Rio Tinto

Rössing Uranium Limited
Working for Namibia

Rössing Uranium mine's tailings dust: What is the risk?

Effective date 30/03/2015

Author Gunhild von Oertzen

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 potential risks to the public from wind-blown tailings material may include:

- inhalation of tailings dust,
- dispersion of the material into the environment and subsequent runoff into the Khan River, contaminating the groundwater supply,
- increase in radon emissions from the distributed dust,
- direct irradiation to people and animals from the tailings material on the ground, and
- biodiversity loss as a result of plants being smothered by dust.

This report aims to quantify each of these risks by providing an upper limit to the potential impact of each.

Acronyms and abbreviations

The following acronyms and abbreviations are used in this report:

Bq – becquerel, disintegrations per second, unit for radioactivity
μg/m^3 – micro-grams per cubic meter, i.e. 10^{-6} grams per cubic metre
μSv – micro-sievert, i.e. 10^{-6} sievert
μSv/a – micro-sieverts per annum
Bq/g – becquerels per gram
ha – hectare, i.e. 10,000 square metres
mg/m^3 – milli-grams per cubic metre, i.e. 10^{-3} grams per cubic metre
PM_{10} – particulate matter less than 10 micro-metre in diameter, i.e. smaller than 10^{-6} metre
Sv – sievert, unit for radiation exposure dose
TSF – Tailings Storage Facility

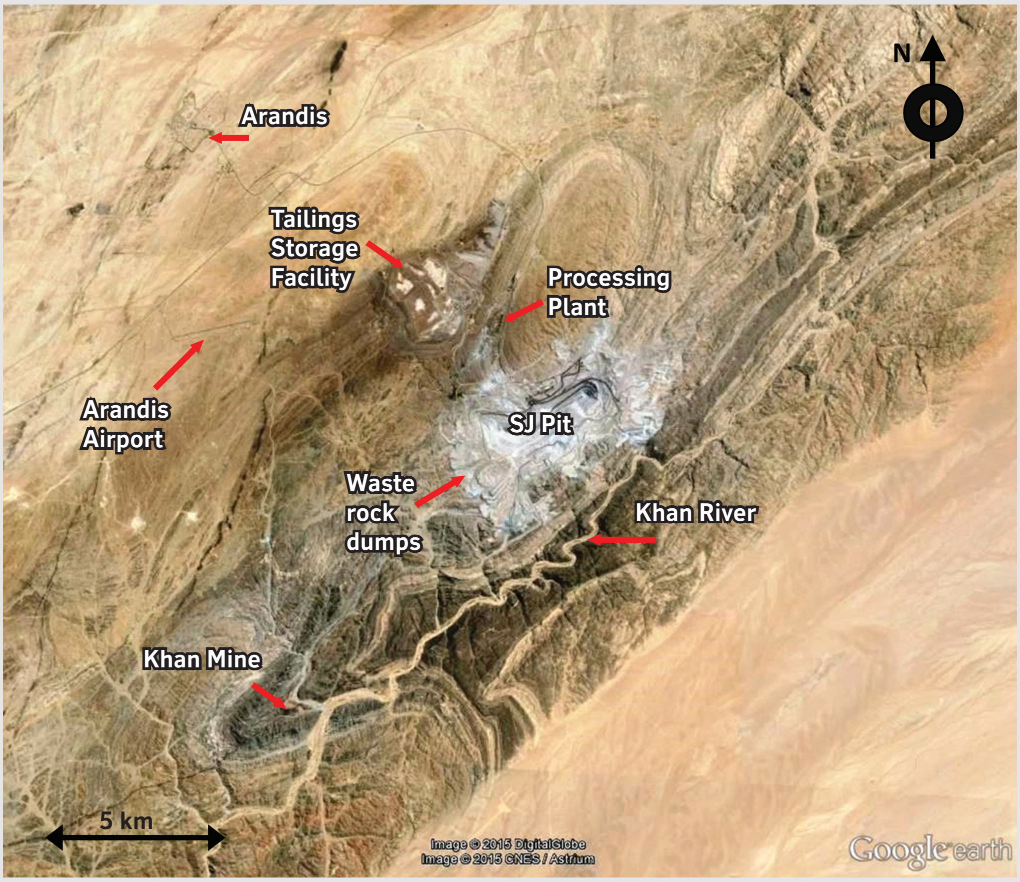
Contents

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, 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.

A satellite map of the area is shown in Figure 1.

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.



At the Rössing Uranium Processing Plant, uranium is leached from the ore and transferred into solution. The material remaining after uranium has been extracted is referred to as tailings and is deposited on the TSF. After almost 40 years of mining, the Rössing Uranium TSF contains roughly 400 million tonnes of tailings material. The surface of most of the TSF is dry, allowing wind to transport surface dust from the TSF into the surrounding areas.

Prevailing wind directions at the TSF are in a north-east-east (NEE) direction during autumn and winter (mid-March to mid-September), and in a south-west-west (SWW) direction during autumn (mid-March to mid-June) and spring (mid-September to mid-December) [1].

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 2, 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.

Public dose assessments performed during the various phases of mining activity at Uranium Rössing have consistently estimated the risk associated with tailings (or other mining-related) dust to be significantly below the public dose limits (see references [3], [4], [5], [6], [7] and [8]).

In the next section of this assessment, we will list and quantify the potential risks associated with wind-blown tailings dust.

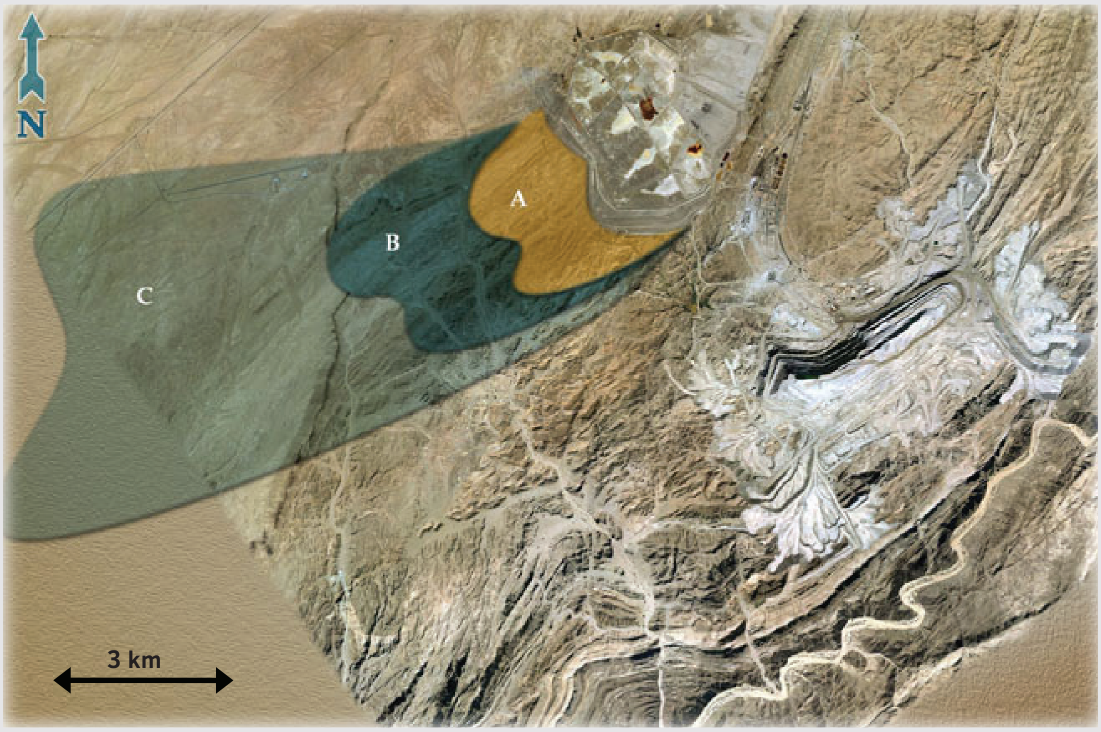


Figure 2: Dust plumes originating from the TSF, after [2].

2. Risk assessment

2.1. Inhalation of tailings dust

Dust content in air is generally of two types: larger particles which can be regarded as a nuisance but are not hazardous to health, and particles which are small enough to be inhaled and hence potentially present a health risk. The latter is referred to as PM_{10} dust, as these particles are smaller than 10 micro-meters (mg/m^3 or $\mu g/m^3$).

The concentration of this type of dust in air is measured in milli-grams or micro-grams per cubic metre. The radiological risk presented by a particular PM_{10} concentration depends on the content of radioactive elements in this dust and is measured in terms of inhalation exposure dose, in dose units per time period. The typical unit for this inhalation dose is micro-sieverts per annum (µSv/a), i.e. a millionth sieverts per annum.

Public dose assessments present a radiological risk assessment for members of the public. This is done by calculating the radiation exposure dose for that group of people that is expected to receive the highest possible dose from a particular agent, typically referred to as the critical group. This dose assessment is then compared with the legal dose limit for members of the public, which is 1 milli-sievert per annum (mSv/a), i.e. 1,000 micro-sieverts per annum (µSv/a) [9].

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 mining operations. There, the highest public dose from the inhalation of radioactive dust for any recipient group is calculated for a hypothetical critical group located at the old Khan Mine, approximately downwind of the tailings area under east wind conditions.

The dose for the dust inhalation pathway and this critical group is assessed to be 84 μSv/a. The second highest public dose (46 μSv/a) is calculated for 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].

Now, we'd like to directly link the public dose assessment to air quality monitoring results: 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 (shown in Figure 3), as this station is directly down of the TSF during the strongest wind events in this region.

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 3 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 between September 2011 and September 2013 is shown in Figure 4. The average PM_{10} dust concentration over this period was measured to be 36 μg/m^3 (the high-dust events represented by narrow peaks in the graph are likely due to short term local dust generation, for example due to building activity, as they are not linked to high wind speeds).

Using a worst case scenario – that the dust sampled at this location is exclusively ore dust from the Rössing mine site – this average dust concentration would result in a public dose of 53 micro-sieverts per annum (μSv/a) per person living at this receptor location.

This dose assessment is consistent with the result obtained from dispersion models using data on mining

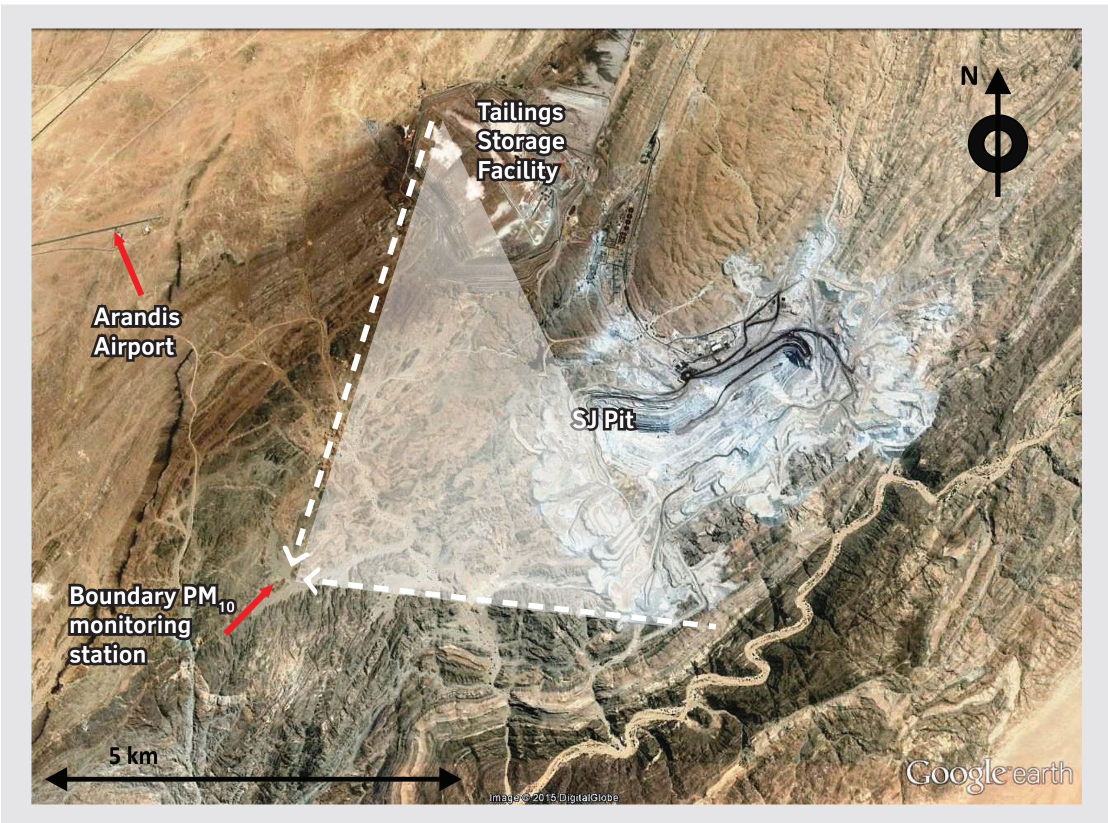


Figure 3: Rössing mine site, with position of boundary PM_{10} monitoring station indicated. The wedge formed by white directional arrows represents the range of potential wind directions at the boundary station leading to dust concentrations that are related to mining activities at Rössing Uranium.

activities, i.e. between 46 and 84 µSv/a, depending on exact location [8].

In reality, the dust found at the boundary comprises tailings and ore dust from the mine site mixed with environmental dust naturally occurring in this area. A better estimate of the dose attributable to mining-related dust is therefore obtained when the wind direction at the time of each measurement is correlated with the direction of the mine, as indicated in Figure 3.

In other words, only if the wind direction is from the mine site will the dust concentration contribute to a public dose; if the wind is blowing from the opposite direction, the dose is associated with naturally occurring environmental dust.

When this is done with the measurements available over the period September 2011 until September 2013, it is found that the average dust concentration at the monitoring station is 44 µg/m^3 when the wind direction is from the mine site and 31 µg/m^3 during all other times. This means that the average excess concentration at this location (i.e. attributable to mining-related activities) was only 13 µg/m^3 over the monitoring period.

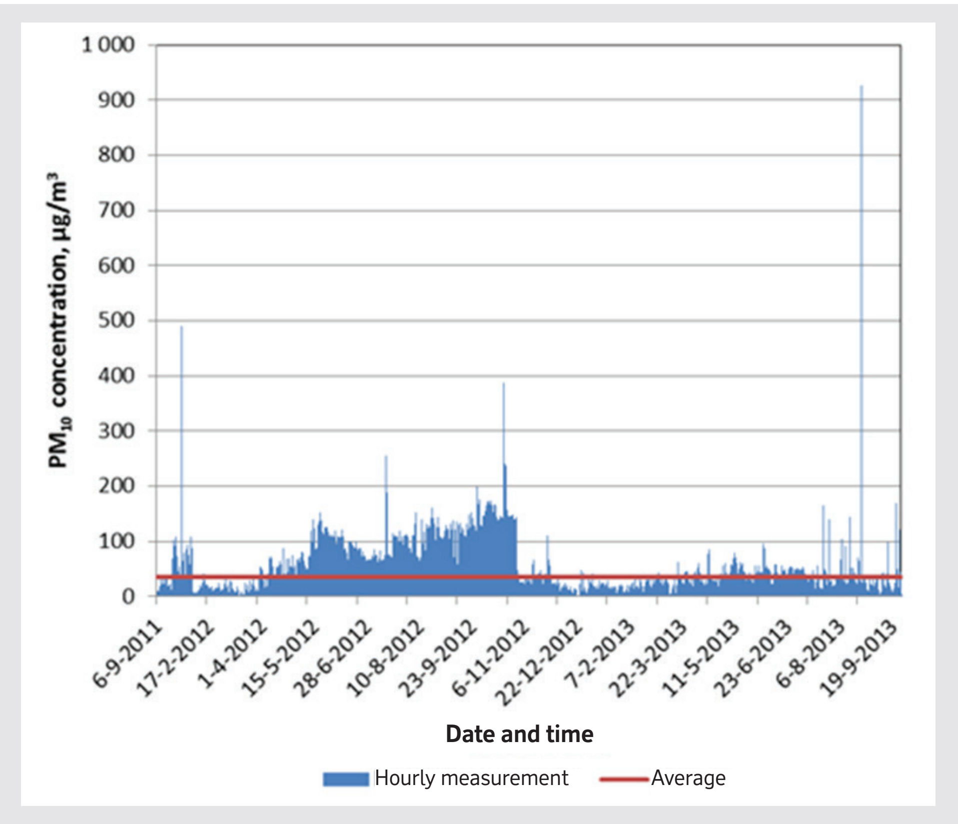
Based on this excess PM_{10} concentration, weighted with the number of hours the wind is blowing from the mine site rather than in the opposite direction, the resulting public dose is calculated to be 7 µSv/a, which is negligible.

In any case, the worst case scenario – i.e. assuming all dust measured at the boundary station is ore dust from the mine site – still leads to a public dose of only roughly 50 µSv/a, very low compared to the public dose limit of 1,000 µSv/a.

The average dust concentration at Arandis is significantly lower than it is at the boundary monitoring station; it was measured to be 11 µg/m^3 in 2014 [12]. The public dose at Arandis can therefore be expected to be significantly below that measured at the boundary monitoring station, which is uninhabited.

This means that the public dose due to the inhalation of mining related dust at any receptor location is negligible and of no concern.

Figure 4: PM_{10} dust concentration in hourly intervals, between September 2011 and September 2013.



2.2. Dispersion of the material into the environment

According to reference [2], dust plumes accumulating to the west of the TSF can be grouped into coarse, fine, and very fine particles. Only coarse particles can contribute significantly to surface accumulation of tailings dust in the environment. The coarse dust plume extends to the south-east of the TSF to a distance of roughly 2 km (see Plume A in Figure 2).

The transportation of particles from the TSF occurs through wind action, particularly during east wind events. Tailings material forms a hardened crust within about one year of formation, so that additional mobilisation by wind is then minimal.

In addition to wind erosion, coarse dust is also subject to water erosion during the infrequent desert rain storms. These latter events lead to distributed tailings material collecting in gulleys and waterways. After mine closure, these visible accumulations of dust will be removed from Plume A so that eventual runoff into the Khan River is prevented.

Fine and very fine dust particles from plumes B and C do not accumulate in measurable quantities in the environment. Their identification and removal is therefore not possible but apart from the inhalation risk discussed above, they do not pose any environmental risk.

2.3. Radon emissions from the distributed dust

Radon concentrations were measured across the Rössing Uranium mine site and surrounding areas from 1987 to 1988 [10], and again from 2010 to 2013 [11].

Both surveys arrived at similar results for the radon concentrations across the mining site and surrounding areas. They also demonstrated that the additional radon emitted into the air as a result of mining activities is restricted to the areas directly affected by mining, in other words the SJ pit and waste rock dumps, as well as the TSF.

This is demonstrated in Figure 5, which displays a three-dimensional contour map of radon concentrations. The TSF is seen to be the area with the highest radon concentrations, followed by the SJ pit and waste rock dumps. Beyond these, the radon concentrations fall off to background levels within a few hundred metres. Thus the small accumulation of tailings dust in the dust plume to the west of the TSF does not measurably contribute to the radon concentrations in that area.

Radon concentrations in select locations can be measured more accurately than was done in the area surveys ([10] and [11]), and the wind direction can then be correlated with measured radon concentrations. This is done at the NamWater reservoir at Arandis, where a radon monitoring station measures radon concentrations some 6 m above the ground at intervals of 10 minutes.

It has been established that at that location, the wind direction and radon concentrations are not correlated (see reference [12]). In other words, at the radon monitoring station at the water reservoir, which is located some 2.8 km to the north from the edge of the TSF, the measured radon concentrations are not related to mining activities despite the proximity to the site.

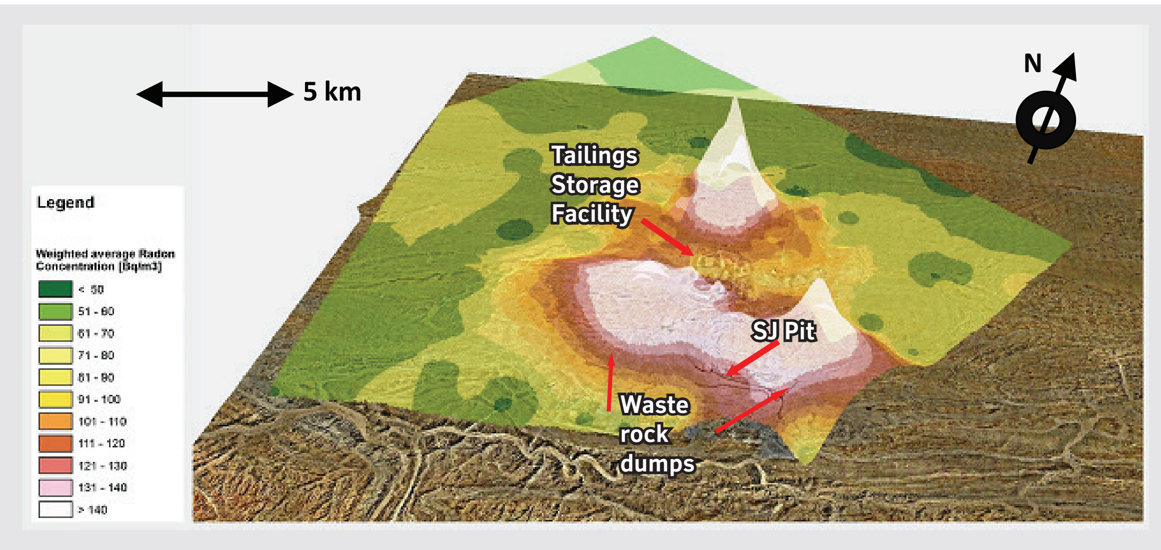


Figure 5: Three-dimensional representation of radon concentrations at Rössing Uranium.

2.4. Direct irradiation from the tailings material on the ground

As discussed in Section 2.2, only the coarse tailings particles that form dust Plume A to the west of the TSF result in visible accumulations. An example is shown in Figure 6, where the lighter grey tailings material accumulating at the base of a dollar bush (Z*ygophyllum stapffii*) is contrasted against the naturally occurring brownish material.

The largest dust accumulations occurring in this area are no more than ½ m deep and extend no more than 100 metres across at the widest part.

For a tailings sand or dust accumulation of this size, the gamma dose rate to people visiting the area is insignificant, i.e. of the order of less than 1 µSv for a visit of one full day. As the area is not, and will not, be inhabited until mine closure, there is no measurable direct irradiation to people from the dust accumulated in Plume A to the west of the TSF.

2.5 Biodiversity loss as a result of plants being smothered by dust

As discussed in Section 2.1, the amount of mining related PM_{10} dust blown across the borders of the mining area in the period 2011 – 2013 was minimal, i.e. only 7 µg/m^3, compared to the naturally occurring environmental dust concentration in the area, which is 31 µg/m^3.

Plant material in the desert is covered with dust during each occurrence of strong desert winds. The amount and characteristic deposition of dust on plants does not differ significantly between tailings dust and any other dust (e.g. ore dust or background dust).

The content of radioactive material in tailings dust is very low – the radioactivity in pure Rössing Uranium tailings dust is approximately 50 Bq/g, in contrast to about 60 Bq/g for ore dust from the Rössing Crushing Circuit.

Plants covered by tailings dust are therefore not expected to be affected more detrimentally than plants covered with any other dust. The tailings plume does not therefore introduce additional risk to plants.

Figure 6: Wind-blown tailings dust accumulates at the base of plants close to the TSF, seen as grey material surrounding the dollar bush at the centre of the image.

3. Summary and conclusions

We have discussed – and where possible and necessary quantified – the potential risks associated with tailings dust blowing from the TSF surface into the environment. The risks can be summarised briefly:

- Inhalation of tailings dust – this dose is negligible (less than 10 μSv/a), when taking into account the amount of inhalable dust in the air that is directly related to mining activities.
- Dispersion of the tailings material into the environment and subsequent runoff into the Khan River, contaminating the groundwater supply – visible accumulations of dust will be collected after closure, which will prevent any runoff into the Khan River aquifer.
- Increase of radon emissions from the distributed dust – radon concentration increases as a result of mining activities are concentrated in the immediate vicinity of the mine and do not reach any public receptors close to the mine.
- Direct irradiation to people and animals from the tailings material on the ground – the accumulation of dust in the environment from the TSF is insignificant where direct irradiation to people is concerned.
- Biodiversity loss as a result of plants being smothered by dust – desert plants are adapted to the high dust concentrations found in their environment and are not significantly affected by additional dust being blown from the TSF.

4. References

[1] Thomas, R.G. (2007): *Air Quality Impact Assessment for the Proposed Expansion Project for Rössing Uranium Mine of Namibia: Phase* 1, Airshed Planning Professionals.

[2] Rössing Uranium Limited (2011): *Closure Management Plan*.

[3] de Beer, G.P. (1990): *Estimation of the Average Radiation Dose to the Population of Arandis from Radioactivity Originating from Natural as well as Mining Related Sources*, AEC of SA.

[4] Isaack, J. D. (2001): *Preliminary Post Closure Radiological Safety Evaluation for Rössing Uranium Mine*.

[5] de Beer, G.P, Ramlaken, A. and Schneeweiss, R. (2002): *An Assessment of the Post-Closure Radiological Impact of Rössing Uranium Mine*, Nuclear Energy Corporation of South Africa.

[6] de Beer, G.P and Ramlaken, A.J. (2003): *Post Closure Public Dose Assessment for the Phase III Expansion of the Rössing Uranium Mine*, Nuclear Energy Corporation of South Africa.

[7] de Beer, G.P and Liebenberg, G.R. (2008): *Dose Assessment for a Life-of-Mine Extension (LOME) of the Rössing Uranium Mine*, Nuclear Energy Corporation of South Africa.

[8] de Villiers, D. and de Beer, G.P. (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*, Nuclear Energy Corporation of South Africa.

[9] Ministry of Health and Social Services (2011): *Radiation Protection and Waste Disposal Regulations*: Atomic Energy and Radiation Protection Act, 2005 (Act No. 5 of 2005).

[10] Grundling, A. and Leuschner, A.H. (1988): *An investigation of 222Rn concentrations at Rossing Uranium Limited. A report for the period October 1987 to September 1988*, AEC of SA.

[11] von Oertzen, G.U. and Schneeweiss, R. (2013): *Baseline and Mining Related Radon Concentrations in the Rössing Mining Area*, Rössing Uranium Limited.

[12] Rössing Uranium Limited (2014): *Implementation of Radiation Management Plan, 2014 Report*