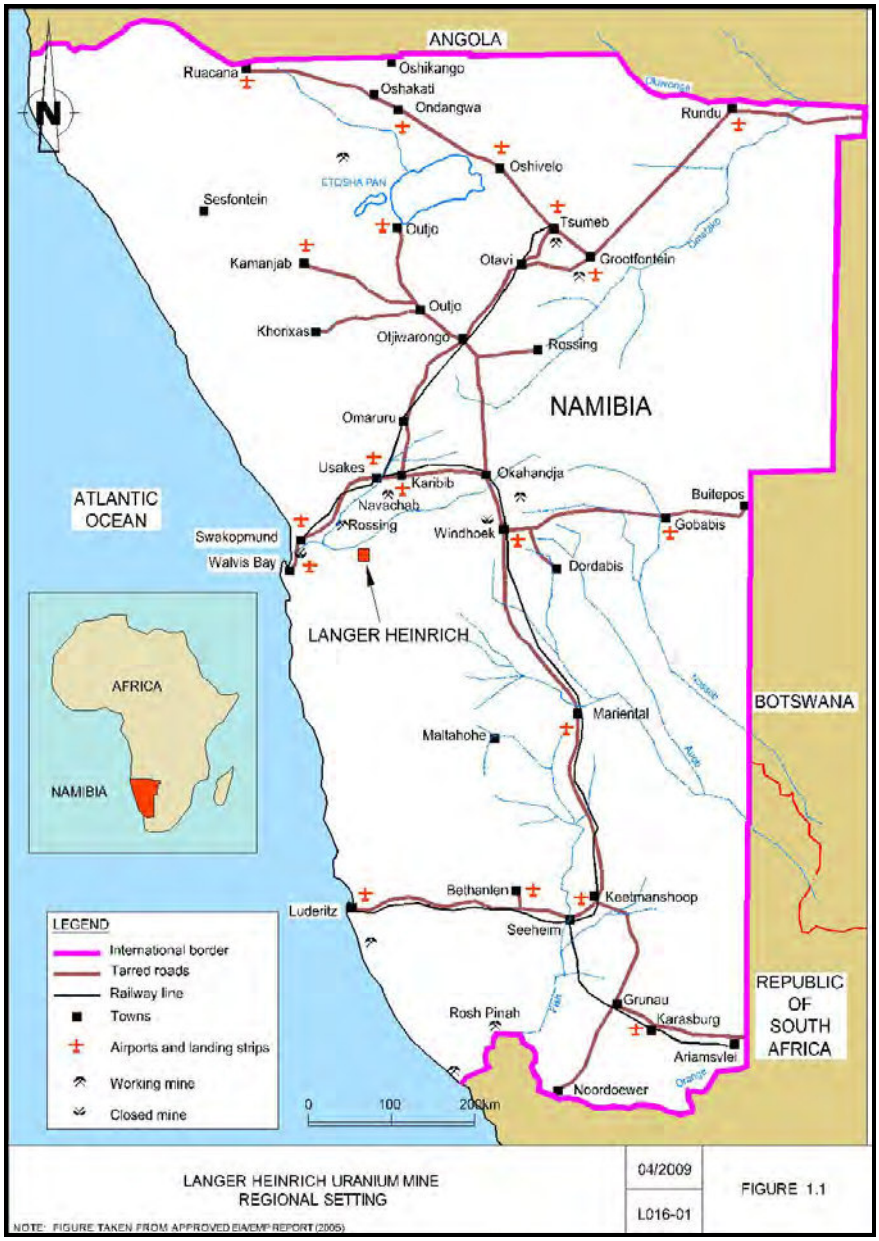


**Figure 1-1: Location of Langer Heinrich Uranium Mine in Namibia (Metago, 2009)**

**Figure 1-2: Regional location of Langer Heinrich Uranium Mine in the Erongo Region (Metago, 2009)**

Langer Heinrich Uranium Mine is an open cast uranium (uranium oxide) mine, with two operational open cast pits (Pit A west and Pit D). The current uranium oxide production rate is 3.7 million tonnes per annum (tpa). However, the mine proposes to expand its operations to increase production to between 5 and 10 million tpa. The main components of the expansion include a new satellite crushing plant, the enlargement of the existing processing plant and new open pit areas. The related components of the processing plant are provided in Table 1-1. Expansion activities will also include a heap leach pad (for the recovery of uranium from low grade ore that is currently stockpiled on site), modifications to tailings management and additional infrastructure and services.

**Table 1-1: Process plant expansion components**

| Processing activity | Description |
|---|---|
| Crushing and scrubbing | Additional crushing and scrubbing facilities |
| Leaching | Additional leach tanks |
| | Heavy fuel oil (HFO)/diesel powered steam boilers and related storage facilities |
| | Additional heat exchangers |
| Ion exchange | Scavenging resin in pulp and elution plant |
| Reagent storage | Expansion of reagent storage and mixing facilities |

Heap leaching is a pre-planned process where arrangements are made to optimise conditions for leaching. The mineral ore is piled in a heap and lixiviant fluid is distributed over the surface to leach metal from the heap. Lixiviant is a liquid medium used in hydrometallurgy to selectively extract the desired metal from the ore or mineral. It assists in rapid and complete leaching. The metal can be recovered from it in a concentrated form after leaching (Figure 1-3).

Major processes in the heap leaching process include:

1. Compacting soil on a slightly sloping ground and then covering it with an impermeable pad like an asphalt layer or a flexible plastic sheet.
2. Stacking crushed ore in big heaps on the pad and the agglomeration of fine particles to increase permeability.
3. As the reagent percolates through the heap, the wanted metal (s) is/are solubilised.
4. The leachate (metal containing solution) drained from the heap is collected in a pond and the solution is subsequently sent for metal recovery.

The reaction conditions is a heap vary from top to bottom and from the core to the surface. Important factors for a successful heap leaching operation are:

- Maintenance of good permeability;
- Good water balance;
- pH control; and,
- Steady supply of leaching reagents.

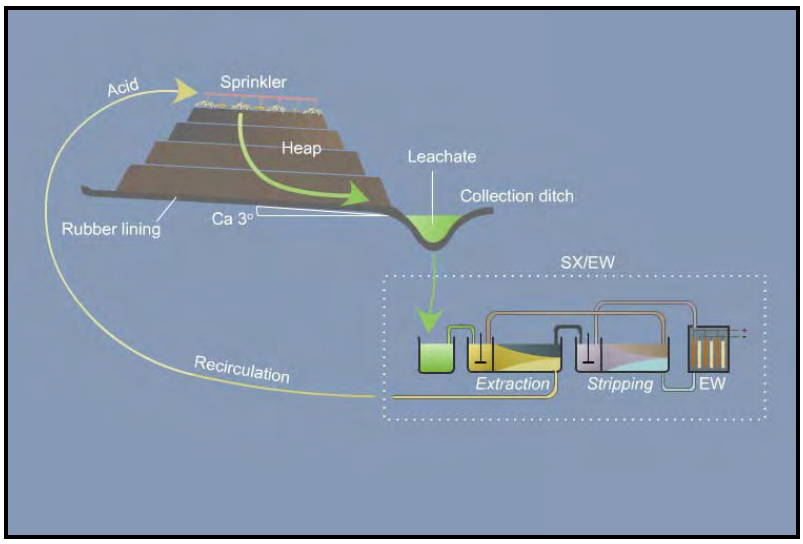


**Figure 1-3: Heap leaching followed by solvent extraction and electro-winning (http://wiki.biomine, 2009).**

Current mining activities at Langer Heinrich Uranium Mine are performed using conventional open pit mining methods. Mining activities include drilling and blasting, hauling of ore and waste rock (and other material handling activities), crushing and screening and processing of the ore at the processing plant (Figure 1-4). In addition, power is generated on an ad-hoc basis at the mine. These mining activities give rise to air pollutants that might have a negative impact on the environment and human health. It is therefore required to determine the possible ground level concentrations and dust fallout levels from the current and proposed mine as part of an environmental impact assessment and management plan to be developed for the mine.

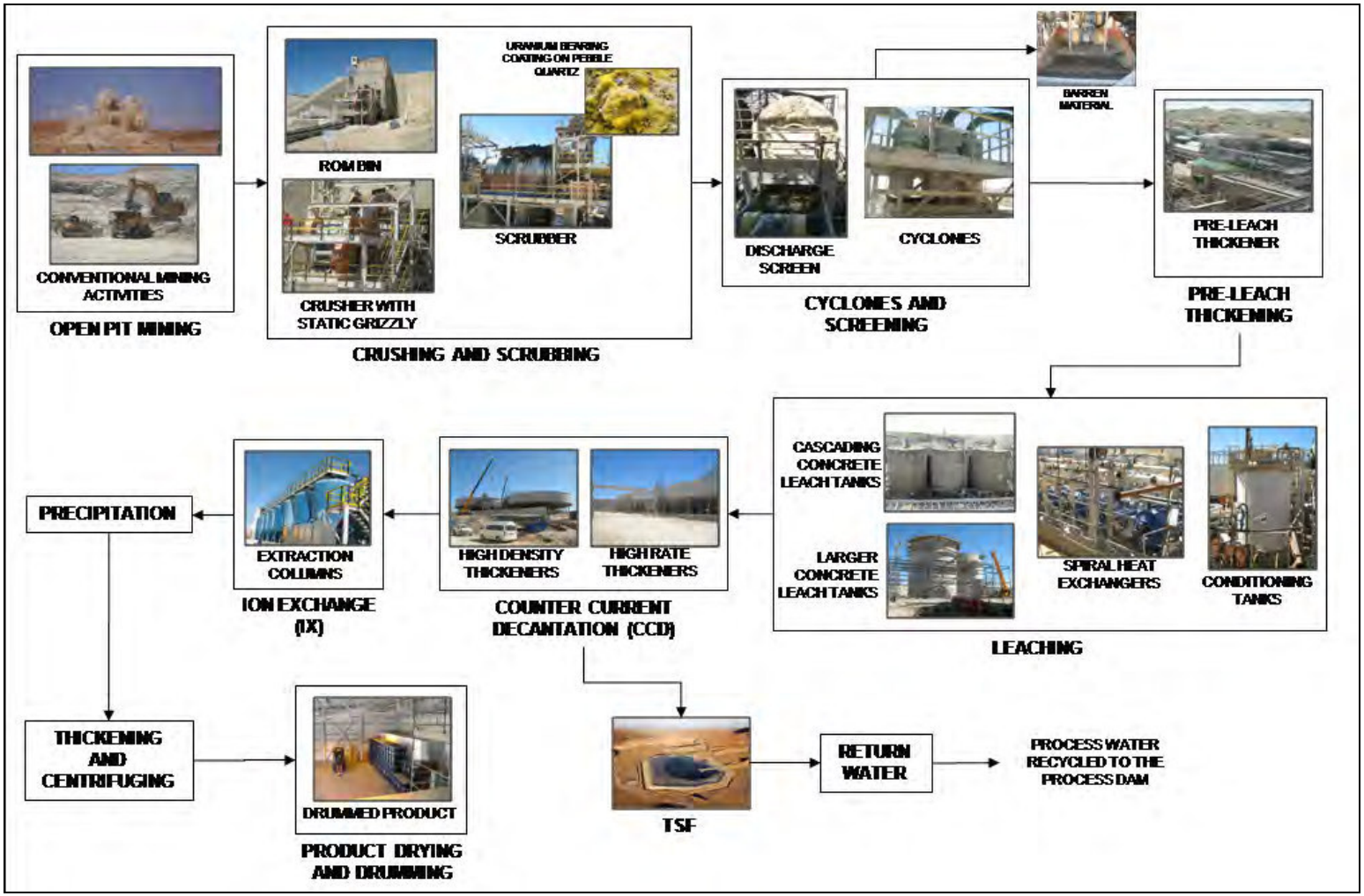


**Figure 1-4: Process flow diagram of main activities at Langer Heinrich Uranium Mine**

## 1.1 Terms of Reference

A ***baseline air quality characterisation***, including the assessment of:

- The regional climate and site-specific atmospheric dispersion potential.
- Preparation of hourly average meteorological data for input to the dispersion model;
  - Preparation of raw meteorological data. Meteorological data were obtained from the Langer Heinrich Uranium Mine weather station. The required meteorological data include hourly average wind speed, wind direction and temperature data.
  - Formatting of meteorological data for input to the dispersion model (surface data are required).
  - Simulation of wind field, mixing depth and atmospheric stability.
- Obtain and process topographical data for input into the dispersion mode l.
- Identification of existing sources of emission and characterisation of ambient air quality within the region based on observational data recorded to date (if available).
- Collate and analyse all monitoring data available from existing mining operations in the region and recorded data from site.
- Identify potentially sensitive receptors within the vicinity of the current and proposed mining operation that would be susceptible to air quality impacts.
- The legislative and regulatory context, including emission limits and guidelines, ambient air quality guidelines and standards, and dustfall classifications with specific reference to the Namibian legislation. Reference will also be made to applicable international requirements such as the World Health Organisation, World Bank Group and European Community.

An ***air quality impact study***, including the assessment of*:*

- Quantification of all current and proposed sources of atmospheric emissions including the following sources:
  - Opencast mining operations;
  - Haul roads from the mine to the processing plant and stockpiles,
  - Crushing and screening operations;
  - Vehicle activity on mine and access roads;
  - Materials handling operations (i.e. tipping, loading and off-loading);
  - Wind erosion from exposed areas such as the waste rock dump, topsoil piles and tailings/slimes dam; and,
  - Power generation on-site.
- Quantification of proposed construction phase emissions.
- Dispersion simulations of ground level PM10 concentrations and dust fallout for the current and proposed operations reflecting highest daily and annual average PM10 concentrations and dust deposition due to *routine* and *upset* emissions from the opencast mining operations. Atmospheric Dispersion Modelling System (ADMS) developed by the Cambridge Environmental Research Consultants (CERC) was used for the study.
- Analysis of dispersion modelling results, including:
  - Determine zones of maximum incremental ground level impacts (concentrations and dust fallout from each source); and,
  - Determine zone of maximum predicted cumulative ground level impacts (concentrations and dust fallout from all sources at the mine).

- Evaluation of potential for human health and environmental impacts.
- Preparation of predicted PM10 concentrations and dust fallout level model output files (for the current and proposed operations) to be used by the Radiation Specialists to determine the potential impacts from radiation within the modelling domain.

A ***dust management plan*** for the mine*:*

- Develop a dust management plan for the mine, including:
  - Estimation of emission control efficiencies required for each significant source;
  - Identification of suitable pollution abatement measures able to realise the required dust control efficiencies, and possible contingency measures;
  - Specification of source-based performance indicators, targets, and monitoring methods applicable for each source;
  - Recommendation of receptor-based performance indicators comprising of a monitoring network and targets; and,
  - Recommendations pertaining to record keeping, environmental reporting and community liaison.

## 1.2 Site Description and Sensitive Receptors

The mine site is located on the eastern edge of the Desert Zone, in the northerly part of the Namib Naukluft Park. It lies within a 1-2 km wide bottomed valley between the Langer Heinrich Mountains to the north and the Schiefer Mountains to the south (Figure 1-5). Elevation on the mine site varies from 550 m above mean sea level (amsl) to 1160 m amsl.

There are a number of significant tourist attractions within the Namib Naukluft Park and the closest of these is Bloedkoppie located ~7 km from the current mining operations. The Park is a popular tourist attraction including amongst other sites war graves at Tinkas Rover further east of Bloedkoppie. Other sensitive receptors include the Drillers Camp and the Contractors Camp which are located within the mine boundary (Figure 1-6). The Contractors Camp will only be temporary for the duration of the construction phase and the Driller Camp are only occupied for 4 days in a week. The closest mining community is located between 20 km to 40 km north of the mining license area. There are no permanent residential areas in close proximity to the Langer Heinrich Mine.

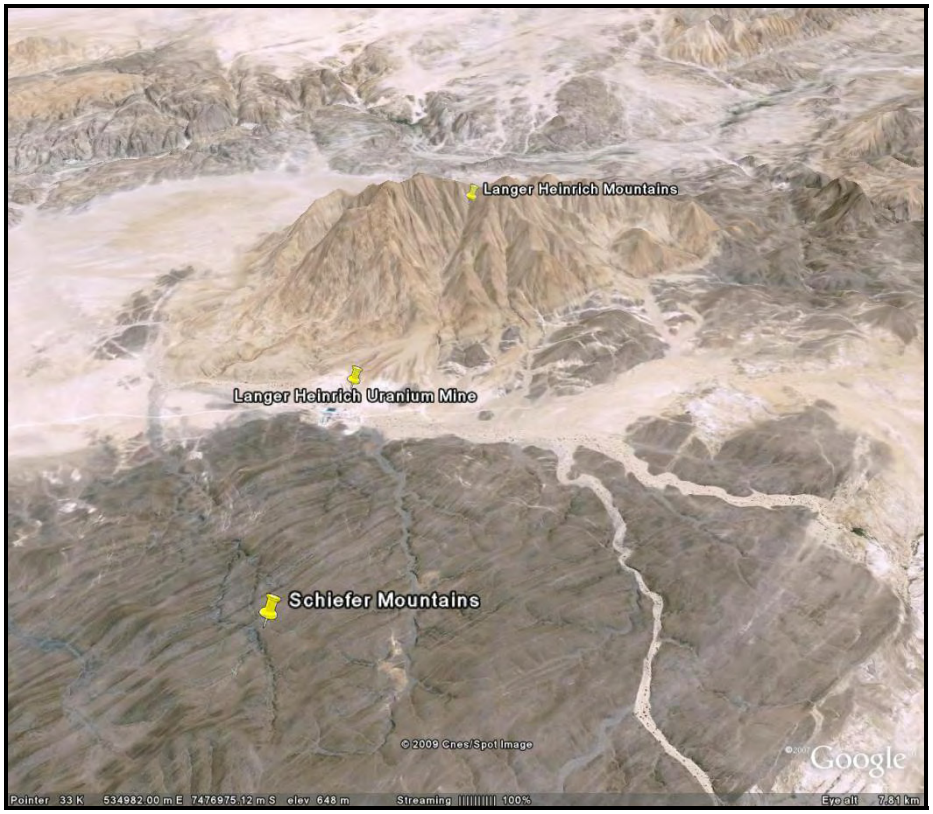


**Figure 1-5: Topography around the Langer Heinrich Mine.**

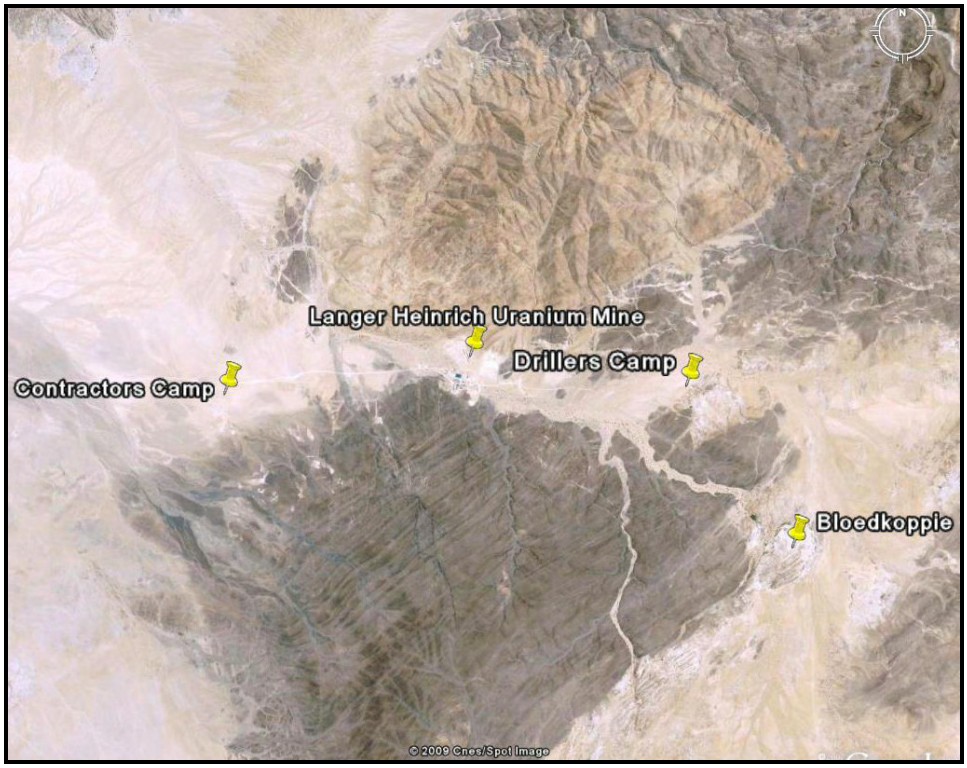


**Figure 1-6: Sensitive receptors located close to or within Langer Heinrich Uranium Mine.**

## 1.3 Assumptions and Limitations

Whereas with the current mining operations emissions and dispersion simulations are based on actual activities, proposed operations are based on design specifications. This usually results in limited data and calls for certain assumptions to be made. It is important to understand these constraints specifically when interpreting the simulated results. Data limitations and assumptions associated with this project are listed below:

- No long-term ambient monitored concentration data were available for the area. A dust fallout monitoring network and PM10/PM2.5 sampler have recently been installed at the mine with only data available on the dust fallout for the period April to May 2009. Dust fallout data from the multi-directional buckets could not be used for data were only reported for the east and west buckets.

- The impact assessment was limited to airborne particulates (including TSP and PM10). Although the current and proposed activities also emit gaseous pollutants from vehicle exhausts, the impact of these compounds are regarded to be low and was omitted from this study. Emissions emanating from the on-site power plant might be more significant but limited information was available at the time of the study and only the emissions were reported on.

- The dispersion model (ADMS) cannot compute real time mining processes, therefore average mining process throughputs were utilised. Thus even though the nature of the open pit mining operations (pit utilisation and roads) change over the life of mine, the current and proposed open pit mining areas were modelled to reflect the worst case condition (i.e. resulting in the highest impacts).

- Routine emissions for the current and proposed operations were simulated. Atmospheric releases occurring as a result of non-routine conditions were not accounted for. Blasting is seen as an intermittent source of emissions (non-routine) but was included in the routine simulations. The reason being that ambient air quality standards and guidelines for particulates are limited to 24-hour averages and cannot determine the significance of short-term releases such as blasting.

- The proposed expansion operations at Langer Heinrich Mine will include open pit operations to the east and west of the current operations. For the purpose of the current study, three future pit locations were selected to provide an indication of the variation in magnitude and spatial extent depending where the operations will be.

- The locations of the waste rock dumps for the proposed future mining operations were assumed to be near the open pit and the dimensions were based on the volume of the waste rock material.

- The mine layout plan used for the quantification of emissions and dispersion simulations reflected the worst-case design of the proposed expansion (i.e. largest footprint of the proposed tailings dam and proposed processing plant located further to the west). It also assumed all waste dumps, stockpiles and the tailings dams to be at the maximum size.

- A natural crusting of the outer layer of stockpiled material was observed during the site visit. This reduces the potential for wind erosion when undisturbed. No literature reference could be found on the control efficiency of this crust and for the purpose of this study it was assumed to be 30%. Crusting is a condition which occurs when wet soil dries, upon which the surface forms a hard crust. Crusting is a surface problem and it has been stated that with a crusting thickness of about 1cm there is virtually no erosion and the threshold friction velocity becomes 1.5 m/s, which under normal conditions will not be exceeded. If crusting does not occur, the predicted

particulate emission rates would be significantly underestimated and result in under-prediction of particulate air concentration and fallout.

- Radiation (radon and various radionuclides) associated with current and proposed future operations has not been covered as part of the air quality study and will be addressed by the Radiation Specialists. The predicted PM10 concentrations and dust fallout levels were used by the Radiation Specialists to determine the potential impacts from radiation within the modelling domain. For radon, separate dispersion simulations were conducted for use by the Radiation Specialists.

### 1.4 Interested and Affected Parties Concerns

The main concerns of the Interested and Affected Parties relating to air quality issues are listed in Table 1-2.

### 1.5 Report Structure

| | |
|---|---|
| Chapter 2 | Comprises a description of the legislative overview and the guidelines and standards to which the results are referenced. |
| Chapter 3 | Outlines the methodology and approach utilised in this study. |
| Chapter 4 | Addresses the atmospheric dispersion potential of the region, with a more detailed discussion on the macro-dispersion potential attached for further perusal in Appendix A. |
| Chapter 5 | Discussion on the background sources of atmospheric pollution in the region as well as available air quality data. Predicted impacts of the current operations are also addressed including an emissions inventory. |
| Chapter 6 | The impact assessment for the construction phase is provided in this section. |
| Chapter 7 | Emissions inventory and impact assessment pertaining to the quantification of atmospheric sources for the proposed operational phases are discussed. |
| Chapter 8 | Provides a qualitative impact assessment for the closure phase of the mine. |
| Chapter 9 | Air Quality Management Plan for Langer Heinrich Mine based on the main findings and recommendations for the mine. |

**Table 1-2: Summary of issues raised by Interested and Affected Parties (I&APs).**

| Category | Issue Raised | Section Addressed | Airshed Comment |
|---|---|---|---|
| Air quality: Dust | Concerns about dust being transported for long distances in the desert environment | Section 2<br>Section 10 | The regional transportation of windblown dust was not dealt with in this study for the main concern is the impacts of Langer Heinrich Mine on the surrounding environment and human health. The Strategic Environmental Assessment currently being undertaken by the Ministry of Mines and Energy will address long range transport of dust emissions from both the natural environment and anthropogenic sources. In this assessment all the sources at the mine were identified and quantified and the impacts from these sources predicted and assessed. |
| Air quality: Dust | Chemical suppression of dust | Section 10 | Chemical suppression can be utilised in the reduction of fugitive dust from various sources such as unpaved roads, and crushing and screening activities. This emissions reduction method can also be used in combination with other methods such as water suppression, especially on haul roads. |
| Air quality: Meteorology | Weather and meteorology: East winds | Section 4 | The meteorological data obtained from the Langer Heinrich mine weather station clearly reflected the occurrence of “east winds” specifically during the autumn and winter months. Also, the strongest wind speeds are associated with winds from the easterly sector. This was accounted for in the dispersion simulations. |

# 2 LEGAL REQUIREMENTS AND HUMAN HEALTH CRITERIA

In addressing the impact of air pollution emanating from the current and proposed mining operations, some background on the health effects of the various pollutants need to be provided.

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. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods. These averaging periods refer to the time-span over which the air concentration of the pollutant was monitored at a location. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average. The application of these standards varies, with some countries allowing a certain number of exceedances of each of the standards per year.

Reference is made to the ambient air quality guidelines as stipulated by the World Bank specifications (such as the European Community (EC), World Health Organisation (WHO) and the United States Environmental Protection Agency (US-EPA). Since South Africa (a neighbouring country) is also a developing country and is in the process of revising its ambient air quality standards, these were also included as reference.

## 2.1 Namibia Legislation

As far as could be ascertained, Namibia has adopted the South African air pollution legislation for air quality control in the form of the Atmospheric Pollution Prevention Act (Act No 45 of 1965) (APPA). Based on the stipulations of this act, the following parts are applicable:

| | | |
|---|---|---|
| Part II | : | Controls of noxious or offensive gases; |
| Part III | : | Atmospheric pollution by smoke; |
| Part IV | : | Dust control; and |
| Part V | : | Air pollution by fumes emitted by vehicles. |

This Act does not include any ambient air standards to comply with, but the Chief Air Pollution Officer (CAPCO) provides air quality guidelines for consideration during the issuing of Air Pollution Certificates. These air pollution guidelines have been provided for a number of criteria pollutants namely, sulphur dioxide, oxides of nitrogen, carbon monoxide, ozone, lead and particulate matter.

## 2.2 International Criteria

### *2.2.1 World Bank Group*

As of April 30, 2007, new versions of the World Bank Group Environmental, Health, and Safety Guidelines (known as the 'EHS Guidelines') are now in use as published by the IFC. These EHS guidelines replaced those documents previously published in Part III of the Pollution Prevention and Abatement Handbook. The new EHS Guidelines were developed as part of a two and a half year review process. The EHS Guidelines are intended to be 'living documents', and will be updated on a regular basis going forward. The EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP).

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

#### *2.2.1.1 Ambient Air Quality Guidelines*

The IFC has adopted the World Health Organisation ambient air quality guidelines (as discussed under Section 2.3.1).

#### *2.2.1.2 Guidelines for Power Generation*

A 10 MW Power Plant is in place at Langer Heinrich Uranium Mine and operates on an ad-hoc basis. The IFC provides guidelines on the stack height design and the emission limits for associated pollutants.

- The IFC prescribes that good international industry practice (GIIP) should be used in the design of any stack height to reduce and control emissions.

- Small combustion processes are systems designed with a heat input capacity of between 3 Megawatt thermal (MWth) and 50 MWht. The guidelines as provided in Table 2-1 apply to installations operating more than 500 hours per year and with a capacity utilisation of more than 30%.

**Table 2-1: World Bank emission limits for small combustion facilities (IFC, 2007)**

| Particulates | Sulphur Dioxide | Nitrogen Oxides, as $NO_2$ |
|---|---|---|
| 50 mg/Nm$^3$ or up to 100 mg/Nm$^3$ if justified by project specific considerations | 1.5% up to 3% sulphur content if justified by project specific considerations | If bore size diameter <400 mm : 1,460 mg/Nm$^3$ (otherwise 1,850 mg/Nm$^3$ ) |
| **Notes:** Emission limits applicable to liquid fuelled engines<br>Dry gas excess $O_2$ content of 15% | | |

### 2.2.2 World Health Organisation

During the 1990s the World Health Organisation (WHO) stated that no safe thresholds could be determined for particulate exposures and responded by publishing linear dose-response relationships for PM10 and PM2.5 concentrations (WHO, 2005). This approach was not well accepted by air quality managers and policy makers. As a result the WHO Working Group of Air Quality Guidelines recommended that the updated WHO air quality guideline document contain guidelines that define concentrations which, if achieved, would be expected to result in significantly reduced rates of adverse health effects. These guidelines would provide air quality managers and policy makers with an explicit objective when they were tasked with setting national air quality standards. Given that air pollution levels in developing countries frequently far exceed the recommended WHO air quality guidelines (AQGs), the Working Group also proposed interim targets (IT) levels, in excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005).

### 2.2.3 Greenhouse Gas Emissions

Although Namibia, is a developing (non-Annex 1) country in terms of the Kyoto protocol and therefore has no obligation to report its greenhouse gas emissions under the protocol, the greenhouse gas (GHG) inventory for this project will be calculated according to the Intergovernmental Panel on Climate Change (IPCC) 'Guidelines for National Greenhouse Gas Inventories' Revised 2006 version, and reported in a suitable format for inclusion in the national inventory.

### 2.2.4 South African Legislation

South Africa, a neighbouring country of Namibia, is in the process of revising their outdated air quality legislation. The National Environmental Management: Air Quality Act (Act no.39 of 2004) (AQA) commenced with on the 11$^{th}$ of September 2005 as published in the Government Gazette on the 9$^{th}$ of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61. Schedule 2 of the AQA provides ambient air quality standards that were based on the previously adopted Department of Environmental Affairs and Tourism (DEAT) guidelines (the "1$^{st}$ generation ambient air quality standards"). The Atmospheric Pollution Prevention Act will be repealed in September 2009, with new ambient air quality standards to form part of the new legislation (the draft standards were published for comment in the *Government Gazette No. 31987, 13 March 2009*).

The South African Bureau of Standards (SABS), through a technical committee, developed ambient air quality standards based on international best practice for particulate matter less than 10 µm in aerodynamic diameter (PM10), dustfall, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide, lead and benzene[1]. These standards informed the revised national ambient standards to be included in AQA.

[1] *SANS 69 - South African National Standard* - Framework for setting & implementing national ambient air quality standards, and *SANS 1929 - South African National Standard* - Ambient Air Quality - Limits for common pollutants.

## 2.3 Ambient Air Quality Standards and Guidelines

In this section, the guidelines and standards as stipulated by the World Bank Group (WBG) and the Namibian Government are discussed. The newly updated Environmental Health and Safety (EHS) guidelines published by the WB's International Finance Corporation (IFC) in April 2007 reference the WHO guidelines or other internationally recognised sources (US and EC) in the absence of national legislated standards. Since the Namibian legislation pertaining to air quality management is based on the South African APPA, the guidelines as is stipulated under the new AQA will be referenced (including the new proposed South African ambient air quality standards). South Africa and Namibia also have similar socio-economic trends and natural environment.

### *2.3.1 Suspended Particulate Matter*

The impact of particles on human health is largely depended on (i) particle characteristics, particularly particle size and chemical composition, and (ii) the duration, frequency and magnitude of exposure. The potential of particles to be inhaled and deposited in the lung is a function of the aerodynamic characteristics of particles in flow streams. The aerodynamic properties of particles are related to their size, shape and density. The deposition of particles in different regions of the respiratory system depends on their size.

The nasal openings permit very large dust particles to enter the nasal region, along with much finer airborne particulates. Larger particles are deposited in the nasal region by impaction on the hairs of the nose or at the bends of the nasal passages. Smaller particles (PM10) pass through the nasal region and are deposited in the tracheobronchial and pulmonary regions. Particles are removed by impacting with the wall of the bronchi when they are unable to follow the gaseous streamline flow through subsequent bifurcations of the bronchial tree. As the airflow decreases near the terminal bronchi, the smallest particles are removed by Brownian motion, which pushes them to the alveolar membrane (CEPA/FPAC Working Group, 1998; Dockery and Pope, 1994).

Air quality guidelines for particulates are given for various particle size fractions, including total suspended particulates (TSP), inhalable particulates or PM10 (i.e. particulates with an aerodynamic diameter of less than 10 µm), and respirable particulates of PM2.5 (i.e. particulates with an aerodynamic diameter of less than 2.5 µm). Although TSP is defined as all particulates with an aerodynamic diameter of less than 100 µm, and effective upper limit of 30 µm aerodynamic diameter is frequently assigned. PM10 and PM2.5 are of concern due to their health impact potentials. As indicated previously, such fine particles are able to be deposited in, and damaging to, the lower airways and gas-exchanging portions of the lung. PM10 limits and standards issued nationally and abroad are documented in Table 2-2.

The air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter are given in Tables 2-3 and 2-4.

**Table 2-2: Air quality guidelines and standards for inhalable particulates (PM10)**

| Authority | Maximum 24-hour concentration (µg/m³) | Annual Average concentration (µg/m³) |
|---|---|---|
| SA proposed standards | 75 (a) | 40 |
| European Community (EC) | 50 (b) | 40 (c) |
| United States EPA | 150 (d) | - |
| World Health Organisation | 50 (e) | 20 (e) |

Notes:
(a) Not to be exceeded more than 4 times per year.
(b) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005. Not to be exceeded more than 35 times per calendar year.
(c) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005.
(d) US National Ambient Air Quality Standards (http://epa.gov/air/criteria.html). Not to be exceeded more than once per year.
(e) WHO (2000) issued linear dose-response relationships for PM10 concentrations and various health endpoints with no specific guideline provided. WHO (2005) made available during early 2006 proposes several interim target levels (see Tables 2-3 and 2-4).

**Table 2-3: WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005)**

| Annual Mean Level | PM10 (µg/m³) | PM2.5 (µg/m³) | Basis for the selected level |
|---|---|---|---|
| WHO interim target-1 (IT-1) | 70 | 35 | These levels were estimated to be associated with about 15% higher long-term mortality than at AQG |
| WHO interim target-2 (IT-2) | 50 | 25 | In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1 |
| WHO interim target-3 (IT-3) | 30 | 15 | In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels. |
| WHO Air Quality Guideline (AQG) | 20 | 10 | These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use of the PM2.5 guideline is preferred. |

**Table 2-4: WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)**

| Annual Mean Level | PM10 (µg/m³) | PM2.5 (µg/m³) | Basis for the selected level |
|---|---|---|---|
| WHO interim target-1 (IT-1) | 150 | 75 | Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG) |
| WHO interim target-2 (IT-2)* | 100 | 50 | Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over AQG) |
| WHO interim target-3 (IT-3)** | 75 | 37.5 | Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG) |
| WHO Air Quality Guideline (AQG) | 50 | 25 | Based on relation between 24-hour and annual levels |

* 99th percentile (3 days/year)

** for management purposes, based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means

## 2.4 Dust Deposition Limits

Nuisance impacts due to dust are associated with dust-fall and soiling impacts and with reductions in visibility. Atmospheric particulates change the spectral transmission, thus diminishing *visibility* by scattering light. The scattering efficiency of such particulates is dependent upon the mass concentration and size distribution of the particulates. Various costs are associated with the loss of visibility, including: the need for artificial illumination and heating; delays, disruption and accidents involving traffic; vegetation growth reduction associated with reduced photosynthesis; and commercial losses associated with aesthetics. The *soiling* of building and materials due to dust frequently gives rise to damages and costs related to the increased need for washing, cleaning and repainting. Dust-fall may also impact negatively on sensitive industries, e.g. bakeries or textile industries.

### *2.4.1 International Dust-fall Criteria*

No standards or guidelines for the evaluation of dust-fall levels are available for the US-EPA, EU, WHO, or the WB. Foreign dust deposition standards issued by various countries are given in Table 2-5. It is important to note that the limits given by Argentina, Australia, Canada, Spain and the USA are based on annual average dust-fall. The standards given for Germany are given for maximum monthly dust-fall and therefore comparable to the dust-fall categories issued locally. Based on a comparison of the annual average dust-fall standards it is evident that in many cases a threshold of ~200 mg/m$^2$/day to ~300 mg/m$^2$/day is given for residential areas.

**Table 2-5: Dust deposition standards issued by various countries.**

| Country | Annual Average Dust Deposition Standards (based on monthly monitoring) (mg/m$^2$/day) | Maximum Monthly Dust Deposition Standards (based on 30 day average) (mg/m$^2$/day) |
|---|---|---|
| Argentina | 133 | |
| Australia | 133 (onset of loss of amenity)<br><br>333 (unacceptable in New South Wales) | |
| Canada<br>Alberta:<br>Manitoba: | 179 (acceptable)<br>226 (maximum acceptable)<br>200 (maximum desirable) | |
| Germany | | 350 (maximum permissible in general areas)<br>650 (maximum permissible in industrial areas) |
| Spain | 200 (acceptable) | |
| USA:<br>Hawaii<br>Kentucky<br><br>New York<br><br><br>Pennsylvania<br><br>Washington<br><br><br>Wyoming | <br>200<br>175<br><br>200 (urban, 50 percentile of monthly value)<br>300 (urban, 84 percentile of monthly value)<br><br>267<br><br>183 (residential areas)<br>366 (industrial areas)<br><br>167 (residential areas)<br>333 (industrial areas) | |

### *2.4.2 South African Dust-fall Criteria*

Dust deposition may be gauged according to the criteria published by SABS. This includes a system of dust-fall rate assessment were dust deposition rates are evaluated against a four-band scale, as presented in Table 2-6. Target, action and alert thresholds for ambient dust deposition, as published by Standards SA, are given in Table 2-7.

**Table 2-6**: **Bands of dust-fall rates, as published by Standards SA (SANS 1929:2009)**

| BAND NUMBER | BAND DESCRIPTION LABEL | DUST-FALL RATE (D) ($mg/m^{-2}/day^{-1}$, 30-day average) | COMMENT |
|---|---|---|---|
| 1 | RESIDENTIAL | D < 600 | Permissible for residential and light commercial |
| 2 | INDUSTRIAL | 600 < D < 1 200 | Permissible for heavy commercial and industrial |
| 3 | ACTION | 1 200 < D < 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 < D | Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority. |

**Table 2-7**: **Target, action and alert thresholds for ambient dust-fall**

| LEVEL | DUST-FALL RATE (D) ($mg\ m^{-2}\ day^{-1}$, 30-day average) | AVERAGING PERIOD | PERMITTED FREQUENCY OF EXCEEDANCES |
|---|---|---|---|
| TARGET | 300 | Annual | |
| ACTION RESIDENTIAL | 600 | 30 days | Three within any year, no two sequential months. |
| ACTION INDUSTRIAL | 1 200 | 30 days | Three within any year, not sequential months. |
| ALERT THRESHOLD | 2 400 | 30 days | None. First exceedance requires remediation and compulsory report to authorities. |

According to the SANS dust-fall 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 dust-fall rates in the Band 4 ALERT.

## 2.5 Proposed Evaluation Criteria for the Langer Heinrich Uranium Project

For the purpose of this study the evaluation criteria used are provided in Table 2-8.

**Table 2-8: Langer Heinrich Uranium proposed evaluation criteria.**

| POLLUTANT | AVERAGING PERIOD | SELECTED CRITERIA | COUNTRY |
|---|---|---|---|
| PM10 | 24-hour Mean (µg/m³) | 50(a) | WHO AQG & EC limit |
| | | 75(b)(c) | Proposed SA Standard |
| | Annual Mean (µg/m³) | 20 | WHO AQG & EC 2010 limit |
| | | 40 | Proposed SA Standard |
| Dust fallout | 30-day average ($mg/m^2/day$) | 600 | SA SANS residential action limit |
| | | 350 | German limit in general areas |

Notes:

(a) Not to be exceeded more than 35 times per calendar year as specified by the EC.

(b) Not to be exceeded more than 4 times per year.

(c) Same as WHO interim target-3 (IT-3)

# 3 METHODOLOGY

In assessing atmospheric impacts from the current and proposed Langer Heinrich Uranium Mine operations, an emissions inventory was undertaken, atmospheric dispersion modelling conducted and predicted air pollutant concentrations evaluated.

## 3.1 Baseline Assessment

The baseline assessment served to give a detailed description of the state of the environment and existing levels of pollution within the region.

### *3.1.1 Dispersion Potential of the Site*

Meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. On-site meteorological data for Langer Heinrich Uranium Mine were obtained for the years 2006 to 2008. The meteorological data included hourly average wind speed, wind direction and temperature. Mixing heights were estimated for each hour, based on prognostic equations. Wind speed and solar radiation were used to calculate hourly stability classes. The analysis of the meteorological data included diurnal temperature profile, wind roses, atmospheric stability classifications. For the purposes of establishing the local climatology, it was necessary to analyse the three year data (2006 to 2008), however, a normal requirement is for a five-year database. An analysis of the data served to provide a general description of the local climate and to calculate fugitive airborne dust emissions to be used in the dispersion simulations.

### *3.1.2 Ambient Concentrations and Dust Fallout levels*

For the completion of a baseline investigation, a good understanding of the existing ambient air quality in the region is required. No such data are available for the region. A dust fallout monitoring network however, currently exists at Langer Heinrich Uranium Mine with data available for the period April to May 2009. A PM10/2.5 sampler has also been installed but only recently became operational with not sufficient data available for inclusion into the report.

## 3.2 Emissions Inventory

An emissions inventory was established and comprised emissions for the construction, current and proposed operational phases. The establishment of an emissions inventory is necessary to provide the source and emissions data required as input to the dispersion simulations. The release of particulates represents the most significant emission and is the focus of the study.

In the quantification of emissions (Chapter 6), use was made of predictive emission factor equations published by the US-EPA (EPA, 1996). An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission rates for pollutants (PM10 and TSP) from the current operations, and the proposed construction and operational phases were calculated using US-EPA emission factors.

### 3.3 Selection of dispersion model

Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

For the purpose of the study, it was decided to use the Atmospheric Dispersion Modelling System developed by the Cambridge Environmental Research Consultants (CERC). CERC was established in 1986, with the aim of making use of new developments in environmental research from Cambridge University and elsewhere for practical purposes. CERC's leading position in environment software development and associated consultancy has been achieved by encapsulating advanced scientific research into a number of computer models which include ADMS 4. This model simulates a wide range of buoyant and passive releases to the atmosphere either individually or in combination. It has been the subject of a number of inter-model comparisons (CERC 2000, Hall *et al* 2001), one conclusion of which is that it tends to provide conservative values under unstable atmospheric conditions in that it predicts higher concentrations than the older models close to the source.

ADMS 4 is a new generation air dispersion model which means that it differs from the regulatory models traditionally used in a number of 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 described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class) and in allowing more realistic asymmetric plume behaviour under unstable atmospheric conditions. Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetric Gaussian expression).

ADMS 4 is currently used in many countries worldwide and users of the model include Environmental Agencies in the UK and Wales, the Scottish Environmental Protection Agency (SEPA) and regulatory authorities including the UK Health and Safety Executive (HSE).

Concentration and deposition distributions for various averaging periods may be calculated. It has generally been found that the accuracy of off-the-shelf dispersion models improve with increased averaging periods. The accurate prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the location. For purposes of this report, the shortest time period modelled is one hour.

There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model description of atmospheric physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

Nevertheless, dispersion modelling is generally accepted as a valid tool to quantify and analyse the atmospheric impact of existing installations and for determination of the impact of future installations.

The dispersion modelling domain for the study included an area covering 20 km by 20 km. This area was further divided into a receptor grid matrix with a resolution of 200 m.

### 3.4 Meteorological data requirements

ADMS 4 requires hourly average meteorological data as input, including wind speed, wind direction, a measure of atmospheric turbulence, ambient air temperature and mixing height. Hourly meteorological data for 2008 observed at the Langer Heinrich Mine weather station was used in the dispersion simulations. The mixing height for each hour of the day, as well as atmospheric stability, is estimated by the ADMS meteorological pre-processor.

### 3.5 Preparation of source data

ADMS 4 is able to model point, area, volume and line sources. For the current and proposed operational phases, the unpaved roads, paved roads, drilling, blasting and the various storage piles were modelled as area sources. Materials handling and crushing and screening activities were modelled as volume sources. Due to the lack of detailed information for the proposed construction activities e.g., number of dozers to be used, size and locations of temporary stockpiles and temporary roads, rate of on–site vehicle activity, emissions were instead estimated on an area wide basis. The quantity of dust emissions was assumed to be proportional to the area of land being worked for the heap leach pad, tailings dam wall, mine workshop and crusher area.

### 3.6 Preparation of receptor grid

The dispersion of pollutants was modelled for an area covering 20 km (north-south) by 20 km (east-west) for the study. ADMS simulates ground-level concentrations for each of the receptor grid points. The nearby settlements (Bloedkoppie and the Drillers Camp) were included as discrete receptors. The Contractors Camp that will be occupied during the construction phase was added as a sensitive receptor during this phase of the project.

### 3.7 Model input and execution

Input into the dispersion model includes prepared surface meteorological data, topographical data, source data, information on the nature of the receptor grid and emissions input data. The model inputs were verified before the model was executed.

### 3.8 Plotting of model outputs

Simulated outputs for PM10 (daily and annual), TSP (average daily) for the various modelled *scenarios (Proposed construction phase, Current: Pit A west and Pit D, Future West Pit, Future Centre Pit, Future East Pit*) were plotted (Figure 3-1). This layout reflects the worst-case scenario for it includes the largest footprint of the tailings dam with the plant located further east. The latest mine plan had the tailings dam covering a smaller area with the proposed plant closer to the current processing plant.

### 3.9 Compliance analysis and impact assessment

The predicted air pollution concentrations and dustfall rates were compared to international air quality limits and health and welfare thresholds to facilitate compliance and impact assessments. These concentrations were summarised and form the basis of the compliance assessment and evaluation.

### 3.10 Metago Methodology for Assessing the Significance of Impacts (after Metago, 2009)

Impacts were assessed based on consideration of the impact severity, spatial scale and duration of impacts, which together determines the impact consequence (Table 3-1).

**Table 3-1: Impact Assessment Criteria (Metago, 2009)**

| | | |
|---|---|---|
| **Criteria for ranking of the SEVERITY of environmental impacts** | **H** | Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action. |
| | **M** | Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints. |
| | **L** | Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. |
| | **L+** | Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints. |
| | **M+** | Moderate improvement. Will be within or better than the recommended level. Nor observed reaction. |
| | **H+** | Substantial improvement. Will be within or better than the recommended level. Favourable publicity. |
| **Criteria for ranking the DURATION of impacts** | **L** | Quickly reversible. Less than the project life. Short term |
| | **M** | Reversible over time. Life of the project. Medium term. |
| | **H** | Permanent. Beyond closure. Long term. |
| **Criteria for ranking the SPATIAL SCALE of impacts** | **L** | Localized – Within the site boundary. |
| | **M** | Fairly widespread – Beyond the site boundary. Local |
| | **H** | Widespread – Far beyond site boundary. Regional/ national. |
| **PROBABILITY (of exposure to impacts** | **H** | Definite/ Continuous |
| | **M** | Possible/ frequent |
| | **L** | Unlikely/ seldom |

**Figure 3-1: Modelled current and proposed construction and operational phases.**

# 4 REGIONAL CLIMATE AND ATMOSPHERIC DISPERSION POTENTIAL

## 4.1 Atmospheric Dispersion Potential of the Region

The meteorological characteristics of a site govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). 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 and atmospheric stability. 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. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

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. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro and meso-scales therefore need be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area.

### *4.1.1 Meso-Scale Atmospheric Dispersion Potential*

The analysis of meteorological data observed for the site provides the basis for the parameterisation of the meso-scale ventilation potential of the site, and to provide the input requirements for the dispersion simulations. Parameters that need to be taken into account in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth. A comprehensive data set for at least one year of site-specific hourly average wind speed, wind direction and temperature data are needed for the dispersion simulations.

### *4.1.2 Site Specific Wind Field*

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. In order to understand the potential for dispersion at a given site, it is preferred to have an on-site meteorological station. Langer Heinrich Uranium Mine has a meteorological station on-site and meteorological data for the period January 2006 to December 2008 were a used for the study. Data availability for wind speed and wind direction over the three year period was 71%. This can be regarded as adequate, with data availability in excess of 80% being preferred.

Wind roses comprise 16 spokes, which represent the directions from which winds blew during the period. The colours reflected the different categories of wind speeds with the dotted circles indicating the frequency of occurrence, and each circle representing a 5% frequency of occurrence. Period,

daytime and night-time average wind roses generated based on meteorological data from the Langer Heinrich Uranium Mine on-site meteorological station are depicted in Figure 4-1.

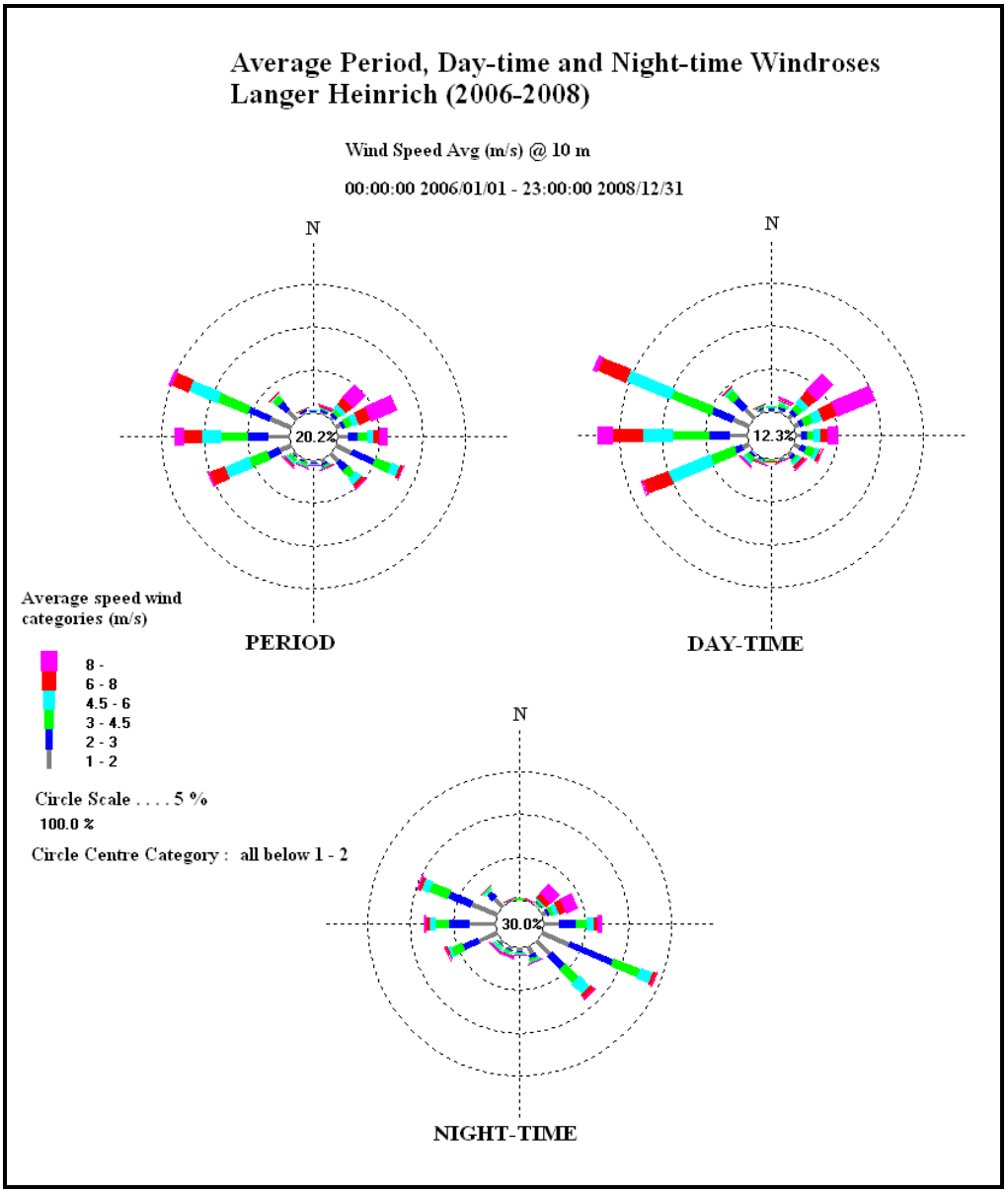


**Figure 4-1: Site- specific average period, day-time and night-time seasonal wind roses for Langer Heinrich Mine for 2006 to 2008.**

Over the three- year period, predominant winds are from the west-northwest, west and west-southwest. The strongest winds are from the east-northeast and northeast even though the frequency of occurrence is for 8% and 6% of the time, respectively. Calm conditions (wind speeds of less than 1 m/s) occurred for 20% of the time. Day-time conditions show a similar pattern with winds being predominantly from the westerly sector, and less frequent but stronger winds from the easterly sector. Night-time conditions are characterised by an increase in winds from the south–easterly sector and a decrease in winds from the westerly and north-westerly sectors. As is typical from night-time conditions, and increase in calm conditions are noted.

The seasonal variability in the wind field for the Langer Heinrich Mine site for the period 2006-2008 is shown in Figure 4-2. During the summer months, strong winds of more than 8 m/s dominate from the westerly sector (67% of the time) with highly infrequent winds from the other sectors. During autumn, strong winds of up to 8 m/s blow more frequently from the easterly sector with the westerly winds still prevailing. Strong east-north-easterly and north-easterly winds occur for 7% of the time. An increase in the easterly winds is noticeable during the winter months with an increase in flow from this sector to 53% (ranging from north-east to south-east). It is also during the winter months that the strongest wind speeds are recorded and these are associated with the "east winds". The highest wind speed recorded at Langer Heinrich Uranium Mine is 17.2 m/s (in May 2006) from the east-northeast. During springtime the westerly flow starts to prevail again with a decrease in winds from the east.

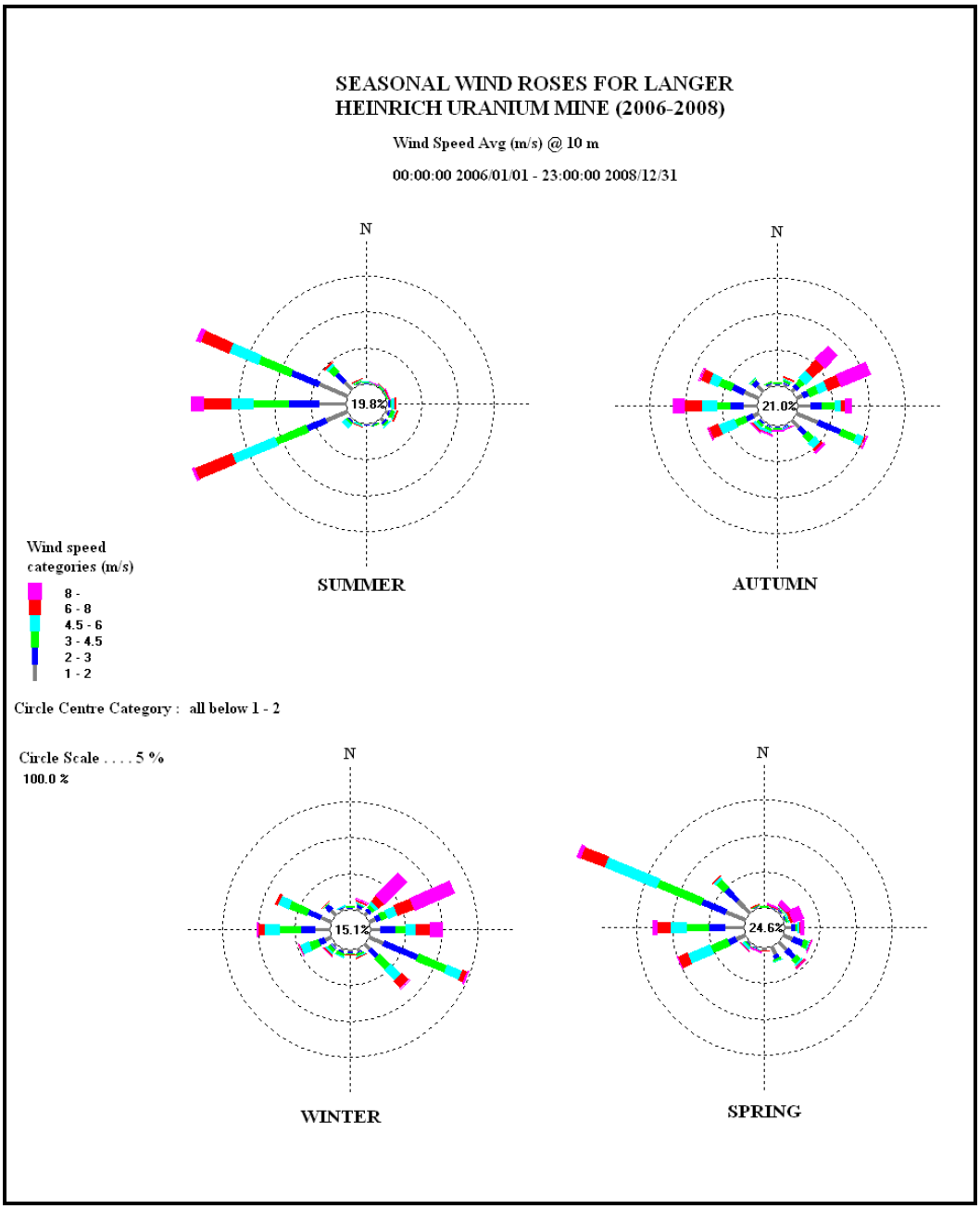


**Figure 4-2: Site- specific seasonal wind roses for Langer Heinrich Mine for 2006 to 2008**

Langer Heinrich Uranium Mine is located in an area with complex terrain. The topography of an area normally has an effect on the localised wind flow and it is for this reason that topographic data was included in the study to account for the variance in wind flow. Figure 4-3 illustrates the extent of the modelling domain and the topography of the study area.

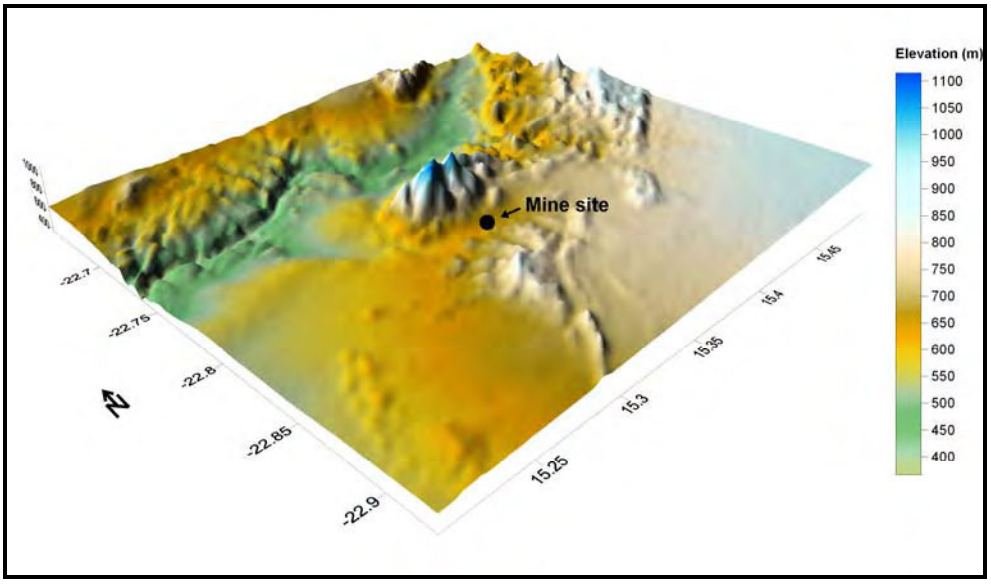


**Figure 4-3: Topography of the area surrounding Langer Heinrich Uranium Mine.**

### *4.1.3 Air 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 is able to rise), and determining the development of the mixing and inversion layers. The temperature trends for the mine site obtained from the site-specific meteorological data for the year 2008 are presented in Figure 4-4.

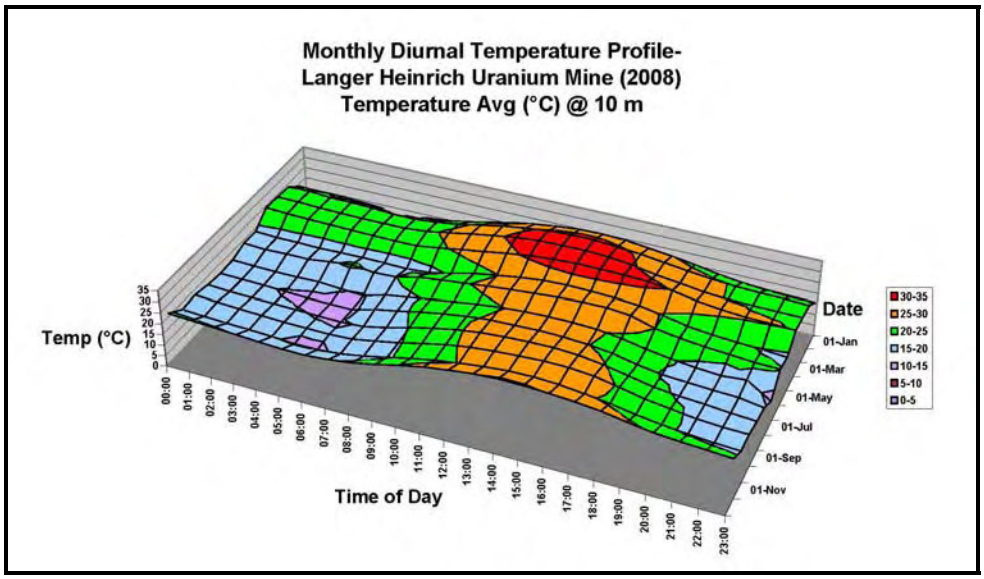


**Figure 4-4: Air temperature trends for Langer Heinrich Uranium Mine site for the year 2008**

The monthly temperature trends recorded at the Langer Heinrich Mine weather station for the year 2008 are presented in Table 4-1. Minimum temperatures have been recorded as ranging from 5°C to 17°C with maximum temperatures ranging between 30°C and 39°C. Mean temperatures range between 20°C and 27°C.

**Table 4-1: Minimum, maximum and mean temperature for Langer Heinrich Mine for 2008**

| Station | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Langer Heinrich Mine | Maximum | 33 | 39 | 37 | 36 | 36 | 30 | 32 | 32 | 37 | 36 | 36 | 39 |
| | Mean | 22 | 26 | 27 | 27 | 22 | 23 | 22 | 20 | 20 | 21 | 20 | 24 |
| | Minimum | 13 | 17 | 17 | 15 | 10 | 17 | 7 | 5 | 8 | 10 | 10 | 12 |

### *4.1.4 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 data recorded at the Langer Heinrich Uranium Mine weather station is shown in Table 4-2 and Figure 4-5. The average total annual rainfall for the site for the year 2008 is 96.6mm. Rain falls mainly in summer with dry winter months.

**Table 4-2: Monthly average rainfall figures (mm) for Langer Heinrich Mine (2008)**

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Ann |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Langer Heinrich Mine Station | 0 | 71 | 18 | 0.4 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 3.2 | 3.2 | 97 |

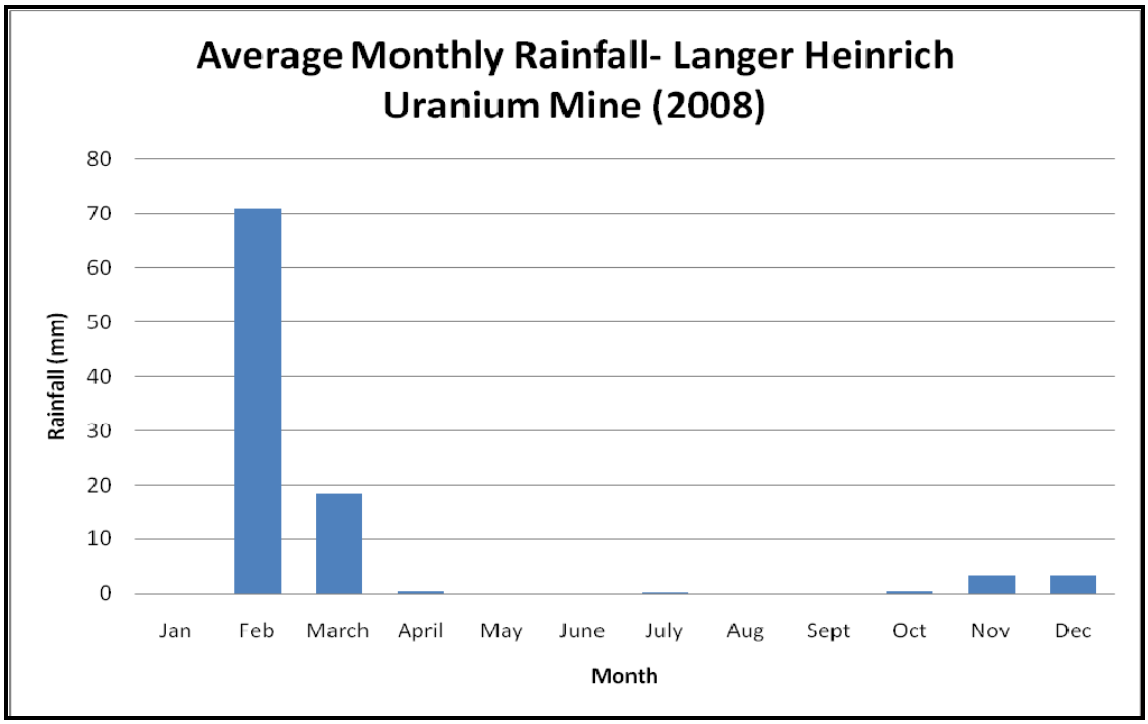


**Figure 4-5: Average monthly rainfall recorded at Langer Heinrich Uranium Mine in 2008**

### *4.1.5 Atmospheric Stability and Mixing Depth*

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground-based inversions and the erosion of the mixing layer. Night times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

The mixed layer (i.e. layer within which air pollutants are able to mix) therefore ranges in depth from a few metres during the evening and early morning to the base of the lowest-level elevated inversion during unstable, daytime conditions. Elevated inversions may occur for a variety of reasons, and on some occasions as many as five may occur in the first 1000 m above the surface. The lowest-level elevated inversion is located at a mean height above ground of 1 550 m during winter months with a 78 % frequency of occurrence. By contrast, the mean summer subsidence inversion occurs at 2 600 m with a 40% frequency.

For elevated releases such as stack emissions, the highest ground level concentrations would occur during unstable, daytime conditions. The wind speed resulting in the highest ground level concentration depends on the plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to the increased ventilation, it would be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. In contrast, the highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions.

# 5 BASELINE AIR QUALITY ASSESSMENT

Various components of the bio-physical and socio-economic environment may be impacted by atmospheric emissions associated with the various phases of the project. These components include the possible impact on:

- ambient air quality;
- the aesthetic environment;
- local residents and neighbouring communities; and,
- employees.

## 5.1 Existing sources

The identification of existing sources of emissions in the region and the characterisation of existing ambient pollutant concentrations is fundamental to the assessment of the potential for cumulative impacts and synergistic effects given the current and proposed operations and their associated emissions.

A comprehensive emissions inventory has not been completed for the region to date. The establishment of such an inventory was not within the scope of the current study. Instead source types present in the area and the pollutants associated with such source types were noted with the aim of identifying pollutants which may be of importance in terms of cumulative impact potentials. Sources identified as possibly impacting on air quality in the region include, but are not limited to:

- Fugitive emissions from mining operations;
- Vehicle tailpipe emissions from national and main roads;
- Biomass burning (veld fires in agricultural areas within the region); and,
- Various miscellaneous fugitive dust sources (agricultural activities, wind erosion of open areas, vehicle-entrainment of dust along paved and unpaved roads).

### *5.1.1 Mining Operations in the Region*

Fugitive dust sources associated with mining activities include drilling and blasting operations, materials handling activities, vehicle-entrainment by haul vehicles and wind-blown dust from tailings impoundments and stockpiles. Mining operations represent potentially the most significant sources of fugitive dust emissions (PM2.5, PM10 and TSP) with small amounts of oxides of nitrogen ($NO_x$), carbon monoxide (CO), sulphur dioxide ($SO_2$), methane, and carbon dioxide ($CO_2$) being released during blasting operations and from mine trucks.

Experience has shown that fugitive dust emissions due to on-site operations are typically only of concern within 3 km of the mine boundary, depending on the location of the mine boundary and extend of the mining operations. This is the reason for the current manner in which atmospheric emissions are treated for mining operations. Dust suppression methods that are most frequently used in local mining operations include wet suppression and chemical stabilisation of haul roads and storage piles, and the vegetation or rock cladding of tailings impoundments.

Mines located in the region include Rössing Uranium Mine, located ~46 km to the north-west (Figure 5-1). Rössing Mine comprises of open-pit mining and is one of the largest uranium mines in the world. Valencia Uranium and Trekkopje mines are approved proposed uranium mines in the region and will also be opencast. Trekkopje is located approximately 62 km to the north-northwest of Langer Heinrich Uranium Mine, with Valencia located ~49 km to the north. The existing Rössing Uranium mine is considered too far away to have a significant influence on the ambient air quality in the vicinity of Langer Heinrich Mine. Other uranium mines currently in the exploration phase include Bannerman's Etango project and Extract Resources Rössing South mine.

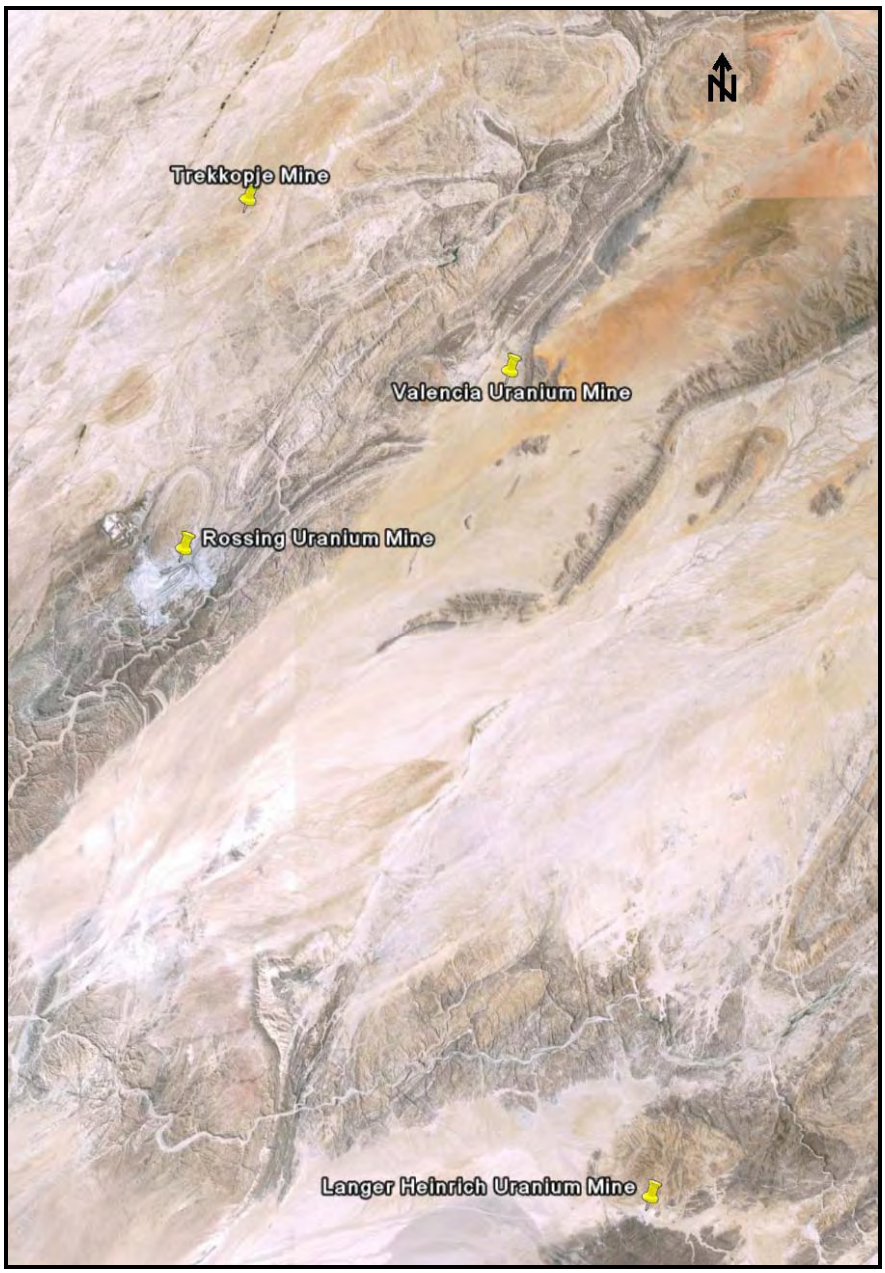


**Figure 5-1: Various existing and proposed mines located close to Langer Heinrich Mine in the region.**

### *5.1.2 Vehicle Tailpipe Emissions*

Air pollution from vehicle emissions may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly into the atmosphere, and secondary, those pollutants formed in the atmosphere as a result of chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The significant primary pollutants emitted by vehicles include $CO_2$, CO, hydrocarbons (HCs), $SO_2$, $NO_x$, particulates and lead. Secondary pollutants include: nitrogen dioxide ($NO_2$), photochemical oxidants (e.g. ozone), HCs, sulphur acid, sulphates, nitric acid, nitric acid and nitrate aerosols. Toxic hydrocarbons emitted include benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons (PAH). Benzene represents an aromatic HC present in petrol, with 85% to 90% of benzene emissions emanating from the exhaust and the remainder from evaporative losses.

Vehicle tailpipe emissions are also localised sources and unlikely to impact far-field. A network of roads exists close to Langer Heinrich Uranium Mine and these include the gravel C28 through the Namib Naukluft Park, linking Swakopmund and Windhoek. This road is primarily utilised by tourists and Langer Heinrich Mine personnel. The Langer Heinrich access road that leads to the mine are only used by mine personnel, the mine commuting busses and delivery trucks.

### *5.1.3 Agricultural Activities*

The main economic activities within the region include agriculture, small scale farming, commercial farming and tourism. These activities are widely scattered throughout the region. The region is too arid for crop farming and the main activity seems to be cattle, sheep, goat and game farming.

Cattle farms (primarily when operated on large scale) are significant sources of fugitive dust especially when feedlots are used and the cattle trample in confined areas. According to the U.S.EPA, cattle emit methane through a digestive process that is unique to ruminant animals called enteric fermentation. The calf-cow sector of the beef industry was found to be the largest emitter of methane emissions. Where animals are confined densely, the main pollutants of concern include dust from the animal movements, their feed and their manure, ammonia ($NH_3$) from the animal urine and manure, and hydrogen sulphide ($H_2S$) from manure pits. This is not likely to be a problem in this region with farms only located far away and covering large areas.

### *5.1.4 Biomass Burning*

Crop-residue burning and general wild fires (veld fires) represent significant sources of combustion-related emissions associated with agricultural areas. This is typically a concern in savannah regions where biomass-burning results in incomplete combustion with carbon monoxide, methane and nitrogen dioxide being emitted during the process. The vegetation cover in the region of Langer Heinrich mine is considered too sparse to be a significant source.

### *5.1.5 Fugitive Dust Sources*

Fugitive dust emissions may occur as a result of vehicle entrained dust from local paved and unpaved roads, and wind erosion from open areas. The extent of particulate emissions from the main roads will depend on the number of vehicles using the roads and on the silt loading on the roadways. The extent, nature and duration of agricultural activities and the moisture and silt content of soils are

required to be known in order to quantify fugitive emissions from this source. The quantity of wind-blown dust is similarly a function of the wind speed, the extent of exposed areas and the moisture and silt content of such areas.

The pollutants listed above are released directly by sources and are therefore termed 'primary pollutants'. 'Secondary pollutants' which form in the atmosphere as a result of chemical transformations and reactions between various compounds include: $NO_2$, various photochemical oxidants (e.g. ozone), hydrocarbon compounds, sulphur acid, sulphates, nitric acid and nitrate aerosols.

## 5.2 Measured Background

### *5.2.1 Dust fallout*

For the completion of a baseline investigation, a good understanding of the existing ambient air quality in the region is required. No such data are available for the region. A dust fallout monitoring network exists at Langer Heinrich Mine and shown below in Table 5-1 are the single dust bucket fallout results for the months of April and May 2009. The positions of the single dust buckets are shown in Figure 10-3.

**Table 5-1: Dust Fallout Results for the months of April and May 2009 at Langer Heinrich Mine**

| Bucket identification | Dust fallout (mg/m²/day)- April 2009 | Dust fallout (mg/m²/day)- May 2009 |
|---|---|---|
| Dust bucket number 2 | 486 | 3 272 |
| Dust bucket number 4 | 226 | No results |
| Dust bucket number 5 | 1 147 | 1 841 |
| Dust bucket number 6 | 1 203 | 1 276 |
| Dust bucket number 7 | 2 576 | 2 900 |

The two months of available dust fallout data indicated relative high dust-fall levels in and around the mining operations. Dust fallout on the western side (Bucket number 2) recorded the highest dust-fallout during May with constantly high dust fallout levels recorded at Bucket number 7 located on the western side. When compared against the German maximum monthly dust deposition standard of 650 mg/m²/day in industrial areas buckets 5, 6 and 7 exceed for both months with bucket 2 only exceeding during may 2009. The South African SANS limits indicate 1,200 mg/m²/day as the industrial action level not to be exceeded for two consecutive months. Again, this limit is exceeded for both months at buckets 5, 6 and 7. Bucket 2 exceeded this action limit in May 2009. Thus, on average is the recorded dust fallout high at the mine site.

### *5.2.1 Ambient monitoring data*

A PM10/PM2.5 E-Sampler is in place at Langer Heinrich Mine with only one month of PM2.5 ambient monitoring data available at the time of the study. The sampler records either PM10 or PM2.5 (depending on the inlet) ambient concentrations. Data for the period 1 June to 5 July 2009 indicated

low PM2.5 concentrations on average ranging between 0.4 µg/m³ and 15 µg/m³. Unrealistically high concentrations were measured for a couple of days casting doubt on the validity of the data measured. Thus, the data must first be verified before it can be used.

## 5.3 Simulated Baseline Air Quality

Due to the limited measured data reflecting the status quo of ambient air quality at Langer Heinrich Mine, all current sources of emissions were identified and quantified and dispersion simulations conducted to provide a current baseline. It should be noted that this exclude background sources in the region.

### *5.3.1 Emissions Inventory*

Impacts and activities associated with the current operations are outlined in Table 5-2. The emission rates for the current mining activities are based on a production rate of 3.7 million tonnes per annum (from both Pit A west and Pit D). Although the mine plant has generators, these are not continuous operational sources and were not included in this study due to limited information available.

**Table 5-2: Activities and aspects identified for the current operational phase at Langer Heinrich Uranium Mine**

| Impact | Source | Activity | Relevant section |
|---|---|---|---|
| Particulates | Materials handling operations | Tipping of run of mine onto haul trucks, crushers and run of mine stockpile. | 5.3.1.1 |
| | | Tipping of waste rock to haul trucks and waste rock dumps. | |
| | | Tipping of low grade ore to haul trucks and low grade stockpile. | |
| | Wind erosion | Current and proposed tailings dam (Option B) | 5.3.1.2 |
| | | ROM and low grade ore stockpiles at the processing plant | |
| | | Waste rock and topsoil storage piles | |
| | Crushing and screening | Crushing and screening activities | 5.3.1.3 |
| | Vehicle activity on unpaved roads | Vehicles travelling on the unpaved roads to and from the processing plant, waste rock dumps, current and proposed open pits | 5.3.1.4 |
| | Drilling | Drilling activities at the current and proposed open pits | 5.3.1.5 |
| | Blasting | Blasting activities at the current and proposed open pits | 5.3.1.6 |
| | Excavation | Excavation activities at the current and proposed open pits | 5.3.1.7 |
| | Generators | Operational phase of the generators | - |
| Gases and Particulates[1] | Vehicle activity[1] | Tailpipe emissions from haul vehicles | Not Significant |
| | | Tailpipe emissions from water tankers | |
| | | Tailpipe emissions from further transport mediums (buses for employees, private motor vehicles, mine personal movement etc) | |
| Gases | Power generation | Intermittent source of emissions (power | Not |

| Impact | Source | Activity | Relevant section |
|---|---|---|---|
| | | generation only operational for short durations, not continuous) | Significant |
| **Notes:** 1. Gases and particulates resultant from vehicle activity were not quantified | | | |

As illustrated in Table 5-2, the current Langer Heinrich mining operations will generate TSP, PM10 and various gaseous emissions. In the quantification of these releases use is made of the predictive emission factors published by the US-EPA (EPA, 1996) since there are no Namibian or local emission factors available.

#### *5.3.1.1 Materials Handling Operations*

Materials handling operations associated with mining activities and predicted to result in significant fugitive dust emissions include the transfer of material by means of tipping, loading and offloading trucks. The quantity of dust which will be generated from such loading and off-loading operations will depend on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature (moisture content) and volume of the material handled. Fine particulates are more readily disaggregated and released to the atmosphere during the material transfer process, as a result of exposure to strong winds. Increase in the moisture content of the material being transferred would decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particles.

Equation 1 as depicted and discussed in Appendix B is used to calculate the emissions from tipping. The PM10 fraction of the TSP is taken to be 35% as indicated in the US-EPA AP42 documentation. A control efficiency of 50% is applied to the materials handling activities. Table 5-3 depicts the various parameters utilised in the calculation of emissions resulting from material handling activities for the current operations.

**Table 5-3: Materials handling operations for the current operations at Langer Heinrich Uranium Mine.**

| Scenario | Tipping Operation | Throughput (tonnes per month) |
|---|---|---|
| Current operations (Pit A west and Pit D) | ROM into trucks in the pit | 308 333 |
| | ROM onto ROM stockpile at processing plant | 308 333 |
| | Waste rock into trucks in the pit | 616 667 |
| | Waste rock onto waste rock dumps | 616 667 |
| | Low grade ROM into trucks | 1 027 |
| | Low grade ROM onto pile | 1 027 |
| | Tipping of ROM into primary and secondary crushers | 150 000 |

#### *5.3.1.2 Wind erosion from Exposed Areas*

Significant emissions arise due to the mechanical disturbance of granular material from open areas and storage piles. Parameters which have the potential to impact on the rate of emission of fugitive dust include the extent of surface compaction, moisture content, ground cover, the shape of the

storage pile, particle size distribution, wind speed and precipitation. Any factor that binds the erodible material, or otherwise reduces the availability of erodible material on the surface, decreases the erosion potential of the fugitive source. High moisture contents, whether due to precipitation or deliberate wetting, promote the aggregation and cementation of fines to the surfaces of larger particles, thus decreasing the potential for dust emissions. Surface compaction and ground cover similarly reduces the potential for dust generation. The shape of a storage pile or disposal dump influences the potential for dust emissions through the alteration of the airflow field. The particle size distribution of the material on the disposal site is important since it determines the rate of entrainment of material from the surface, the nature of dispersion of the dust plume, and the rate of deposition, which may be anticipated (Burger, 1994; Burger et al., 1995).

The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model is based on the dust emission model proposed by Marticorena and Bergametti (1995). The model attempts to account for the variability in source erodibility through the parameterisation of the erosion threshold (based on the particle size distribution of the source) and the roughness length of the surface. Equations used in calculating emission rates from wind erosion sources are shown in Appendix B (Equations 2-5).

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). Information pertaining to the stockpiles utilised for the current operations is listed in Table 5-4.

Particle size data used in the ADDAS and ADMS models was obtained from sample analysis results for the various sources at LHU (tailings dam wall, tailings dam beach, waste rock dumps, topsoil stockpiles, ROM and low grade ore). In this part of Namibia, a natural crusting form when material is undisturbed. Thus to account for this a control efficiency of 30% was assumed on all waste rock dumps, topsoil, ROM and tailings wall. The tailings surface has a large moist area and this was assumed to account for 60% control.

**Table 5-4: Information Input into the ADMS and ADDAS Models for the Current Operations Stockpiles at Langer Heinrich Uranium Mine.**

| Stockpile | Height (m) | Volume ($m^3$) | Area ($m^2$) | X-length (m) | Y-length (m) | Bulk density ($kg/m^3$) | Moisture (%) |
|---|---|---|---|---|---|---|---|
| Topsoil 1 | 4 | 158 256 | 39 000 | 100 | 390 | 2 883 | 3 |
| Topsoil 2 | 3 | 158 256 | 56 700 | 180 | 315 | 2 883 | 3 |
| Topsoil 3 | 3 | 1582 56 | 56 700 | 180 | 315 | 2 883 | 3 |
| ROM Low Grade | 36 | 15 000 000 | 415 200 | 600 | 692 | 2 567 | 3 |
| ROM High Grade | 20 | 4 800 000 | 245 000 | 350 | 700 | 2 783 | 3 |
| Tailings dam | 20 | 10 322 800 | 516 140 | 985 | 524 | 2 900 | 3 and 12.6 (a) |
| Barren Waste rock dump | 10 | 2 000 000 | 193 698 | 306 | 633 | 2 700 | 3 |
| Dormant Waste rock dump | 20 | 4 000 000 | 204 600 | 300 | 682 | 2 700 | 3 |
| Pit D Waste rock dump (b) | 35 | 8 000 000 | 226 300 | 310 | 730 | 2 700 | 3 |
| Waste rock dump close to Plant | 4 | 350 000 | 90 000 | 300 | 300 | 2 700 | 3 |

**Notes:** (a) 3% moisture content for the tailings dam wall and 12.6% for the tailings dam beach.
(b) Pit D rock dump was assumed to be the same for Pit A West

#### *5.3.1.3 Crushing and Screening Activities*

Crushing operations, especially primary crushing, represent significant dust-generating sources if uncontrolled. Dust fallout in the vicinity of crushers also give rise to the potential for the re-entrained of dust emitted by vehicles or by the wind at a later date. The large percentage of fines in this dustfall material enhances the potential for it to become airborne. The revised US-EPA emission factors for crushing are only available for tertiary crushing and are given for TSP as 0.0027 kg of particulate per tonne of material crushed (Equations 6 and 7– Appendix B) and as 0.0012 kg of particulate per tonne of material crushed for PM10. The tertiary crushing US-EPA emission factors are used for TSP and PM10 in this study since the revised emission factors for primary and secondary crushing and screening are not available.

The parameters used in the calculation of emissions for crushing and screening activities for the current operations are shown in Table 5-5.

**Table 5-5: Parameters used for the calculation of emissions from crushing and screening operations for the current Langer Heinrich Uranium Mine operations**

| Crushing and screening | Tonnes per day | Moisture (%) |
|---|---|---|
| ***Primary and secondary crushing and screening*** | | |
| Current operations (Pit A west and Pit D) | 4 934 | 3 |

#### *5.3.1.4 Vehicle Activity on Unpaved Roads*

Vehicle-entrained dust emissions from the current unpaved haul roads within the Langer Heinrich Uranium mining area potentially represent a significant source of fugitive dust. Such sources have been found to account for the greatest portion of fugitive emissions from many mining operations. The quantification of the release of fugitive dust from the current unpaved roads was calculated assuming 75% control efficiency due to regular water application to the road surfaces. The current unpaved roads for the mine were split into segments for purposes of dispersion simulation (see Figure 5-2). The parameters of the unpaved roads used in the dispersion model are presented in Table 5-6. The unpaved road size-specific emission factor equation of the US.EPA, used in the quantification of emissions for the study, is given in Appendix B, Equation 8.

In addition to traffic volumes, emissions also depend on a number of parameters which characterise the condition of a particular road and the associated vehicle traffic. Such parameters include average vehicle speed, mean vehicle weight, average number of wheels per vehicle, road surface texture, and road surface moisture (EPA, 1996). The silt percentage utilised for the unpaved roads is 25.2%, given as the US-EPA maximum silt content for the unpaved road equation. The analysed sample result for the unpaved haul roads indicates a silt content of 31.7%, exceeding the 25.2%. Unpaved haul roads to and from the current pits, haul roads to and from the ROM stockpile and the waste rock dumps were modelled (Table 5-6). The access road was omitted from the modelling due to the intermittent traffic on this road. It is however understood that when used, this road is a potential significant source of dust emissions.

**Table 5-6: Parameters of the unpaved haul roads simulated for the current mining operations at Langer Heinrich Uranium Mine**

| Roads | Length (m) | Width (m) | Emission rate (g/m²/s) | |
|---|---|---|---|---|
| | | | PM10 | TSP |
| Unpaved haul road 1 to ROM pad: Pit A west | 125 | 10 | 2.30E-04 | 6.5E-04 |
| Unpaved haul road 2 to ROM pad: Pit A west | 229 | 10 | 2.30E-04 | 6.5E-04 |
| Unpaved haul road 3 to ROM pad: Pit A west | 320 | 10 | 2.30E-04 | 6.5E-04 |
| Unpaved haul road 4 to waste rock dump: Pit A west | 96 | 10 | 4.61E-04 | 1.3E-03 |
| Unpaved haul road 5 to ROM pad: Pit D | 182 | 10 | 2.30E-04 | 6.5E-04 |
| Unpaved haul road 6 to ROM pad: Pit D | 846 | 10 | 2.30E-04 | 6.5E-04 |
| Unpaved haul road 7 to ROM pad: Pit D | 1 070 | 10 | 2.30E-04 | 6.5E-04 |
| Unpaved haul road 8 to ROM pad: Pit D | 358 | 10 | 2.30E-04 | 6.5E-04 |
| Unpaved haul road 9 to waste rock dump: Pit D | 517 | 10 | 4.61E-04 | 1.3E-03 |

**Figure 5-2: Haul roads as segmented for use in the dispersion model**

#### *5.3.1.5 Drilling*

Fugitive dust emissions due to current in-pit drilling operations at the mine were quantified using the Australian NPI single value emission factors for mining (Equations 9 and 10-Appendix B). The drilling parameters that were utilised for the current operations are presented in Table 5-7. No mitigation measures were assumed for the drilling operations.

**Table 5-7: Drilling source specific information: Current operations**

| Drilling parameter | Parameter units/ value |
|---|---|
| Blasting area | 5 000m² (71m x 71m) |
| No of drill holes (including exploration drill holes) | 349 drill holes |
| Depth of each drill hole | 9m |
| Distance between drill holes (row) | 4.1m |
| Distance between drill holes (column) | 4.5m |

#### *5.3.1.6 Blasting*

Fugitive dust emissions due to blasting at the mine were quantified using the US EPA predictive emission factor equation for mining (Equation 11-Appendix B). Source specific information used in the calculation of emissions due to current blasting activities is presented in Table 5-9. No mitigation measures were assumed for the blasting operations.

**Table 5-8: Blasting source specific information: Current operations**

| Drilling parameter | Parameter units/ value |
|---|---|
| Blasting area | 5 000m² (71m x 71m) |
| Blasts per day | 1 |
| Days per year | 365 |

#### *5.3.1.7 Excavation*

The US –EPA Equation (Equation 12-Appendix B) was used to calculate emissions due to current excavation activities. The area of topsoil disturbance in preparation for mining is given as between 80 and 100ha. It was assumed that the excavated area for the current operations will be 80 000 m². Table 5-9 depicts the parameters that were used in calculating emissions due to excavating activities.

**Table 5-9: Parameters used for the calculation of emissions from excavation for the current operations**

| Scenario | Parameters of excavated area | | |
|---|---|---|---|
| | Length (m) | Width (m) | Total area (m²) |
| Current operations: Pit A west and Pit D | 282 | 282 | 80 000 |

#### *5.3.1.8 Power Generation*

A 10 MW power plant are currently in place at the mine to provide ad-hoc power supply to the processing plant. The power plant is diesel fuelled using approximately 417 litres of fuel per hour when operational. The main pollutants associated with the power generation are sulphur dioxide ($SO_2$), oxides of nitrogen ($NO_x$) and particulates (PM10). Source information on the power generators are provided in Table 5-10.

**Table 5-10: Source parameters for the 10 MW Power Plant at the mine.**

| Stack parameter | Units | Per Generator |
|---|---|---|
| Stack height | m | 8.83 |
| Stack diameter | mm | 489 |
| Stack exit temperature | °C | 305 |
| Stack exit velocity | m/s | 34.1 |
| Stack exit volumetric flow | $Nm^3/s$ | 3.94 |
| Fuel used | kg/hr | 880 |
| Power continuous output | kW (m) | 1 800 |
| Fuel consumption | g/kWh (m) | 196.9 |
| $SO_2$ concentration (based on 0.05% S in fuel) | $mg/Nm^3$ | 504(a) |
| $NO_x$ concentration | $mg/Nm^3$ | 1 614(a) |
| PM10 concentration | $mg/Nm^3$ | 67 (a) |
| **Notes:** (a) based on 15% $O_2$ | | |

The IFC provides guidelines on the allowable emission concentrations from a power generation unit. This however applies when the unit is utilised for more than 30% of the time or more than 500 hours per year. If this is the case at Langer Heinrich Uranium Mine, the emission concentrations comply with the IFC limits as provided in Table 2-1.

### *5.3.2 Synopsis of Estimated Emissions for the Current Operational Phase*

A synopsis of the estimated particulate and gaseous emissions as a result of the current mining operations at Langer Heinrich Uranium Mine is presented in Table 5-10 and depicted in Figure 5-3 (PM10 source contributions) and Figure 5-4 (TSP source contributions). Wind erosion is the most contributing source to PM10 and TSP emissions (83% for both). The second most significant source of PM10 and TSP emissions are the unpaved roads with contributions of 13% and 14% respectively. Blasting is predicted to be the third most significant source of PM10 and TSP (2% and 1.5% respectively). The fourth most significant source of PM10 (1.4%) and TSP (1%) is predicted to be drilling. Crushing and screening activities are predicted to be the least significant sources of both PM10 and TSP (0.1% and 0.1% respectively). Mitigation measures were applied to the unpaved roads (75% control efficiency) and to the windblown dust sources (30% control efficiency on all except the tailings dam surface where it is 60%).

**Table 5-11: TSP and PM10 emissions (tpa) due to current mining operations at Langer Heinrich Uranium Mine.**

| Source | PM10 | TSP | PM10 % | TSP % | Rank PM10 | Rank TSP |
|---|---|---|---|---|---|---|
| **Crushing and screening** | 2.0 | 4.0 | 0.1 | 0.1 | 7 | 7 |
| **Materials handling** | 12.0 | 34.4 | 0.4 | 0.5 | 6 | 5 |
| **Wind erosion** | 2 454.0 | 6 270.8 | 83.3 | 82.9 | 1 | 1 |
| **Unpaved roads** | 368.0 | 1037.2 | 12.5 | 13.7 | 2 | 2 |
| **Blasting** | 57.5 | 110.5 | 2.0 | 1.5 | 3 | 3 |
| **Excavation** | 12.2 | 28.0 | 0.4 | 0.4 | 5 | 6 |
| **Drilling** | 40 | 75 | 1.4 | 1.0 | 4 | 4 |
| **Total** | **2 945.7** | **7 559.9** | **100.0** | **100.0** | | |

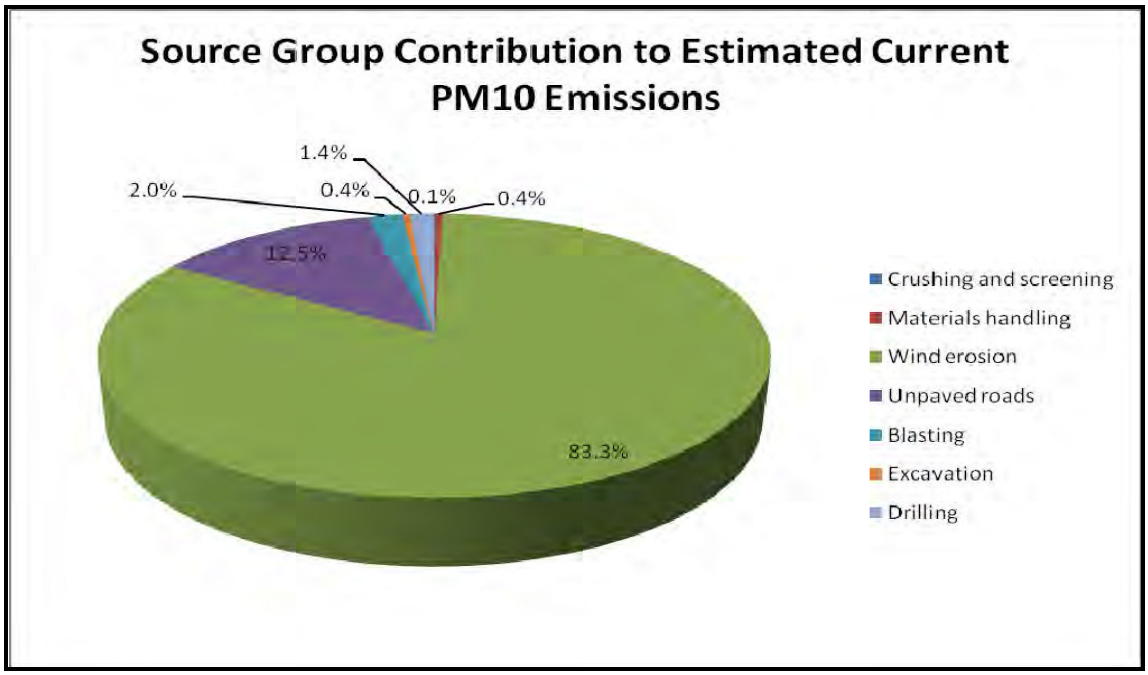


**Figure 5-3: Source contribution to estimated current mining operations PM10 emissions**

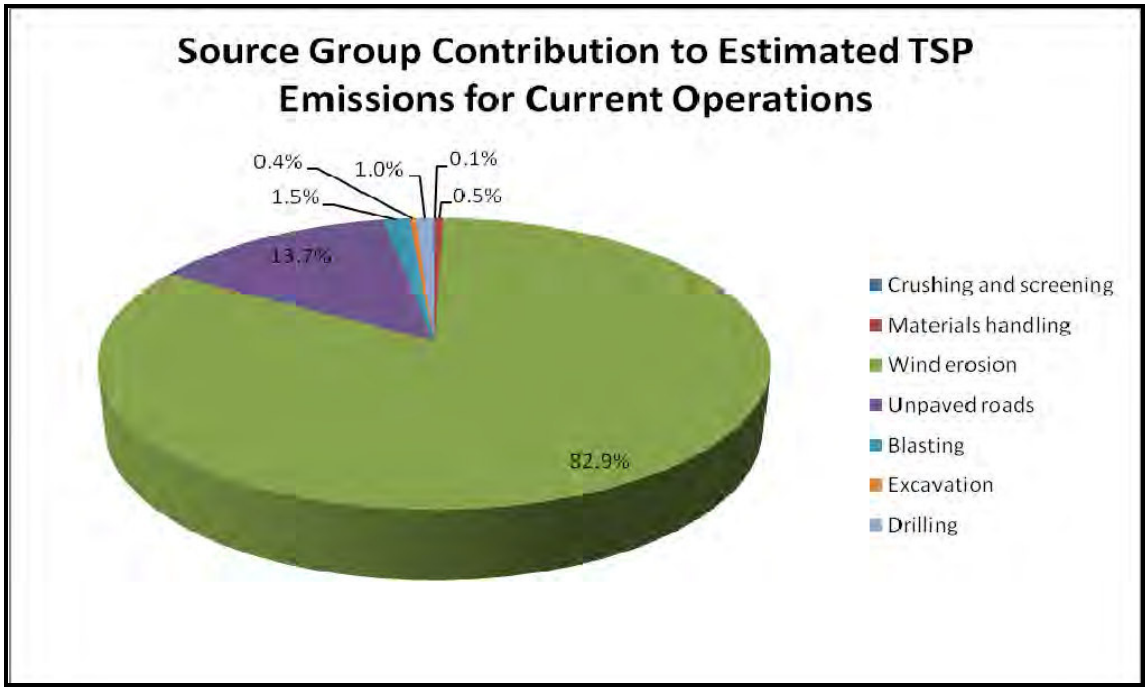


**Figure 5-4: Source contribution to estimated current mining operations TSP emissions**

### *5.3.3 Dispersion Modelling Results*

Since ambient air quality guidelines and standards aim to protect public health, these are applied to off-site areas rather than on-site occupational impacts[2]. There are no formal settlements in the vicinity of the Langer Heinrich Mine and the only sensitive receptors identified included the Drillers Camp and Bloedkoppie.

#### *5.3.3.1 Predicted PM10 Concentrations Due to Current Operational Phase Activities*

- The predicted partially mitigated daily average ground level concentrations for the current operations exceed the EC PM10 standard and WHO PM10 air quality guideline of 50 µg/m³ at the Drillers Camp (Table 5-12 and Figure 5-5). The EC standard and WHO guideline are however, not exceeded at the sensitive receptor area of Bloedkoppie.

- The predicted partially mitigated annual average ground level concentrations for the operations do not exceed the EC air quality standard of 40 µg/m³ at all the sensitive receptor sites (Table 5-12 and Figure 5-6). The WHO annual PM10 air quality guideline of 20 µg/m³ and the various interim targets (IT-1, IT-2) are also predicted not to be exceeded at the sensitive receptor sites.

[2] The National Ambient Air Quality Standards (NAAQS) of the US-Environmental Protection Agency defines ambient air as *air in the breathing zone to which the public has access*. Occupational regulations (e.g., OSHA) set standards for nonpublic areas (Erbes, 1996).

**Table 5-12: Predicted highest daily average and annual PM10 concentrations (µg/m³) at the sensitive receptor sites due to the current mining operations.**

| Sensitive Receptor Area | *Scenario* | PM10 Concentration (µg/m³) | |
|---|---|---|---|
| | | Daily concentration | Annual concentration |
| Bloedkoppie | Current mining operations | 19 | 13 |
| Drillers Camp | Current mining operations | 79 | 17 |

*5.3.3.2 Dust deposition due to Current Operational Phase Activities*

Dust impacts are generally confined to the near-field (<1km to 3km) of sources. This is due to the fact that the larger particles, which contribute most to dust-fall rates given their mass, are likely to settle out in close proximity to the source (assuming a ground-base source). The US-EPA (1992) estimates that for a typical mean wind speed (16km/hr (~4.4m/s)) particles larger than about 100µm are likely to settle out within 6 to 9 metres from the edge of the source. Particles that are between 30µm and 100µm are subject to impeded settling, and are likely to settle out within 100 metres from the source.

Predicted dust deposition rates at the identified sensitive receptors are depicted in Table 5-13.

- The predicted maximum and daily dust deposition rates due to the current mining activities do not exceed the German maximum permissible deposition in general areas (350 mg/m²/day) at the Drillers Camp and Bloedkoppie (Table 5-13, Figures 5-7 and Figure 5-8 respectively). The SANS residential dust fallout limit of 600 mg/m²/day is also predicted not to be exceeded at all the sensitive receptor areas.

**Table 5-13: Predicted annual average dust fallout levels (mg/m²/day) at the sensitive receptor sites due to current mining activities.**

| Sensitive Receptor Area | *Scenario* | Average Daily Dust Fallout (mg/m²/day) | Maximum Daily Dust Fallout (mg/m²/day) |
|---|---|---|---|
| Bloedkoppie | Current mining operations | 8 | 0.3 |
| Drillers Camp | Current mining operations | 11 | 4.3 |

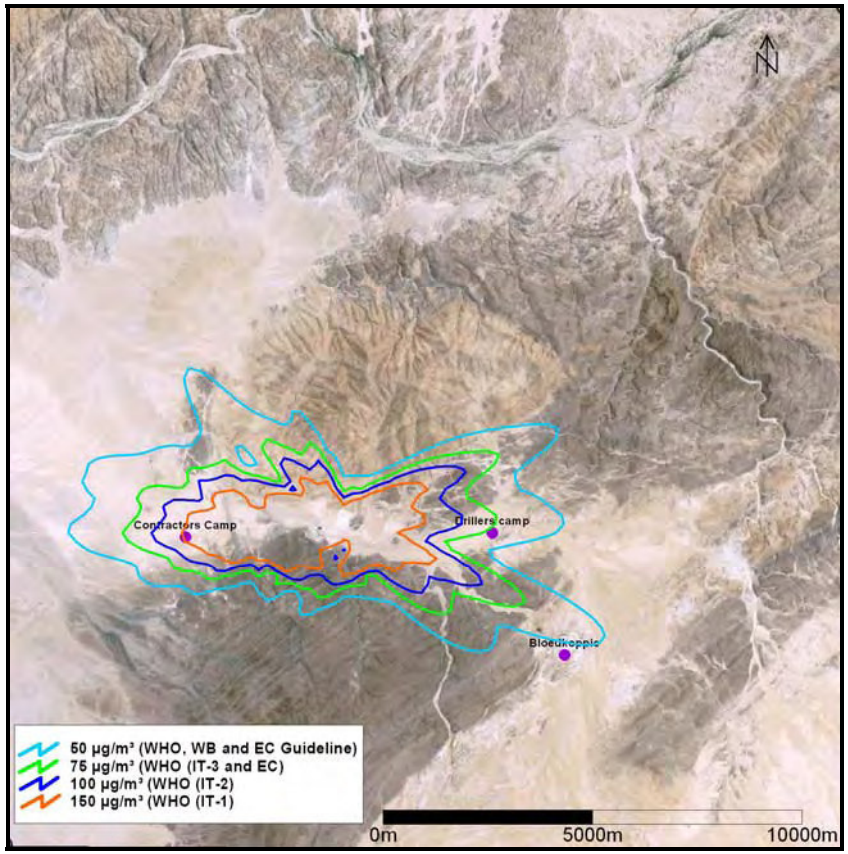


**Figure 5-5: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the current Langer Heinrich mining operations (Current *Scenario*).**

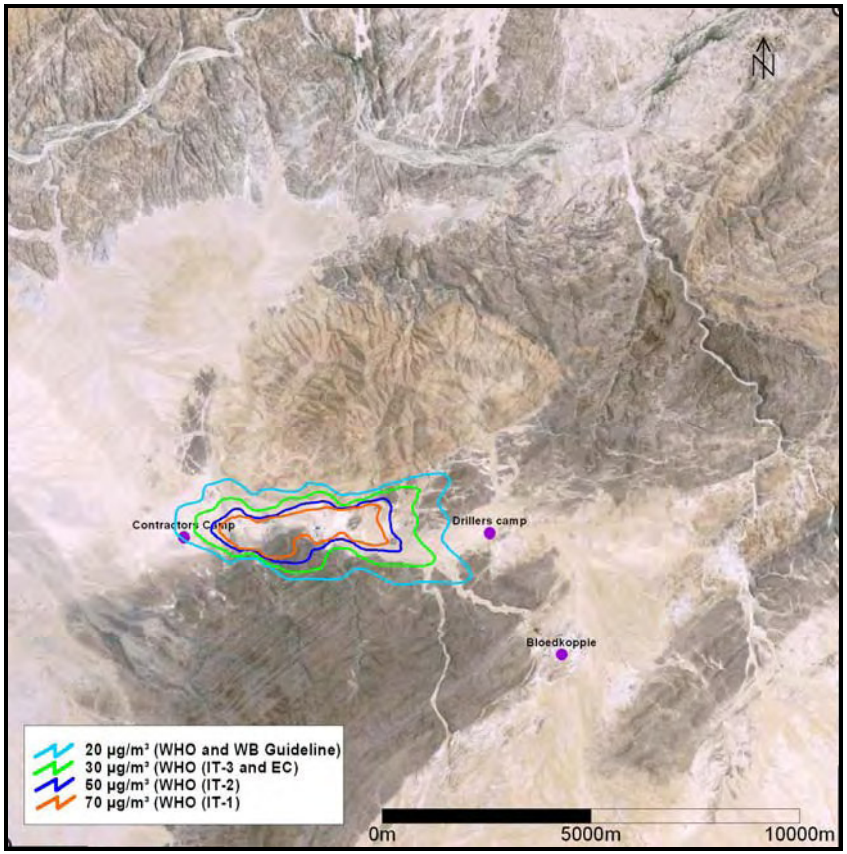


**Figure 5-6: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the current Langer Heinrich mining operations (Current *Scenario*)**

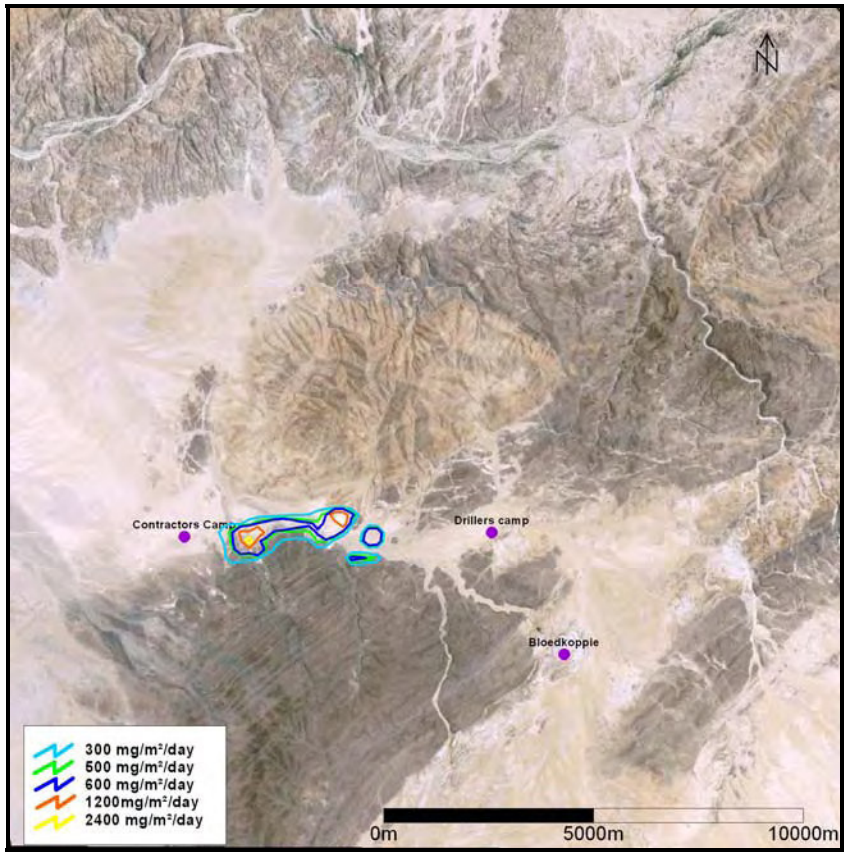


**Figure 5-7: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to partially controlled emissions during the current Langer Heinrich mining operations (*Current Scenario*)**

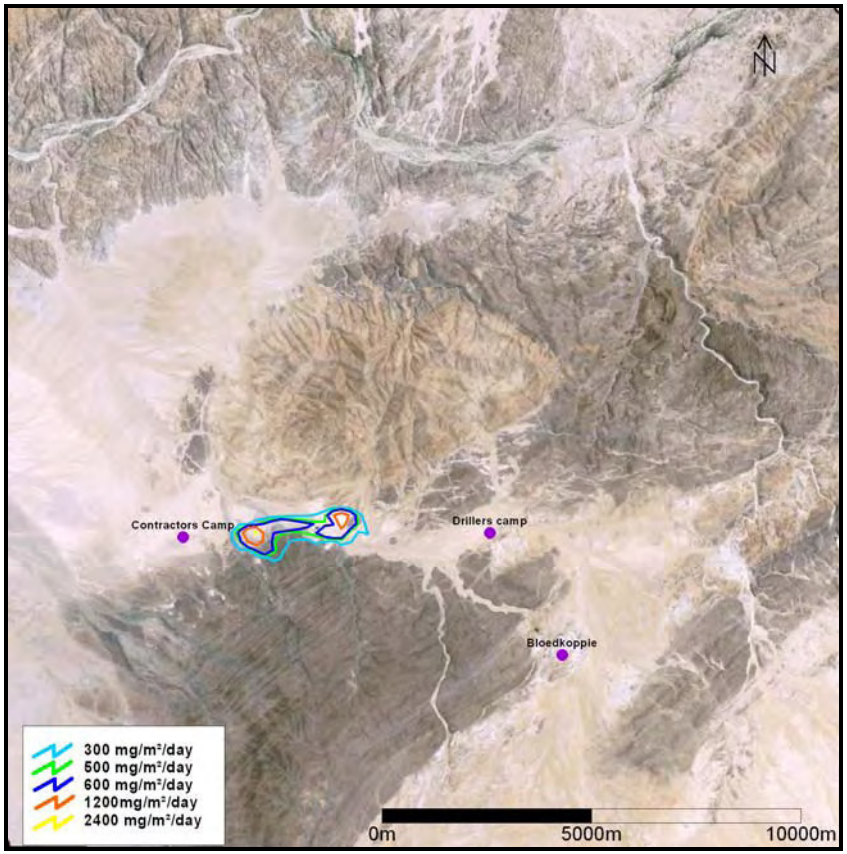


**Figure 5-8: Predicted average daily dust deposition rates (mg/m²/day) for all sources due to partially controlled emissions during the current Langer Heinrich mining operations (*Current Scenario*)**

## 5.4 Significance Evaluation of Predicted Impacts

Isopleth plots reflecting daily averaging periods contain only the highest predicted ground level concentrations/depositions for that averaging period, over the entire period for which simulations were undertaken. It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, this may only be true for one day during the entire period of operation. It is therefore necessary to evaluate the number of days (frequency of exceedance) the relevant standard was exceeded at a specific location to determine the significance of the predicted impact.

For instance, the EC allows for 35 exceedances of the PM10 daily standard of 50 µg/m³ whilst South Africa proposes only 4 allowable exceedances of the 75 µg/m³ daily standard. In the significance evaluation of the Langer Heinrich Uranium project, the predicted impacts were assessed against these criteria.

Frequency of exceedances for the current operations at Langer Heinrich Uranium was evaluated at the two sensitive receptor sites of Bloedkoppie and the Drillers Camp. It should be noted that the frequency of exceedance plot reflects the total number of days when the standards were exceeded over the 1 year modelling period. When the predicted concentrations were evaluated against these for the current operations, predictions at Bloedkoppie and the Drillers Camp were less than 35 days and 4 days over the 1 year period as depicted in Figure 5-9.

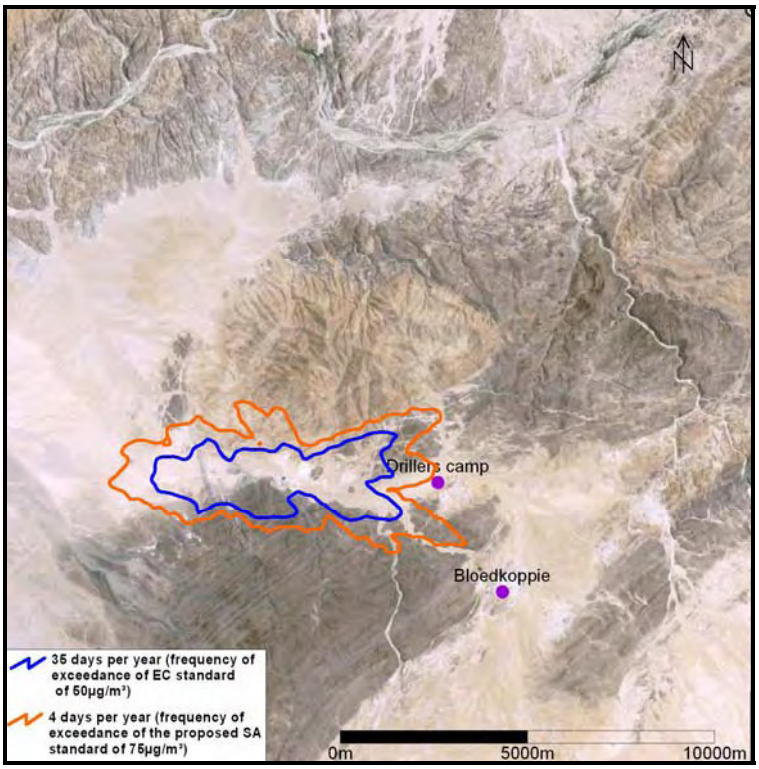


**Figure 5-9: Frequencies of exceedance for predicted PM10 concentrations when compared to the EC and SA standards (Current mining operations)**

## 5.5 Significance rating of current operations

In assessing the potential significance of impacts which may be related to the proposed construction activities, reference was made to the impact assessment model applied by Metago (Section 3). The impact assessment summary table is depicted in Table 5-14 below.

**Table 5-14: Impact Assessment Summary Table for the Current and Proposed Operational Phases**

| *Scenario* | Impact | Severity/ Nature of Impact | Spatial Scale of Impacts | Duration of Impact | Probability of Impact |
|---|---|---|---|---|---|
| ***Current operations*** | Respirable dust (PM10) | M | M | M | M |
| | Dust fallout (nuisance) | M | M | M | M |

# 6 CONSTRUCTION PHASE

Activities for the proposed construction phase of Langer Heinrich Mine were identified and quantified. Dispersion simulations were executed incorporating construction activities for the tailings dam wall, heap leach pad, process plant, mine work shop and the low grade crusher area. However, due to the fact that the construction phase will run concurrently with the current mining operations for twelve months, cumulative impacts due to both operations are discussed in this section. Calculated emission rates for the various current phase sources as discussed in Section 5 were utilised in the cumulative impact assessment study. International standards and guidelines for organisations such as the EC, WHO and SA were applied for compliance assessment.

## 6.1 Emissions Inventory

The construction phase will comprise land clearing and site development operations at various proposed areas and the associated infrastructure.

Activities associated with this phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, (etc.). Each of these operations has its own duration and potential for dust generation. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. Aspects associated with the construction phase in terms of air quality are outlined in Table 6-1.

**Table 6-1: Environmental impacts and associated activities during the construction phase**

| Impact | Source | Activity |
|---|---|---|
| **TSP and PM10** | Unpaved roads | Vehicle entrainment on unpaved road surfaces<br>Clearing and levelling of roads |
| | Construction of the tailings dam wall, heap leach pad, mine workshop and construction activities at the low grade crusher area | Clearing of groundcover |
| | | Drilling and blasting |
| | | Materials handling (loading and hauling) |
| | | Wind erosion from stockpiles |
| | | Vehicle entrainment on unpaved roads surface |
| | | Establishment of infrastructure edifice |
| | Expansion of the existing processing plant (a) | Already built-up area, additional infrastructure. |
| **Gases and particulates** | Vehicles | Tailpipe emissions from construction vehicles at the site. |
| **Notes:** (a) plant expansion were not quantified for the activities are expected to have limited impacts since it is already a built-up area | | |

The fact that the extent of dust emissions would vary substantially from day to day during construction makes it often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process. For the Langer Heinrich Mine proposed construction phase, it was therefore decided to quantity dust emissions for the areas where construction activities would commence by assuming the emissions to be proportional to the area of land being worked and the level of construction activity.

The US-EPA documents emission factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations. Based on field measurements of total suspended particulate, the approximate emission factors for construction activity operations are given as:

$$\boldsymbol{E} = 2.69 \text{ Mg/hectare/month of activity } (269 \text{ g/m}^2\text{/month})$$

These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. Because the above emission factor is referenced to TSP, use of this factor to estimate PM10 emissions will result in conservatively high estimates. Even for TSP the emission factors are considered to be conservatively high since they assume that construction activity occurs 30 days per month. Information regarding the location and extent of site disturbances, land clearing and/or construction activities as provided by the client was used in the estimation of construction phase emissions.

The emission factor given above was applied to the following areas: heap leach pad, mine workshop tailings dam and crusher area as shown in Figure 6-1.

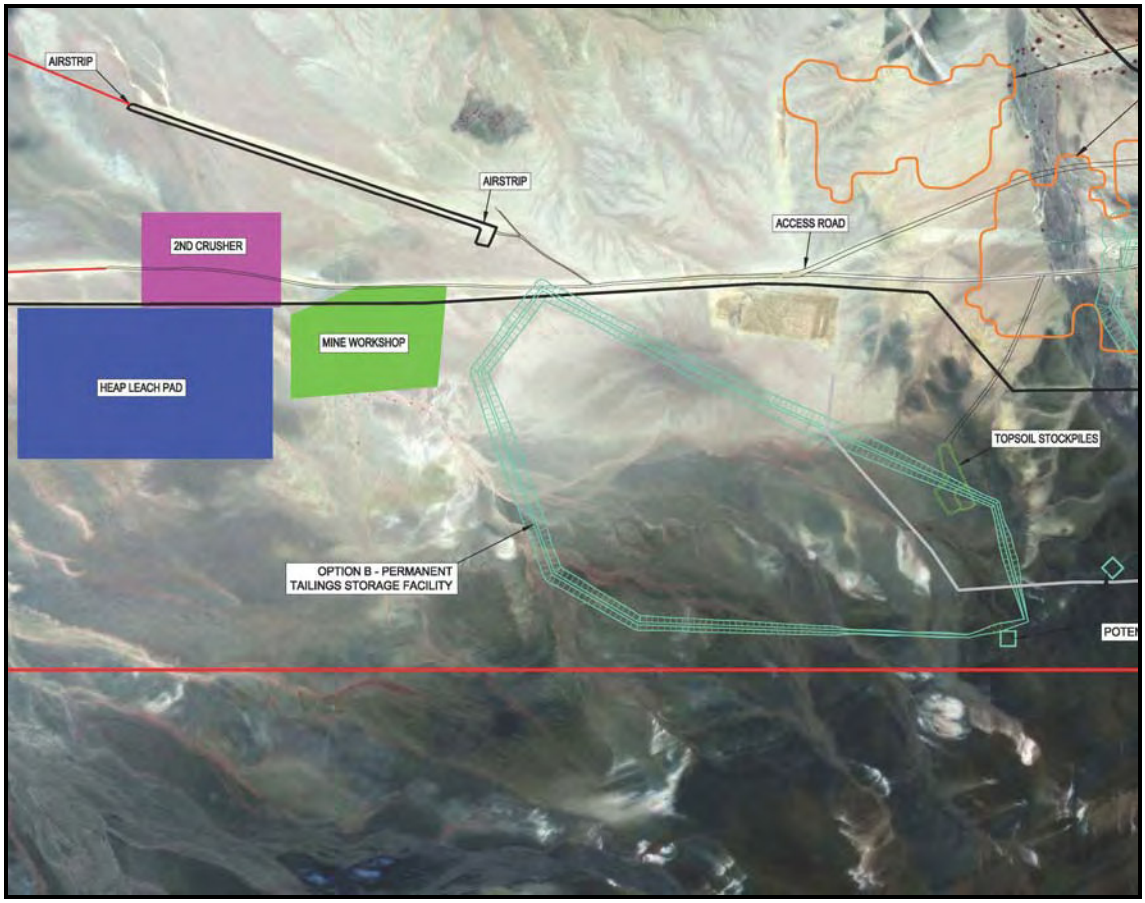


**Figure 6-1: Position of the modelled proposed construction areas at Langer Heinrich Uranium Mine.**

### *6.1.1 Synopsis of Estimated Emissions for the Proposed Construction Phase*

A synopsis of the estimated particulate and gaseous emissions as a result of the proposed construction activities at Langer Heinrich Uranium Mine is presented in Table 6-2 and depicted in Figure 6-2 (PM10 source contributions) and Figure 6-3 (TSP source contributions). The pparameters utilised in the calculation of emissions from the proposed construction phase at Langer Heinrich Uranium Mine are also depicted in Table 6-2.

The most significant source of PM10 and TSP emissions are predicted to be tailings dam wall construction activities, with the second most significant source of particulates being the heap leach pad construction activities. The low grade crusher construction area is predicted to result in the least significant PM10 emissions during the proposed construction phase.

**Table 6-2: Parameters utilised in the calculation of emissions from the proposed construction phase at Langer Heinrich Uranium Mine.**

| Construction area | Length (m) | Width (m) | Area ($m^2$) | Area (hectare) | TSP ($g/s/m^2$) | PM10 ($g/s/m^2$) | TPA (TSP) | TPA (PM10) |
|---|---|---|---|---|---|---|---|---|
| **Heap leach pad** | 509 | 1 052 | 535 468 | 53.5 | 1.03E-04 | 5.34E-05 | **1 735** | **902** |
| **Low grade crusher** | 309 | 478 | 147 702 | 14.8 | 1.03E-04 | 5.34E-05 | **479** | **249** |
| **Mine workshop** | 361 | 497 | 179 417 | 17.9 | 1.03E-04 | 5.34E-05 | **581** | **302** |
| **Tailings dam** | 416 | 1 737 | 722 592 | 72.3 | 1.03E-04 | 5.34E-05 | **2 342** | **1 218** |
| **Total** | | | | | | | **5 737** | **2 671** |

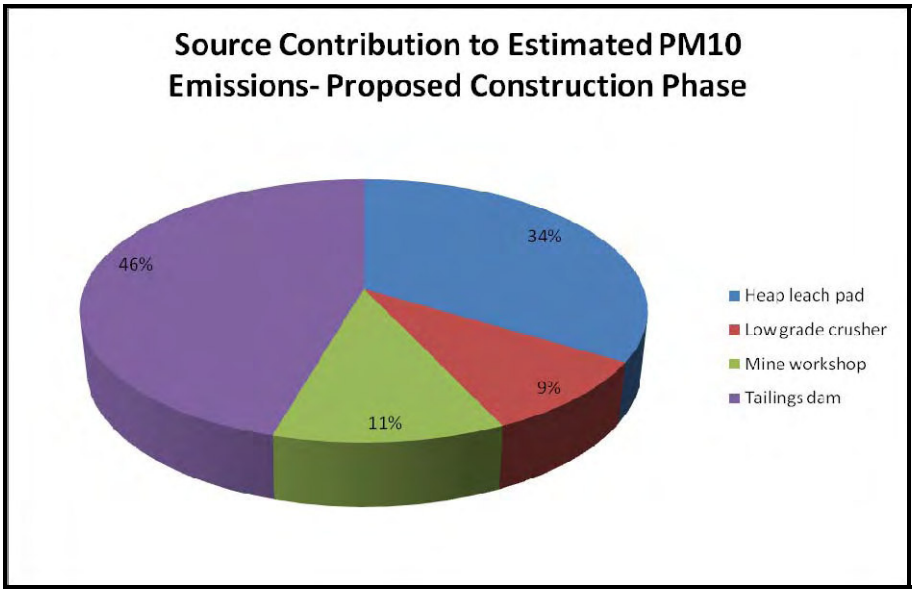


**Figure 6-2: Source contribution to PM10 emissions during the proposed construction phase at Langer Heinrich Uranium Mine.**

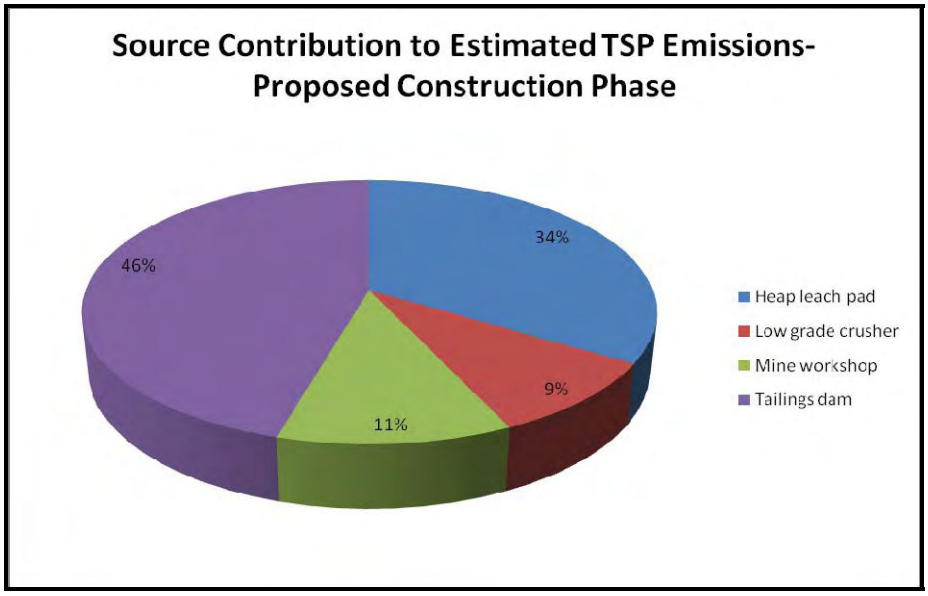


**Figure 6-3: Source contribution to TSP emissions during the proposed construction phase at Langer Heinrich Uranium Mine.**

## 6.2 Dispersion Model Results (Cumulative Impacts)

This section focuses on potential cumulative impacts (due to the current mining operations and proposed construction activities) at human sensitive receptor sites closest to the mine boundary. Aside from Bloedkoppie and the Drillers Camp, a Contractors Camp will be in place near the proposed processing plant for the 12-month construction period.

- The predicted unmitigated daily average ground level concentrations for the proposed construction activities and current operations exceed the EC PM10 standard and WHO daily PM10 air quality guideline of 50 µg/m³ and the all the WHO interim targets at Bloedkoppie, the Drillers Camp and the Contractors Camp (Table 6-3 and Figure 6-4). Similarly the proposed SA standard of 75 µg/m³ is exceeded at all receptors. Due to the construction activities, predicted ground level concentrations at Bloedkoppie increased almost 4 times and 3 times at the Drillers Camp.

- The predicted unmitigated annual average ground level concentrations for the proposed construction and current operations exceed the EC air quality standard of 40 µg/m³ and the WHO annual PM10 air quality guideline of 20 µg/m³ at the Contractors Camp as shown in Table 6-3 and Figure 6-5. The predicted impacts exceed the WHO air quality guideline and WHO IT-3 at the Drillers Camp, while all the WHO interim targets are exceeded at the Contractors Camp. Although the more stringent WHO guideline is predicted to be exceeded at Bloedkoppie, the EC standard and the various WHO interim targets are predicted not to be exceeded.

**Table 6-3: Predicted highest daily average and annual PM10 concentrations (µg/m³) at the sensitive receptor sites due to current operational and proposed construction activities (cumulative impacts)**

| Sensitive Receptor Area | *Scenario* | PM10 Concentration (µg/m³) | |
|---|---|---|---|
| | | Daily concentration | Annual concentration |
| Bloedkoppie | Proposed construction phase and current operations | 133 | 24 |
| Drillers Camp | Proposed construction phase and current operations | 236 | 35 |
| Contractors Camp | Proposed construction phase and current operations | 652 | 132 |

It is possible that the predicted concentrations at the sensitive receptors as a result of the current operational and proposed construction activities would be much higher when background concentrations[3] in the region are taken into consideration and if reasonable mitigation measures are not applied. Reasonable mitigation measures would lead to further reduction of emissions at the sensitive receptor areas.

### 6.3 Dust Fallout Levels due to the Proposed Construction Phase Activities

- The predicted maximum and average daily dust deposition rates for the proposed construction and current activities exceed the German deposition standards of 350 mg/m²/day (as maximum in general areas) at the Contractors Camp. However, the predicted dust fallout levels at all the sensitive receptor areas fall within the SANS residential limit of 600 mg/m²/day (Table 6-4 and Figure 6-6 and Figure 6-7). Dust fallout levels increased between 2.5 times at Bloedkoppie and 2 times at the Drillers Camp.

**Table 6-4: Predicted annual average dust fallout levels (mg/m²/day) at the sensitive receptor sites due to the proposed construction activities.**

| Sensitive Receptor Area | *Scenario* | Maximum Daily Dust Fallout (mg/m²/day) | Average Daily Dust Fallout (mg/m²/day) |
|---|---|---|---|
| Bloedkoppie | Proposed construction phase | 20 | 2 |
| Drillers Camp | Proposed construction phase | 26 | 10 |
| Contractors Camp | Proposed construction phase | 420 | 234 |

[3] Background concentrations are expected to be high only during intermittent periods of high wind speeds as measured during the autumn and winter months.

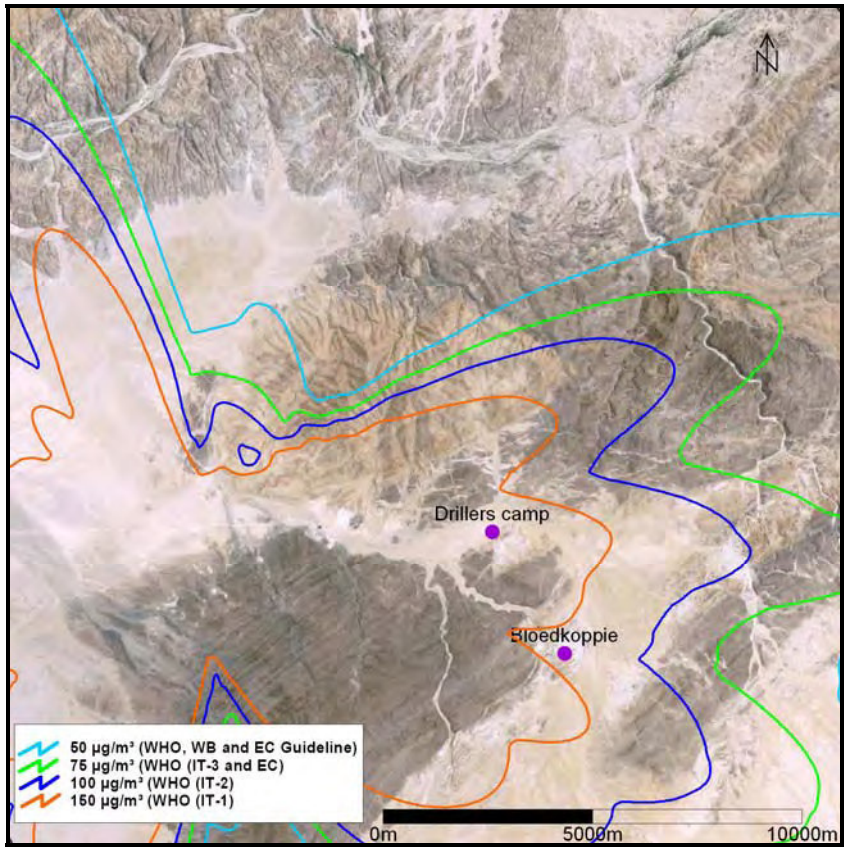


**Figure 6-4: Highest daily average predicted PM10 ground level concentrations (µg/m³) due to proposed construction and partially mitigated current activities' emissions at Langer Heinrich Uranium Mine.**

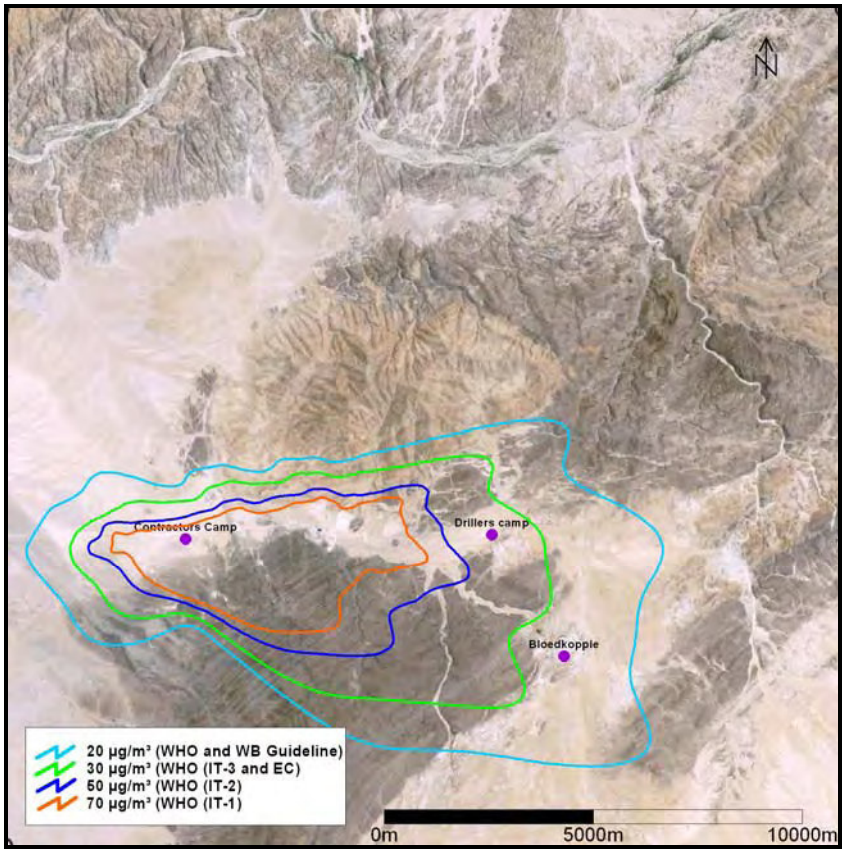


**Figure 6-5: Annual average predicted PM10 ground level concentrations (µg/m³) due to proposed construction and partially mitigated current activities' emissions at Langer Heinrich Uranium Mine.**

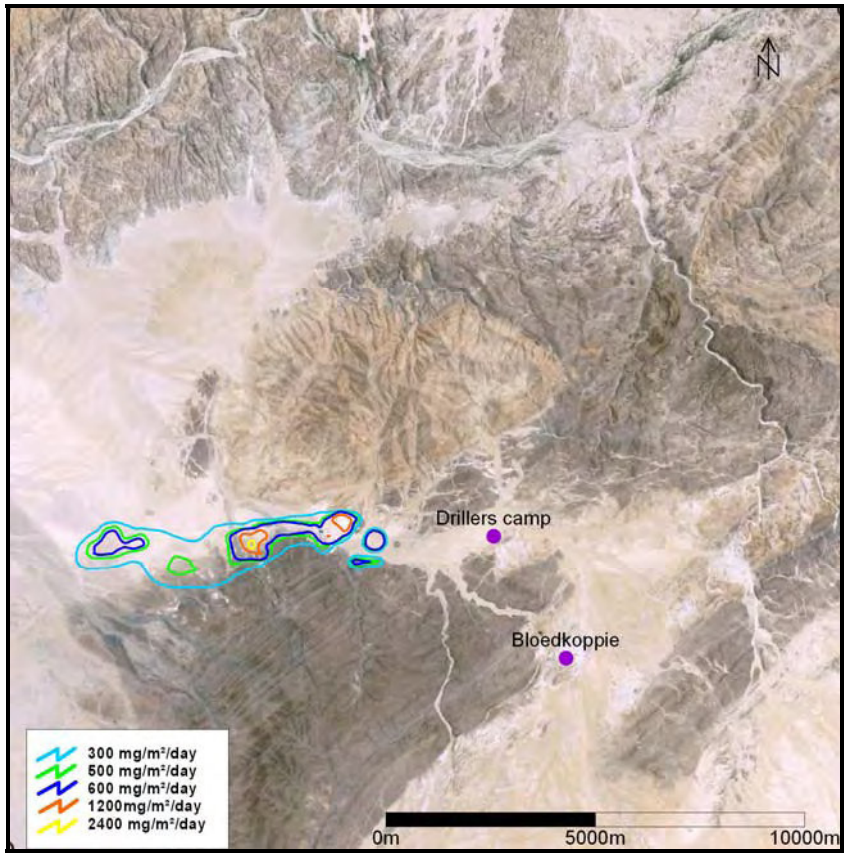


**Figure 6-6: Maximum daily dust deposition rates (mg/m²/day) due to uncontrolled emissions during the proposed construction activities at Langer Heinrich Uranium Mine.**

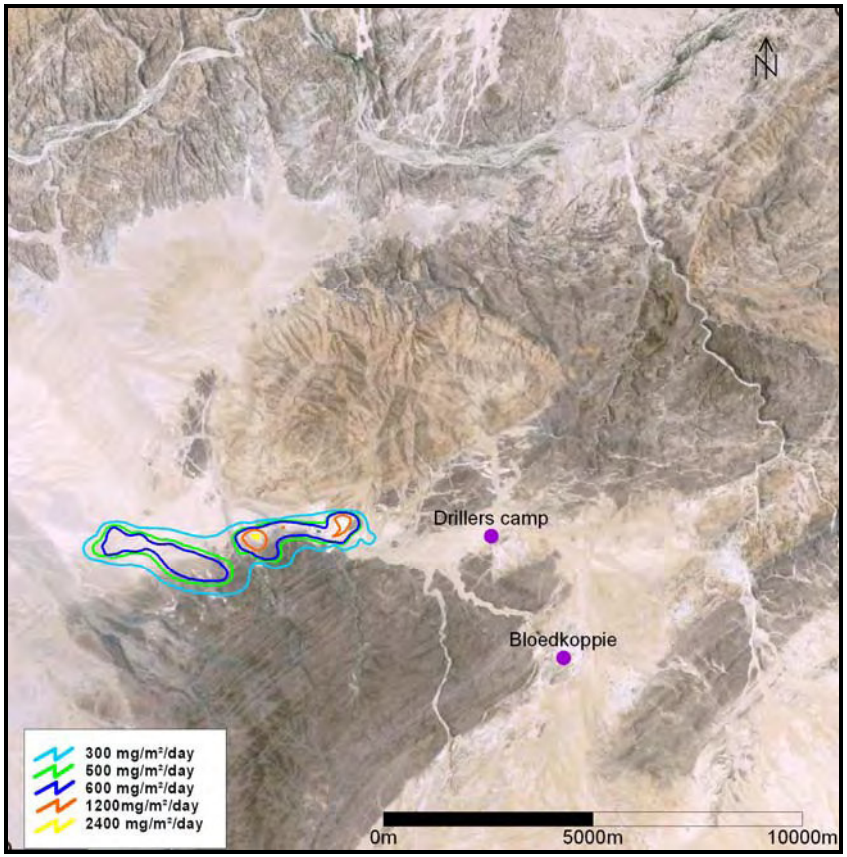


**Figure 6-7: Average daily dust deposition rates (mg/m²/day) due to uncontrolled emissions during the proposed construction activities at Langer Heinrich Uranium Mine.**

## 6.4 Significance rating of construction activities

The impact assessment summary table is depicted in Table 6-5 below.

**Table 6-5: Impact Assessment Summary Table for the Proposed Construction Phase and Current Mining Operations**

| Source | Impact | Severity/ Nature of Impact | Spatial Scale of Impacts | Duration of Impact | Probability of Impact |
|---|---|---|---|---|---|
| **Construction and Current Operations** | Respirable dust (PM10) | M | M | M | M |
| | Dust fallout (nuisance) | M | M | M | M |

# 7 FUTURE OPERATIONAL PHASE

## 7.1 Emissions Inventory

The release of emissions represents the environmental impact of concern during the proposed operational phases at Langer Heinrich Uranium Mine. In the development of an emissions inventory the first approach is to establish a comprehensive list of all sources that would generate the pollutants of concern. Such sources were identified by firstly utilising the inputs and outputs to the proposed operational processes and secondly considering the disturbance to the environment. The environmental impacts and associated activities identified for the proposed mining activities are similar to those of the current mining activities (Table 5-2). The areas of open cast mining will extend further east and west with a new processing plant and tailings dam in place to accommodate the increase in production from 3.7 Mtpa to 10 Mtpa[4]. Three proposed future scenarios were modelled in an attempt to present the spatial variation in the proposed mining operations. These are as follows:

- *Future Scenario 1: Future West Pit;*
- *Future Scenario 2: Future Centre Pit;* and,
- *Future Scenario 3: Future East Pit.*

The proposed Langer Heinrich mining operations will generate TSP, PM10 and various gaseous emissions. In the quantification of these releases use is made of the predictive emission factors published by the US-EPA (EPA, 1996).

### *7.1.1 Materials Handling Operations*

Similar to the current operations, Equation 1 as depicted and discussed in Appendix B is used to calculate the emissions from tipping. The PM10 fraction of the TSP is taken to be 35% as indicated in the US-EPA AP42 documentation. A control efficiency of 50% is applied to the materials handling activities. Table 7-1 depicts the various parameters utilised in the calculation of emissions resulting from material handling activities for the proposed operations. The throughput is based on the maximum proposed production rate of 10 Mtpa.

**Table 7-1: Materials handling operations for the proposed operations at Langer Heinrich Uranium Mine.**

| Scenario | Tipping Operation | Throughput (tonnes per month) |
|---|---|---|
| *Future Scenario 1: West Pit* Proposed operations | ROM into trucks in the pit | 833 33 |
| *Future Scenario 2: Centre Pit* Proposed operations | | 833 33 |
| *Future Scenario 3: East Pit* Proposed operations | | 833 33 |
| *Future Scenario 1: West Pit* Proposed operations | ROM onto ROM | 833 33 |

[4] The proposed expansion it to accommodate an increase of between 6 Mtpa and 10 Mtpa, with the latter taken to reflect the worst case scenario.

| Scenario | Tipping Operation | Throughput (tonnes per month) |
|---|---|---|
| *Future Scenario 2: Centre Pit* Proposed operations | stockpile at processing plant | 833 33 |
| *Future Scenario 3: East Pit* Proposed operations | | 833 33 |
| *Future Scenario 1: West Pit* Proposed operations | Waste rock onto waste rock dumps | 1 666 667 |
| *Future Scenario 2: Centre Pit* Proposed operations | | 1 666 667 |
| *Future Scenario 3: East Pit* Proposed operations | | 1 666 667 |
| *Future Scenario 1: West Pit* Proposed operations | Low grade ROM into trucks | 1 666 667 |
| *Future Scenario 2: Centre Pit* Proposed operations | | 1 666 667 |
| *Future Scenario 3: East Pit* Proposed operations | | 1 666 667 |
| *Future Scenario 1: West Pit* Proposed operations | Low grade ROM onto pile | 2 785 |
| *Future Scenario 2: Centre Pit* Proposed operations | | 2 785 |
| *Future Scenario 3: East Pit* Proposed operations | | 2 785 |
| *Future Scenario 1: West Pit* Proposed operations | Tipping of ROM into primary and secondary crushers | 2 785 |
| *Future Scenario 2: Centre Pit* Proposed operations | | 2 785 |
| *Future Scenario 3: East Pit* Proposed operations | | 2 785 |
| *Future Scenario 1: West Pit* Proposed operations | Tipping of ROM into primary and secondary crushers | 700 000 |
| *Future Scenario 2: Centre Pit* Proposed operations | | 700 000 |
| *Future Scenario 3: East Pit* Proposed operations | | 700 000 |
| *Future Scenario 1: West Pit* Proposed operations | | 291 667 |
| *Future Scenario 2: Centre Pit* Proposed operations | | 291 667 |
| *Future Scenario 3: East Pit* Proposed operations | | 291 667 |

### *7.1.2 Wind erosion from Exposed Areas*

Equations used in calculating emission rates from wind erosion sources are shown in Appendix B (Equations 2 to 5). Information pertaining to the stockpiles utilised for the current and proposed operations is listed in Table 7-2.

**Table 7-2: Information Input into the ADMS and ADDAS Models for the Proposed Operations Stockpiles at Langer Heinrich Uranium Mine.**

| Stockpile | Height (m) | Volume ($m^3$) | Area ($m^2$) | X-length (m) | Y-length (m) | Bulk density ($kg/m^3$) | Moisture (%) |
|---|---|---|---|---|---|---|---|
| Topsoil 1 | 4 | 158 256 | 39 000 | 100 | 390 | 2 883 | 3 |
| Topsoil 2 | 3 | 158 256 | 56 700 | 180 | 315 | 2 883 | 3 |
| Topsoil 3 | 3 | 1582 56 | 56 700 | 180 | 315 | 2 883 | 3 |
| ROM Low Grade | 36 | 15 000 000 | 415 200 | 600 | 692 | 2 567 | 3 |
| ROM Super High Grade | 20 | 4 800 000 | 245 000 | 350 | 700 | 2 783 | 3 |
| Tailings dam (a) | 40 | 63 434 000 | 1 585 850 | 1970 | 805 | 2 900 | 3 |
| Barren Waste rock dump | 10 | 2 000 000 | 193 698 | 306 | 633 | 2 700 | 3 |
| Dormant Waste rock dump | 20 | 4 000 000 | 204 600 | 300 | 682 | 2 700 | 3 |
| Future Pit Waste rock dump (b) | 35 | 8 000 000 | 226 300 | 310 | 730 | 2 700 | 3 |
| Waste rock dump close to Plant | 4 | 350 000 | 90 000 | 300 | 300 | 2 700 | 3 |

**Notes:** (a) 3% moisture content for the tailings dam wall and 12.6% for the tailings dam beach.
(b) Future Pit Waste rock dump was assumed to be the same for West Pit, Centre Pit and East Pit scenarios with only different locations

Particle size data used in the ADDAS and ADMS models was obtained from sample analysis results for the various sources (tailings dam wall, tailings dam beach, waste rock dumps, topsoil stockpiles, ROM and low grade ore). The samples used in the analysis were obtained from the mine.

### *7.1.3 Crushing and Screening Activities*

The revised US-EPA emission factors for crushing are only available for tertiary crushing and are given for TSP as 0.0027 kg of particulate per tonne of material crushed (Equations 6 and 7– Appendix B) and as 0.0012 kg of particulate per tonne of material crushed for PM10. The tertiary crushing US-EPA emission factors are used for TSP and PM10 in this study since the revised emission factors for primary and secondary crushing and screening are not available.

The parameters used in the calculation of emissions for crushing and screening activities for the proposed operations for the modelled *scenarios* are shown in Table 7-3. The crushed ore tonnes per day for the proposed *West Pit, Centre Pit* and *East Pit* operations take into consideration the amount of low grade ore that would be crushed at the proposed low grade crusher.

**Table 7-3: Parameters used for the calculation of emissions from crushing and screening operations for the proposed Langer Heinrich Uranium Mine operations**

| Crushing and screening | Tonnes per day | Moisture (%) |
|---|---|---|
| ***Primary and secondary crushing and screening*** | | |
| *Future Scenario 1: West Pit* Proposed operations | 23 426 | 3 |
| *Future Scenario 2: Centre Pit* Proposed operations | 23 426 | 3 |
| *Future Scenario 3: East Pit* Proposed operations | 23 426 | 3 |

### *7.1.4 Vehicle Activity on Unpaved Roads*

Parameters utilised in the calculation of emissions from the unpaved roads are depicted in Table 7-4 with the roads used depicted in Figures 7-1 to 7-3 for the three scenarios respectively. The unpaved road size-specific emission factor equation of the US.EPA, used in the quantification of emissions from the proposed unpaved roads, is given in Appendix B, Equation 8. The silt percentage utilised for the unpaved roads is 25.2% and this silt percentage is the US-EPA maximum silt content for the unpaved road equation. Unpaved haul roads to and from the current and proposed pits, haul roads to and from the ROM stockpile and the waste rock dumps were modelled, with control efficiencies of 75% given the water trucks currently utilised by the mine.

**Table 7-4: Parameters of the unpaved haul roads simulated for the proposed mining operations at Langer Heinrich Uranium Mine**

| Roads | Length (m) | Width (m) | Emission rate (g/m²/s) | |
|---|---|---|---|---|
| | | | PM10 | TSP |
| ***Future Scenario 1: West Pit proposed operations*** | | | | |
| Unpaved haul road 1 to ROM pad and West Pit | 400 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 2 to ROM pad and West Pit | 330 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 3 to ROM pad and West Pit | 1000 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 4 to ROM pad and West Pit | 695 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 5 to ROM pad and West Pit | 430 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 6 to ROM pad and West Pit | 295 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 7 to ROM pad and West Pit | 547 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 8 to waste rock dump and West pit | 168 | 10 | 2.9E-03 | 8.2E-03 |
| ***Future Scenario 2: Centre Pit proposed operations*** | | | | |
| Unpaved haul road 1 to ROM pad and Centre Pit | 523 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 2 to ROM pad and Centre Pit | 387 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 3 to ROM pad and Centre Pit | 340 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 4 to ROM pad and Centre Pit | 916 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 5 to ROM pad and Centre Pit | 657 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 6 to ROM pad and Centre Pit | 628 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 7 to ROM pad and Centre Pit | 1 440 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 8 to waste rock dump and Centre Pit | 340 | 10 | 2.9E-03 | 8.2E-03 |
| ***Future Scenario 3: East Pit proposed operations*** | | | | |
| Unpaved haul road 1 to ROM pad: East pit | 523 | 10 | 1.45E-03 | 4.08E-03 |

| Roads | Length (m) | Width (m) | Emission rate (g/m²/s) | |
|---|---|---|---|---|
| | | | PM10 | TSP |
| Unpaved haul road 2 to ROM pad: East Pit | 387 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 3 to ROM pad: East Pit | 340 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 4 to ROM pad: East Pit | 916 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 5 to ROM pad: East Pit | 657 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 6 to ROM pad: East Pit | 628 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 7 to ROM pad: East Pit | 1 440 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 8 to ROM pad: East Pit | 939 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 9 to ROM pad: East Pit | 895 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 10 to ROM pad: East Pit | 1 118 | 10 | 1.45E-03 | 4.08E-03 |
| Unpaved haul road 11 to waste rock dump: East Pit | 620 | 10 | 2.9E-03 | 8.2E-03 |

### *7.1.5 Drilling*

Fugitive dust emissions due to in-pit drilling operations at the mine were quantified using the Australian NPI single value emission factors for mining (Equations 9 and 10 Appendix B). The drilling parameters that were utilised for the proposed operations are presented in Table 7-5. No mitigation measures were assumed for the drilling operations.

**Table 7-5: Drilling source specific information: Proposed operations (per proposed pit)**

| Drilling parameter | Parameter units/ value |
|---|---|
| Drilling area | 10 000m² (100m x 100m) |
| No of drill holes (including exploration drill holes) | 689 drill holes |
| Depth of each drill hole | 9m |
| Distance between drill holes (row) | 4.1m |
| Distance between drill holes (column) | 4.5m |

### *7.1.6 Blasting*

Fugitive dust emissions due to blasting at the mine were quantified using the US.EPA predictive emission factor equation for mining (Equations 11-Appendix B). Source specific information used in the calculation of emissions due to blasting activities is presented in Table 7-6 for the proposed operations. No mitigation measures were assumed for the blasting operations.

**Table 7-6: Blasting source specific information: Proposed operations (per proposed pit)**

| Drilling parameter | Parameter units/ value |
|---|---|
| Blasting area | 10000m² (100m x 100m) |
| Blasts per day | 1 |
| Days per year | 365 |

**Figure 7-1: Assumed roads for Future Scenario 1: West Pit operations**

**Figure 7-2: Assumed roads for Future Scenario 2: Centre Pit operations**

**Figure 7-3: Assumed roads for Future Scenario 3: East Pit operations**

### *7.1.7 Excavation*

The US.EPA Equation (Equation 12-Appendix B) was used to calculate emissions due to excavation activities. The area of topsoil disturbance in preparation for mining is given as between 80 and 100ha. It was assumed that the excavated area will be 100 000 m² for each proposed operation. Table 7-7 depicts the parameters that were used in calculating emissions due to excavating activities.

**Table 7-7: Parameters used for the calculation of emissions from excavation for the proposed operations**

| Scenario | Parameters of excavated area | | |
|---|---|---|---|
| | Length (m) | Width (m) | Total area (m²) |
| *Future Scenario 1: West Pit* Proposed operations | 316 | 316 | 100 000 |
| *Future Scenario 2:Centre Pit* Proposed operations | 316 | 316 | 100 000 |
| *Future Scenario 3: East Pit* Proposed operations | 316 | 316 | 100 000 |

## 7.2 Synopsis of Estimated Emissions for the Proposed Operational Phases

### *7.2.1 Proposed operations: West Pit*

A synopsis of the estimated particulate and gaseous emissions as a result of the proposed mining operations at Langer Heinrich Uranium Mine West Pit is presented in Table 7-8 and depicted in Figure 7-4 (PM10 source contributions) and Figure 7-5 (TSP source contributions). Wind erosion was predicted to be the main contributing source to PM10 and TSP emissions (63% and 62% respectively). The second most significant source of PM10 and TSP emissions were the unpaved roads (34% and 36% respectively). Blasting was predicted to be the third most significant source of PM10 and TSP (1% and 0.7% respectively). As with the baseline, mitigation measures were applied to the unpaved roads assuming a control efficiency of 75% and 30% control efficiency in windblown sources (with 60% CE on tailings dam surface).

**Table 7-8: TSP and PM10 emissions (tpa) due to proposed mining operations at West Pit at Langer Heinrich Uranium Mine**

| Source | PM10 | TSP | PM10 % | TSP % | Rank PM10 | Rank TSP |
|---|---|---|---|---|---|---|
| **Crushing and screening** | 9.0 | 18.5 | 0.2 | 0.1 | 7 | 7 |
| **Materials handling** | 32.0 | 91.0 | 0.6 | 0.6 | 5 | 4 |
| **Wind erosion** | 3 535.0 | 9 468.0 | 63.1 | 62.3 | 1 | 1 |
| **Unpaved roads** | 1 917.0 | 5 399.0 | 34.2 | 35.5 | 2 | 2 |
| **Blasting** | 57.5 | 110.5 | 1.0 | 0.7 | 3 | 3 |
| **Excavation** | 15.0 | 35.0 | 0.3 | 0.2 | 6 | 6 |
| **Drilling** | 40 | 75 | 0.7 | 0.5 | 4 | 5 |
| **Total** | **5 605.5** | **15 197.0** | **100.0** | **100.0** | | |

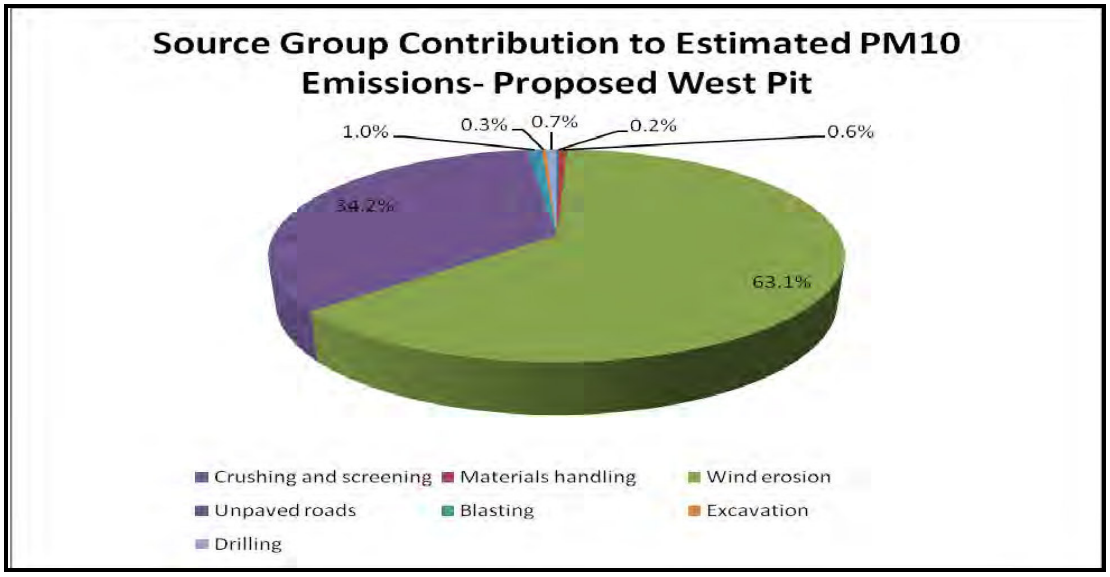


**Figure 7-4: Source group contribution to estimated PM10 emissions for proposed operations at West Pit**

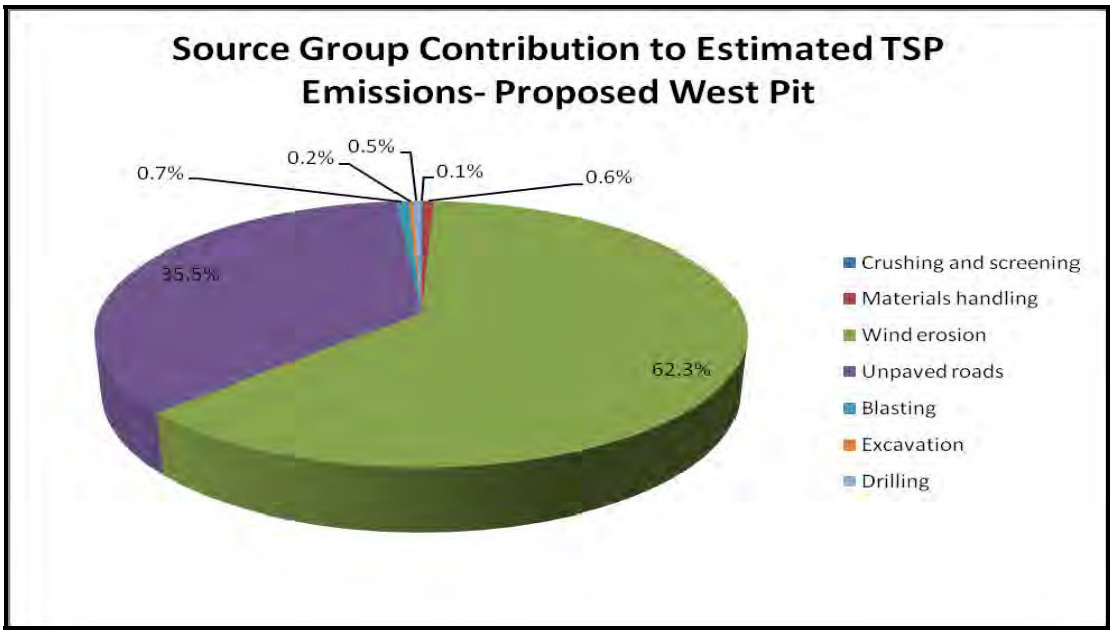


**Figure 7-5: Source group contribution to estimated TSP emissions for proposed operations at West Pit**

### *7.2.2 Proposed operations: Centre Pit*

Estimated particulate and gaseous emissions as a result of the proposed mining operations at Centre Pit are presented in Table 7-9 and depicted in Figure 7-6 (PM10 source contributions) and Figure 7-7 (TSP source contributions). Similar to the previous scenario wind erosion remained the main source of PM10 and TSP emissions (57% and 56% respectively). The second most significant source of was unpaved roads (41% for PM10 and 42% for TSP). The higher emissions from roads could be attributed to the lengthy and numerous unpaved roads that will be required to access the processing plant, mining operations and other areas at the proposed Centre Pit. Blasting activities remained to be third on the list with drilling activities predicted to be the fourth significant source of PM10 (0.6%) and the fifth significant source of TSP (0.4%). The same control efficiencies were assumed (i.e. 75% for roads and 30% for wind erosion sources).

**Table 7-9: TSP and PM10 emissions (tpa) due to proposed mining operations at Centre Pit at Langer Heinrich Uranium Mine**

| Source | PM10 | TSP | PM10 % | TSP % | Rank PM10 | Rank TSP |
|---|---|---|---|---|---|---|
| **Crushing and screening** | 9.0 | 18.5 | 0.1 | 0.1 | 7 | 7 |
| **Materials handling** | 32.0 | 91.0 | 0.5 | 0.5 | 5 | 4 |
| **Wind erosion** | 3 535.0 | 9 468.0 | 56.7 | 55.8 | 1 | 1 |
| **Unpaved roads** | 2 546.0 | 7 170.0 | 40.8 | 42.3 | 2 | 2 |
| **Blasting** | 57.5 | 110.5 | 0.9 | 0.7 | 3 | 3 |
| **Excavation** | 15.0 | 35.0 | 0.2 | 0.2 | 6 | 6 |
| **Drilling** | 40 | 75 | 0.6 | 0.4 | 4 | 5 |
| **Total** | **6 234.5** | **16 968.0** | **100.0** | **100.0** | | |

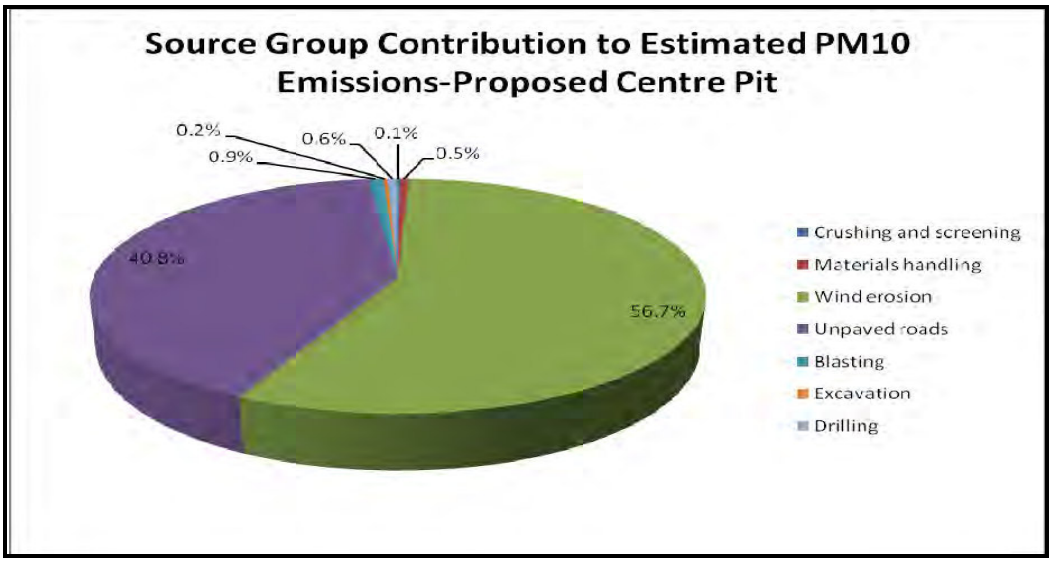


**Figure 7-6: Source group contribution to estimated PM10 emissions for proposed operations at Centre Pit**

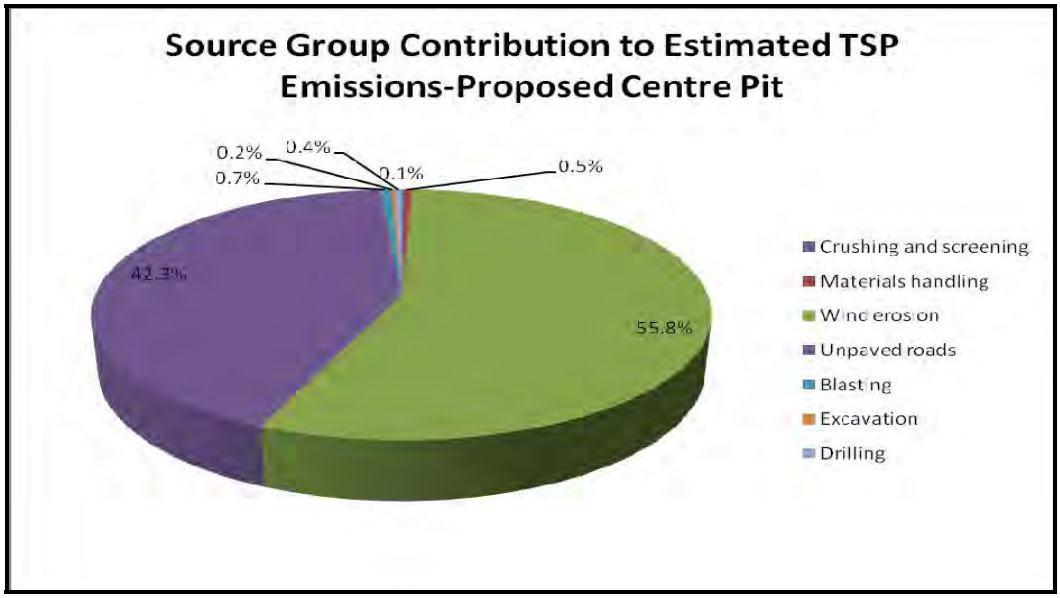


**Figure 7-7: Source group contribution to estimated TSP emissions for proposed operations at Centre Pit**

### *7.2.3 Proposed operations: East Pit*

Estimated particulate and gaseous emissions as a result of the proposed mining operations at East Pit are depicted in Table 7-10 and shown in Figure 7-8 (PM10 source contributions) and Figure 7-9 (TSP source contributions). Unpaved roads were predicted to be the most significant source of PM10 and TSP emissions (53% and 54%) respectively. Similar to proposed Centre Pit, the high source contributions of unpaved roads to PM10 and TSP emissions compared to the other modelled scenarios could be attributed to the lengthy and numerous unpaved roads that are required to access the mining operations, processing plant and other areas to and from the proposed East Pit. The second most significant source of PM10 and TSP emissions was predicted to be wind erosion (45% and 44% respectively).

**Table 7-10: TSP and PM10 emissions (tpa) due to proposed mining operations at East Pit at Langer Heinrich Uranium Mine**

| Source | PM10 | TSP | PM10 % | TSP % | Rank PM10 | Rank TSP |
|---|---|---|---|---|---|---|
| **Crushing and screening** | 9.0 | 18.5 | 0.1 | 0.1 | 7 | 7 |
| **Materials handling** | 32.0 | 91.0 | 0.4 | 0.4 | 5 | 4 |
| **Wind erosion** | 3 535.0 | 9 468.0 | 45.1 | 44.1 | 2 | 2 |
| **Unpaved roads** | 4 151.0 | 11 690.0 | 52.9 | 54.4 | 1 | 1 |
| **Blasting** | 57.5 | 110.5 | 0.7 | 0.5 | 3 | 3 |
| **Excavation** | 15.0 | 35.0 | 0.2 | 0.2 | 6 | 6 |
| **Drilling** | 40 | 75 | 0.5 | 0.3 | 4 | 5 |
| **Total** | **7 839.5** | **21 488.0** | **100.0** | **100.0** | | |

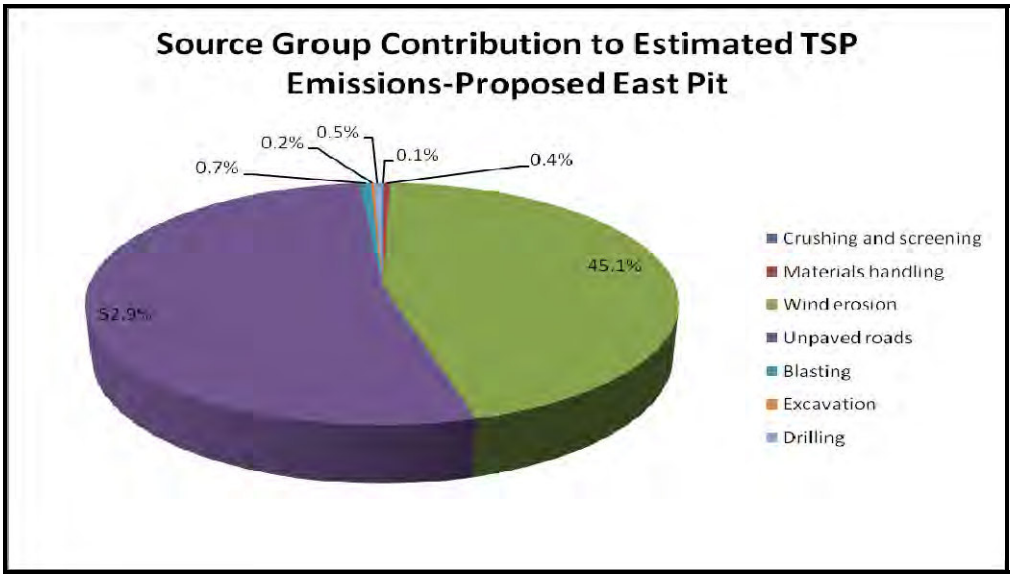


**Figure 7-8: Source group contribution to estimated PM10 emissions for proposed operations at East Pit**

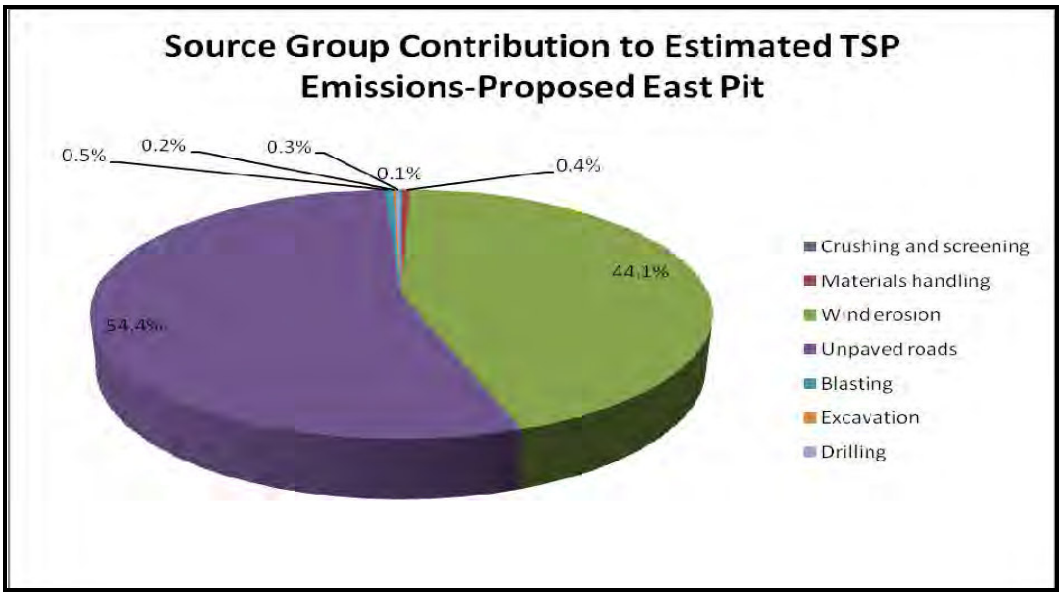


**Figure 7-9: Source group contribution to estimated TSP emissions for proposed operations at East Pit**

## 7.3 Dispersion Model Results

Dispersion simulations were executed incorporating all significant sources for the proposed operations to determine the cumulative impacts. The predicted concentrations for inhalable particulates (PM10) and dust-fall levels (TSP) are discussed in the following section. International standards and guidelines for organisations such as the EC, SA, WB and WHO were applied for compliance assessments.

Since the Contractors camp will only exist for the duration of the construction activities, only Bloedkoppie and the Drillers Camp were addressed as part of the future scenarios assessment.

### *7.3.1 PM10 Concentrations due to the Proposed Operational Phase Activities*

The PM10 concentrations were simulated for three scenarios and the description is outlined in Table 7-11.

**Table 7-11: Scenarios simulated for the PM10 concentrations**

| | |
|---|---|
| ***Future Scenario 1: West Pit operations*** | ○ All sources were simulated to determine the impacts of the proposed operations at West Pit<br>○ Mitigation measures were applied to unpaved roads, crushing and screening, material handling activities and wind erosion |
| ***Future Scenario 2: Centre Pit operations*** | ○ All sources were simulated to determine the impacts of the proposed operations at Centre Pit<br>○ Mitigation measures were applied to unpaved roads, crushing and screening, material handling activities and wind erosion |
| ***Future Scenario 3: East Pit operations*** | ○ All sources were simulated to determine the impacts of the proposed operations at East Pit<br>○ Mitigation measures were applied to unpaved roads, crushing and screening and material handling activities |

*Future Scenario 1: Proposed West Pit Mining Operations*

- The proposed West Pit will be located to the west of the current mining operations and the increase in production is evident from the predicted ground level concentrations at the sensitive receptors. The predicted PM10 concentrations increased by between 24% at the Drillers Camp and 49% at Bloedkoppie. This resulted in exceedances of both the EC standard and WHO guideline at the Drillers Camp over a daily average (Table 7-12 and Figure 7-10). The predicted concentrations are also predicted to exceed WHO IT-2 and IT-3 interim targets (at the Drillers Camp) and the South African (SA) proposed standard of 75 µg/m³. The impacts at Bloedkoppie comply with the EC daily standard, WHO air quality guideline and all the WHO interim targets.

- Over an annual average, the predicted ground level concentrations for the proposed West Pit mining operations do not exceed the EC or proposed SA air quality standard at both sensitive receptor sites (Table 7-12 and Figure 7-11). The WHO guideline and all the interim targets are predicted not to be exceeded at the sensitive receptor sites.

**Table 7-12: Predicted highest daily average and annual PM10 concentrations (µg/m³) at the sensitive receptor sites due to the proposed West Pit mining operations.**

| Sensitive Receptor Area | *Scenario* | PM10 Concentration (µg/m³) | |
|---|---|---|---|
| | | Daily concentration | Annual concentration |
| Bloedkoppie | Proposed West Pit mining operations | 37 | 17 |
| Drillers Camp | Proposed West Pit mining operations | 110 | 19 |

*Future Scenario 2: Proposed Centre Pit Mining Operations*

- The proposed future mining operations at Centre Pit resulted in significantly higher predicted ground level concentrations than the West Pit. This is due to the location of Centre Pit on the eastern side of the current operations, fairly close to the Drillers Camp and closer to Bloedkoppie. The EC daily standard and WHO air quality guideline are predicted to be exceeded at the both sensitive receptor sites. Only the impacts at Bloedkoppie comply with the proposed SA standard of 75 µg/m³ and the WHO interim targets. All standards and guidelines are predicted to be exceeded at the Drillers Camp (Table 7-13 and Figure 7-12).

- The annual average ground level concentrations are predicted to exceed the WHO guideline at both receptor sites and the WHO interim targets at the Drillers Camp (Table 7-13 and Figure 7-13). No exceedances of the EC standard and the proposed SA standard are predicted at Bloedkoppie.

**Table 7-13: Predicted highest daily average and annual PM10 concentrations (µg/m³) at the sensitive receptor sites due to the proposed Centre Pit mining operations.**

| Sensitive Receptor Area | *Scenario* | PM10 Concentration (µg/m³) | |
|---|---|---|---|
| | | Daily concentration | Annual concentration |
| Bloedkoppie | Proposed Centre Pit mining operations | 72 | 21 |
| Drillers Camp | Proposed Centre Pit mining operations | 268 | 123 |

*Future Scenario 3: Proposed East Pit Mining Operations*

- The predicted PM10 daily average ground level concentrations for the proposed East Pit mining operations resulted in the highest impacts at the sensitive receptors. This is due to the location of East Pit even further eastwards resulting in a long haul road between the pit and the plant running past the Drillers Camp. This resulted in predicted exceedances of all the relevant standards and guidelines at the both sensitive receptor sites (Table 7-14 and Figure 7-14). An overall increase in predicted ground level concentrations between the baseline and future Scenario 3 are 75% at Bloedkoppie and 73% at the Drillers Camp.

- This scenario also resulted in high predicted impacts over an annual average at the Drillers Camp. Predicted concentrations at Bloedkoppie do not exceed the EC and SA air quality standards of 40 µg/m³. The WHO air quality guideline is predicted to be exceeded at Bloedkoppie but comply with all the WHO interim targets (Table 7-14 and Figure 7-15). The predicted high impacts for this scenario could be attributed to the fact that the proposed East Pit sources (and

pit) are located closer to the sensitive receptors compared to the other proposed pits. These emission sources include unpaved roads and these have been predicted to be the most significant sources of PM10 and TSP during the proposed East Pit operations.

**Table 7-14: Predicted highest daily average and annual PM10 concentrations (µg/m³) at the sensitive receptor sites due to the proposed East Pit mining operations.**

| Sensitive Receptor Area | *Scenario* | PM10 Concentration (µg/m³) | |
|---|---|---|---|
| | | Daily concentration | Annual concentration |
| Bloedkoppie | Proposed East Pit mining operations | 76 | 24 |
| Drillers Camp | Proposed East Pit mining operations | 289 | 140 |

Since mining operations at Langer Heinrich are proposed to progress eastwards, it is highly likely that impacts will increase at the sensitive receptors as mining operations progress eastwards.

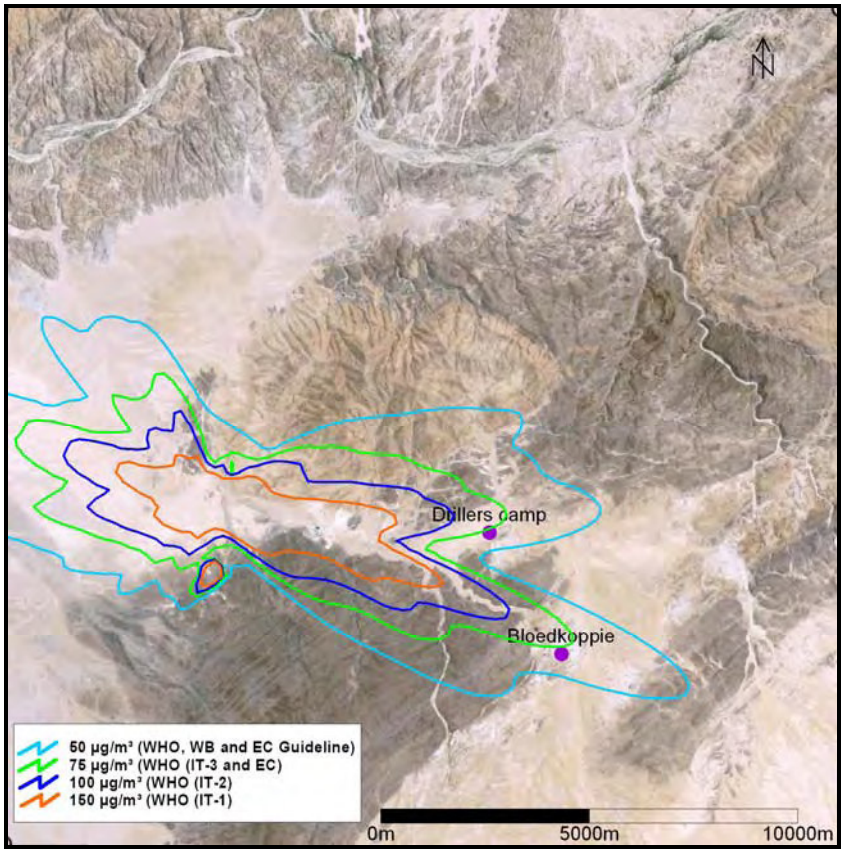


**Figure 7-10: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (West Pit) (Future *Scenario 1*).**

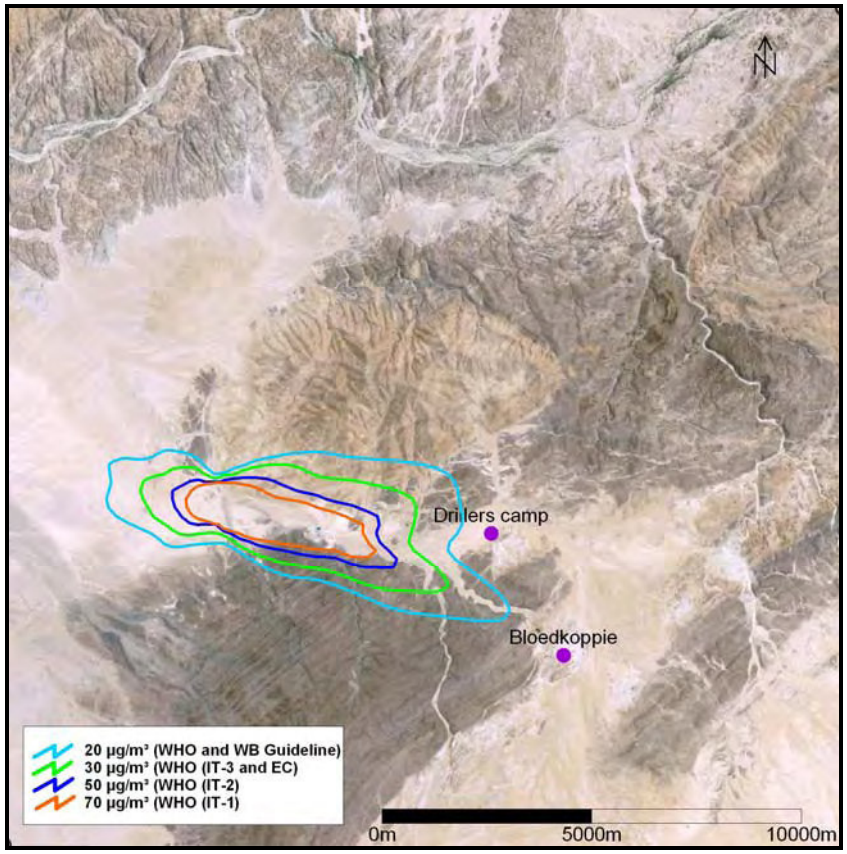


**Figure 7-11: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (West Pit) (Future *Scenario1*).**

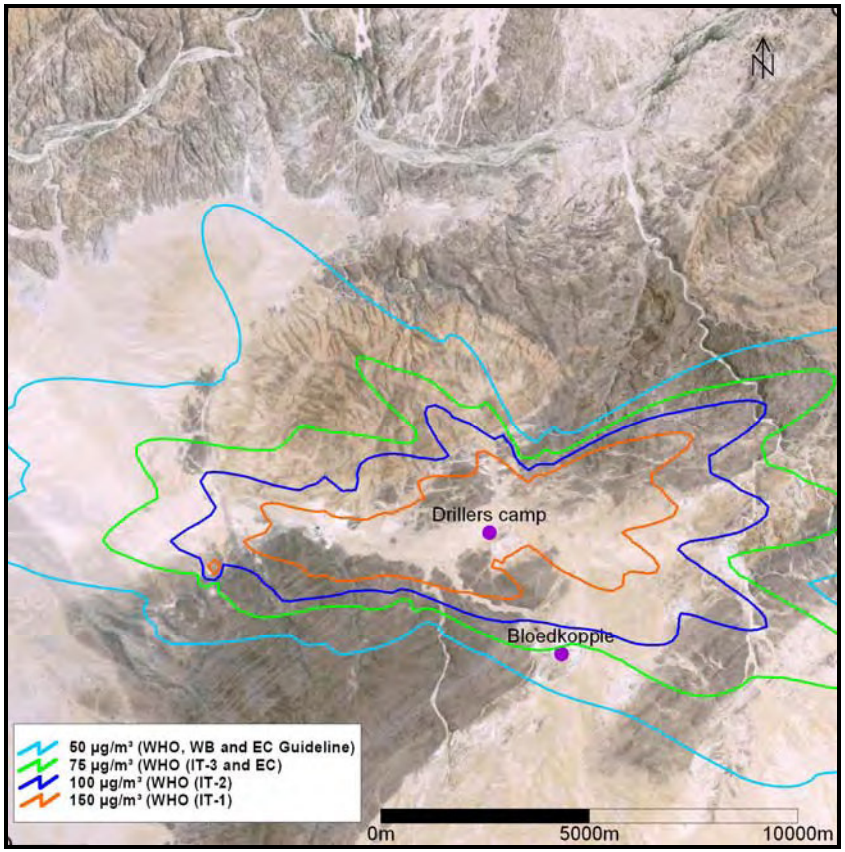


**Figure 7-12: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Centre Pit) (Future *Scenario 2*).**

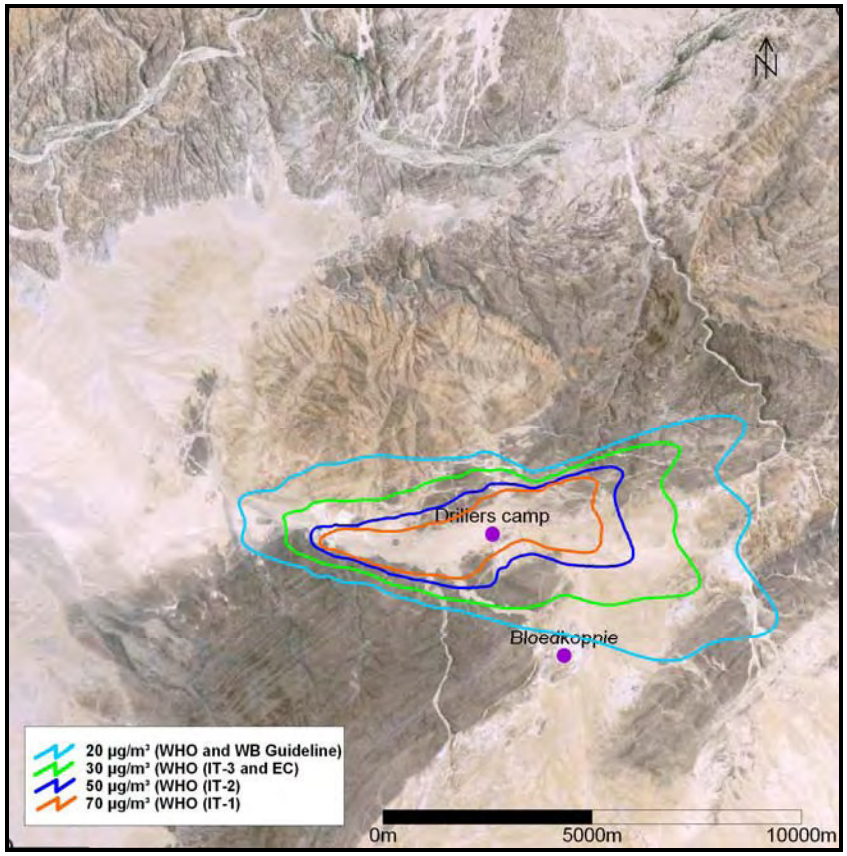


**Figure 7-13: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Centre Pit) (Future *Scenario 2*).**

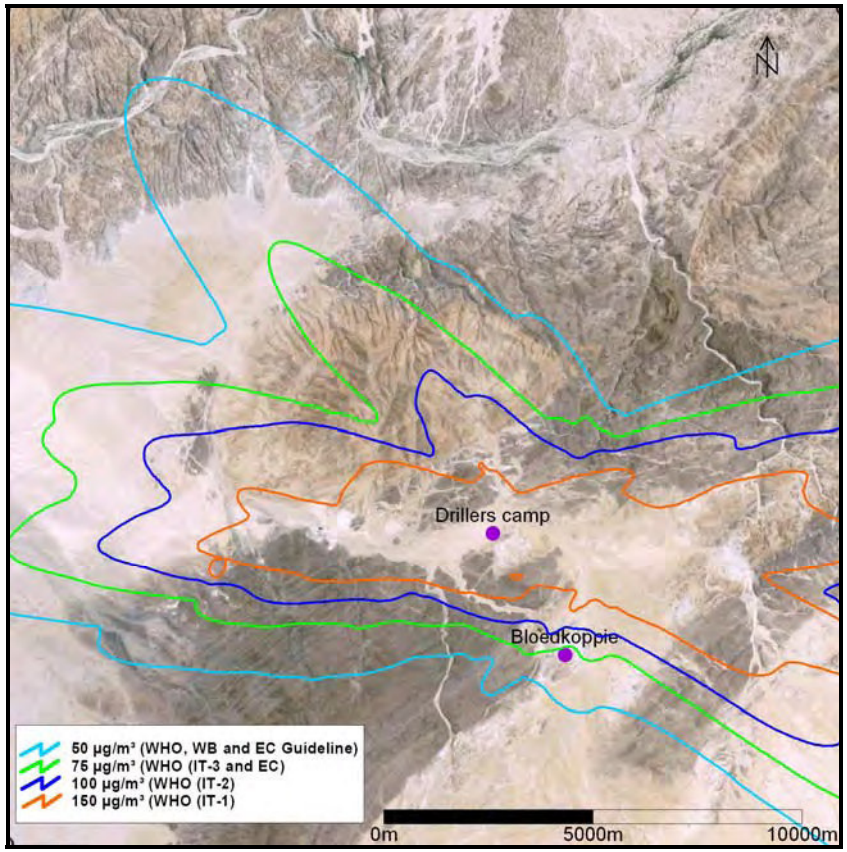


**Figure 7-14: Highest daily average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (East Pit) (Future *Scenario 3*)[5].**

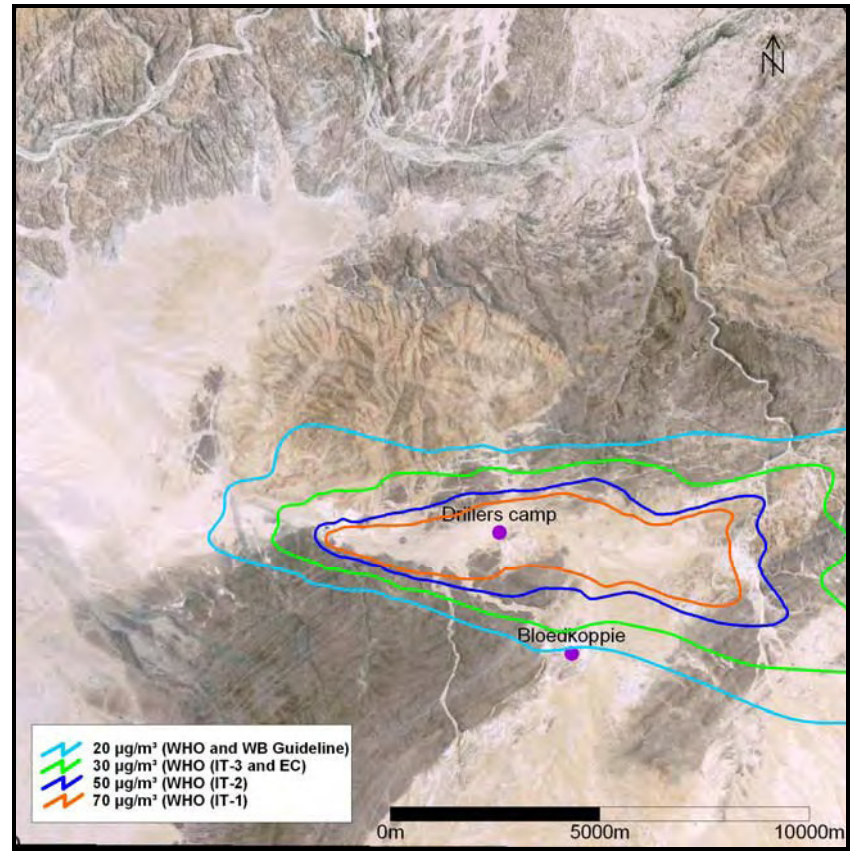


**Figure 7-15: Annual average predicted PM10 ground level concentrations (µg/m³) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (East Pit) (Future *Scenario 3*).**

[5] The high concentrations on the western side are not realistic since there are no additional sources for this scenario located on the western side. This is currently being investigated.

### 7.3.2 Predicted Dust Fallout Rates due to the Proposed Operational Phase Activities

This section discusses the predicted dust fallout levels at the sensitive receptors located close the mine as a result of the various proposed mining activities.

*Future Scenario 1: Proposed West Pit Mining Operations*

- Proposed West Pit, which is located to the west of the current operations, resulted in lower maximum daily and average daily dust fallout levels at the two sensitive receptors. This is due to the location of the open pit furthest away from these receptors. The predicted average daily dust deposition rates did not exceed the German deposition level for general areas and the SANS residential dust fallout limit at both sensitive receptor sites (Table 7-15, Figure 7-16 and Figure 7-17).

**Table 7-15: Predicted annual average dust fallout levels (mg/m²/day) at the sensitive receptor sites due to proposed West Pit mining operations.**

| Sensitive Receptor Area | *Scenario* | Maximum Daily Dust Fallout (mg/m²/day) | Average Daily Dust Fallout (mg/m²/day |
|---|---|---|---|
| Bloedkoppie | Proposed West Pit mining operations | 56 | 2 |
| Drillers Camp | Proposed West Pit mining operations | 73 | 27 |

*Future Scenario 2: Proposed Centre Pit Mining Operations*

- When the proposed operations move eastwards, the predicted maximum daily and average daily dust fallout levels increase significantly at the sensitive receptor areas, especially at the Drillers Camp. Both the German and the SANS residential limit are predicted to be exceeded at the Drillers Camp. The SANS industrial limit is also predicted to be exceeded at the Drillers Camp (Table 7-16, Figure 7-18 and Figure 7-19).

**Table 7-16: Predicted annual average dust fallout levels (mg/m²/day) at the sensitive receptor sites due to proposed Centre Pit mining operations.**

| Sensitive Receptor Area | *Scenario* | Maximum Daily Dust Fallout (mg/m²/day) | Average Daily Dust Fallout (mg/m²/day |
|---|---|---|---|
| Bloedkoppie | Proposed Centre Pit mining operations | 68 | 53 |
| Drillers Camp | Proposed Centre Pit mining operations | 1492 | 1269 |

*Future Scenario 3: Proposed East Pit Mining Operations*

- The predicted maximum daily and average daily dust deposition rates due to the proposed East Pit mining operations exceed the maximum permissible limit for general areas of 350 mg/m²/day at the Drillers Camp. Both the SANS residential and industrial dust fallout limit of 600 mg/m²/day is exceeded at this sensitive receptor site (Table 7-17, Figure 7-20 and Figure 7-21).

**Table 7-17: Predicted annual average dust fallout levels (mg/m²/day) at the sensitive receptor sites due to proposed East Pit mining operations.**

| Sensitive Receptor Area | *Scenario* | Maximum Daily Dust Fallout (mg/m²/day) | Average Daily Dust Fallout (mg/m²/day |
|---|---|---|---|
| Bloedkoppie | Proposed East Pit operations | 78 | 57 |
| Drillers Camp | Proposed East Pit operations | 1713 | 1525 |

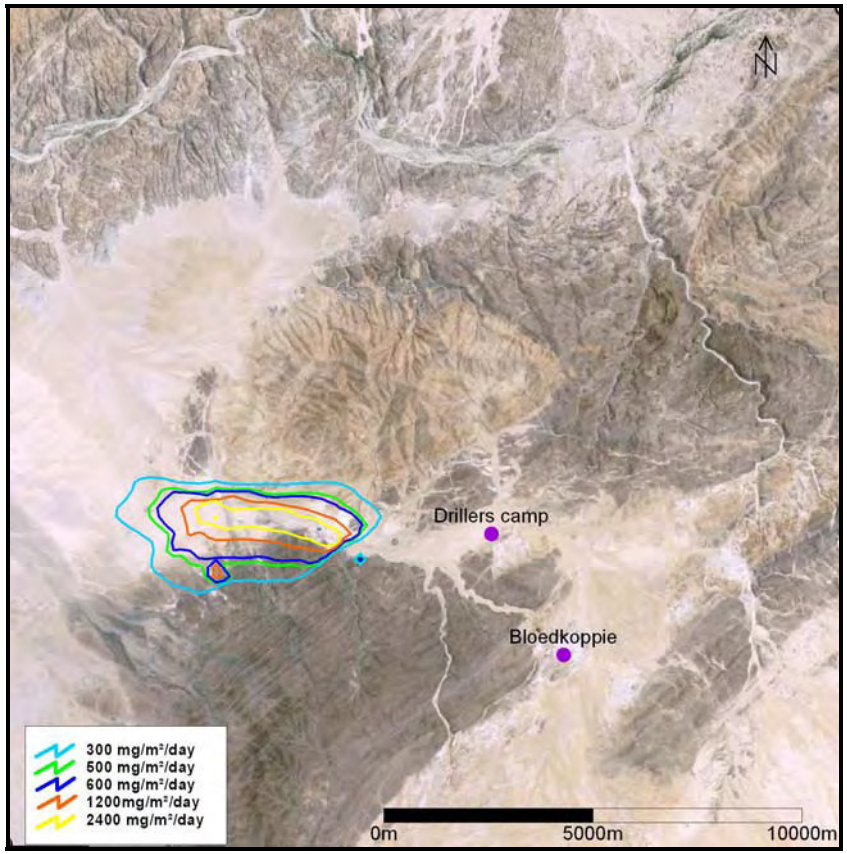


**Figure 7-16: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Future *Scenario 1- West Pit*)**

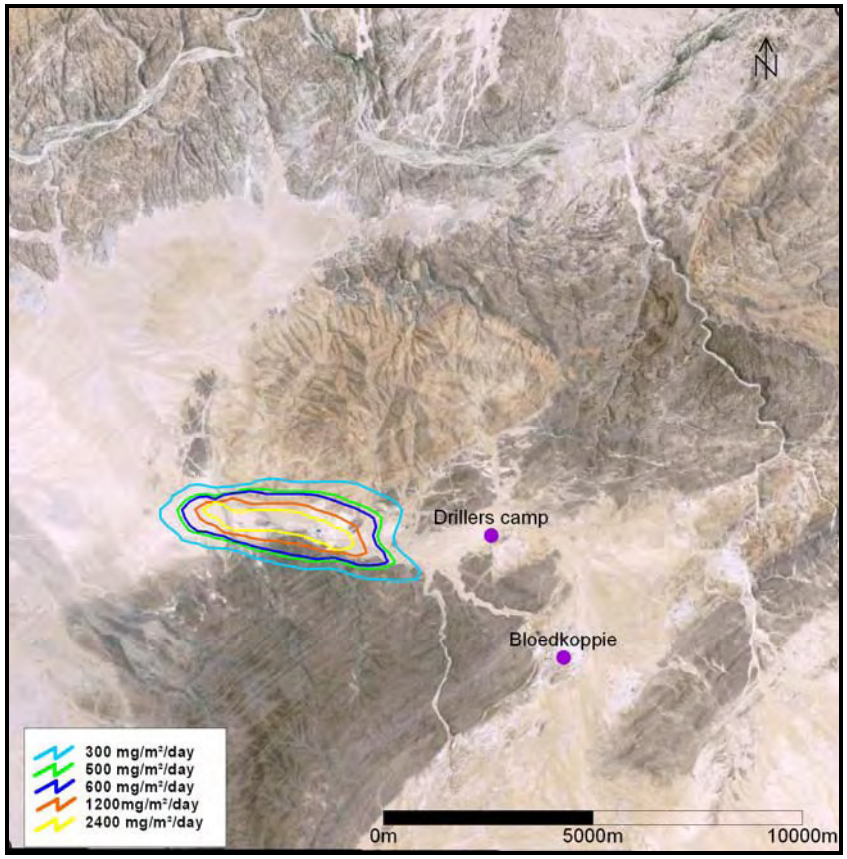


**Figure 7-17: Predicted average daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Future *Scenario 1- West Pit*)**

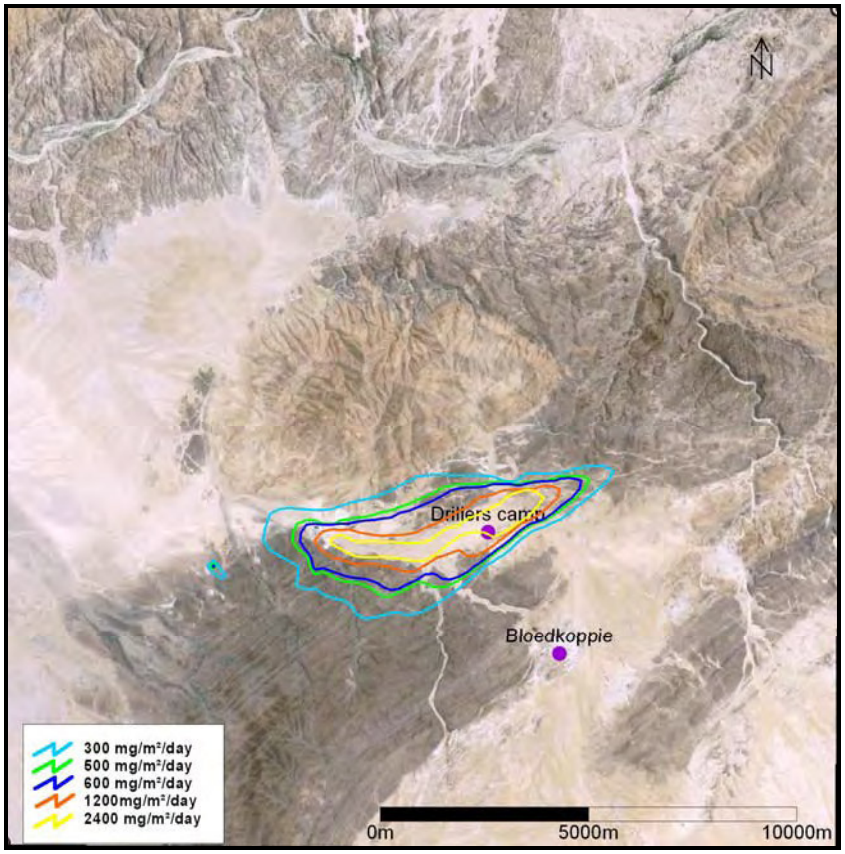


**Figure 7-18: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Future *Scenario 2- Centre Pit*)**

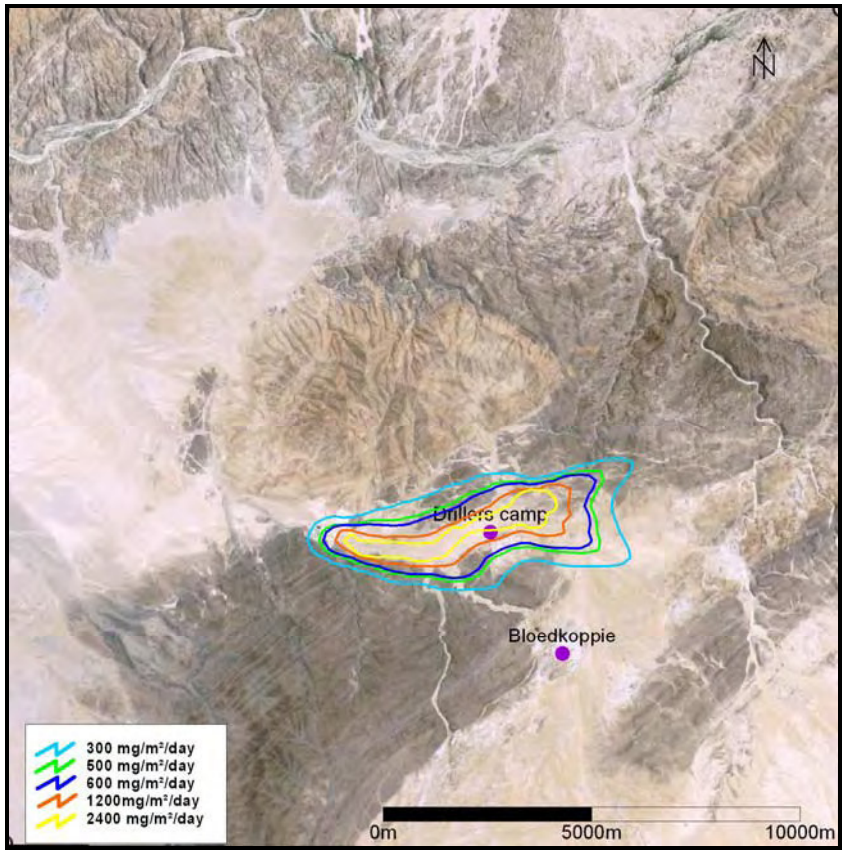


**Figure 7-19: Predicted average daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Future *Scenario 2- Centre Pit*)**

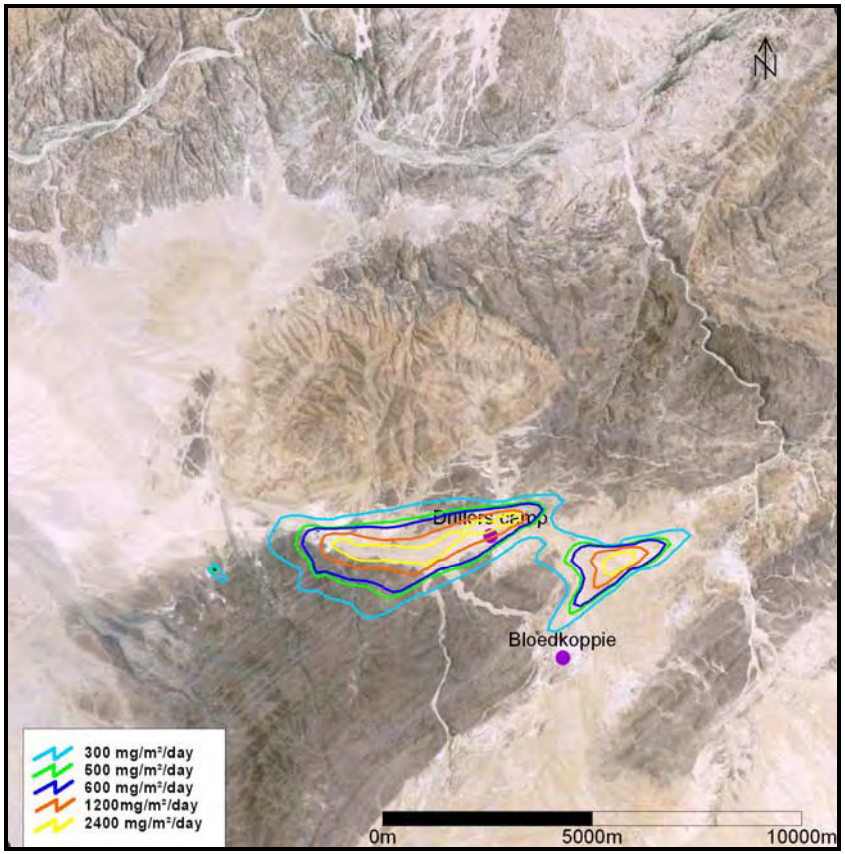


**Figure 7-20: Predicted maximum daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Future *Scenario 3- East Pit*)**

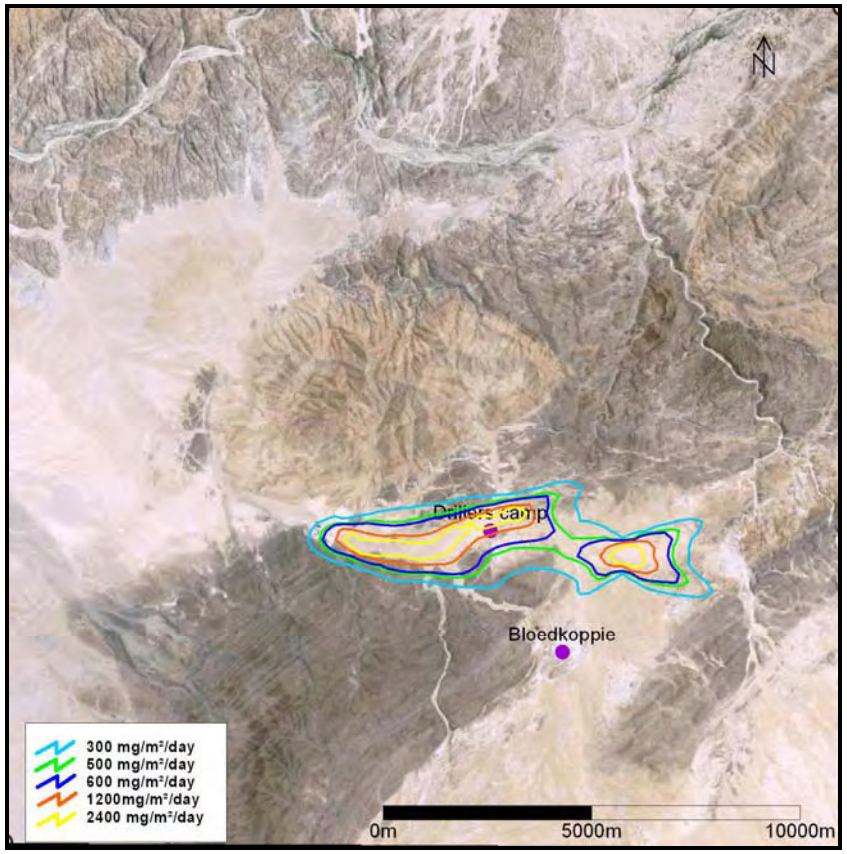


**Figure 7-21: Predicted average daily dust deposition rates (mg/m²/day) for all sources due to partially mitigated emissions for the proposed future Langer Heinrich mining operations (Future *Scenario 3- East Pit*)**

## 7.4 Significance Evaluation of Predicted Impacts

As with the baseline evaluation, the number of days the relevant standards were predicted to be exceeded was assessed. Reference was made to the EC frequency of exceedance for daily PM10 concentrations (35 days exceeding 50 µg/m³) and the proposed South African standard (4 days exceedance of 75 µg/m³).

The frequency of exceedance plots reflect the total number of days when the standards were exceeded over the1 year modelling period.

***Future Scenario 1: West Pit operations*** - For the proposed West Pit operations, off-site predictions at the Drillers Camp indicated frequencies of exceedances of more than 35 days (EC standard) and 4 days (SA standard) over the one year period (Figure 7-22).

***Future Scenario 2: Centre Pit operations***- Off-site predictions due to the proposed Centre Pit operations indicated frequencies of exceedances of more than 35 days and 4 days at the Drillers Camp over 1 year (Figure 7-23).

***Future Scenario 3: East Pit operations*** - For the proposed East Pit operations, off-site predictions at the Drillers Camp also indicated frequencies of exceedances of more than 35 days (EC standard) and 4 days (SA standard) over the 1 year period (Figure 7-24).

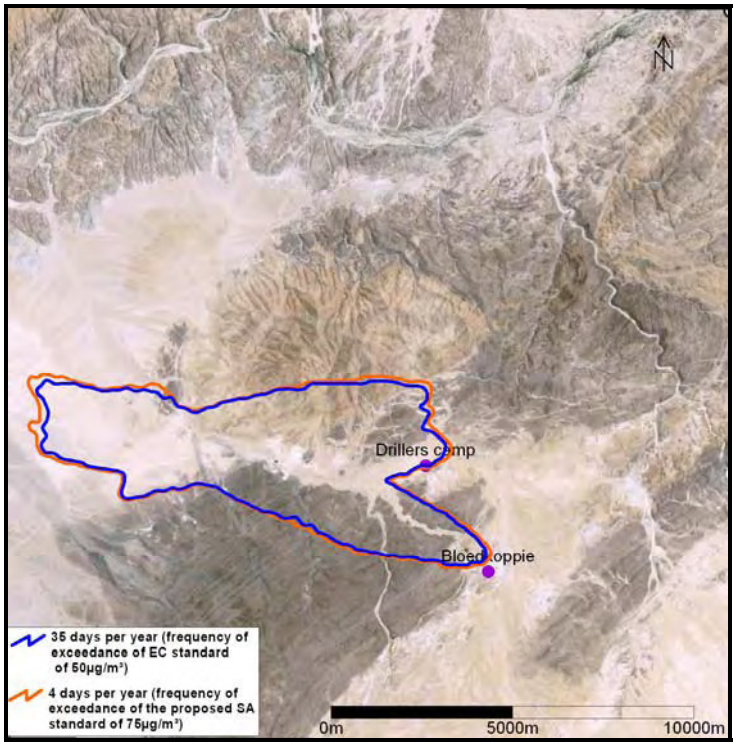


**Figure 7-22: Frequencies of exceedance over the one year period for predicted PM10 concentrations when compared to the EC and SA standards (West Pit mining operations).**

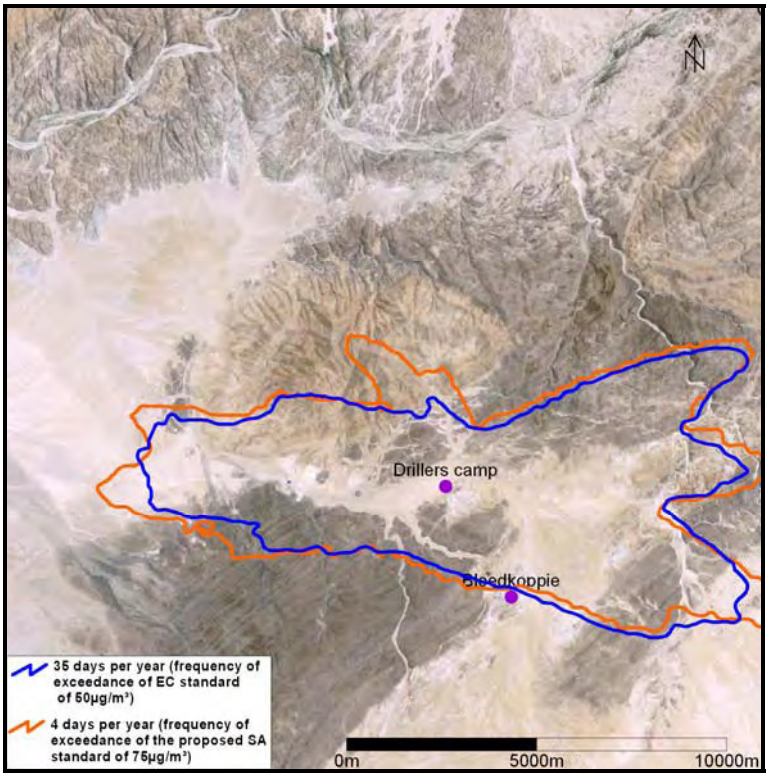


**Figure 7-23: Frequencies of exceedance over the three year period for predicted PM10 concentrations when compared to the EC and SA standards (Centre Pit mining operations).**

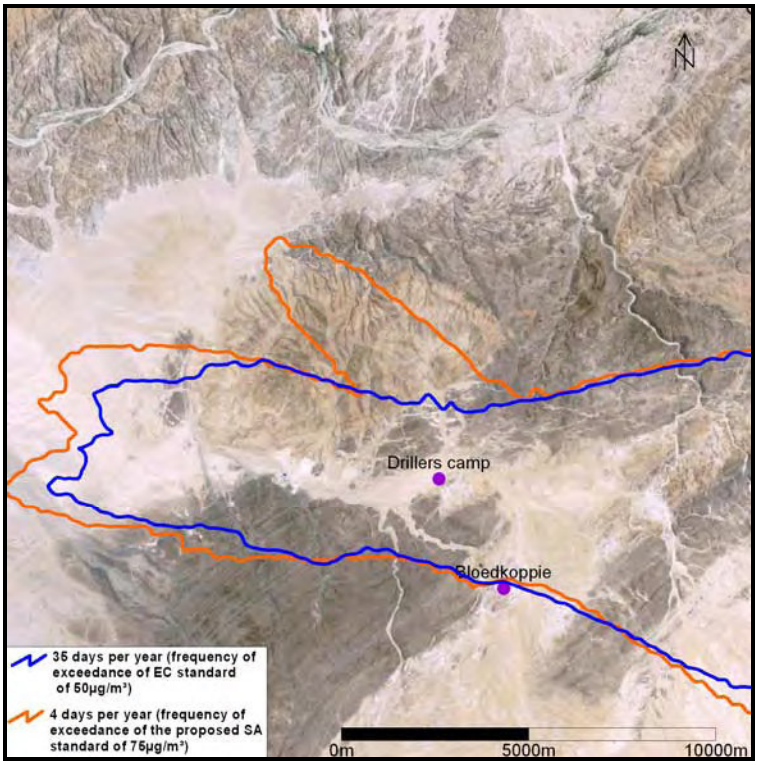


**Figure 7-24: Frequencies of exceedance over the three year period for predicted PM10 concentrations when compared to the EC and SA standards (East Pit mining operations).**

## 7.5 Impacts of Particulates on Plants and Animals

Not much reference data exists on the impacts of particulates on plants and animals and therefore the impacts of the current and proposed operations at Langer Heinrich Uranium Mine on vegetation and animals could not be determined. However, most of the studies done on the effects of particulate matter on animals, particularly cattle, have concurred that the main impacts of dusty environments are causing animal stress which is detrimental to their health. However, no threshold levels exist to indicate at what levels these are having a negative effect.

The Canadian Environmental Protection Act (CEPA) has published a document on the effects of particulates on vegetation. The conclusion was however that the information about the effects of particulates on vegetation is quite limited and robust quantitative, and that dose-response information is lacking (CEPA, 1998). Research found that the primary mechanisms by which, particles affect vegetation are by physical smothering of the leaf surface. The main impacts are on the physical blocking of stomata through particle lodging or penetration of stomata apertures. The chemical composition of the dust particles can also affect the plant and have indirect effects on the soil pH and ionic composition.

## 7.1 Significance rating of Proposed Operations Impacts

An impact assessment summary for the proposed operational phases is depicted in Table 7-18.

**Table 7-18: Impact Assessment Summary Table for the Proposed Operational Phases**

| *Scenario* | Impact | Severity/ Nature of Impact | Spatial Scale of Impacts | Duration of Impact | Probability of Impact |
|---|---|---|---|---|---|
| ***Future Scenario 1: West Pit operations*** | Respirable dust (PM10) | M | M | M | M |
| | Dust fallout (nuisance) | M | M | M | M |
| ***Scenario 2: Centre Pit operations*** | Respirable dust (PM10) | M | M | M | M |
| | Dust fallout (nuisance) | M | M | M | M |
| ***Scenario 3: East Pit operations*** | Respirable dust (PM10) | M | M | M | M |
| | Dust fallout (nuisance) | M | M | M | M |

# 8 IMPACT ASSESSMENT: CLOSURE PHASE

It is assumed that all mining activities and processing operations will have ceased by the closure phase of the mining project. The potential for impacts during this phase will depend on the extent of demolition and rehabilitation efforts during closure and on features which will remain, such as the tailings impoundment.

Aspects and activities associated with the closure phase of the mining operations at Langer Heinrich Uranium Mine are listed in Table 8-1.

**Table 8-1: Activities and aspects identified for the closure phase of mining operations.**

| Impact | Source | Activity |
|---|---|---|
| Generation of TSP and PM10 | Tailings facility | Reshaping and rehabilitation of tailings dams to reflect the natural surroundings |
| | Topsoil stockpiles | Topsoil recovered from stockpiles for rehabilitation and re-vegetation of surroundings |
| | Plant site/s | Infrastructure removal at processing plant site |
| | Unpaved roads | Vehicle entrainment on unpaved road surfaces |
| Gas emissions (1) | Blasting | Demolition of infrastructure may necessitate the use of blasting. |
| | Vehicles | Tailpipe emissions from vehicles utilised during the closure phase. |

**Notes:**
(1) Gaseous emissions from tailpipes typically include: sulphur dioxide, oxides of nitrogen, carbon monoxide, hydrocarbons, lead (petrol powered vehicles only), potentially carbon dioxide.

The impact assessment for the closure phase is depicted in Table 8-2.

**Table 8-2: Impact Assessment Summary Table for the Closure Phase.**

| Source | Impact | Severity/ Nature of Impact | Spatial Scale of Impacts | Duration of Impact(a) | Probability of Impact |
|---|---|---|---|---|---|
| **Demolition of Structure** | Respirable dust (PM10) | M | M | L | M |
| | Dust fallout (nuisance) | M | M | L | M |
| **Vehicle activity on unpaved roads** | Respirable dust (PM10) | M | M | L | M |
| | Dust fallout (nuisance) | M | M | L | M |
| **Materials Handling** | Respirable dust (PM10) | M | M | L | M |
| | Dust fallout (nuisance) | M | M | L | M |

(a) For closure period only

# 9 AIR QUALITY MANAGEMENT PLAN FOR LANGER HEINRICH URANIUM MINE

The main aim of this investigation was to determine the impacts associated with the current and proposed operations at the Langer Heinrich Uranium Mine. All sources of pollutants have been identified and emission rates quantified. Dispersion simulations were undertaken to reflect the impacts from all operations. The comparison of predicted pollutant concentrations to ambient air quality guidelines and standards facilitated a preliminary screening of the potential, which exists for human health and environmental impacts.

Radiation impacts were not included in this study but addressed in a separate specialist report compiled by NECSA. The simulated PM10 and dust fallout results were however used by the radiation specialists, together with specific radon exhalation simulations, to determine the radiation impacts from the various phases of the Langer Heinrich Uranium Project.

## 9.1 Main Impact Assessment Findings

The comparison of predicted pollutant concentrations to ambient air quality guidelines and standards facilitated a preliminary screening of the potential, which exists for human health impacts. The sensitive receptors identified to be included in the assessment are Bloedkoppie and the Drillers Camp. It was assumed that people reside at the Drillers Camp and at Bloedkoppie for a minimum of 24-hours, with the frequency of exceedances evaluated as if people are there every day. In reality this is not the case with people staying at the Drillers Camp for four days in a week and likely to only be there at night. Bloedkoppie only comprises a camp site where visitors are unlikely to stay for periods exceeding 24-hours.

When interpreting the modelling results it is therefore important to take cognisance of the temporary occupancy of the sensitive receptor sites, the assumptions and limitations (Section 1.3) and the inherent range of uncertainty of the dispersion model (between -50% to 200%). The predicted results are a function of the meteorological data and the source strengths (emissions data). For the purpose of this project, on-site meteorological data and maximum emissions rates (based on the maximum production rate of 10 Mtpa) were used thus providing a conservative approach (worst-case scenario) in predicted results.

### *9.1.1 Baseline Assessment*

Over the three- year period (from 2006 to 2008), the predominant winds recorded were from the west-northwest, west and west-southwest. The strongest winds were from the east-northeast and northeast. The easterly winds started to prevail during the autumn months and dominated during the winter months. Summer and spring months mainly reflected westerly flow.

The dust fallout measured at Langer Heinrich Uranium mine for the period April to May 2009 indicated high dust deposition levels in excess of both the German maximum allowable deposition level for industrial operations of 650 mg/m²/day and the SANS industrial action level of 1,200 mg/m²/day. At bucket numbers 5, 6 and 7 the SANS action limit was exceeded for both months. No validated ambient PM10 or PM2.5 data were available at the time of the study.

All current operations at the mine were identified and emission rates quantified. The predicted daily PM10 concentrations indicated exceedances of the EC standard and WHO air quality guideline at the Drillers Camp. PM10 concentrations at Bloedkoppie were however within the required standards and guidelines. The number of days when the PM10 concentrations exceeded the EC standard of 50 µg/m³ at the Drillers Camp was 16 days over the one year period. No exceedances of the screening criteria were predicted at the sensitive receptor sites over an annual average. The significance of these impacts can be regarded as Moderate to Low.

Maximum daily dust fallout levels were predicted to be well below the SANS residential dust fallout limit of 600 mg/m²/day and the German maximum permissible limit for general areas of 350 mg/m²/day at all the sensitive receptor sites. Similarly the predicted dust deposition can be regarded as Moderate to Low.

### *9.1.2 Impact Assessment: Construction Phase*

The predicted daily average PM10 ground level concentrations for the proposed construction activities in addition to the current operations exceeded the EC PM10 standard, the WHO daily air quality guideline and all the all the interim targets at the sensitive receptors. It also exceeded the proposed SA standard of 75 µg/m³. At the Contractors Camp the predicted impacts were very high, in excess of 650 µg/m³. Over an annual average the WHO guideline was exceeded at all the receptors with the EC standard and proposed SA standard exceeded at the Contractors camp. Similarly the predicted maximum daily dust fallout levels were higher at the Contractors Camp, exceeding the German limit but not the SANS residential limit. The Contractor's Camp had the highest predicted impacts during construction due to its location in close proximity to the main sources of emissions. The significance was regarded as Moderate mainly during to the limited duration of the construction operations (i.e. for 12 months).

### *9.1.3* Impact Assessment: Current and Proposed Operational Phases

*Future Scenario 1: Proposed West Pit Mining Operations*

During the proposed future operations the production at the mine will increase by 6.3 million tonnes per annum, thus resulting in expected higher predicted ground level concentrations. The proposed *West Pit,* located on the western side of the mine resulted in exceedances of the EC standard and WHO ambient guideline at the Drillers Camp. The concentrations were also predicted to exceed WHO IT-1 (at the Drillers Camp) and the proposed standard SA of 75 µg/m³. The number of days the EC standard was exceeded at the Drillers Camp totalled 86 over the one year period and 44 for the SA Standard. Predicted ground level concentrations over an annual average complied with all the relevant screening criteria at both sensitive receptor sites. The significance of the predicted concentrations was regarded as Moderate due to the fact that there are no permanent residents at Bloedkoppie and the Drillers Camp.

Predicted maximum daily dust fallout levels did not exceed both the German limits and the SANS limit for residential areas both at Bloedkoppie and the Drillers Camp.

*Future Scenario 2: Proposed Centre Pit Mining Operations*

Future Centre Pit will be located to the east of the current operations with all processing operations at the expanded plant located next to the existing plant. This will result in ROM material to be hauled over greater distances and running past the Drillers Camp. Thus, not surprisingly, the predicted PM10 daily concentrations were higher than for Scenario 1, exceeding all standards and guidelines at the Drillers Camp. Only the impacts at Bloedkoppie complied with all the screening criteria. The number of days when the EC standard was exceeded at the Drillers Camp was 334 over the one year period, with 299 days exceeding the SA Standard. The annual average ground level concentrations were also predicted to exceed the EC standard, the WHO guideline and the SA Standard at the Drillers Camp. The impacts also exceeded all the WHO interim targets at the Drillers Camp. A moderate significance rating was based on the non-permanent residency of either the Drillers Camp or the Bloedkoppie Camp site.

Predicted maximum daily dust fallout levels were higher at the Drillers Camp, exceeding both the German and SANS limits for residential areas. It also exceeded the SANS limit for industrial areas at the Drillers Camp.

*Future Scenario 3: Proposed East Pit Mining Operations*

Proposed East Pit was the furthest eastward simulated pit also involving the use of a lengthy haul road. Similar impacts as predicted for *Future Scenario 2* were predicted with higher impacts at both sensitive receptor areas. This resulted in non-compliance with all the screening criteria at both sensitive receptor sites. The frequency of exceedance increased to 355 and 343 days over the 1 year period at the Drillers Camp for the EC limit and SA Standard, respectively. Annual average predicted PM10 concentrations were also higher than for *Future Scenario 2* resulting in exceedances of all the selected standards and guidelines at the Drillers Camp. Although the more stringent WHO air quality guideline was exceeded at Bloedkoppie, the EC standard and proposed SA standard were not exceeded. This scenario, even though resulting in higher impacts than the other scenarios also resulted in a Moderate significance rating.

Maximum dust fallout levels were also slightly higher than in Scenario 2, exceeding the residential criteria at the Drillers Camp and the SANS industrial limit.

## 9.2 Conclusions

The main conclusion is that the proposed expansion operations will result in an increase in ground level PM10 concentrations and dust fallout levels at the various sensitive receptors. The significance of these impacts can be regarded as Moderate since these locations are not permanently inhabited. For instance, people reside at the Drillers Camp for 4 days in a week, whereas Bloedkoppie comprises of a camp site where people are likely to only overnight or stay for a few days at a time.

The modelling also followed a conservative approach to ensure that the worst-case scenarios are reflected in the assessment. Even though the pit operations will extend further eastward and westward, the magnitude of the impacts is unlikely to be higher. This will have to be monitored throughout the life of mine to ensure the impacts are acceptable (see Section 9.3.5 for specific monitoring recommendations).

Reference data on the impacts of particulates on plants and animals are scarce and therefore the impacts of the current and proposed operations at Langer Heinrich Uranium Mine on vegetation and animals could not be quantified. Given that it is a desert area, it is expected that the natural vegetation will have a tolerance for dust impacts. This however will have to be confirmed through monitoring certain species in the region.

## 9.3 Project-specific Management Measures

Air Quality Management measures will ensure that the future expansion operations at Langer Heinrich Uranium Mine will have the lowest possible impacts on the surrounding environment. This can be achieved through a combination of mitigation measures and ambient monitoring. Mitigation measures are usually implemented at the main sources of pollution with the monitoring network designed as such to track the effectiveness of the mitigation measures. To identify the most significant sources, these need to be ranked according to sources strengths (emissions) and impacts. Once the main sources have been identified, target control efficiencies for each source can be defined to ensure acceptable cumulative ground level concentrations.

### *9.3.1 Source Ranking by Emissions*

The main pollutant of concern at the current and proposed mining operations is particulates (PM10/PM2.5 and TSP). The main sources of *emissions* were similar for the current and proposed scenarios and can be identified as follows:

- Windblown dust from the various waste dumps, stockpiles and tailings dam; and,
- Vehicle entrainment on the unpaved haul roads*;*

Wind dependant sources, (such as wind erosion from stockpiles) will mainly result in fugitive emissions during periods of strong winds, whereas wind independent sources (such as unpaved roads) will result in constant emissions throughout the year. Thus, even though wind erosion are the main source of emissions it did not result in the main source of impacts.

### *9.3.2 Source Ranking by Impacts*

#### *9.3.2.1 Current operations*

For the current operations the main impacting sources resulting in impacts at the sensitive receptor areas as shown in Table 9-1 (PM10 daily) and Table 9-2 (maximum daily dust fallout) were in order of importance:

- Vehicle entrainment from the unpaved roads; and,
- Blasting.

**Table 9-1: A synopsis of the off-site impacts (PM10 daily) of the various sources at sensitive receptor sites for the *Current Scenario***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) | Contractors Camp (Source Impact %) |
|---|---|---|---|
| **Crushing** | 0.09 | 0.13 | 0.1 |
| **Drilling** | 5.37 | 6.36 | 8.74 |
| **Unpaved Roads** | 58.67 | 58.50 | 58.81 |
| **Excavation** | 0.02 | 0.02 | 0.34 |
| **Blasting** | 35.83 | 34.97 | 31.93 |
| **Materials Handling** | 0.02 | 0.03 | 0.08 |
| **Wind Erosion** | 0 | 0 | 0 |
| **Total** | **100.0** | **100.0** | **100** |

**Table 9-2: A synopsis of the off-site impacts (maximum daily TSP) of the various sources at sensitive receptor sites for the C*urrent Scenario***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) | Contractors Camp (Source Impact %) |
|---|---|---|---|
| **Crushing** | 0.03 | 0.02 | 0.07 |
| **Drilling** | 0.39 | 0.74 | 0.23 |
| **Unpaved Roads** | 91.71 | 92.72 | 87.20 |
| **Excavation** | 0.00 | 0.02 | 0.05 |
| **Blasting** | 7.86 | 6.49 | 12.46 |
| **Materials Handling** | 0.01 | 0.01 | 0.00 |
| **Wind Erosion** | 0.00 | 0.01 | 0.00 |
| **Total** | **100.0** | **100.0** | **100.0** |

#### *9.3.2.2 Construction Phase*

Emissions from the construction operations were quantified as a single emission factor accounting for all associated activities during construction, thus the main impacting sources cannot be singled out. However based on the types of activities during construction it is likely that the vehicle activity on the unpaved roads and land clearing activities will be the main dust generation sources.

#### *9.3.2.3 Proposed operations: West Pit*

For the proposed scenario with increased production, the main contributing sources resulting in impacts at the sensitive receptor areas were in order of importance (as shown in Table 9-3 and Table 9-4):

- Vehicle entrainment from the unpaved roads; and,
- Blasting.

**Table 9-3: A synopsis of the off-site impacts (PM10 daily) of the various sources at sensitive receptor sites for *Future Scenario 1: West Pit***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) |
|---|---|---|
| **Crushing** | 0.08 | 0.17 |
| **Drilling** | 0.83 | 0.83 |
| **Unpaved Roads** | 88.72 | 88.10 |
| **Excavation** | 0.00 | 0.05 |
| **Blasting** | 10.32 | 10.80 |
| **Materials Handling** | 0.05 | 0.05 |
| **Wind Erosion** | 0.00 | 0.00 |
| **Total** | **100.0** | **100.0** |

**Table 9-4: A synopsis of the off-site impacts (maximum daily TSP) of the various sources at sensitive receptor sites for *Future Scenario 1: West Pit***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) |
|---|---|---|
| **Crushing** | 0.01 | 0.01 |
| **Drilling** | 0.54 | 0.54 |
| **Unpaved Roads** | 91.21 | 92.62 |
| **Excavation** | 0.00 | 0.00 |
| **Blasting** | 8.23 | 6.81 |
| **Materials Handling** | 0.01 | 0.01 |
| **Wind Erosion** | 0.00 | 0.00 |
| **Total** | **100.0** | **100.0** |

#### *9.3.2.4 Proposed operations: Centre Pit and East Pit*

Future Centre Pit and East Pit scenarios resulted in similar sources of impact significance (Tables 9-5 to 9-8), namely:

- Vehicle entrainment from the unpaved roads; and,
- Blasting.

**Table 9-5: A synopsis of the off-site impacts (PM10 daily) of the various sources at sensitive receptor sites for *Future Scenario 2: Centre Pit***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) |
|---|---|---|
| **Crushing** | 0.26 | 0.04 |
| **Drilling** | 0.64 | 3.21 |
| **Unpaved Roads** | 91.37 | 91.90 |
| **Excavation** | 0.00 | 0.00 |
| **Blasting** | 7.72 | 4.82 |
| **Materials Handling** | 0.01 | 0.03 |
| **Wind Erosion** | 0.00 | 0.00 |
| **Total** | **100.0** | **100.0** |

**Table 9-6: A synopsis of the off-site impacts (maximum daily TSP) of the various sources at sensitive receptor sites for *Future Scenario 2: Centre Pit***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) |
|---|---|---|
| **Crushing** | 0.01 | 0.00 |
| **Drilling** | 1.47 | 0.27 |
| **Unpaved Roads** | 66.06 | 94.01 |
| **Excavation** | 0.03 | 0.00 |
| **Blasting** | 32.29 | 5.70 |
| **Materials Handling** | 0.15 | 0.03 |
| **Wind Erosion** | 0.00 | 0.00 |
| **Total** | **100.0** | **100.0** |

**Table 9-7: A synopsis of the off-site impacts (PM10 daily) of the various sources at sensitive receptor sites for *Future Scenario 3: East Pit***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) |
|---|---|---|
| **Crushing** | 0.04 | 0.03 |
| **Drilling** | 1.03 | 0.75 |
| **Unpaved Roads** | 72.11 | 85.65 |
| **Excavation** | 0.01 | 0.00 |
| **Blasting** | 26.78 | 13.46 |
| **Materials Handling** | 0.02 | 0.11 |
| **Wind Erosion** | 0.00 | 0.00 |
| **Total** | **100.0** | **100.0** |

**Table 9-8: A synopsis of the off-site impacts (maximum daily TSP) of the various sources at sensitive receptor sites for *Future Scenario 3: East Pit***

| Source | Bloedkoppie (Source Impact %) | Drillers Camp (Source Impact %) |
|---|---|---|
| **Crushing** | 0.00 | 0.00 |
| **Drilling** | 0.13 | 2.92 |
| **Unpaved Roads** | 97.31 | 96.49 |
| **Excavation** | 0.00 | 0.01 |
| **Blasting** | 2.56 | 0.58 |
| **Materials Handling** | 0.00 | 0.01 |
| **Wind Erosion** | 0.00 | 0.00 |
| **Total** | **100.0** | **100.0** |

### *9.3.3 Target controls for the Main Sources*

Even though the main source of emissions is windblown dust, the main sources of impacts are unpaved haul roads and materials handling operations. This is true for current and future operations. The main pollutant if concern is particulates, specifically PM10 and TSP. The proposed target controls on the various sources are provided below.

#### *9.3.3.1 Construction Phase*

- Construction of the tailings dam wall, mine workshop and heap leach pad, crusher area – 50% control efficiency through effective water sprays.
- Vehicle entrainment on temporary unpaved roads – 75% control efficiency through effective water sprays on haul roads.

#### *9.3.3.2 Operational Phase (current and future operations)*

- Vehicle entrainment on unpaved haul roads – 90% control efficiency through the application of chemical surfactants or paving.
- Vehicle entrainment on in-pit haul roads – these roads change depending on the area to be mined and hence it is not practical to apply chemicals. It is recommended that a minimum of 75% control efficiency is achieved through affective water sprays in combination with chemicals.
- Although emissions from blasting would be of significance during the current and future phases, the duration of blasting would only be for a couple of minutes per day. It is recommended that controlled blasting techniques be investigated since the visual reduction in dust emissions between a conventional blast and a controlled blast is significant.

#### *9.3.3.3 Closure Phase*

The potential for impacts during the closure phase are dependent on the extent of demolition and rehabilitation efforts during closure and on features which remain (viz. the tailings dams). It was assumed that the potential for fugitive dust impacts due to these sources could be rendered negligible (and proven to be so) through comprehensive rehabilitation prior to closure. It is expected that the natural crusting of stockpiled material will occur once these sources are not disturbed.

### *9.3.4 Identification of Suitable Mitigation Measures*

#### *9.3.4.1 Vehicle Entrainment on Unpaved Haul Roads*

Three types of measures may be taken to reduce emissions from unpaved roads: (a) measures aimed at reducing the extent of unpaved roads, e.g. paving, (b) traffic control measures aimed at reducing the entrainment of material by restricting traffic volumes and reducing vehicle speeds, and (c) measures aimed at binding the surface material or enhancing moisture retention, such as wet suppression and chemical stabilization (EPA, 1987; Cowhert *et al.*, 1988; APCD, 1995).

The main dust generating factors on unpaved road surfaces include:

- Vehicle speeds
- Number of wheels per vehicle
- Traffic volumes
- Particle size distribution of the aggregate
- Compaction of the surface material
- Surface moisture
- Climate

When quantifying emissions from unpaved road surfaces, most of these factors are accounted for. Vehicle speed is one of the significant factors influencing the amount of fugitive dust generated from unpaved roads surfaces. According to research conducted by the Desert Research Institute at the University of Nevada, an increase in vehicle speed of 10 miles per hour resulted in an increase in PM10 emissions of between 1.5 and 3 times. A similar study conducted by Flocchini et.al. (1994) found a decrease in PM10 emissions of 42±35% with a speed reduction from 40 km/hr to 24 km/hr (Stevenson, 2004). The control efficiency obtained by speed reduction can be calculated by varying the vehicle speed input parameter in the predictive emission factor equation given for unpaved roads. An evaluation of control efficiencies resulting from reductions in traffic volumes can be calculated due to the linear relationship between traffic volume, given in terms of vehicle kilometres travelled, and fugitive dust emitted. Similar affects will be achieved by reducing the truck volumes on the roads. Thus, by increasing the payload of the truck, fewer trips will be required to transport the same amount of material.

Water sprays on unpaved roads is the most common means of suppressing fugitive dust due to vehicle entrainment at mines, but it is not necessarily the most efficient means (Thompson and Visser, 2000). Thompson and Visser (2000) developed a model to determine the cost and management implications of dust suppression on mine haul roads using water or other chemical palliatives. The study was undertaken at 10 mine sites in Southern Africa. The model was first developed looking at the re-application frequency of water required for maintaining a specific degree of dust palliation. From this the cost effectiveness of water spray suppression could be determined and compared to other strategies. Factors accounted for in the model included climate, traffic, vehicle

speed and the road aggregate material. A number of chemical palliative products, including hygroscopic salts, lignosulponates, petroleum resins, polymer emulsions and tar and bitumen products were assessed to benchmark their performance and identify appropriate management strategies. Cost elements taken into consideration included amongst others capital equipment, operation and maintenance costs, material costs and activity related costs. The main findings were that water-based spraying is the cheapest dust suppression option over the short term. Over the longer term however, the polymer-emulsion option is marginally cheaper with added benefits such as improved road surfaces during wet weather, reduced erosion and dry skid resistance (Thompson and Visser, 2000).

An empirical model, developed by the US-EPA (EPA, 1996), was used to estimate the average control efficiency of certain quantifies of water applied to a road. The model takes into account rainfall, evaporation rates and traffic. Water and chemical sprays resulting in at least 90% control efficiency would be a requirement to result in a significant reduction in ground level concentrations and dustfall levels. Should only water be applied, the amounts needed to ensure 90% control efficiency on the main and in-pit haul roads (assuming 50 trucks/hour) are 1.37 l/m²/hour excluding mitigation due to rainfall. Watering rates for a variety of control efficiencies are presented in Figure 9-1.

Chemical suppressant has been proven to be affective due to the binding of fine particulates in the road surface, hence increasing the density of the surface material. In addition, dust control additives are beneficial in the fact that it also improves the compaction and stability of the road. The effectiveness of a dust palliative include numerous factors such as the application rate, method of application, moisture content of the surface material during application, palliative concentrations, mineralogy of aggregate and environmental conditions. Thus, for different climates and conditions you need different chemicals, one chemical might not be as effective as another under the same conditions and each product comes with various advantages and limitations of each own. In general, chemical suppressants are given to achieve a PM10 control efficiency of 80% when applied regularly on the road surfaces (Stevenson, 2004).

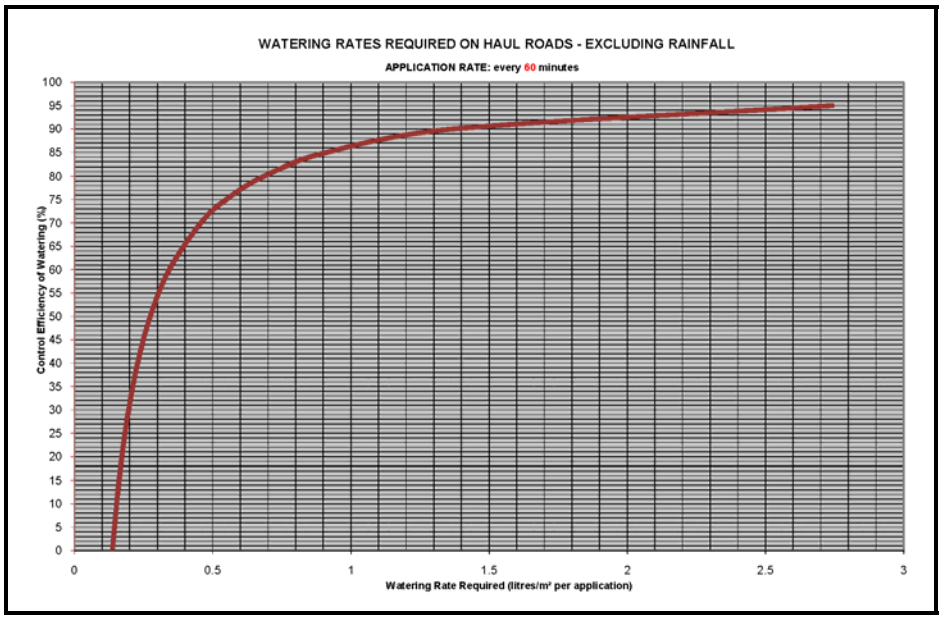


**Figure 9-1: Monthly watering rates excluding rainfall**

There is however no cure-all solution but rather a combination of solutions. A cost-effective chemical control programme may be developed through establishing the minimum control efficiency required on a particular roadway, and evaluating the costs and benefits arising from various chemical stabilization practices. Appropriate chemicals and the most effective relationships between application intensities, reapplication frequencies, and dilution ratios may be taken into account in the evaluation of such practices.

Spillage and track-on from the surrounding unpaved areas may result in the deposition of materials onto the chemically treated or watered road resulting in the need for periodic "housekeeping" activities (Cowherd et al., 1988; EPA, 1996). In addition, the gradual abrasion of the chemically treated surface by traffic will result in loose material on the surface which would have to be controlled. The minimum frequency for the reapplication of watering or chemical stabilizers thus depends not only on the control efficiency of the suppressant but also on the degree of spillage and track-on from adjacent areas, and the rate at which the treated surface is abraded. The best way to avoid dust generating problems from unpaved roads is to properly maintain the surface by grading and shaping for cross sectional crowing to prevent dust generation caused by excessive road surface wear (Stevenson, 2004).

One of the main benefits of chemical stabilisation in conjunction with wet suppression is the management of water resources (MFE, 2001). It is therefore recommended that water be used in combination with chemical surfactants to reduce the amount of water required to achieve control efficiencies in excess of 90% on the main haul roads at Langer Heinrich Uranium Mine.

#### *9.3.4.2 Materials Handling Operations*

Materials handling operations including primary crushing and screening of ore and materials transfer point were identified as significant sources of emissions during the proposed mining operations.

Enclosure of crushing operations is very effective in reducing dust. The Australian NPi indicates that a telescopic chute with water sprays would ensure 75% control efficiency and enclosure of storage piles where tipping occur would reduce the emissions by 99%. In addition, chemical suppressants or water sprays on the primary crusher and dry dust extraction units with wet scrubbers on the secondary and tertiary crushers and screens will assist in the reduction of the cumulative dust impacts. According to the Australian NPi, water sprays can have up to 50% control efficiency, and hoods with scrubbers up to 75%. If in addition, the scrubbers and screens were to be enclosed, up to 100% control efficiency can be achieved. With these control measures in place, the impacts would reduce to negligible levels. It is important that these control equipment be maintained and inspected on a regular basis to ensure that the expected control efficiencies are met.

The control efficiency of pure water suppression can be estimated based on the US-EPA emission factor which relates material moisture content to control efficiency. This relationship is illustrated in Figure 9-2. From the relationship between moisture content and dust control efficiency it is apparent that by doubling the moisture content of the material an emission reduction of 62% could be achieved. Thus chemicals mixed into the water will not just save on water consumption but also improve the control efficiency of the application even further.

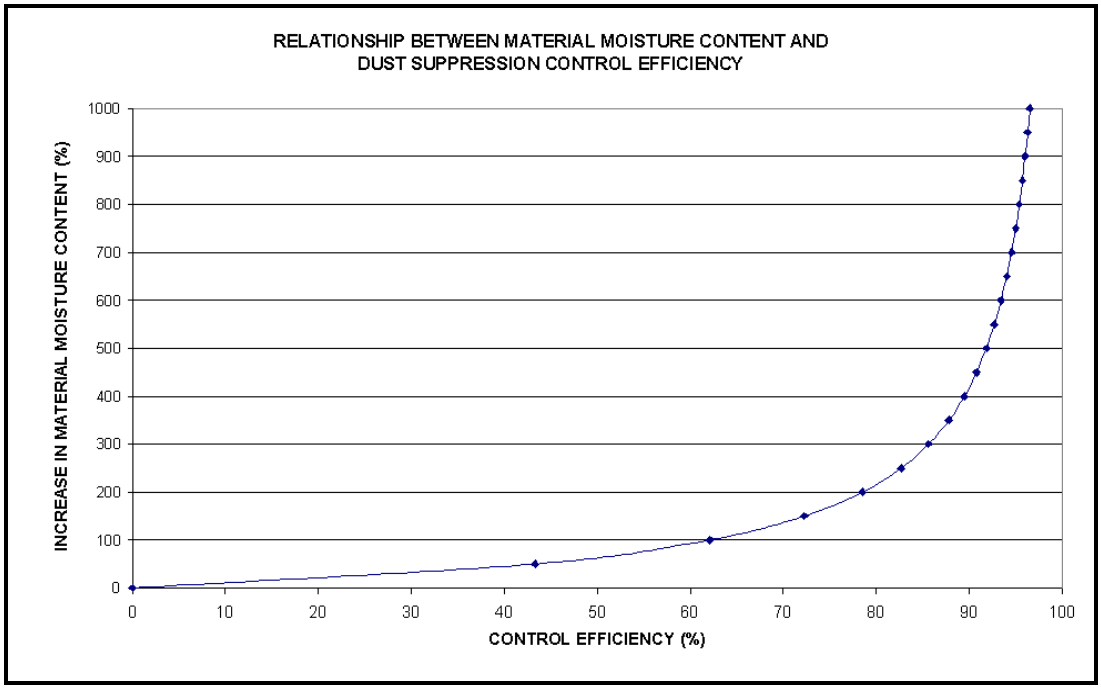


**Figure 9-2: Relationship between the moisture content of the material handled and the dust control efficiency (calculated based on the US-EPA predictive emission factor equation for continuous and batch drop operations).**

*9.3.4.3 Open Pit Operations: Drilling and Blasting*

All materials handling operations within the open pit will reduce dust generation by 62% by merely doubling the moisture content of the material handled. A 75% reduction in dust emissions from unpaved in-pit haul roads can be achieved through effective water sprays combined with chemicals. The Australian NPi in their Emission Estimation Technique Manual for Mining states that a 70% reduction in dust emissions from drilling can be achieved through effective water sprays.

In addition, the Australian NPi stipulates a 50% reduction of TSP emissions due to pit retention, and 5% for PM10 emissions. This is based on the increase in volume (the deeper the pit becomes) and thus resulting in better dispersion potential for specifically PM10 emissions before reaching the surface. Similarly for TSP, the potential for deposition on the surface becomes smaller for more dust would settle within the pit. This as the pit becomes bigger and deeper; the impacts from the in-pit operations should reduce.

### *9.3.5 Monitoring Requirements*

*Key performance indicators* against which progress may be assessed form the basis for all effective environmental management practices. Performance indicators are usually selected to reflect both the source of the emission directly and the impact on the receiving environment. Ensuring that no visible evidence of windblown dust exists represents an example of a source-based indicator, whereas maintaining off-site dustfall levels to below 250 mg/m$^2$/day represents an impact- or receptor-based performance indicator. Source-based performance indicators have been included in regulations abroad.

- Source based performance indicators for the unpaved roads would be no visible dust when trucks/vehicles drive on the roads. It is recommended that dust fallout in the immediate vicinity of the road perimeter be less than 1,200 mg/m$^2$/day and less than 600 mg/m$^2$/day at the sensitive receptors.
- The absence of visible dust plume at all tipping points and outside the primary crusher would be the best indicator of effective control equipment in place. In addition the dust fallout in the immediate vicinity of the tipping and crushing sources should be less than 1,200 mg/m$^2$/day.
- From all activities associated with Langer Heinrich Uranium Mine, dust fallout levels should not exceed 600 mg/m$^2$/day at the sensitive receptor areas.

#### *9.3.5.1 Current dust fallout monitoring network*

As discussed in Section 5, a dust fallout network exists for the current Langer Heinrich Uranium Mine (Figure 9-3). This network provides management with an indication of what the reduction in fugitive dust levels are once mitigation measures are implemented. In addition, a dust fallout network can serve to meet various objectives, such as:

- Compliance monitoring;
- Validate dispersion model results;
- Use as input for health risk assessment;
- Assist in source apportionment;
- Temporal trend analysis;
- Spatial trend analysis;
- Source quantification; and,
- Tracking progress made by control measures.

The current dust fallout network comprises of four directional dust buckets and six single buckets positioned at various areas close to the mining operations (Figure 9-3). The directional buckets are located on the outskirts of the mining operations to capture both dust generated by the mining activities and background dust. Single dust fallout buckets are located close to the dust generating sources to determine the contribution from these sources to dust fallout levels at the mine.

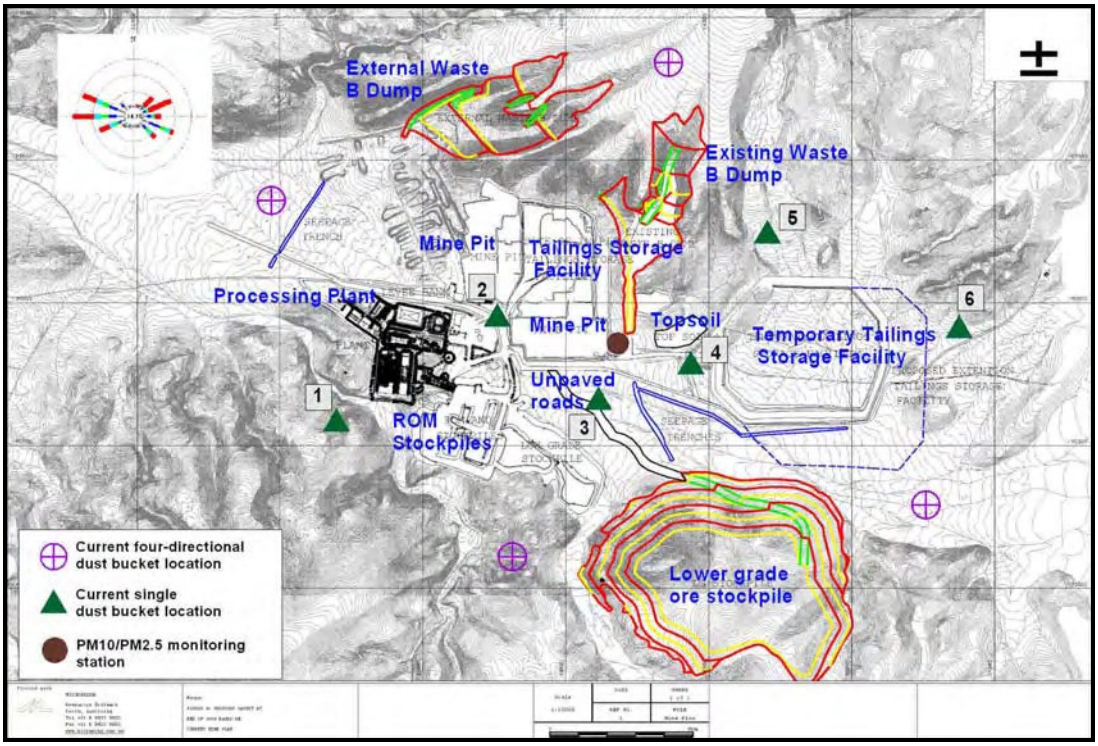


**Figure 9-3: Ambient monitoring and dust fallout network for the current operations at Langer Heinrich Uranium Mine.**

*9.3.5.2 Proposed future dust fallout monitoring network*

Open pit mining operations changes location as the open pit areas change. At Langer Heinrich Uranium the pit operations will stretch over an area of approximately 15 km (east-west) over the life of mine. It is therefore necessary to design a dust fallout monitoring network that will support both current and future operations.

It is recommended that the dust fallout monitoring network be expanded to include a total of 10 single dust fallout buckets and 6 directional buckets. The proposed bucket locations are indicated in Figure 9-5. Only 5 directional buckets are indicated with the sixth one to be located at Bloedkoppie.

The single dust buckets should be placed at various locations within the mining area. It is proposed that a single dust bucket be placed to near the proposed leach pad and future crushing operations, one should be placed to the southwest of the proposed East Pit and one to the north of these mining operations. One should be placed near the current processing plant (and proposed expanded processing plant) with another one north of the waste rock dumps located to the north east of the current Pit A west. A single bucket should be placed south of the current tailings dam next to the haul road. Two single buckets can be placed to the southwest of the eastern mining operations and to the east thereof with another one near the central mining operations. Another single bucket should be placed near the haul road between the central and eastern mining operations (Figure 9-4).

Four of the directional buckets should be placed on the outskirts of the mining operations, one on the west-northwestern side and one on the west-southwestern side. One should be placed on the east-northeastern side and another on the east-southeastern side. One directional bucket is proposed to be placed at the Drillers Camp with another one at Bloekoppie (not indicated on the map).

Dust fallout monitoring procedures and data evaluation guidelines are provided in Appendix C.

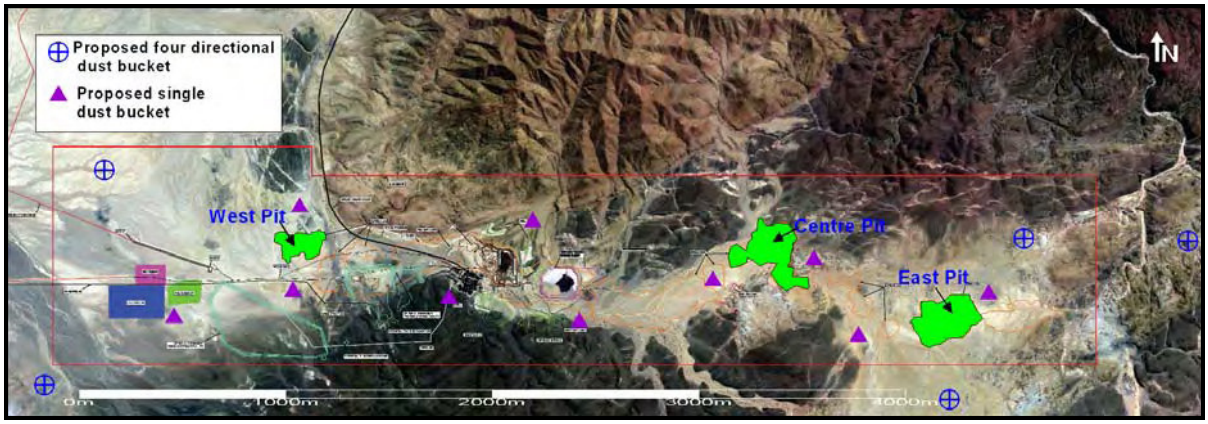


**Figure 9-4: Proposed dust fallout network for future mining operations at Langer Heinrich Uranium Mine.**

*9.3.5.3 Ambient monitoring*

Due to the potential for impacts of inhalable particulates due to the various mining and processing activities, a PM10/PM2.5 monitor was installed at the mine close to the processing plant (Figure 9-4). It is recommended that this station be moved to the Drillers Camp to ensure the mining and processing plant operations are in compliance with the relevant ambient air quality guidelines.

The E-Sampler as is currently in place at Langer Heinrich Uranium Mine provides real-time particulate measurement through near-forward light scattering. The advantages of this sampler include the fact that the filters can easily be extracted and replaced and the filter medium can be collected based on laboratory analysis.

It is recommended that one filter per month be send for radionuclide analysis. The E-Sampler should also be calibrated at least every 6 months and the data should be validated before reporting on it. Appendix C provides monitoring procedures for the E-Sampler at Langer Heinrich Uranium Mine.

*9.3.5.4 Meteorological monitoring*

The basic requirements for a weather station would be the recoding of hourly average wind speed and wind direction data, as well as temperature. The wind monitor must be a high performance wind sensor to cover a wind speed range of up to 60 m/s, including a gusts survival. A rain gauge would be optional, usually comprising of a tipping bucket for simple and effective rainfall measurements. In addition a solar radiation sensor could be added to measure global radiation for agricultural, meteorological and hydrological applications.

It is recommended that the operation of the meteorological station at Langer Heinrich Uranium Mine be continued. As with the E-Sampler, the meteorological station must be calibrated at least once a year with regular span checks and data validation carried out to ensure the data reported are correct.

## 9.4 Record-keeping, Environmental Reporting and Community Liaison

### *9.4.1 Periodic Inspections and Audits*

It is recommended that site inspections and progress reporting be undertaken at regular intervals (at least quarterly) during operations, with annual environmental audits being conducted. Annual environmental audits form part of the overall EMS at Langer Heinrich Uranium Mine. Results from site inspections and off-site monitoring efforts should be combined to determine progress against source- and receptor-based performance indicators. Progress should be reported to all interested and affected parties, including authorities and persons affected by pollution.

Corrective action or the implementation of contingency measures must be proposed to the stakeholder forum in the event that progress towards targets is indicated by the quarterly/annual reviews to be unsatisfactory.

### *9.4.2 Liaison Strategy for Communication with I&APs*

Stakeholder forums provide possibly the most effective mechanisms for information dissemination and consultation. Specific intervals at which forums will be held, and provide information on how people will be notified of such meetings.

### *9.4.3 Financial Provision (Budget)*

The budget should provide a clear indication of the capital and annual maintenance costs associated with dust control measures and dust monitoring plans. It may be necessary to make assumptions about the duration of aftercare prior to obtaining closure. This assumption must be made explicit so that the financial plan can be assessed within this framework. Costs related to inspections, audits, environmental reporting and I&AP liaison should also be indicated where applicable. Provision should also be made for capital and running costs associated with dust control contingency measures and for security measures.

The financial plan should be audited by an independent consultant, with reviews conducted on an annual basis.

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**http://wiki.biomine.skelleftea.se**

**http://ec.europa.eu/environment/air/quality/legislation/directive.htm**

**Appendix A:**
**Macro – Scale Atmospheric Dispersion Potential**

The macro-ventilation characteristics of the region are determined by the nature of the synoptic systems which dominate the circulation of the region, and the nature and frequency of occurrence of alternative systems and weather perturbations over the region.

**A.1 Regional Climate**

Situated in the subtropical high pressure belt, southern Africa is influenced by several high pressure cells, in addition to various circulation systems prevailing in the adjacent tropical and temperature latitudes. The mean circulation of the atmosphere over southern Africa is anticyclonic throughout the year (except near the surface) due to the dominance of three high pressure cells, viz. the South Atlantic HP off the west coast, the South Indian HP off the east coast, and the continental HP over the interior.

Five major synoptic scale circulation patterns dominate (Figure A-1) (Vowinckel, 1956; Schulze, 1965; Taljaard, 1972; Preston-Whyte and Tyson, 1988). The most important of these is the semi-permanent, subtropical continental anticyclones which are shown by both Vowinckel (1956) and Tyson (1986) to dominate 70 % of the time during winter and 20 % of the time in summer. This leads to the establishment of extremely stable atmospheric conditions which can persist at various levels in the atmosphere for long periods.

Seasonal variations in the position and intensity of the HP cells determine the extent to which the tropical easterlies and the circumpolar westerlies impact on the atmosphere over the subcontinent. The tropical easterlies, and the occurrence of easterly waves and lows, affect most of southern Africa throughout the year. In winter, the high pressure belt intensifies and moves northward, the upper level circumpolar westerlies expand and displace the upper tropical easterlies equatorward. The winter weather of South Africa is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones or anticyclones moving eastwards around the coast or across the country. During summer months, the anticyclonic belt weakens and shifts southwards, allowing the tropical easterly flow to resume its influence over South Africa. A weak heat low characterises the near surface summer circulation over the interior, replacing the strongly anticyclonic winter-time circulation (Schulze, 1986; Preston-Whyte and Tyson, 1988).

Anticyclones situated over the subcontinent are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions with little or no rainfall, and light variable winds occur as a result of such widespread anticyclonic subsidence. Anticyclones occur most frequently over the interior during winter months, with a maximum frequency of occurrence of 79 percent in June and July. During December such anticyclones only occur 11 percent of the time. Although widespread subsidence dominates the winter months, weather occurs as a result of uplift produced by localized systems.

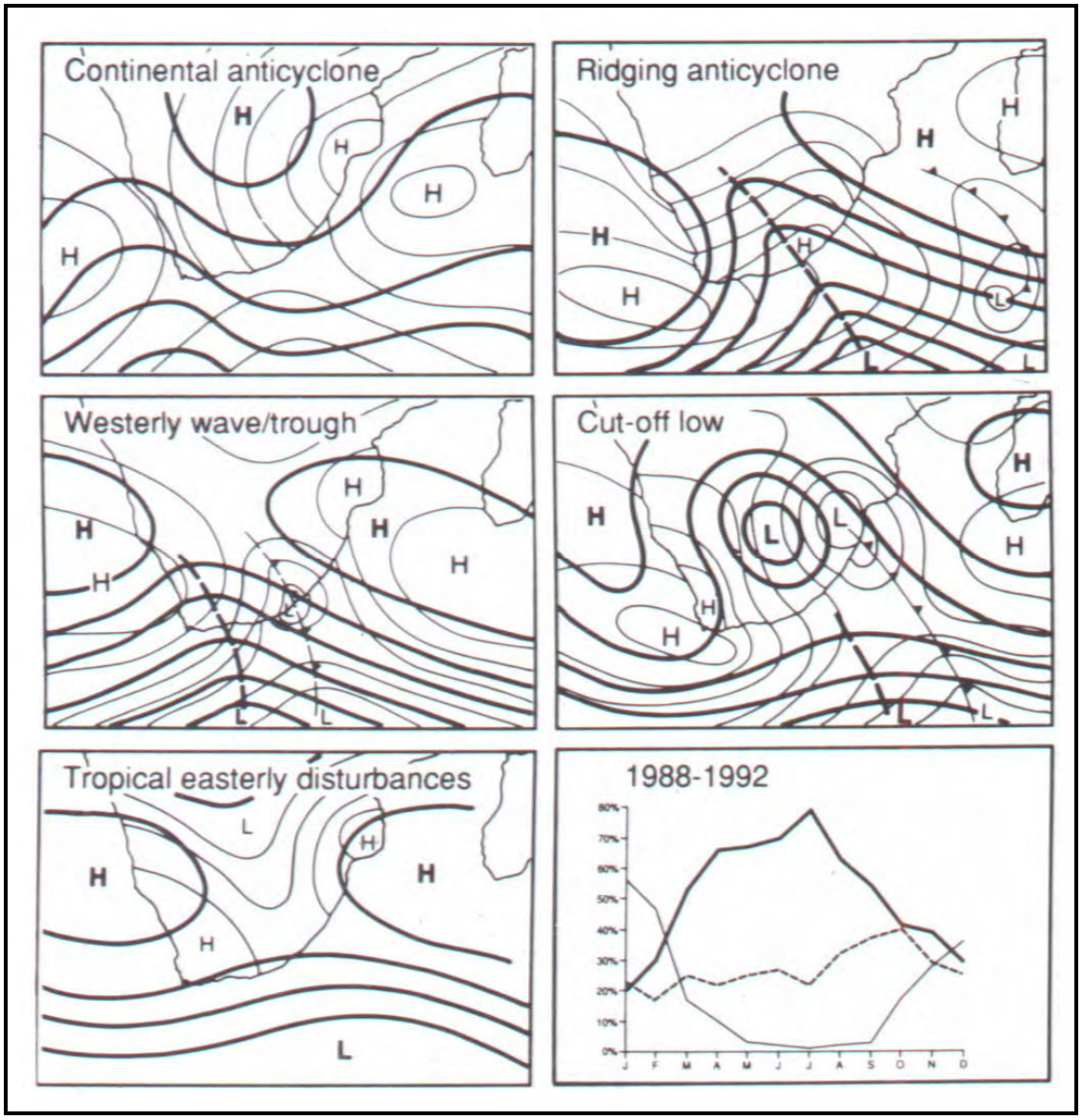


**Figure A-1. Major synoptic circulation types affecting southern Africa and their monthly frequencies of occurrence over a five year period (after Preston-Whyte and Tyson, 1988 and Garstang et al., 1996a).**

Tropical easterly waves give rise to surface convergence and upper air (500 hPa) divergence to the east of the wave resulting in strong uplift, instability and the potential for precipitation. To the west of the wave, surface divergence and upper-level convergence produces subsidence, and consequently fine clear conditions with no precipitation. Easterly lows are usually deeper systems than are easterly waves, with upper-level divergence to the east of the low occurring at higher levels resulting in strong uplift through the 500 hPa level and the occurrence of copious rains. Easterly waves and lows occur almost exclusively during summer months, and are largely responsible for the summer rainfall pattern and the northerly wind component which occurs over the interior.

Westerly waves are characterised by concomitant surface convergence and upper-level divergence which produce sustained uplift, cloud and the potential for precipitation to the rear of the trough. Cold fronts are associated with westerly waves and occur predominantly during winter when the amplitude

of such disturbances is greatest. Low-level convergence in the southerly airflow occurs to the rear of the front producing favourable conditions for convection. Airflow ahead of the front has a distinct northerly component, and stable and generally cloud-free conditions prevail as a result of subsidence and low-level divergence. The passage of a cold front is therefore characterised by distinctive cloud bands and pronounced variations in wind direction, wind speeds, temperature, humidity, and surface pressure. Following the passage of the cold front the northerly wind is replaced by winds with a distinct southerly component. Temperature decrease immediately after the passage of the front, with minimum temperatures being experienced on the first morning after the cloud associated with the front clears. Strong radiational cooling due to the absence of cloud cover, and the advection of cold southerly air combining to produce the lowest temperatures.

### A.2 Regional Atmospheric Dispersion Potential

The impact of various synoptic systems and weather disturbances on the dispersion potential of the atmosphere largely depends on the effect of such systems on the height and persistence of elevated inversions. Elevated inversions suppress the diffusion and vertical dispersion of pollutants by reducing the height to which such pollutants are able to mix, and consequently result in the concentration of pollutants below their bases. Such inversions therefore play an important role in controlling the long-range transport, and recirculation of pollution.

Subsidence inversions, which represent the predominant type of elevated inversion occurring over South Africa, result from the large-scale anticyclonic activity which dominates the synoptic circulation of the subcontinent. Subsiding air warms adiabatically to temperatures in excess of those in the mixed boundary layer. The interface between the subsiding air and the mixed boundary layer is thus characterised by a marked elevated inversion. Protracted periods of anticyclonic weather, such as characterize the plateau during winter, result in subsidence inversions which are persistent in time, and continuous over considerable distances. The fairly constant afternoon mixing depths, with little diurnal variation, associated with the persistence of subsidence inversions, are believed to greatly reduce the dispersion potential of the atmosphere over the plateau, resulting in the accumulation of pollutants over the region.

Multiple elevated inversions occur in the middle to upper troposphere as a result of large-scale anticyclonic subsidence. The mean annual height and depth of such absolutely stable layers are illustrated in Figure A-2. Three distinct elevated inversions, situated at altitudes of approximately 700 hPa (~3 km), 500 hPa (~5 km) and 300 hPa (~7 km), were identified over southern Africa. The height and persistence of such elevated inversions vary with latitudinal and longitudinal position. During winter months the first elevated inversion is located at an altitude of around 3 km over the plateau. In summer this inversion is known to increase in to 4 to 5 km over the plateau (Diab, 1975; Cosijn, 1996).

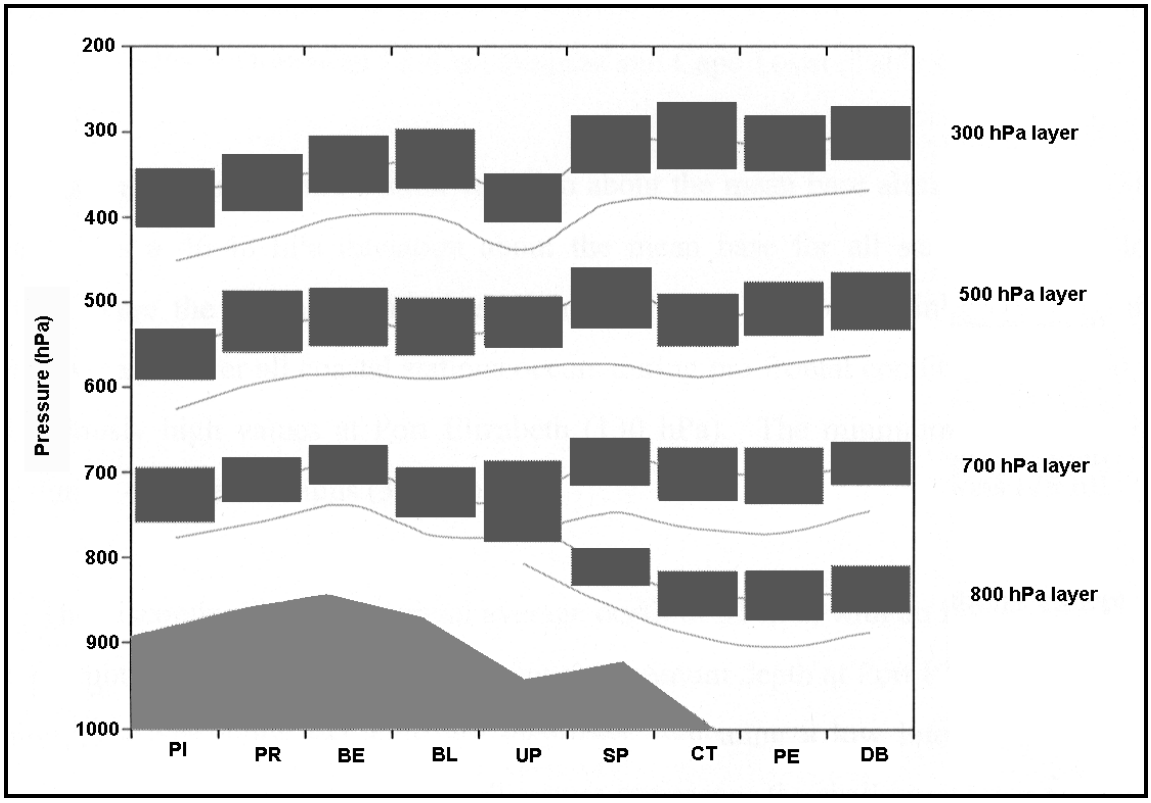


**Figure A-2: Mean annual stable layers (shaded) over Pietersburg (PI), Pretoria (PR), Bethlehem (BE), Bloemfontein (BL), Upington (UP), Springbok (SP), Cape Town (CT), Port Elizabeth (PE) and Durban DB). Upper and lower 95% confidence limits for the base heights of the layers are shown in each case (after Cosijn, 1996).**

In contrast to anticyclonic circulation, convective activity associated with westerly and easterly wave disturbances hinders the formation of inversions. Cyclonic disturbances, which are associated with strong winds and upward vertical air motion, either destroy, weaken, or increase the altitude of, elevated inversions. Although cyclonic disturbances are generally associated with the dissipation of inversions, pre-frontal conditions tend to lower the base of the elevated inversion, so reducing the mixing depth. Pre-frontal conditions are also characterised by relatively calm winds. Over the interior due to the passage of a cold front, there is a tendency for the lowest mixing depths to coincide with the coldest air temperatures and rising pressure. Following the passage of the front, a gradual rise in the mixing depth occurs over the interior (Cosijn, 1996; Preston-Whyte and Tyson, 1988).

**Appendix B:**
**Technical Description of Emissions Quantification**

## B.1: Fugitive Dust Emissions from Materials Handling Operations

The following predictive equation was used to estimate emissions from anticipated material tipping operations:

$$E_{TSP} = 0.0016 \frac{(U/2.2)^{1.3}}{(M/2)^{1.4}} \quad \textbf{(1)}$$

where,

| | | |
|---|---|---|
| $\mathbf{E}_{TSP}$ | = | Total Suspended Particulate emission factor (kg dust / t transferred) |
| U | = | mean wind speed (m/s) |
| M | = | material moisture content (%) |
| k | = | particle size multiplier (dimensionless) |

The particle size multiplier varies with aerodynamic particle sizes and is given as a fraction of TSP. For PM30 the fraction is 74%, with 35% of TSP given to be equal to PM10, and the PM2.5 fraction is 11% of TSP (EPA, 1998a). Hourly emission factors, varying according to the prevailing wind speed, were used as input in the dispersion simulations. Moisture content for the different types of material were not available and use was made of the typical moisture contents given by US-EPA in the section pertaining aggregate handling and storage piles (EPA, 1998a).

Hourly emission rates, varying according to the prevailing wind speed, were used as input in the dispersion simulations.

## B.2 Wind Erosion from Exposed Areas

In the quantification of wind erosion emissions, the model incorporates the calculation of two important parameters, viz. the threshold friction velocity of each particle size, and the vertically integrated horizontal dust flux, in the quantification of the vertical dust flux (i.e. the emission rate). The equations used are as follows:

$$E_i = G_i 10^{(0.134C-6)} \quad \textbf{(2)}$$

where,

$$G_i = 0.261 \frac{\rho_a}{g} U_*^3 (1+R_i)(1-R_i^2) \quad \textbf{(3)}$$

$$R_i = \frac{U_{t*i}}{U_*} \quad \textbf{(4)}$$

and,

| | |
|---|---|
| $\mathbf{E_i}$ | = Emission rate (size category i) |
| **C** | = clay content (%) |
| $\boldsymbol{\rho_a}$ | = air density |
| **g** | = gravitational acceleration |
| $\mathbf{U_*}$ | = frictional velocity |
| $\mathbf{U_{t*i}}$ | = threshold frictional velocity (size category i) |

Dust mobilisation occurs only for wind velocities higher than a threshold value, and is not linearly dependent on the wind friction and velocity. The threshold friction velocity, defined as the minimum friction velocity required to initiate particle motion, is dependent on the size of the erodible particles and the effect of the wind shear stress on the surface. The threshold friction velocity decreases with a decrease in the particle diameter, for particles with diameters >60 µm. Particles with a diameter <60 µm result in increasingly high threshold friction velocities, due to the increasingly strong cohesion forces linking such particles to each other (Marticorena and Bergametti, 1995). The relationship between particle sizes ranging between 1 µm and 500 µm and threshold friction velocities (0.24 m/s to 3.5 m/s), estimated based on the equations proposed by Marticorena and Bergametti (1995), is illustrated in Figure C.1.

The logarithmic wind speed profile may be used to estimate friction velocities from wind speed data recorded at a reference anemometer height of 10 m (EPA, 1996):

$$U^{*} = 0.053U_{10}^{+} \qquad \textbf{(5)}$$

(This equation assumes a typical roughness height of 0.5 cm for open terrain, and is restricted to large relatively flat piles or exposed areas with little penetration into the surface layer.)

The wind speed variation over the dump was based on the work of Cowherd et al. (1988). With the aid of physical modelling, the US-EPA has shown that the frontal face of an elevated pile (i.e. windward side) is exposed to wind speeds of the same order as the approach wind speed at the top of the pile. The ratios of surface wind speed ($u_s$) to approach wind speed ($u_r$), derived from wind tunnel studies for two representative pile shapes, are indicated in Figure C.2 (viz. a conical pile, and an oval pile with a flat top and 37° side slope. The contours of normalised surface wind speeds are indicated for the oval, flat top pile for various pile orientations to the prevailing direction of airflow. (The higher the ratio, the greater the wind exposure potential.)

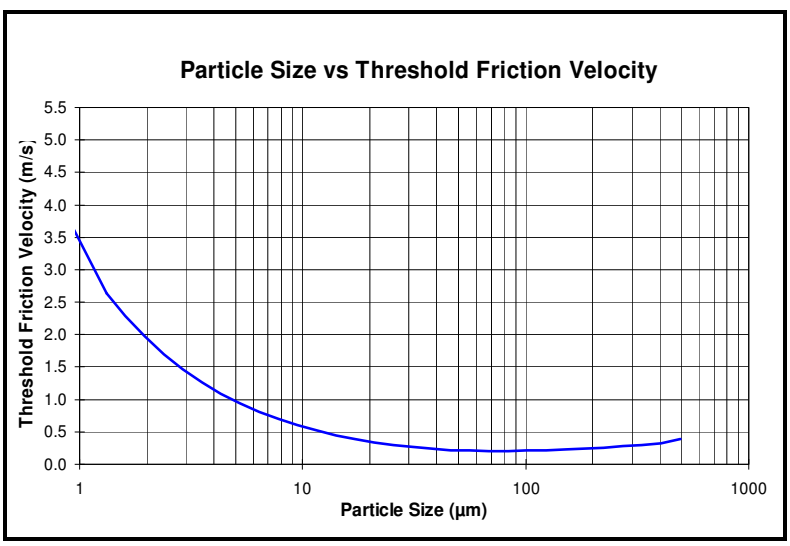


**Figure B.1: Relationship between particle sizes and threshold friction velocities using the calculation methods proposed by Marticorena and Bergametti (1995)**

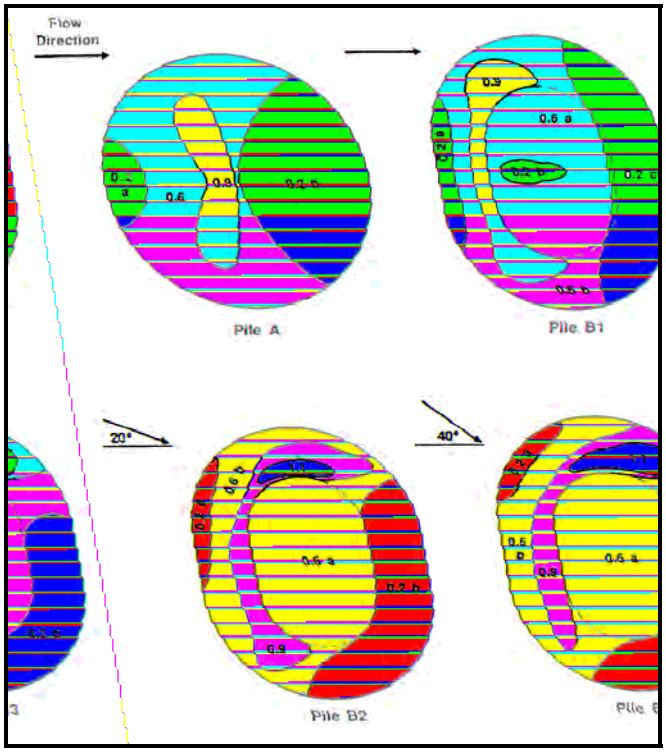


**Figure B.2: Contours of normalised surface wind speeds (i.e. surface wind speed / approach wind speed (After EPA, 1996)**

## B.3 Crushing and Screening

Metallic mineral processing typically involves the mining of ore from either open pit or underground mines; the crushing and grinding of ore; the separation of valuable minerals from matrix rock though various concentration steps and at some operations, the drying, calcining, or palletizing of concentrated to ease further handling and refining.

The number of crushing steps necessary to reduce ore to the proper size varies with the type of ore. Hard ores, including some copper, gold, iron, and molybdenum ores, may require as much as a tertiary crushing. Softer ores, such as some uranium, bauxite, and titanium/zirconium ores, require little or no crushing. Particulate matter emissions result from metallic mineral plant operations such as crushing and dry grinding ore, drying concentrates, storing and reclaiming ores and concentrates from storage bins, transferring materials and loading final products for shipment. The particulate matter emission factors are provided for various metallic mineral process operations including primary, secondary, and tertiary crushing, dry grinding, drying, and material handling and transfer (US-EPA, 1995).

The emission factors provided below are for the process operations as a whole since at most metallic mineral processing plants, each process operation requires several types of equipment. The revised US-EPA emission factors for crushing are only available for tertiary crushing and are given for TSP as 0.0027 kg of particulate per tonne of material crushed and 0.0012 kg of particulate per tonne of material crushed for PM10.

$E_{TSP}$ = 0.0027 kg of dust / ton of material crushed **(6)**

$E_{PM10}$ = 0.0012 kg of dust / ton of material crushed **(7)**

### B.4 Vehicle Entrained Dust from Unpaved Roads

Vehicle-entrained dust emissions have been found to account for a great portion of fugitive dust emissions from open pit mining operations. The force of the wheels of vehicles travelling on unpaved haul roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

The unpaved road size-specific emission factor equation of the US-EPA, used in the quantification of emissions, is given as follows:

$$E = k\left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{b} \cdot 281.9 \qquad \textbf{(8)}$$

Where,

| | | |
|---|---|---|
| *E* | = | *emissions in lb of particulates per vehicle mile travelled (g/VKT)* |
| *K* | = | *particle size multiplier (dimensionless);* |
| *S* | = | *silt content of road surface material (%);* |
| *W* | = | *mean vehicle weight (tons)* |

The particle size multiplier in the equation (k) varies with aerodynamic particle size range and is given as 1.5 for PM10 and 4.9 for total suspended particulates (TSP). The constants a and b are given as 0.9 and 0.45 respectively for PM10 and as 0.7 and 0.45 respectively for TSP.

### B.5 Drilling

Australian NPI emission factors for drilling operations

$$E_{TSP} = 0.59 \text{ kg TSP/hole drilled} \qquad \textbf{(9)}$$

$$E_{PM10} = 0.31 \text{ kg PM10/hole drilled} \qquad \textbf{(10)}$$

### B.6 Blasting

Fugitive dust emissions due to blasting were quantified using the NPI predictive emission factor for mining:

$$E_{TSP} = 344\left(\frac{A^{0.8}}{M^{1.9} \times D^{1.8}}\right) \qquad \textbf{(11)}$$

This equation takes into account other variables that are likely to be important in the generation of dust. Thus the equation was used to calculate emissions for the study. The PM10 fraction constitutes 52% of the TSP for blasting (US-EPA, 1998).

Where,

*M is the moisture content of the material*

*D* is the depth of the hole

*A* is the blasting area

**B.7 Excavating**

The excavation equation used in the study is shown below

$$EF = k * 0.0056 * M^{-0.9} \quad \textbf{(12)}$$

Where,

k=1.56 for TSP
k=0.75 for PM10

**Appendix C:**
**Monitoring Procedure for Langer Heinrich Uranium Mine.**

## C.1 DUST FALLOUT MONITORING

A dust fallout network for Langer Heinrich Uranium Mine was implemented to provide management with an indication of what the reduction in fugitive dust levels are once mitigation measures are implemented.

This section provides dust fallout monitoring procedures to ensure that the dust fallout network is properly maintained and that the results from the monitoring are reported in the correct manner.

### C.1.1 Dustfall Monitoring Apparatus

Dust fallout monitoring is a crude and non-specific test method primarily focused to study long-term trends and to obtain samples of settleable particulate matter for further chemical analysis. It is not suitable for determining dust fallout in small areas affected by specific sources. The advantage of dust fallout buckets is the simplicity of the method, the relative low costs associated with it and that it can be operated without a large technically-skilled staff (ASTM D1739-98).

Two types of dustfall monitors are used, viz. (i) single dust bucket monitors; and (ii) four-bucket wind directional monitors.

The single dust bucket monitors are deployed following the American Society for Testing and Materials standard method for collection and analysis of dustfall (ASTM D1739-98). This method employs a simple device consisting of a cylindrical container (not less than 150 mm in diameter, with height not less than twice its diameter) half-filled with de-ionised water exposed for one calendar month (30 ±2 days). The water is treated with an inorganic biocide to prevent algal growth in the buckets. The most common reagent used for this is a 10% copper sulphate solution (approximately 3 ml per litre of water bucket).

The bucket stand should comprise a wind shield at the level of the rim of the bucket to provide an aerodynamic shield (Figure C-1). The bucket holder is connected to a 2 m galvanized steel pole, which is either directly attached to a fence post or can be attached to a galvanized steel base plate. This allows for a variety of placement options for the fallout samplers. Exposed buckets, when returned to the laboratories, are rinsed with deionised water to remove residue from the sides of the bucket, and the bucket contents filtered through a coarse (>1 mm) filter to remove insects and other course organic detritus. The sample is then filtered through a pre-weighed paper filter to remove the insoluble fraction, or dust fallout. This residue and filter are dried, and gravimetrically analysed to determine the insoluble fraction (dust fallout).

**Figure C-1: Single dust bucket monitor**

The four bucket wind directional bucket monitors also comprises cylindrical 5 L containers half-filled with de-ionised, treated water which are exposed for one calendar month (30 ±2 days). The monitor however comprises a cluster of four buckets, a rotating lid above the buckets and a wind vane (Figure C-2). The lid is designed so as to close three of the buckets whilst allowing the fourth bucket to be open. The prevailing wind direction determines which of the buckets is open at any given time. E.g. the monitor could be installed so that northerly, southerly, easterly and westerly winds result in buckets 1, 2, 3 and 4 being open respectively. The aim of using this monitor is to link dust deposition to different airflow field and hence to sources located in the direction from which the wind is blowing. Wind directional bucket monitors are typically used to identify neighbouring source contributions to dust deposition at the monitoring location according to the relative quantity of dust collect in each of the buckets. The quantitative results are however not directly comparable to the results of the ASTM method.

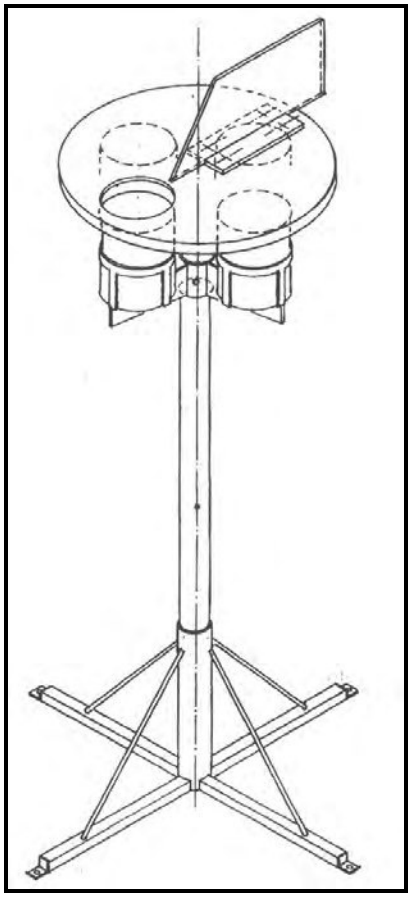

**Figure C-2: Four bucket wind directional bucket monitor**

### C.1.2 Dust Fallout Monitoring Procedure

**Table C-1: Dust fallout monitoring guidelines**

| Heading | Description | Comments |
|---|---|---|
| *Responsible persons* | Charles Cleghorn / Werner Petrick / Jefta Ampueja | |
| *Operating procedures (collection of dustfall and its measurement)* | 1. The dust buckets must be prepared and sealed in a laboratory and then opened and set up at the appropriately chosen sites so that particulate matter can settle into them for periods of about 30 days.<br>2. The dust bucket must be on a stand located at a height of 2m above ground.<br>3. A file containing information specific to each dust bucket site, such as the bucket number, the time and date set out and the map co-ordinates should be maintained.<br>4. During the sampling period any unusual events such as construction, fires, etc., should be recorded, as they may be helpful in interpreting the results obtained.<br>5. The sampling period shall be one calendar month with an allowance of ± 2 days (i.e. 28-32 days).<br>6. At the end of the sampling period, the date and time of collection, and the bucket number should be recorded, and the bucket should be resealed and returned to the laboratory for analysis.<br>7. Rain will collect in and evaporate from the container during the exposure period, and containers may have liquid in them when they are picked up. This liquid is later processed and therefore should not be discarded.<br>8. After the 30 days of exposure, the containers are then closed and returned to the laboratory.<br>9. The new bucket can be set up as the old bucket is collected. | Method obtained from the American Society for Testing and Materials (ASTM) standard test method for collection and measurement of dustfall (Settleable Particulate Matter) - D1739-98 (1998). |
| *Reporting procedures* | 1. The masses of the water-soluble and insoluble components of the material collected are determined (see ASTM D1739-98 for a detailed description of determining mass).<br>2. The results should be reported as mg/m²/day on a monthly basis.<br>3. The average filter weight needs to be subtracted from the initial filter weight to determine the mass of dust collected in mg.<br>4. The collection area is the cross sectional area of the inside diameter of the top of the container (if the inside diameter of the top of the container is 27.5 cm, the collection area is $\pi r^2$ or $\pi d^2/4$, which is 0.059 m². | See reporting example in Table C-10-2. |

| | | |
|---|---|---|
| | 5. The dust fallout can be calculated by mass/number of days/area of bucket to obtain dust fallout per bucket in mg/m²/day.<br>6. The results should be reported to the environmental manager every month on the results from the previous production month. This report should include a table with the bucket locations and descriptions, a dust fallout graph indicating the bucket results expressed in mg/m²/day, and a comparison to the dust fallout guidelines (see Tables 2-6 and 2-7).<br>7. Any missing buckets or damage to buckets should be reported immediately.<br>8. The replacement of the missing or damaged buckets should be within one month from logging the report. | |
| *Monitoring objectives* | 1. Compliance monitoring.<br>2. Validation of dispersion modelling results.<br>3. Assist in source apportionment.<br>4. Facilitate the measurement of progress against environmental targets within the main impact zone of the operation.<br>5. Temporal trend analysis to determine the potential for nuisance impacts within the main impact zone of the operation.<br>6. Tracking of progress due to pollution control measure implementation.<br>7. Informing the public of the extent of localised dust nuisance impacts occurring in the vicinity of the operations. | |
| *Performance indicators* | Dust fallout should be less than 1 200 mg/m²/day over a monthly average and 600 mg/m²/day at the sensitive receptors. | Key performance indicators against which progress may be assessed are usually selected to reflect both the source of the emission directly and the impact on the receiving environment |

**Table C-2: Example of dust fallout reporting (exceedances over 1200 mg/m²/day highlighted).**

| Single dust buckets (April 2009) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Bucket identification** | **Dust bucket location** | **Date and time set out** | **Date and time collected** | **Number of days exposed** | **Mass dust collected (mg)** | **Collection area (m²)** | **Dust fallout (mg/m²/day)** |
| Dust bucket number 2 | ROM stockpiles 22.93°S, 15.24°E | 1 April 2009 10:00 AM | 30 April 2009 2:00 PM | 30 | 860 | 0.059 | 486 |
| Dust bucket number 4 | East of tailings ___°S, ___°E | Etc. | Etc. | 30 | 400 | 0.059 | 226 |
| Dust bucket number 5 | Etc. | Etc. | Etc. | 30 | 2 030 | 0.059 | 1 147 |
| Dust bucket number 6 | Etc. | Etc. | Etc. | 30 | 2 130 | 0.059 | **1 203** |
| Dust bucket number 7 | Etc. | Etc. | Etc. | 30 | 4 560 | 0.059 | **2 576** |

## C.2 AMBIENT MONITORING

Particulate matter is the main pollutant of concern at Langer Heinrich Uranium Mine. Particulate matter is usually characterized by its size (diameter), most samplers collect and separate particulate matter based on particle inertia which is related to the particle size, geometry and density. Based on the impact assessment results, it is recommended that P10 be monitored at the Drillers Camp to track the impacts during the various phases of the mine. I

### C.2 Monitoring equipment for PM10

There are various types of monitoring equipment and these include the E Sampler and the Tapered Element Oscillating Microbalance (TEOM) monitor used for measuring ambient PM10 concentrations and for regulatory purposes.

The TEOM is a filter-based, continuous monitor able to facilitate the real-time access to measured concentrations. The TEOM operates by continuously measuring the weight of particles deposited onto a filter. The filter is attached to a hollow tapered element which vibrates at its natural frequency of oscillation - as particles progressively collect on the filter, the frequency changes by an amount proportional to the mass deposited. As the airflow through the system is regulated, it is possible to determine the concentration of particulates in the air. The filter requires changing periodically, typically every 2 to 4 weeks, and the instrument is cleaned whenever the filter is changed. TEOMs can monitor PM10, PM2.5, PM1 and TSP continuously depending on the inlet arrangement selected. (Only one particle size can be measured at any one time.) Data averages and update intervals include: 5-minute total mass average (every 2 seconds), 10-minute rolling averages (every 2 seconds), 1-hour averages, 8-hour averages, 24-hour averages (etc.). The TEOM has a minimum detection limit of 0.01 $\mu g/m^3$.

Beta attenuation monitors (BAM) also collect particulates on a filter paper over a specified cycle time. The attenuation of beta particles through the filter is continuously measured over this time. BAMs give real-time measurement of *either* TSP, PM10 or PM2.5 depending on the inlet arrangement. At the start of the cycle, air is drawn through a glass fibre filter tape, where the particulates deposit. Beta particles that are emitted from either a C14 or a K85 sources are attenuated by the particles collecting on the filter. The radiation passing through the tape is detected by a scintillator and photomultiplier assembly. A reference measurement is made through a clean portion of the filter, either during or prior to the accumulation of the particles - the measurement enables baseline shifts to be corrected for.

The application of filter-based, on-line samplers such as either the BAM or TEOM monitors have several distinct advantages including:

- continuous, near-real-time aerosol mass monitoring,
- self-contained, automated monitoring approach requiring limited operator intervention following installation,
- a choice of averaging times from 1 minute to 24 hours,
- low labour costs, minimal filter handling and a reduction in the risk of filter contamination, and
- non-destructive monitoring methods providing the potential of supplying samples which may be submitted for chemical analysis.

The TEOM is US-EPA approved (EQPM-1090-079) as an equivalent method for measuring 24-hour average PM10 concentrations in ambient air quality (Figure C-10-3). It represents the only continuous monitor that meets the California Air Resources Board acceptance criteria for 1-hour mass

concentration averages. TEOM instrumentation also has German TÜV approval for TSP measurements. Not all beta gauges are US-EPA approved, with only the Andersen (FAG-Kigelfischer, Germany) and Wedding beta monitor having been approved. The performance of the TEOM ad BAM monitors are compared in Table C-3. The TEOM tends to perform better than BAMs in many respects, particularly with regard to the precision of measurements made.

**Table C-3: Comparison of TEOM and BAM performances**

| | TEOM | BAM |
|---|---|---|
| Principle of operation | *Measured mass* on a filter based upon inertia (as fundamental as gravimetric method). | *Inferred mass* on a filter based upon the strength of a radioactive beam. |
| | Measures *only mass* (represents a true mass measurement) | Do *not* measure mass but rather the transmission of beta rays |
| Advantages and disadvantages | Performs well under varying humidity conditions. Samples and measures at a defined filter face velocity and conditioning temperature to ensure standardized data under low humidities | Can produce erroneous measurements under changing humidity conditions |
| | Not sensitive to particulate composition since it makes a mass-based measurement. | Sensitive to interferences (site/season specific) arising due to: particle composition, particle distribution across the filter, radioactive decay and the effect of air density in the radioactive beam. |
| Precision (measured by standard deviation) | Standard deviation for hourly data: ± 1.5-2.0 µg/m³. (Precision of ±5 µg/m$^3$ for 10-minute averaged data.) | Beta monitors with strong source: standard deviation for hourly data: ± 15-20 µg/m³.<br>Beta monitors with weak source: hourly data not acceptable. |

TEOMs have been found to typically under-predict actual particulate concentrations by a consistent amount (typically 18% to 25%). In the US TEOM results are typically multiplied by a factor of 1.3 to determine actual concentrations (this single factor is made possible by the consistency or high precision of the instrument). TEOMs tend to be less effective in environments with elevated nitrate concentrations or high potentials for the adsorption of volatile compounds on particles. Beta attenuation monitors perform poorly in areas with soils which have a radioactive component.

Limitations of the TEOM and BAM monitors are that they all require electricity to operate thus limiting the potential sites for the location of such monitors. These monitors are also relatively costly. Despite the relatively high costs of purchasing continuous real-time monitors such as the TEOM and beta gauge monitors, significant savings can be achieved in the operation of such monitors due to the low labour costs and the minimal filter handling required by these techniques.

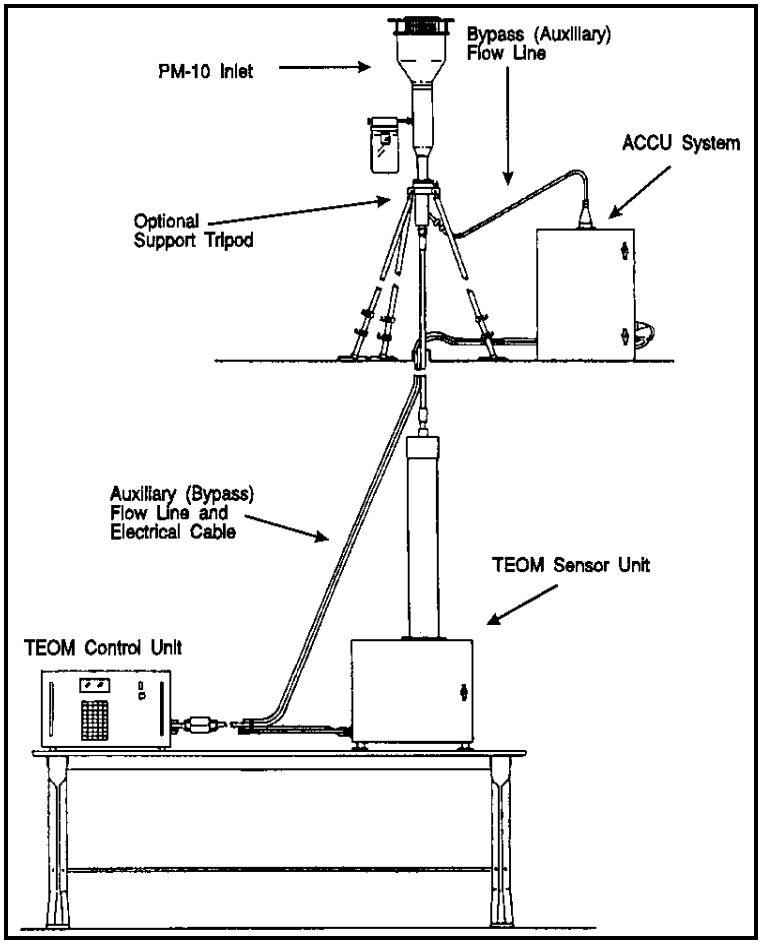


**Figure C-3: Sketch of TEOM sampler**

The E-sampler is a dual technology instrument that combines real-time measurement of light scatter with the accuracy standard of filter methods (Figure C-10-4). The E-Sampler provides real-time particulate measurement through near-forward light scattering. An internal rotary vane pump draws air at 1 to 3.5 LPM into the sensing chamber where it passes through visible laser light. Aerosols in the sir scatter light in proportion to the particulate load in the air. Scattered light is collected by precise glass optics and focused in a PIN diode. Rugged state of the art electronics measure the intensity of the focused light and focused the output a signal to the central processing unit (CPU). The output is linear for concentrations greater than 100 000 µg/m³. Every E-Sampler is factory calibrated using Polysterene Latex Spheres of known index of refraction and diameter and multiple points to validate linearity.

The advantages of the E-Sampler include the fact that the filters can be extracted and replaced in less than one minute and the filter medium can be collected based on laboratory analysis. Particulate loading on the filter does not reduce performance its performance. The E-Sampler is portable and easy to use.

**Figure C-4: Photo of E-Sampler (Met One Instruments Inc, http: // www.metone.com, 2007)**

### C.2.2 Ambient Monitoring Procedure

**Table C-4: Ambient air monitoring, performance assessment and reporting programme**

| Heading | Description | Comments |
|---|---|---|
| *Responsible persons* | Charles Cleghorn / Werner Petrick / Jefta Ampueja | |
| *Operating procedures (collection of PM10/PM2.5 data)* | 1. The filter must be pre-weighed at an accredited laboratory.<br>2. The filters must be placed in a sealed container that is clearly marked.<br>3. The laboratory will provide the list of filters with the associated pre-weight.<br>4. The filter is placed in the inlet holder of the sampler and exposed for the required period.<br>5. The filter must be carefully removed to ensure that it is not contaminated and placed back in the marked container.<br>6. The sampling period shall be for 24-hours when filters are used and continuous for the light scattering.<br>7. At the end of the sampling period, the date and time of collection, and the filter number should be recorded, and the filter should be resealed and returned to the laboratory for analysis.<br>8. The laboratory post weighs the filters and presents the results in $mg/Nm^3$.<br>9. The data should be continuously downloaded and automatically "pushed" in near real-time<br>9. The E-sampler should be calibrated at least every 6-months | The E-Sampler combined light scattering with accuracy standard of filter methods. The device measures light scatter and absorption and correlates that measurement with particulate concentrations. The filters can be used very sixth day to ensure that the same day of the week is not measured continuously. This can also be used to verify the continuous measurement through the light scattering methodology.<br><br>One filter per month should be send for radionuclide analysis. |
| *Reporting procedures* | 10. The results should be reported as $\mu g/m^3$ on a daily basis.<br>11. The average filter weight needs to be subtracted from the initial filter weight to determine the mass of dust collected in mg.<br>12. The air intake in litres per minute is required to determine the volume and relate the mass to a mass per volume.<br>13. The PM10/PM2.5 can be calculated by mass/number of minutes/volume to obtain PM10/PM2.5 concentrations in $\mu g/m^3$.<br>14. The results should be reported to the environmental manager every month on the results from the previous production month. This report should include a table with the monitoring location, a concentration graph indicating all the results expressed in $\mu g/m^3$, and a comparison to the WHO ambient guidelines (see Tables 2-3 and 2-4).<br>15. Comprehensive QA/QC protocol implemented. The data should be | |

| | | |
|---|---|---|
| | validated to ensure there are no outliers or data gaps | |
| *Monitoring objectives* | 8. Compliance monitoring.<br>9. Validation of dispersion modelling results.<br>10. Assist in source apportionment.<br>11. Facilitate the measurement of progress against environmental targets within the main impact zone of the operation.<br>12. Temporal trend analysis to determine the potential for nuisance impacts within the main impact zone of the operation.<br>13. Tracking of progress due to pollution control measure implementation.<br>14. Informing the public of the extent of localised dust nuisance impacts occurring in the vicinity of the operations. | |
| *Performance indicators* | PM10 concentrations should be less than 75 µg/m³ over a daily average and 40 µg/m³ over an annual average | Key performance indicators against which progress may be assessed are usually selected to reflect both the source of the emission directly and the impact on the receiving environment |