Rio Tinto

Rössing Uranium Limited

Working for Namibia

Risk assessment on Rössing Uranium mine's tailings dust (technical report)

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Abstract

Rössing Uranium Ltd's Tailings Storage Facility is subject to wind erosion, resulting in a dust plume to the west of the facility.

The risks to the public from wind-blown tailings material include the potential inhalation of tailings dust; dispersion of the material into the environment and subsequent runoff into the Khan River; potential increases of the inhalation dose of radon progeny from the distributed dust; direct irradiation of people and animals from the presence of tailings material on the ground; and the potential impact on biodiversity as a result of plants being smothered by dust.

This report assesses the maximum risk associated with the inhalation of tailings dust to be insignificant at less than 53 micro-sieverts per annum (the actual dose assessed will depend on the assessment methodology and on whether a suitable background value is subtracted).

Risks additional to dust inhalation are shown to be negligible: the impacts from increased radon concentrations or direct irradiation from tailings material to public receptor groups, dispersion of tailings material into the environment, or loss of biodiversity from tailings dust are all insignificant.

Based on this assessment, remediation of the dust plume is restricted to the activities designed in the Rössing Uranium Closure Management Plan, which consist of collecting consolidated amounts of tailings material from the environment for disposal in the Tailings Storage Facility.

Acronyms and abbreviations

The following acronyms and abbreviations are used in this report:

µg/m^3	–	micro-grams per cubic metre, i.e. 10^{-6} grams per cubic metre
µSv	–	micro-sievert, i.e. 10^{-6} sievert
µSv/a	–	micro-sieverts per annum
µSv/h	–	micro-sieverts per hour
AEC	–	Atomic Energy Corporation of South Africa
Bq	–	becquerel, counts per second, unit for radioactivity
Bq/g	–	becquerels per gram
h/a	–	hours per annum
ha	–	hectare, i.e. 10,000 square metres
IAEA	–	International Atomic Energy Agency
mg/m^3	–	milli-grams per cubic metre, i.e. 10^{-3} grams per cubic meter
mg/m^2/day	–	milli-grams per square metre per day
m/s	–	metres per second
mSv	–	milli-sievert, i.e. 10^{-3} sievert
mSv/a	–	milli-sieverts per annum
PM_{10}	–	particulate matter less than 10 micro-metre in diameter, i.e. smaller than 10^{-6} metre
ppm	–	parts per million
SEA	–	Strategic Environmental Assessment
SEIA	–	Social and Environmental Impact Assessment
Sv	–	sievert, unit for radiation exposure dose
Sv/Bq	–	sieverts per becquerel
TSF	–	Tailings Storage Facility
WHO	–	World Health Organization

Contents

1. Introduction

Rössing Uranium Limited (Rössing Uranium) is an open pit uranium mine located in the Namib Desert, about 60 km inland from the coastal town of Swakopmund and about 10 km from the town of Arandis, which is home to many Rössing Uranium's workers, both those employed there currently and those who are retired or otherwise no longer employed at the mine. The mine has a footprint of 2,300 ha (Figure 1), with the Tailings Storage Facility (TSF) covering an area of about 750 ha, which is raised to an elevation of about 100 m above the surrounding surface at its highest point.

The purpose of this report is to present an assessment of the risk presented by the tailings dust that is blown by the wind from the surface of the TSF into the surrounding environment.

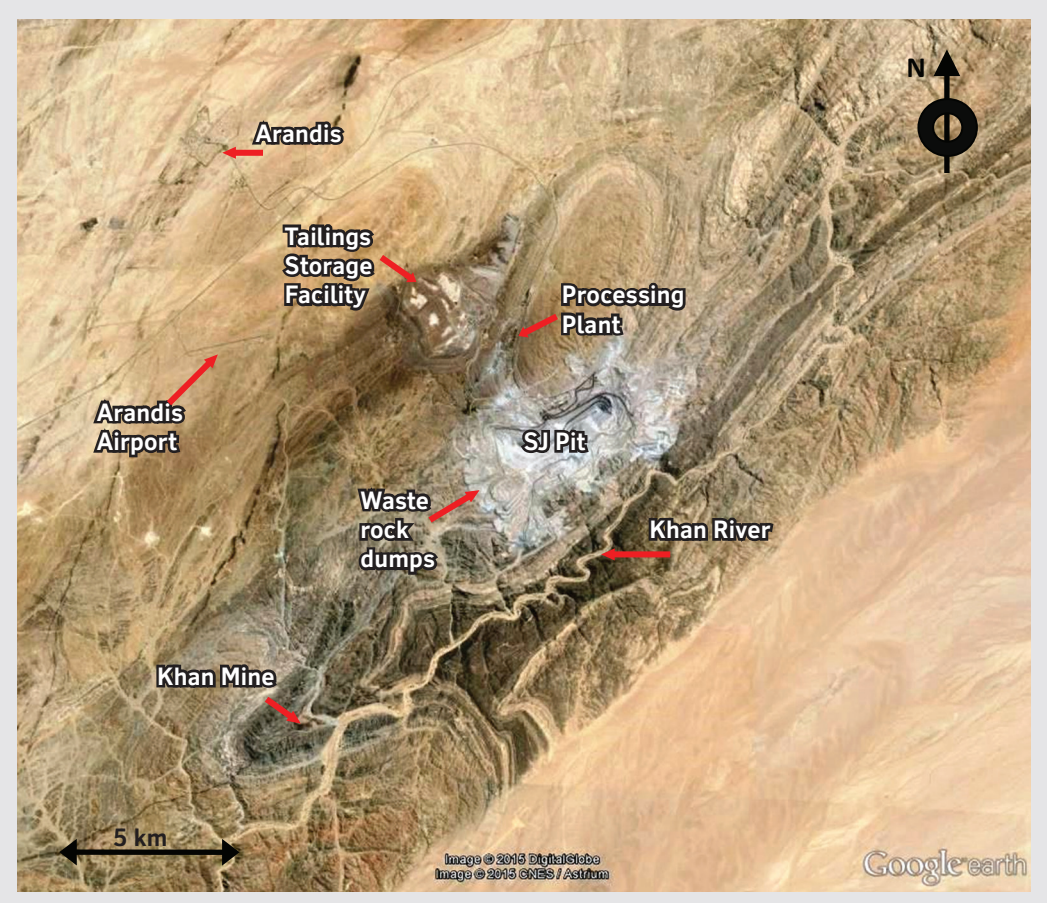

Figure 1: Footprint of Rössing Uranium mine, showing disturbed areas of the open pit (SJ Pit), waste rock dumps, Processing Plant, and Tailings Storage Facility. The receptor locations at Arandis, Arandis Airport, and the old Khan Mine are also indicated.

2. Tailings Material at the Rössing Uranium Mine

At the Rössing Uranium Processing Plant, uranium is leached from the mined ore and transferred into solution. The remaining sand is removed from the leachate and transported to the TSF by conveyor. Uranium-rich slimes (very fine-grained material) are then washed in a thickener circuit, after which the barren slimes are pumped to the TSF.

Here, sand and slimes are recombined and deposited on the TSF in a paddock deposition system. The paddock system reduces surface evaporation by restricting the size of the tailings deposition area, at the same time optimising the recovery of water from the surface for recycling.

Whilst effective for optimising water utilisation, the TSF design results in a dry tailings surface that is subject to wind erosion, particularly during the very strong east winds (Bergwinds) that occur during the winter months.

Tailings dust is consolidated and is therefore not readily dispersed by wind action: This means that about one year after deposition, the surface of the tailings material hardens, with further dispersion of dust by wind erosion becoming much less substantial.

The prevailing wind directions at the Rössing Uranium mine site are shown in Figure 2, averaged out over the four seasons for almost a 2-year period [1]. The highest wind speeds are reached in autumn and winter in a north-east-east (NEE) direction, and in autumn in the south-west-west (SWW) direction. During spring and summer, the prevailing winds are from westerly directions.

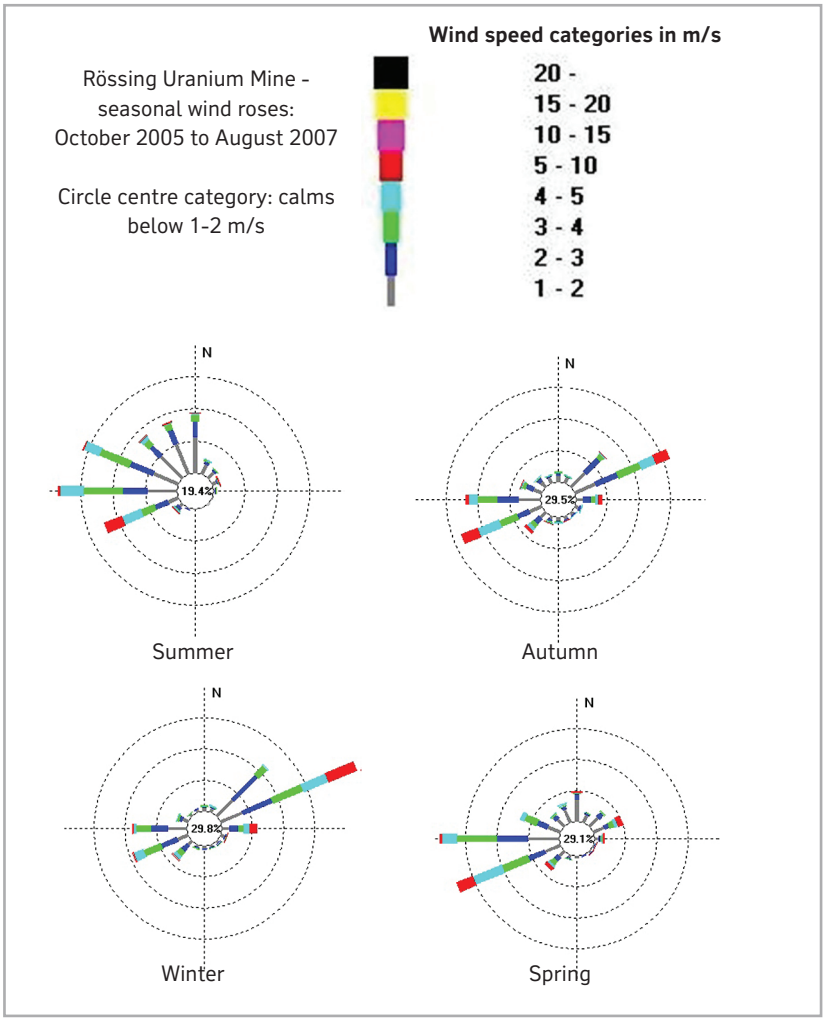

Figure 2: Prevailing wind directions at the Rössing Uranium mine site (after [1]). The frequency interval between one circle and the next (bigger) one is 5 per cent, and the colour codes indicate the wind speed in metres per second (m/s). Seasons run from mid-December till mid-March (summer), mid-March to mid-June (autumn), mid-June to Mid-September (winter) and mid-September to mid-December (spring).

Wind-blown tailings material accumulates mostly to the southwest of the TSF, with particles of different size moving at different rates [2].

The distribution of dust plumes originating from the TSF are presented in Figure 3, with three distinct dust plumes shown: Plume A is characterised by substantial accumulations of dust; Plume B is characterised by small accumulations of dust that are barely visible; and Plume C consists of very small particles only detectable by radiometric methods.

Dust plumes A, B and C have developed over time through the accumulation of wind-blown tailings dust and further dust deposition in this pattern is still taking place. Transition from one plume into the next is gradational.

The main risk from wind-blown tailings material is the inhalation of airborne radioactive dust, which causes an inhalation exposure dose to members of critical groups of people living downwind of the TSF.

Other potential risks include the dispersion of the tailings material and subsequent runoff into the Khan River, where it may impact water sources, as well as the emanation of radon from the TSF in excess of the natural radon levels characteristic of the area.

Public dose assessments on the inhalation dose as a result of mining-related tailings dust, including tailings dust, have been performed by Rössing Uranium and the Nuclear Energy Corporation of South Africa for various mining and closure plans, and are summarised in Section 3.

Current dust monitoring programmes are designed to confirm the validity of such dose assessments, and a dose assessment based on the monitoring results is presented in Section 4.

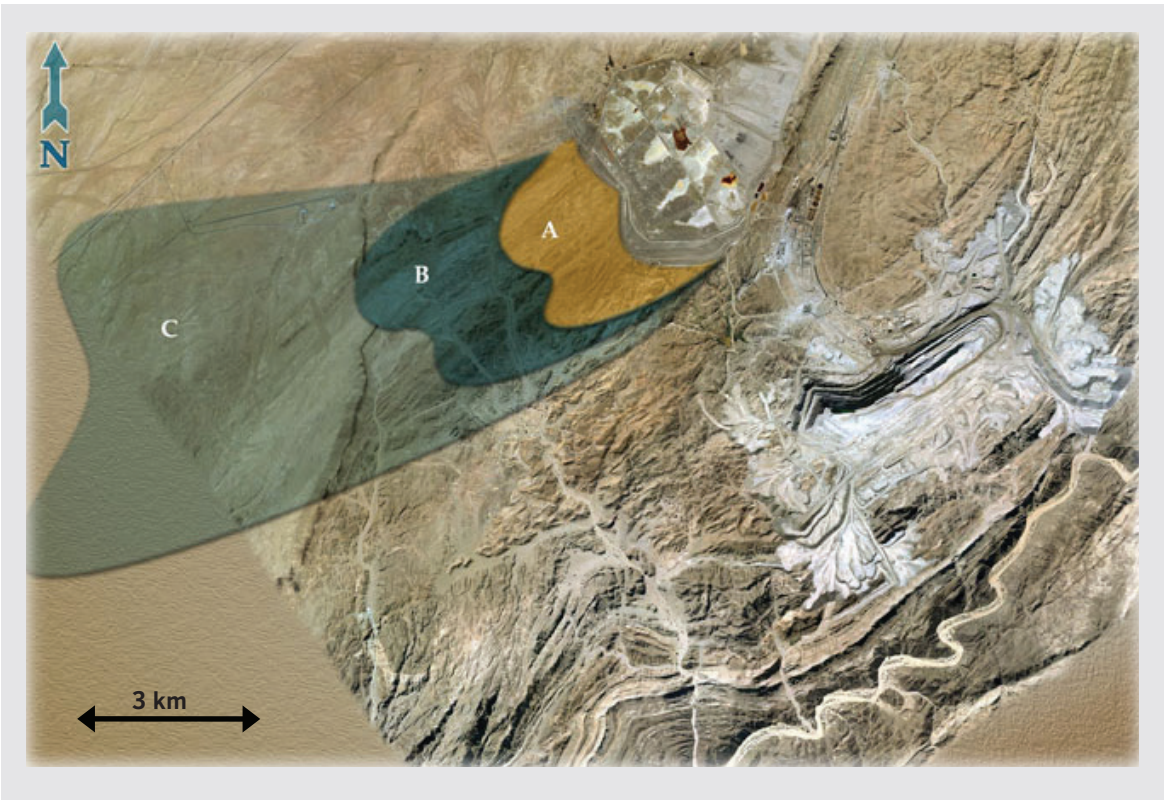

Figure 3: Dust plumes originating from the TSF (after [2]).

3. Previous public dose assessments on dust inhalation

Public dose assessments have been performed for each change in mining scope at Rössing Uranium over the years, and include the following:

- 1990: *Estimation of the Average Radiation Dose to the Population of Arandis from Radioactivity Originating from Natural as well as Mining Related Sources* [3],
- 2001: *Preliminary Post Closure Radiological Safety Evaluation for Rössing Uranium Mine* [4],
- 2002: *An Assessment of the Post-Closure Radiological Impact of Rössing Uranium Mine* [5],
- 2003: *Post Closure Public Dose Assessment for the Phase III Expansion of the Rössing Uranium Mine* [6],
- 2008: *Dose Assessment for a Life-of-Mine Extension (LOME) of the Rössing Uranium Mine* [7], and
- 2011: *Report on the Radiological Public Hazard Assessment for the Expansion of Rössing Uranium Mine in Namibia, as a Specialist Study for the Phase II SEIA* [8].

Each of the above public dose assessments used information collected for previous assessments, then refined and detailed the calculations in an iterative process. Therefore, the 2011 dose assessment [8] can be considered to be the one that is most up to date.

In relation to the inhalation of dust from the mine site (including tailings dust), the dose assessment in reference [8] includes all sources of dust arising from Rössing Uranium's mining operations. The highest public dose from the inhalation of radioactive dust for any recipient group is calculated for the hypothetical critical group located at the old Khan Mine, situated approximately downwind of the TSF under east wind conditions.

The dose for the dust inhalation pathway and this critical group is assessed to be 84 micro-sieverts per annum (μSv/a). The second highest public dose (46 μSv/a) is calculated for the Arandis airport, located to the southwest of the TSF, and therefore also a potential receptor location for dust from the TSF. Both of these dust inhalation doses are well below the public dose limit of 1,000 μSv/a, as specified in the *Radiation Protection Regulations* [9].

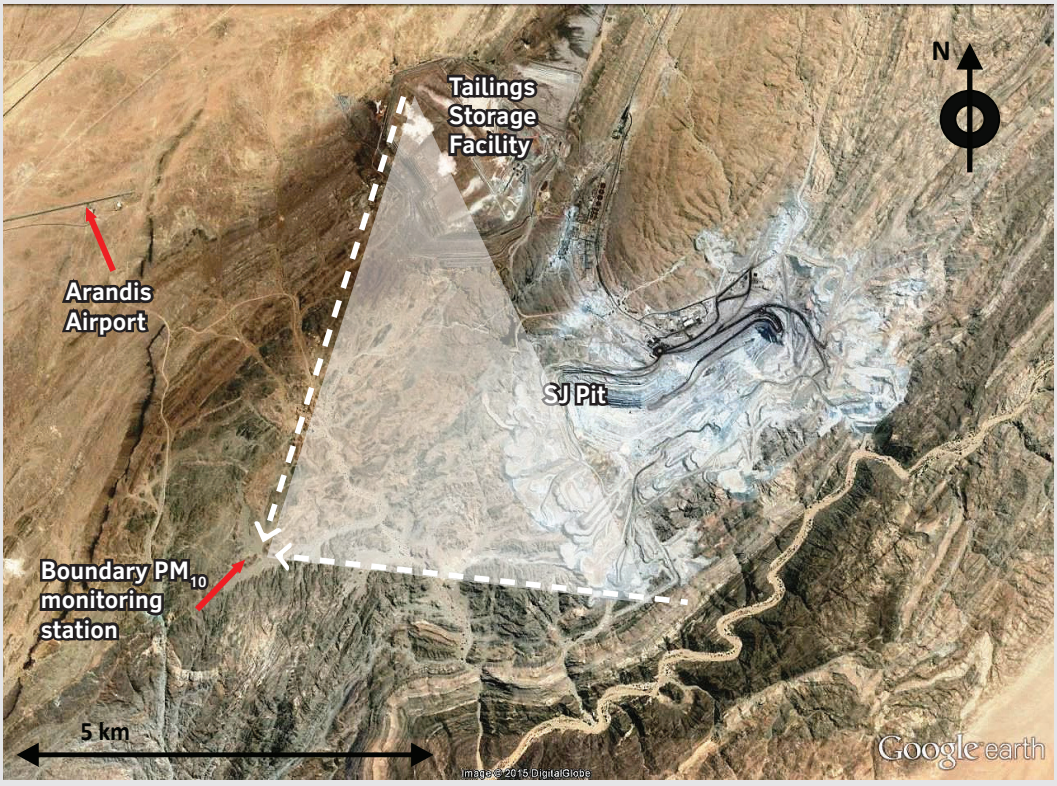

Figure 4: Rössing mine site, with position of boundary PM_{10} monitoring station indicated. The wedge formed by white directional arrows represents the range of potential wind directions at the boundary station leading to dust concentrations that are related to mining activities at Rössing Uranium.

The public dose assessment above is based on air quality dispersion models that account for all sources of dust emitted from the mine, including from tailings. In reality, the dust sourced from the TSF and from the mining operations cannot be measured and considered separately, and any inhaled dust will be a combination of naturally occurring background dust, tailings dust, and ore dust originating from the mine site.

The best method to quantify an upper limit to the dose from tailings dust is to rely on the monitoring results from the dust monitoring station located at the western border of the mine, as shown in Figure 4. This will be discussed in the following sections of this report.

4. Risk assessment based on dust monitoring results

In the following, a 'worst case' public dose assessment for the mine site boundary, where a Rössing PM_{10} monitoring station is located, will be developed in stages.

4.1 Total amount of PM_{10} dust considered

At the western boundary of the mining site, a PM_{10} dust monitoring station collects dust samples at hourly intervals. This monitoring station has intentionally been located downwind of the TSF in the direction of the prevailing north-easterly winds that occur during the winter months. The map in Figure 4 shows the location of the monitoring station relative to the mine site and relative to the TSF. Also indicated on the map is the wedge from the monitoring station to the mine site which includes all wind directions that could potentially carry particulates to the station from the mining site.

Data collected at this boundary station over 23 months (with a gap of two months in the data) is shown in Figure 5.[1] The average PM_{10} dust concentration over this period is measured to be 36 micro-grams per cubic meter (µg/m³). The largest measured value in a single hour was 927 µg/m³, or almost 1 mg/m³. Monthly averages are summarised in Figure 6, with a maximum monthly average of 119 µg/m³ measured in October 2012. As discussed later, the monthly average PM_{10} concentrations at this location exceeded the WHO PM_{10} standard guideline value for outdoor air quality [2] for a number of months; however these exceedances occurred during a period of intense roadworks close to the monitoring station, and were not a result of mining activities at Rössing Uranium.

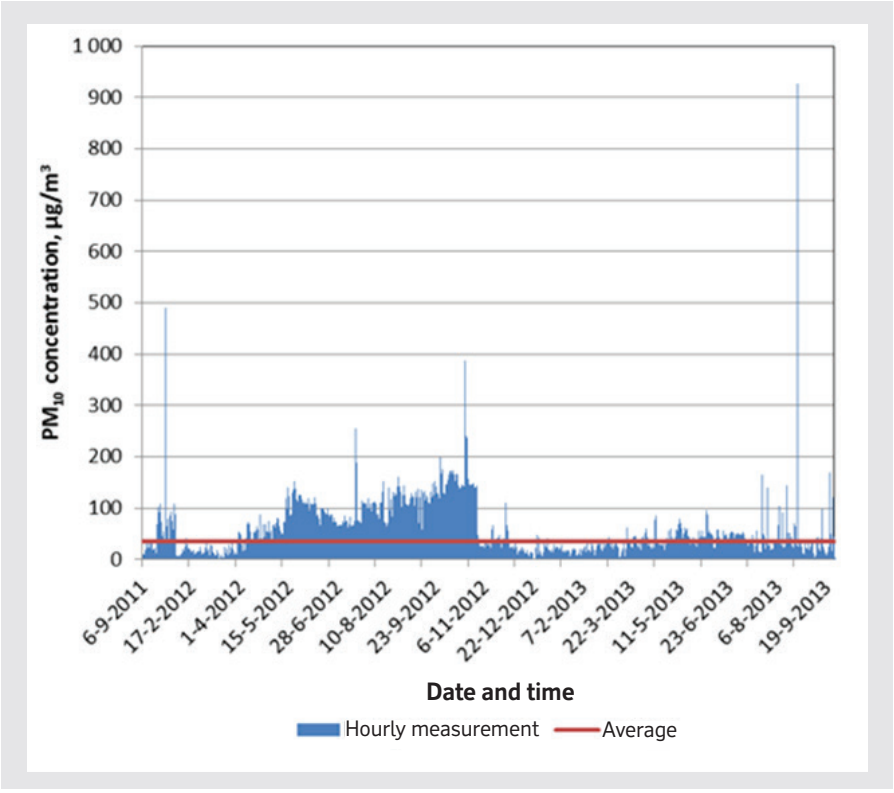

Figure 5: PM_{10} dust concentration in hourly intervals, between September 2011 and September 2013.

[1] Data gaps occurred in the months December 2011 to January 2012, due to instrument breakdown.

[2] 50 µg/m³ when averaged over a 24-hour period. See WHO fact sheet: 'Ambient (outdoor) air quality and health', http://www.who.int/mediacentre/factsheets/fs313/en/

The inhalation exposure dose corresponding to the dust concentration in air depends on the composition of the dust, i.e. whether the dust is made up of natural uranium/thorium ore in secular equilibrium, or whether it has components of tailings dust. Tailings dust contains about 80 per cent less uranium than the original ore. However, all the radionuclides from the uranium, thorium and actinium decay chains (except uranium) are still present in their original concentrations, so that the dose from the inhalation of tailings dust is only about 30 per cent less than that resulting from the corresponding original ore.

A detailed dust radionuclide analysis was not possible for the PM_{10} dust sampled because the instrument does not collect sufficient material for such an analysis. However, a simple geological assay found the dust to contain uranium at 7 parts per million (ppm).

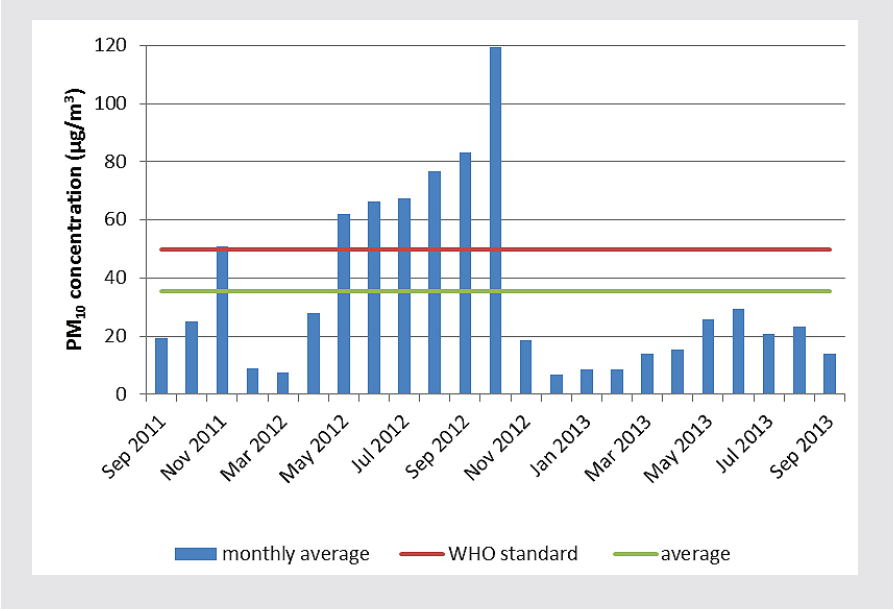

Figure 6: Monthly average PM_{10} monitoring results at Rössing Uranium mine's western mine boundary.

The inhalation dose from the sampled dust may be calculated as follows:

$$Dose = Conc_m \cdot SA \cdot DCF \cdot BR \cdot t$$

$$= Conc_m \cdot F,$$

where

Dose = dose in µSv/a

$Conc_m$ = mass concentration in µg/m³,

SA = specific activity of material in Bq/g

DCF = dose conversion factor in Sv/Bq

BR = breathing rate of members of the public, assumed to be 0.9 m³/h

t = time for exposure, assumed to be a full year for members of the public, i.e. 8,760 h/a, and

$F = SA \cdot DCF \cdot BR \cdot t$.

The dose conversion factor *DCF* may be calculated using the method described in the International Atomic Energy Agency (IAEA) Regulations, [10] and does not differ significantly between uranium ore dust and tailings dust. For the Rössing Uranium mine it is given as 3.6 µSv/Bq for uranium/thorium ore and as 3.0 µSv/Bq for tailings dust.

Notwithstanding the measured value of 7 ppm of uranium in the dust found on the mine boundary, the following scenarios may be considered for the composition of the sampled dust:

Scenario A: Pure Rössing Uranium ore dust directly from the Crushing Circuit, with a grade of 300 ppm uranium in ore;

Scenario B: Pure Rössing Uranium tailings, originating from ore with 300 ppm uranium and with 80 per cent of uranium removed in the extraction process [3];

Scenario C: Tailings dust from Rössing Uranium, mixed with natural background dust that has a uranium content of 2 ppm uranium. The mixture is assumed to consist of 8 per cent Rössing tailings dust and 92 per cent natural background dust, which would result in 7 ppm uranium in the mixture, as has been measured; and

Scenario D: Natural background dust mixed with ore dust from the Rössing Uranium Crushing Circuit, resulting in a dust mixture containing uranium at 7 ppm, as has been measured.

[3] Note that this is not the same as ore dust at 60 ppm uranium content, as all the radionuclides of the uranium and thorium chains, except uranium, are present at activities corresponding to 300 ppm uranium.

The resulting inhalation dose calculated from the measured values is summarised in Table 1 for the four scenarios developed.

Table 1: Scenarios for composition of dust at the mine boundary and the resulting dose to members of the public at this location

Dust composition scenario	Scenario A	Scenario B	Scenario C	Scenario D
Value for F, μSv.m^3/μg/a	1.48	1.09	0.11	0.034
Inhalation dose from average dust concentration in period 2011 to 2013, μSv/a	53	39	4	1

The maximum public dose calculated in this manner – 53 μSv/a for Scenario A – slightly exceeds the dose assessment for Arandis Airport described in reference [8] (46 μSv/a), while it is less than the dose assessment arrived at in the same reference for the old Khan Mine, 84 μSv/a. However, the result is similar in magnitude and therefore consistent with these two dose assessments.

It must be cautioned here that the public dose calculated for Scenario A is characterised by some worst-case assumptions, i.e.:

i: It represents the total calculated inhalation dose from all dust found in this location, including background dust,

ii: It is calculated using the assumption that all dust found at this location is pure Rössing Uranium ore dust containing 300 ppm uranium, which is demonstrably not the case,

iii: The sampling location is directly downwind of the prevailing winds from the site, unlike Arandis Airport, which is located further to the north, and

iv: The measured values include a period of significantly increased roadworks in the vicinity of the dust monitoring station, roughly between May and October 2012. The roadworks are conceivably the main reason for the elevated month average PM_{10} dust concentration of 199 μg/m^3 measured at the station in October 2012 (see Figure 6).

Notwithstanding these confounders, the public dose assessment calculated for Scenario A, which represents the maximum possible exposure scenario, is similar in magnitude to that of the two critical groups for which the highest dose was calculated in the public dose assessment in reference [8].

For all the other scenarios B, C and D above, which are successively more realistic, the public dose assessment based on the measured dust concentrations arrives at values less than reference [8] for both critical receptor locations.

4.2 Dust concentration corrected for other potential dust sources

Figure 6 reveals that the monthly average PM_{10} dust concentrations are not consistent for similar seasons in different years. It transpires that the increased dust concentrations observed in the latter half of the year 2012 were largely correlated with roadworks to the west of the dust monitoring station.

Therefore in order to correct for the dusty conditions that occurred in 2012, a period of measurements covering 12 months but excluding this specific period can be utilised, i.e. measurements from October to November 2011, and from December 2012 to September 2013 (see Figure 7).[4]

When this is done, the dose results are as summarised in Table 2 for the same scenarios as discussed in Section 4.1 above: the average concentration and hence the public dose for the different scenarios is now seen to be about a factor 2 less than if the data from 2012 are included.

The maximum dose calculated is now 27 μSv/a, which applies to Scenario A, which assumes that all the dust arriving at the monitoring station is pure ore dust from the Rössing Uranium Crushing Circuit.

The calculations here are based on measured monitoring results and several different scenarios related to dust composition. When actual measured dust concentrations are taken into consideration in this way, it is seen that the public dose ends up being significantly less than the values arrived at in reference [8] (i.e. 86 and 46 μSv/a respectively for the Khan Mine and Arandis Airport), which were theoretical values based on dispersion models.

[4] Unfortunately, due to instrument breakdown, there are no monitoring results for October and November 2013 - hence the inclusion of these months from 2011 so as to cover a full year.

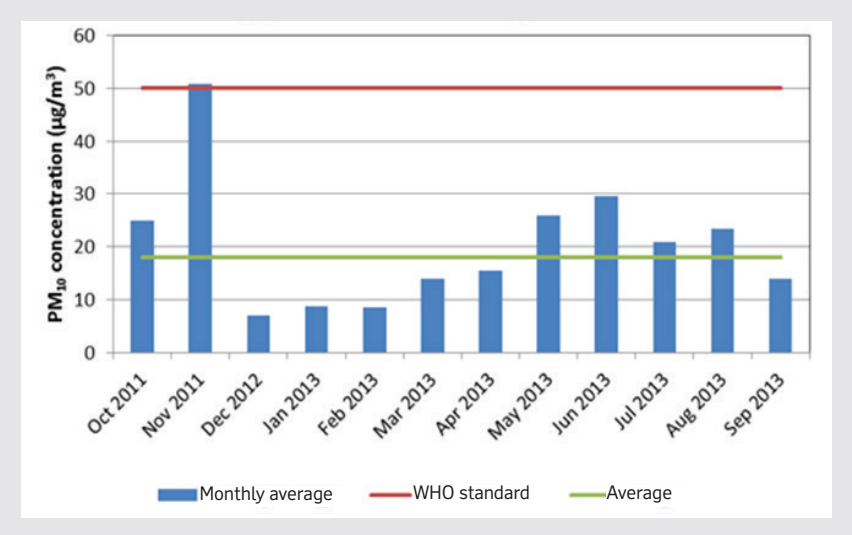

Figure 7: Monthly average PM_{10} monitoring results at the Rössing Uranium western mine boundary for 12 months unaffected by roadworks in the vicinity.

Table 2: Inhalation dose for measured PM_{10} dust concentrations when correcting for increased dust generation from source to the west of monitoring station

Dust composition scenario	Scenario A	Scenario B	Scenario C	Scenario D
Inhalation dose from average dust concentration October to November 2011 and December 2012 to September 2013, µSv/a	27	20	2	1

4.3 Dust concentration correlated with wind direction

The dose assessments described in Sections 4.1 and 4.2 above do not consider wind direction, i.e. they assume that any dust measured at this location is due to mining activities at Rössing Uranium, at least in part, whereas in reality this is definitely not the case.

In fact the increased dust concentrations observed in the latter half of 2012 were largely correlated with roadworks to the west of the dust monitoring station, i.e. in a wind direction towards the Rössing mine site rather than away from the mine.

An interesting calculation therefore involves correlating wind directions with dust concentrations. Both hourly wind directions and speeds and PM_{10} concentration measurements are available; these can therefore be correlated into those directly downwind from mining operations at Rössing Uranium, and those not correlated with this specific wind direction.

Wind direction measurements every hour were correlated with wind directions towards the boundary PM_{10} dust monitoring station, the location of which is indicated in Figure 4.

All the wind directions located within the wedge indicated in Figure 4 are regarded as 'downwind', i.e. potentially contributing to the public dose at this location. If this correlation is applied to the PM_{10} dust concentration data from October 2011 to September 2013, a correlation pattern emerges, which is summarised in Table 3.

Table 3: Dust concentrations at the boundary station, separated into downwind (public dose relevant) and upwind (not public dose relevant) measurements

Dust composition scenario	Overall	Downwind (dose relevant)	Upwind (not dose relevant)
PM_{10} dust concentration, µg/m³	36	44	31
Number of measurements	14,871	5,349	9,522
Time fraction	100%	36%	64%

The fraction of time in which the wind direction is from the Rössing Uranium mining area towards the monitoring station is therefore 36 per cent, as 5,349 out of 14,871 wind measurements were in the relevant 'downwind' direction.

The same criteria can now be applied to the measured concentrations as were applied in Section 4.1, i.e. a dose is calculated based on each of four possible scenarios for dust composition. In this case however, the downwind (dose relevant) dust concentration of 44 µg/m^3 only contributes to the public dose 36 per cent of the year, so this fraction is considered in the public dose calculation. Also, the dust concentration during times when the wind is blowing towards the mine site (31 µg/m^3) can be considered to be a baseline measurement, and the corresponding dose can be subtracted as it is not mining related. The outcome is summarised in Table 4. In this table, all measured PM_{10} dust concentration values from 2011 to 2013 were considered – including the elevated concentrations measured between May and October 2012. This is valid as those dust concentrations that would have resulted from roadworks (to the west of the monitoring station) are now automatically excluded because they are not correlated with wind that is blowing from the mine site towards the monitoring station.

Table 4: Public dose due to measured dust concentrations at the western mine boundary for four dust composition scenarios, in µSv/a

Dust composition scenario	Scenario A	Scenario B	Scenario C	Scenario D
Dose in µSv/a	7	5	1	0.02

When accounting for wind direction, the resulting public dose at this monitoring station on the western mine boundary is calculated to be trivial, i.e. less than 10 µSv per annum for any of the scenarios considered.

This correlation method and the calculation of a resulting dose is nevertheless an oversimplification: the same volume of air is moving back and forth as the wind direction changes, so that dust exposure during upwind conditions may still contain amounts of dust blown from the Rössing mine site. Nevertheless, the dose assessment gives an indication of the impact on the public dose assessment when accounting for the wind direction at the monitoring station.

4.4 Comparison with baseline PM_{10} concentrations

The Strategic Environment Assessment [11] reported baseline PM_{10} concentrations in select locations. Unfortunately, these concentrations were based measurements for a period of 157 days only, so that the results cannot be expected to be statistically valid on an annual basis. In addition, the concentrations given were not measured directly in each of these locations but were obtained from air dispersion models based on fixed point monitoring in Swakopmund and Gobabeb for 157 days. The predicted baseline average PM_{10} concentrations from this approach are summarised in Table 5 for Swakopmund, Arandis and Gobabeb.

The corresponding baseline annual dose is also given in Table 5 assuming two scenarios with an average 'grade' of uranium in dust of 2 ppm and 7 ppm respectively. In addition, an unrealistically high grade of 70 ppm is also included as a third scenario for the purposes of comparison. Finally, a comparison is also made with the hypothetical dose that would result if the dust inhaled at these locations were pure Rössing uranium ore dust at 300 ppm. The average grade of uranium in the Erongo Region's dust is not known but can be expected to be less than the values measured in Arandis and on the western Rössing mine border, i.e. less than 7 ppm.

Table 5: Baseline PM_{10} concentrations reported for select locations and corresponding total inhalation dose to adult recipients

	Swakopmund	Arandis	Gobabeb
Average PM_{10} dust concentration, µg/m^3, after [11]	46	65	20
Dose in µSv/a (assuming 2 ppm uranium)	**0.5**	**1**	**0.2**
Dose in µSv/a (assuming 7 ppm uranium)	**2**	**2**	**1**
Dose in µSv/a (assuming 70 ppm uranium)	12	17	5
Dose in µSv/a (assuming 300 ppm uranium)	68	96	30

Compared to the dose calculated in Section 4.1, and as calculated under Scenario A and Scenario B in sections 4.2 and 4.3, the background dose contributions are negligible and can be disregarded (i.e. the dose estimates in Table 5 given in bold). A valid dose assessment can therefore be obtained by assuming the background dose to be zero.

5. Other risks associated with tailings dust

The discussion in the previous sections has demonstrated that the inhalation risk from wind-blown tailings material is negligible, i.e. at most a few tens of µSv/a, but realistically even less than that.

Other risks from this material include:

1. Dispersion of the material and subsequent runoff through rainstorm activity into the Khan River,
2. Impact on biodiversity as plants are smothered by dust,
3. Radon emanation from tailings dust covering areas surrounding the TSF, and
4. Direct irradiation from distributed tailings material.

5.1 Runoff of material into the Khan River

As specified in the Rössing Uranium Closure Management Plan [2], the material from the TSF is subject to capping, so that fresh material deposited onto the TSF forms a solid crust after a period of a few months. After this, very little material can be mobilised by wind from this surface.

This means that it is the freshly deposited and dried material on the TSF that is most likely to be mobilised by wind. Dust that is deposited in the dust plumes to the west of the TSF (see Figure 3) generally also forms a hard surface crust within a few months. An example of this is shown in Figure 8, where the hardened surface of tailings dust accumulated at the base of vegetation is evident.

Dust that has been deposited in the plume during the season of east wind tends to have formed a hard crust by the time the next east wind season occurs, and very little further distribution of this material then occurs through wind erosion.

Further mobilisation of this material now occurs through water erosion during infrequent rainstorm events, which collect dust from the surface and accumulate the material in gullys. Water erosion therefore collects material which was distributed in a thin layer on the surface and gathers it in small accumulations in lower-lying areas.

Figure 8: Hardened surface of tailings dust accumulated at the base of vegetation is evident.

As rainfall in the desert is rare, transportation of material in this manner is very slow; it would therefore take hundreds of years before material would be able to reach the Khan River. The eventual transportation of material into the Khan River through water erosion will in any case be prevented by collecting any visible accumulations of material from this area after mine closure.

The material gathered in this clean-up will be deposited on the TSF before its surface is covered with a protective rock layer, which will prevent further material being transported into the environment. The rock layer on the TSF is also intended to reduce the radon emissions from its surface to below the levels required for public occupation.

5.2 Loss of biodiversity from tailings dust

Plant material in the desert is covered with dust during each occurrence of strong desert winds. The impact on desert biota from the additional dust in the environment from the TSF could result from:

- direct irradiation of plants from dust deposited, and
- dust deposition resulting in suffocation of plants.

The content of radioactive material in tailings dust is very low and is similar to that of the uranium ore dust from which it originated. For comparison, the radioactivity in pure Rössing Uranium tailings dust is approximately 50 Bq/g, in contrast to about 60 Bq/g for uranium ore dust from the Rössing Uranium Crushing Circuit.

The dose rate associated with thin layers of tailings dust on plants is therefore insignificant as the additional dose from such low level radioactive dust is not measurable relative to the dose accountable to background radiation in the area. Thus there can be no loss of biodiversity as a direct result of irradiation by tailings dust in the environment.

The potential impact on plants, if any, would therefore arise from fallout dust, which might suffocate plants. Fallout dust in the vicinity of the TSF is measured monthly at a number of receptor locations, including locations to the north-east and to the south-west of the TSF, consistent with the prevailing strong wind directions. The fallout at locations beyond the perimeter of the mining site is measured to be well within accepted standards for residential occupancy, such as the South African dustfall standard, i.e. 600 mg/m^2/day [12].

The maximum fallout measured in any month at the boundary fallout monitoring station was 36 mg/m^2/day, with representative values between 10 and 20 mg/m^2/day. This is a fallout rate that will not result in any additional risk of suffocation to desert plants as baseline fallout rates are comparable to this. For example, the baseline fallout rate measured during the SEA [11] for the Erongo Region was found to range between a few mg/m^2/day to some extreme incidents exceeding 600 mg/m^2/day, during events of high wind velocity.

5.3 Radon emanation from tailings material

Whilst the surface of the TSF represents the area with the highest radon exhalations anywhere in the Rössing mining area, small amounts of tailings material in the environment do not contribute significantly to an increase in radon concentrations in the environment.

This has been demonstrated in a recent radon survey conducted at Rössing Uranium [13], which demonstrates that radon concentrations outside the source areas (i.e. the TSF, the SJ Pit, and the waste rock dumps) drops to environmental background concentrations within a few hundred metres of the areas in question.

A three-dimensional representation of the measured radon concentrations is shown in Figure 9.

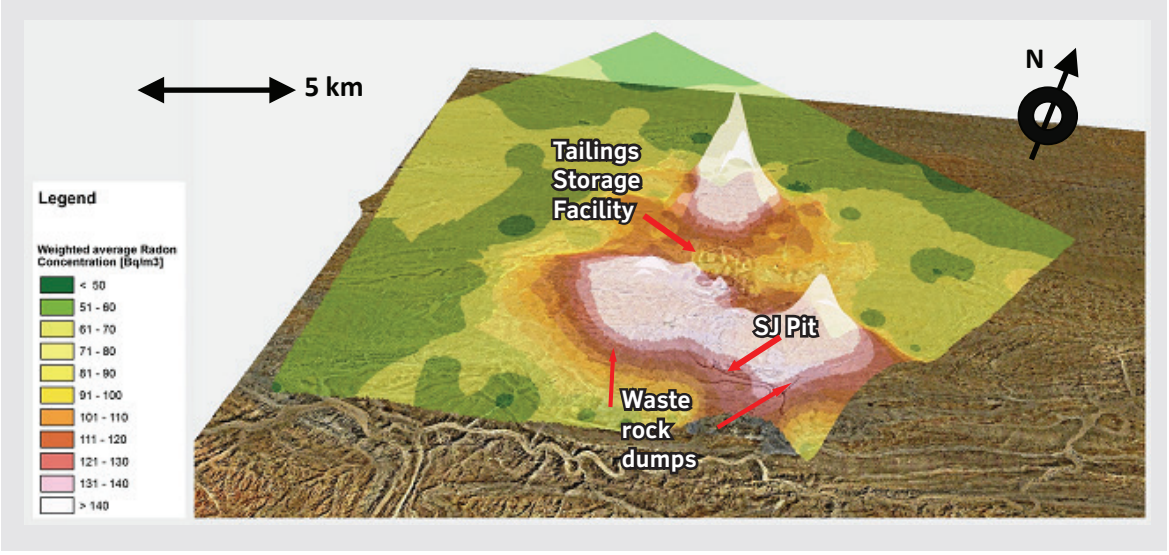

Figure 9: Three-dimensional representation of radon concentrations at Rössing Uranium

5.4 Direct irradiation from distributed tailings material

Direct irradiation on the surface of the TSF results in a dose rate of approximately 1 µSv per hour. With small accumulations of tailings material such as exist in the tailings plumes, the dose rate is not measurably different from the background dose rate for this area, which is about 0.2 µSv/h. Even where tailings material has accumulated in the wind shade of bushes, the amount of material is not sufficient to significantly affect the background radiation dose rate. Direct exposure from this material is therefore not regarded as a risk because the area of the tailings plume is not inhabited by people who could ingest significant quantities of this material or be exposed to increased gamma radiation levels as a result of accumulated material.

6. Summary and conclusions

Public dose assessments are typically based on calculated values, which are underpinned by various assumptions. The validity of such assessments depends, to a large extent, on the appropriateness of the actual measurements made in support of the calculated values.

The calculated values obtained from making worst-case assumptions about the composition of the measured PM_{10} dust can be regarded as representing an upper limit to the actual public dose. The measurements and corresponding calculations are summarised in Table 6:

Table 6: Summary of public dose from inhalation of radioactive dust of Rössing Uranium origin

Public dose on western mine boundary, in µSv/a	Based on measured PM_{10} concentrations, assuming all dust is mining related, and using all measured dust concentrations from 2011 to 2013	Based on measured PM_{10} concentrations, but using 12 months not affected by roadworks in the mine vicinity	Based on 'downwind' conditions only	Based on dispersion models, Arandis area, from the SEA report
Maximum (Scenario A, ore dust)	53	27	7	2
Minimum (Scenario D, mixture of ore dust and background dust)	1	1	0.02	

The maximum value obtained in this report for the public dose downwind of the TSF, and assuming the maximum possible radioactivity of this dust, is 53 µSv/a. This value almost certainly overestimates the public dose as the real radioactivity of the dust will be considerably less, and the dose value includes all contributions from background sources. It is also notable that the maximum dose is only 5 per cent of the public dose limit (1,000 µSv/a) and therefore not of significance.

Apart from the accumulation of tailings dust material, which will be collected and disposed of in the TSF on closure, risks to people and the environment from tailings material dispersed by wind erosion are therefore negligible.

7. References

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