Rio Tinto

Rössing Uranium Limited
Working for Namibia

Report: Risk Assessment on the Rössing Uranium Waste Rock Dump Site bordering the Khan River

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Author G von Oertzen
Reviewed by R Schneeweiss

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Abbreviations

The following abbreviations are used in this report:

μSv – micro-sievert, ie 10^{-6} sievert
μSv/h – micro-sieverts per hour
mSv – milli-sievert, ie 10^{-3} sievert
mSv/a – milli-sieverts per annum
Bq/m^3 – becquerels per cubic meter
SEA – Strategic Environment Assessment

1. Introduction

Rössing Uranium Limited is an open pit uranium mine located in the Namib Desert. The area disturbed by mining activities is about 2,300 ha in extent, a significant portion of which is made up of waste rock dumps close to the large open pit (SJ Pit, see Figure 1).

The Rössing mine site is situated close to the Khan River, a popular tourist destination. Whilst most of the mining area is not accessible to the public as it is fenced and the terrain is remote, one of the waste rock dumps, W7, is located in Dome Gorge and the rock face is close to the Khan River (see circled area in Figure 2).

The Waste Rock Dump W7 in Dome Gorge is fenced off from the Khan River, and is not accessible to the public. Figure 3 shows the area of the rock face, with Dome Gorge clearly distinguished from the Khan River by its colour (the riverbed in Dome Gorge has a slightly bluish tint, whereas in the Khan River the sand is grey).

The purpose of this report is to provide a public dose assessment for the access restricted area directly bordering the Waste Rock Dump W7 in Dome Gorge, up to the opening of Dome Gorge into the Khan River.

Figure 1: Rössing mine site including the SJ Pit, Waste Rock Dumps (lighter grey areas surrounding the pit) and Tailings Storage Facility. The Khan River is located to the south-east of the site. (Source of map: Google Earth)

Figure 2: Location of waste rock dumps relative to the SJ Pit. The purple-coded Waste Rock Dump W7 borders the Dome Gorge. The Dome Gorge confluence with the Khan River is circled in red. (Source of map: Google Earth)

2. Radon characteristics at Rössing Uranium

Radon is a radioactive gas formed as part of the uranium decay chain (see for example [1] for a simple overview of the uranium decay chain). Radon occurs everywhere on Earth but its concentration in air depends on the uranium content of the soil: the higher the uranium content of the soil, and the higher the permeability of the soil, the higher the potential for radon to be emitted into the air.

Radon is a noble gas with a half-life of roughly four days. When it decays, a series of very short-lived solids are formed, which are referred to as ‘radon progeny’. Radon and its progeny present a radiation exposure risk because of the potential for radon progeny to be attached to the human lung. Radioactive decay of radon progeny in the lung is a recognised cause of lung cancer worldwide [2], and remediation of public spaces high in radon is therefore an important consideration.

Because of the volatility of radon, its concentration in air strongly depends on environmental conditions such as wind, humidity, temperature, and suspended particulates. Any radon monitoring programme is therefore subject to considerable measurement variability if the measuring period is too short or if conditions are variable between different measurement samples.

Figure 3: Waste Rock Dump W7 in the Dome Gorge facing the Khan River. (Source: Google Earth)

At Rössing Uranium, a three-year survey project designed to measure the radon concentration distribution on and around the mine site [3] was completed in 2013. A map displaying the monitoring positions in the Khan River is shown in Figure 4. The reader is referred to the Rössing Uranium documents *Radiation Management Plan* [4] and *Annual Radiation Report to Authority* 2013 [5] for a short summary of the survey activities and results. The survey included the stretch of the Khan River close to the mine site and radon monitoring there revealed average radon concentrations of between 46 and 68 Bq/m^3, with an average for all monitoring locations in the Khan River of 57 Bq/m^3. It should be noted that the radon survey at the Rössing mine site was conducted using radon track etch cups placed 1 m above the ground.

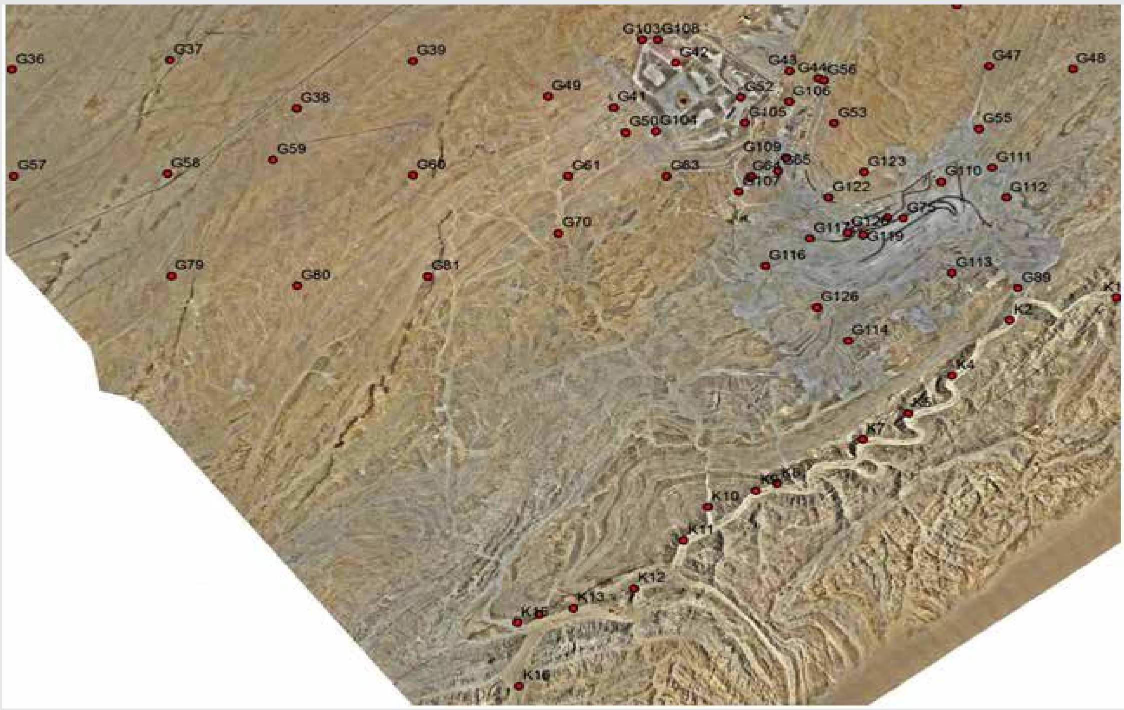


Figure 4: Rössing Uranium radon monitoring grid, 2011-2013, with monitoring stations in the Khan River denoted by the letter 'K'. (Source of map: Google Earth)

For comparison, the average radon concentration at the town of Arandis is 22 Bq/m^3, and at Swakopmund it is 11 Bq/m^3. Both averages were obtained over a three-year period from 2011 to 2014 using Saphymo™ AlphaGuard fixed monitoring stations placed some 5 m above the ground. The location of these fixed monitoring stations high above ground level will inevitably lead to significantly lower measured radon concentrations as the air higher up from the ground typically experiences more movement by wind and thermal convection. The measured radon concentration in the Khan River of 57 Bq/cm^3, and the measured concentrations in Arandis and Swakopmund of 22 and 11 Bq/m^3 respectively, can therefore not be directly compared to each other as they are not measured in the same way. As a general rule, the radon concentration is highest at ground level, and drops rapidly with distance from the ground.

According to the *Strategic Environmental Assessment (SEA) for the Central Namib Uranium Rush* [6], the average dose due to radon and progeny in the Erongo Region is 0.46 milli-sievert per annum (mSv/a), which corresponds to an average radon concentration of 21 Bq/m^3. (1) Measurements for the SEA were performed with track etch cups placed 1 m above ground level.

3. Radon monitoring in the Dome Gorge

For the radon concentration measurements in this report, two SARAD™ instruments were used: the Radon Scout and the DoseMan. Both instruments measure radon concentrations in air in Bq/m^3. Measurement error is generally large for lower radon concentrations (up to100 per cent for concentrations below 10 Bq/m^3) but becomes smaller for higher concentrations (up to 30 per cent for concentrations of 300 Bq/m^3 or higher).

Radon concentrations were measured for several days at each of 32 monitoring locations selected in Dome Gorge. Instruments were placed on the ground between rocks so as to capture maximum radon concentrations and avoid dispersion by wind; this method would lead to maximum radon concentrations as wind movement is lowest at ground level and local radon concentrations are relatively stable between rocks.

(1) An average equilibrium factor of 0.4 is used. This equilibrium factor is consistent with measurements made at the *Strategic Environment Management Plan* radon monitoring station at Arandis (operated by the Geological Survey of the Ministry of Mines and Energy) from 2011 onwards.

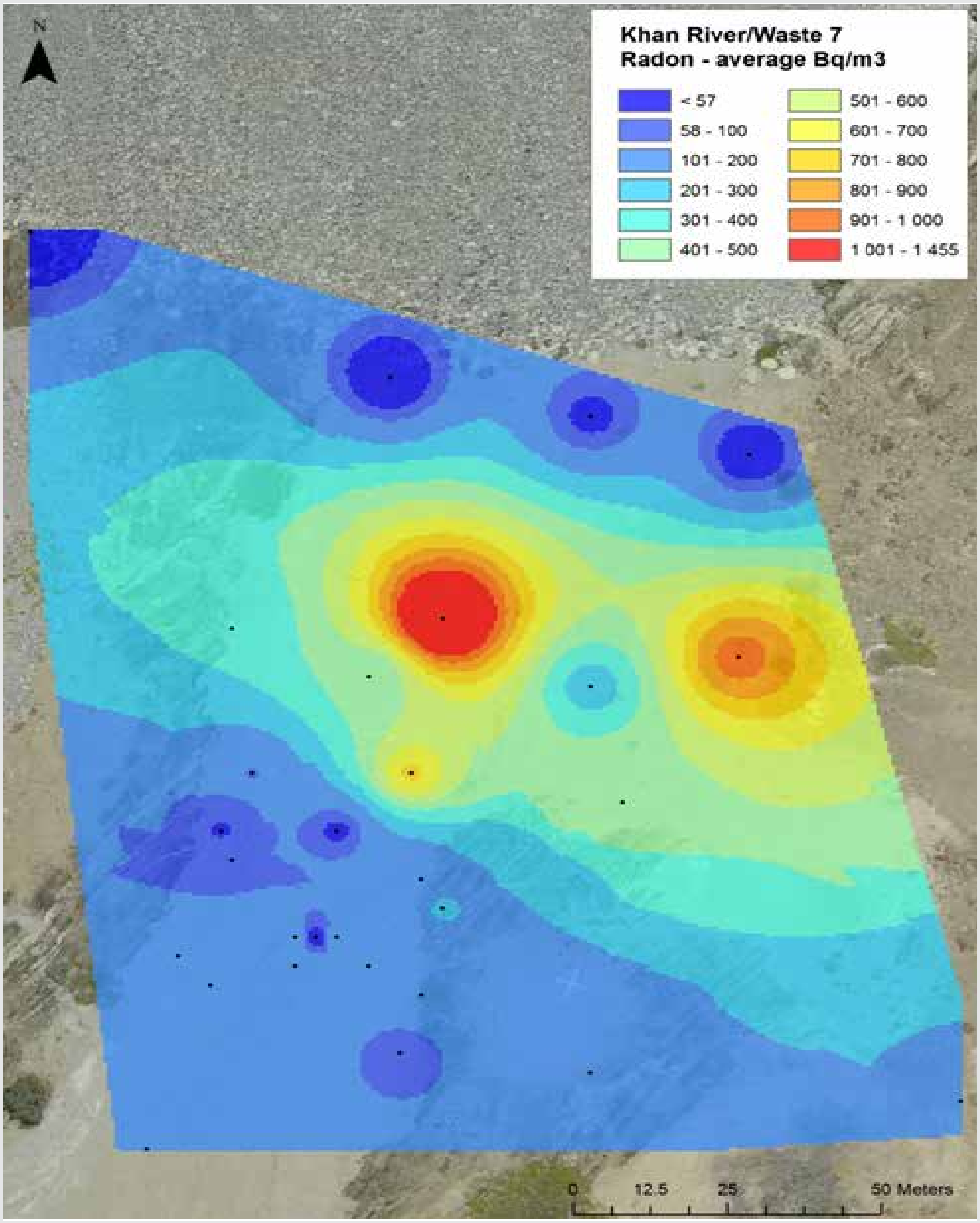
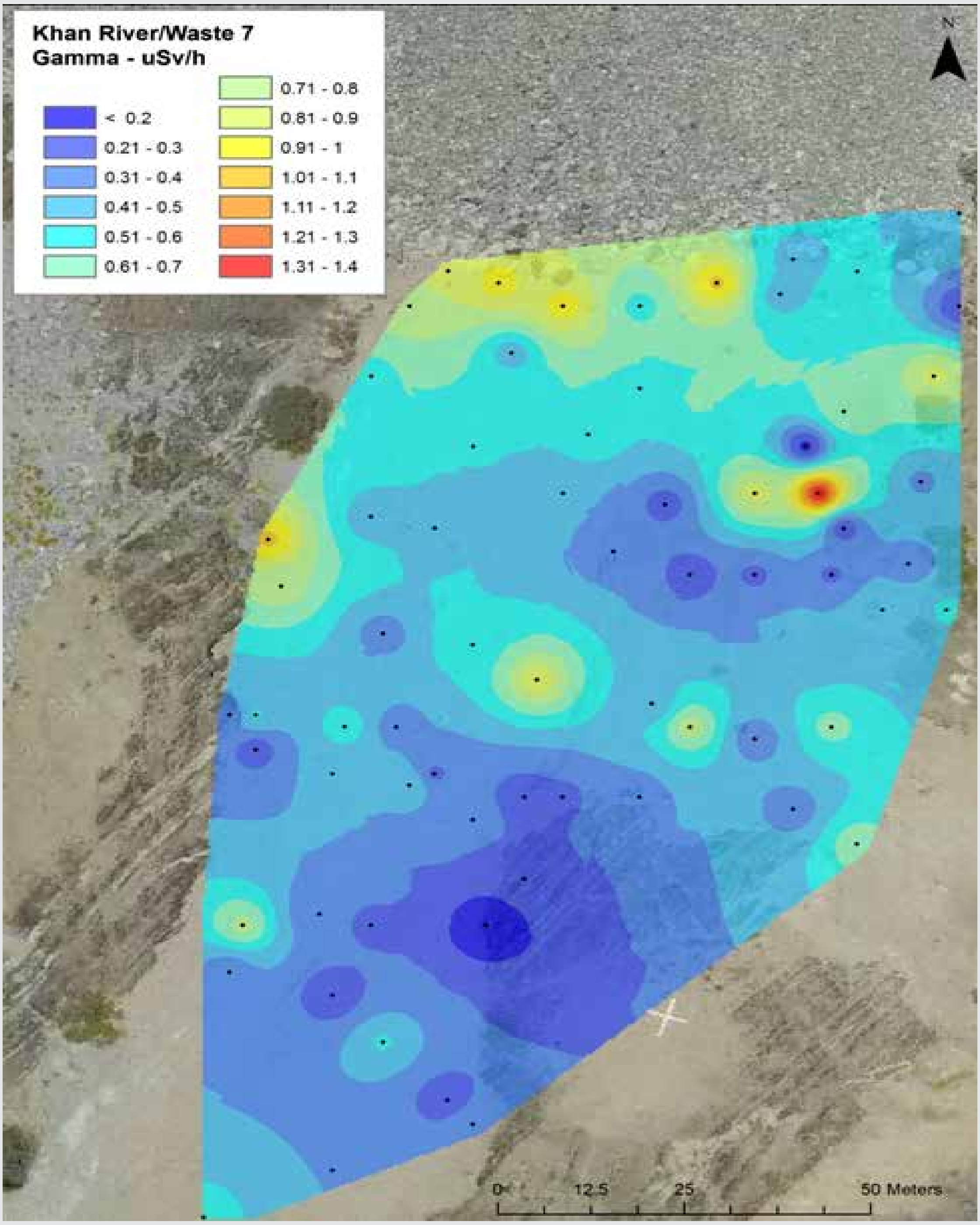


Figure 5: Waste Rock Dump W7 face in the Dome Gorge, with radon concentration contours superimposed. (Source of map: Google Earth)

The resulting 'radon concentration distribution' is displayed in Figure 5. It is evident that radon concentrations at most locations are similar to the background value for the Khan River (57 Bq/m^3) with two 'hot spots', ie localised higher concentrations, at the centre of the gorge. The public dose for visitors to this area therefore strongly depends on their exact location and mobility. Inevitably, actual inhaled radon concentrations will be significantly lower than the values measured here since measurements were not taken 1 m above the ground, the typical level at which inhalation would take place. Averaging the radon concentrations over all of these locations gives an approximate indication of the radon concentration in this gorge, giving an average concentration of roughly 230 Bq/m^3. The corresponding dose for a member of the public for two full days' of camping, for example, would be 27 micro-sievert (μSv), which includes the local radon background.

For comparison, the dose from a single lateral chest x-ray would be 40 μSv.

Figure 6: Gamma dose rate in µSv/h in the Dome Gorge, adjacent to Rössing Uranium's Waste Rock Dump W7. (Source of map: Google Earth)



Despite yielding an extremely low value, this public dose estimate must be regarded as a highly speculative worst case value because:

- Access to the area is restricted and camping there involves climbing the fence and trespassing,
- Measurements represent the maximum possible concentrations when measured on the ground and between rocks; air inhaled by a potential visitor at 1 m above ground level will therefore be of a lower radon concentration, and
- The radon concentration is extremely variable, and a better estimate would only be possible if radon measurements were averaged over a full year. This was done in the Rössing Uranium survey in the Khan River, yielding an average radon concentration there of 57 Bq/m^3. This radon concentration would lead to an inhalation dose of 7 µSv over a representative period of two full days, which can be regarded as natural background radiation.

Nevertheless, the calculated dose is extremely small compared with the public dose limit of 1,000 µSv and is therefore not regarded as a risk internationally. (See for example [8].)

4. Gamma monitoring in the Dome Gorge

In addition to the radon inhalation dose, a visitor to the Waste Rock Dump W7 in Dome Gorge would be exposed to gamma radiation from the waste rocks that could be expected to exceed the natural background gamma radiation in the area.

For monitoring purposes, a 'gamma radiation dose rate distribution' was produced using a Thermo™ Electra GM rate meter and by integrating the gamma dose rate on contact with the ground over a period of one minute for each of 70 locations.

The resulting distribution is shown in Figure 6. It is characterised by a few individual hot spots – which is to be expected in a granite-rich area. In addition, the waste rock dump face displays slightly elevated dose rates, as expected for waste rock from a uranium ore body. An average over all the monitoring points yields a dose rate of 0.5 ± 0.3 micro-sievert per hour (μSv/h). ([2]) Note that the 'average' dose rate depends on the spacing and selection of points and therefore only serves as a guidance value.

The average background gamma dose rate in the mountainous area bordering the Khan River close to Arandis may be obtained from the *Strategic Environment Assessment for the Central Namib Uranium Rush* [5], ie 0.2 μSv/h. The observed 'excess' dose rate in the Dome Gorge is therefore 0.3 μSv/h, equal to the standard deviation obtained for the average value above.

A person spending two full days in the area would therefore be exposed to an excess gamma dose of about 14 μSv, which is insignificant compared with the public dose limit of 1,000 μSv/a. In addition, dose rate measurements recorded in the area were obtained in contact with the ground; the typical dose rate a visitor would be exposed to would be lower as a representative location for the gamma dose rate would be 1 m above the ground.

5. Dose assessment based on monitoring results

Access to the Waste Rock Dump W7 in the Dome Gorge, close to the main riverbed of the Khan River, is restricted because it is affected by Rössing Uranium's mining activities nearby. However, a public dose assessment for the area can be made based on the measurements described above.

For a person camping in this area for two days, the excess dose from gamma radiation would be of the order of 14 μSv at most. In addition, the dose due to the inhalation of radon progeny could be expected to be up to 27 μSv, ie an excess of 20 μSv over and above the area natural background radiation dose of 7 μSv for that period. Thus, a typical maximum dose for a camping weekend could be around 34 μSv — meaning that a member of the public could undertake 29 camping weekends of this sort per year until the public dose limit of 1,000 μSv/a is reached. However, both the radon and the gamma dose experienced are likely to be much smaller because camping would take place in the open air, ie in well-ventilated conditions lower in radon, and because gamma radiation levels are highest on direct contact with the ground. The maximum public dose obtained for a two-day camping weekend is equal to the dose from one lateral chest x-ray and hence a dose of no concern.

[2] average ± standard deviation over all measurements

6. Summary and conclusions

Radon exhalation and gamma radiation are typical radiation risks in the vicinity of a uranium mine, and more specifically close to a waste rock dump such as W7 in Dome Gorge close to the main Khan River bed. For members of the public, the excess radiation dose over and above naturally-occurring background radiation must not exceed the public dose limit of 1,000 μSv/a, as specified, for example, in the *Radiation Protection and Waste Disposal Regulations* [7].

A representative two-day camping weekend is shown here to result, at most, in a public dose of 34 μSv, which is a dose of no concern. For example, the International Atomic Energy Agency regards an individual radiation dose, regardless of its origin, as trivial if it is of the order of a few tens of micro-sievert per year [9]. Remediation of the area for public occupation is not justified because illegitimate visits to the area are at most short term in nature, lasting not more than a few hours.

It must be noted that the dose estimates obtained here represent worst case assumptions, as radon concentrations and gamma dose rates were measured on contact with the ground, not at 1 m above the ground as would be the case of a real public exposure. In addition, Dome Gorge is not accessible to campers and hence public exposures from this activity are negligible.

7. References

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[4] Rössing Uranium Limited, *Radiation Management Plan*, Version 2.1, August 2014.

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