Rio Tinto

Rössing Uranium Limited
Working for Namibia

Implementation of Radiation Management Plan
Annual Report 2014

The Rössing Uranium Mine

Uranium was discovered in the Namib Desert in 1928, but it was not until intensive exploration in the late 1950s that much interest was shown in the area. After discovering numerous uranium occurrences, Rio Tinto secured the rights to the low-grade Rössing Uranium deposit in 1966. Ten years later, Rössing Uranium, Namibia's first commercial uranium mine, began operating.

Today, Namibia has two significant uranium mines, which together provide for 5.8 per cent of the world's uranium oxide mining output. Rössing Uranium produces 2.3 per cent of the world's uranium oxide production. The mine has a nameplate capacity of 4,500 tonnes of uranium per year and, by the end of 2014, had supplied a total of 127,405 tonnes of uranium oxide to the world.

The mine is located 12 km from the town of Arandis, which lies 70 km inland from the coastal town of Swakopmund in Namibia's Erongo Region. Walvis Bay, Namibia's only deep-water harbour, is located 30 km south of Swakopmund.

The mining operation is in a semi-desert environment. Insolation at Rössing Uranium is high, and as a result, daytime ranges of temperatures are wide, especially during June until August, when the difference between minimum and maximum temperatures exceeds 20°C daily. The lowest temperatures are normally recorded during August, but frost is rare. The highest temperatures are recorded in the late summer, particularly March.

The mine site encompasses a mining licence and accessory works areas of about 180 km^2, of which 25 km^2 is used for mining, processing and waste disposal.

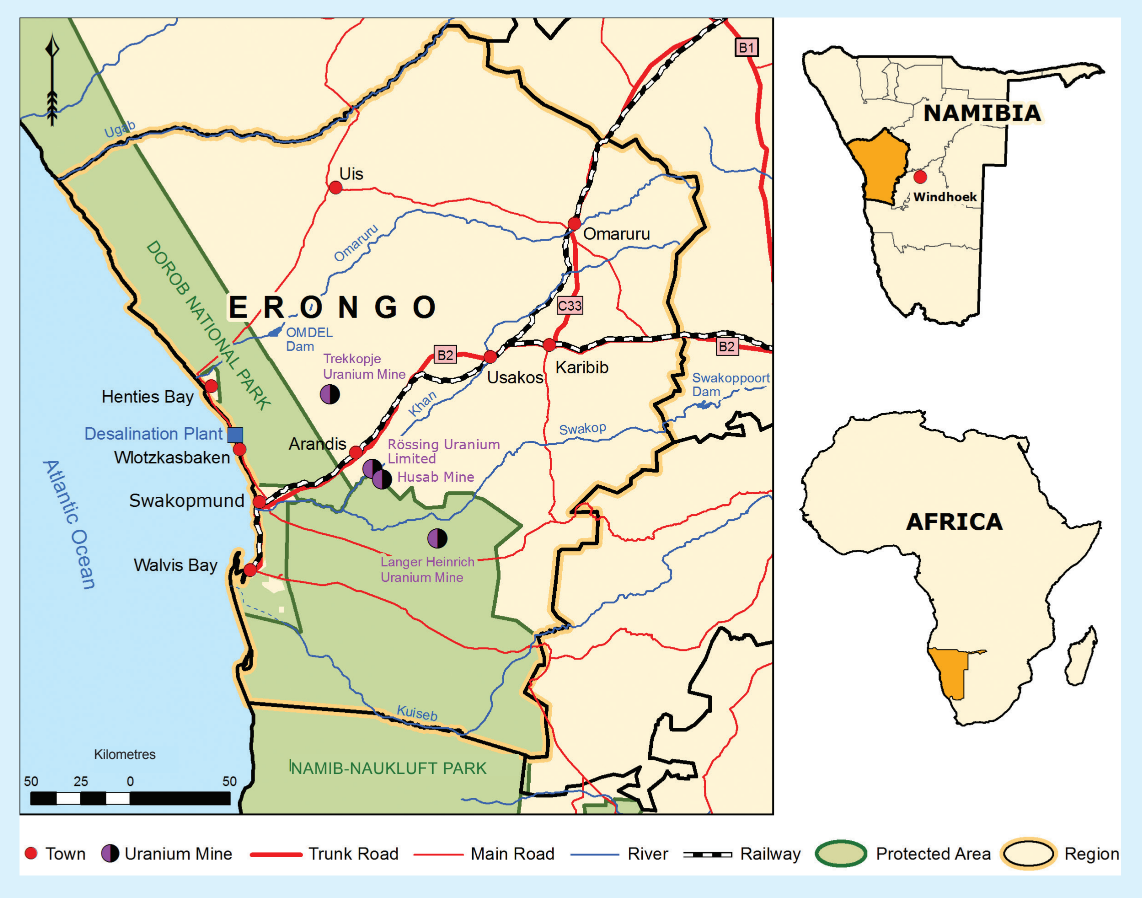
Mining is done by blasting, loading and hauling from the open pit, referred to as the SJ Pit, before the uranium-bearing rock is processed to produce uranium oxide. The open pit currently measures 3 km by 1.5 km, and is 390 m deep.

Our partnerships include individual citizens and their communities as well as non-governmental organisations, small-scale enterprises and multinational corporations. Thus, the benefits are felt locally, nationally, across the African region and internationally.

Shareholding

Rio Tinto owns the majority of shares (69 per cent) in Rössing Uranium Limited. The Namibian Government has a 3 per cent shareholding, but it has the majority (51 per cent) when it comes to voting rights. The Iranian Foreign Investment Company owns 15 per cent, a stake that was acquired during the set-up of the company in the early 1970s. The Industrial Development Corporation of South Africa owns 10 per cent, while local individual shareholders own a combined 3 per cent shareholding. The shareholders have no uranium product off-take rights.

Right: Map of the Erongo Region indicating the location of the Rössing Uranium mine.



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JK85/RMP/002
HSE MS Element 4

Effective date	**30/03/2015**
Version no.	**2.1**
Status	**Revision**
Author	**G. von Oertzen**

Acronyms and abbreviations

The following acronyms and abbreviations are used throughout the report:

µg/L	micro-grams per litre, 10^{-6} grams per litre
µm	micro-metre, 10^{-6} m
µSv	micro-sievert, 10^{-6} sievert
µSv/Bq	micro-sieverts per becquerel
µSv/a	micro-sieverts per annum
Bq	becquerel, decays (counts) per second, unit for measuring radioactivity
Bq/kg	becquerels per kilogram of material
CL	Confidence level
g	grams
GBq	giga-becquerel, 10^{9} becquerel
IAEA	International Atomic Energy Agency
kBq	kilo-becquerel, 10^{3} becquerel
mg/m^{3}	milligrams per cubic metre, 10^{-3} g per cubic metre
mSv	milli-sievert, 10^{-3} sievert
mSv/a	milli-sieverts per annum
NRPA	National Radiation Protection Authority
NUI	Namibian Uranium Institute
PM_{10}	Particulate matter smaller than 10 microns (µm) in diameter
ppm	parts per million
RMP	*Radiation Management Plan*
RPO	Radiation Protection Officer
RSO	Radiation Safety Officer (statutory role)
SEG	Similar exposure group
TLD	Thermo-luminescent dosimeter
TSF	Tailings Storage Facility
UOC	Uranium oxide concentrate
WHO	World Health Organization

1. Introduction

1.1 Background

In terms of Section 29(2) of the Atomic Energy Act[1], it is required that every licence holder submits an annual report and data relating to radiation protection and safety or any matter concerned with the administration of the Act and the Regulations[2] pertaining to the Act.

From the reporting year 2013, all operations have been requested to supplement the annual report and data with a narrative report, structured to replicate the framework of the Radiation Management Plan (RMP), and as outlined in the guidance document issued in 2014.[3]

This report is prepared in accordance with the above requirements, and supplements the annual data reported to the National Radiation Protection Authority (NRPA). It is the second report of its kind, following the first narrative report which was issued in March 2014 and covered the monitoring year January to December, 2013. The 2013 Report to the Radiation Protection Authority has been made available to the public on the Rössing Uranium Limited (Rössing Uranium) website, http://www.rossing.com/reports-research2.htm .

The present report covers the monitoring year January to December, 2014. Following its acceptance by the NRPA, it will also be made publicly available on the Rössing Uranium website.

1.2 Rössing Uranium's operations in 2014

Rössing Uranium Limited (Rössing Uranium) mined a total of 23 million tonnes of rock from the SJ Pit (the open pit) during 2014, compared with 36 million tonnes of rock mined during the previous reporting year. The main reason for the reduced tonnage mined was a management decision to restrict levels of production to those necessary to meet contract commitments only, due to prevailing poor market conditions; this led to a restructuring of the business that took effect in the second half of the year. Production shortfall in the first half of the year exacerbated this situation due to the repair work required on the leach tank that failed in December 2013, and due to a one-month maintenance shutdown of the Processing Plant in June 2014.

The restructuring and change in operations also had an impact on the Processing Plant; the workforce was reduced and shifts changed from a four-shift to a three-shift system. As a result, although the total number of workers was reduced, the number of designated radiation workers was kept roughly the same. This was unavoidable because for the maintenance workers working in the Processing Plant, the area of responsibility was often increased from a specific area in the plant to the plant as a whole. Hence these workers had to be designated 'radiation workers' even if their work was in a high risk area only for part of their working time.

1.3 Rössing Uranium's Radiation Management Plan updates

Like the company's safe work procedures, the Rössing Uranium RMP is a 'living' document — this means that with each operational change, the RMP is updated. The latest version of the RMP is always available to Rössing Uranium employees via the intranet, and changes are made available and communicated to all affected stakeholders via the 'management of change' framework.

The Rössing RMP was updated most recently in August 2014, after the retrenchment and restructuring process was completed.[4] With that update, the RMP layout was aligned with the Rio Tinto guidelines for reports and the document was published on the Rössing website for the public to access.

A DVD with the latest RMP and all the Rössing Uranium safe work procedures relevant to radiation safety was handed to the NRPA in December 2014.

In addition to making the RMP publicly available, several other reports that may hold public interest were published on the Rössing Uranium website in 2014 for public access:

- *Implementation of Radiation Management Plan, 2013 Annual Report;*
- Report: *Risk Assessment on the Rössing Uranium Waste Rock Dump Site Bordering the Khan River*, 2014;
- Report: *Baseline and Mining-related Radon Concentrations in the Rössing Mining Area*, 2013; and
- Report: *Risk Assessment on the Rössing Uranium Car Park Area*, 2014.

Further reports on issues relating to radiation protection of workers and the public will follow later.

[1] Atomic Energy and Radiation Protection Act, 2005 (Act No. 5 of 2005).
[2] Radiation Protection and Waste Disposal Regulations (Government Notices No. 221 of 2011).
[3] *Guide to Facilitate the Reporting by Licensees on the Implementation of the Radiation Management Plan* (RMP), Ministry of Health and Social Service, National Radiation Protection Authority, 2014.
[4] Rössing Uranium *Radiation Management Plan*, August 2014.

2. Organisational arrangements

2.1 Organisational structure

The organisational structure in the Radiation Safety Section remains unchanged from 2013. The Radiation Protection Officer position that was vacant in 2013 has been filled by the employee who was acting in this position, following the standard recruitment process.

The organisational structure relating to the Radiation Safety Section is shown in Figure 1.

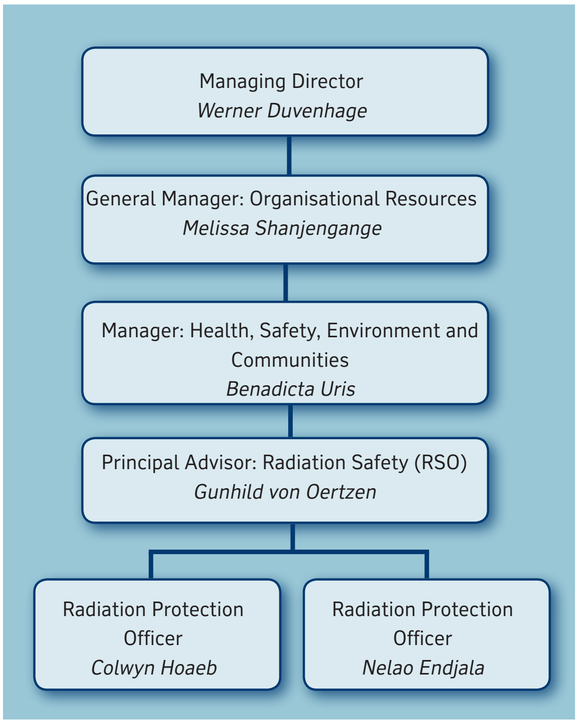

Figure 1: Organisational structure for the Radiation Safety Section, 2014

2.2 Changes in working arrangements

The change from a four- to a three-shift system has resulted in significant organisational changes, particularly in the area of the Processing Plant. As a result, the risk assessment on radiation workers had to be reviewed. Throughout 2014, 52 workers were de-registered as designated radiation workers with the South African Bureau of Standards while there were 38 new registrations. At the end of 2014, a total of 138 workers remain registered as designated radiation workers.

Some workers who were registered as designated radiation workers before 2014 were moved to work areas where registration as a designated radiation worker is not required as per the risk assessment. For these, registration was nevertheless maintained in order to ensure continuity of dose records. In addition, having continuous gamma dose monitoring in work areas not assessed to be at elevated risk was considered to be a good tool for confirming the low risk assessment.

2.3. Capacity building

Radiation safety workers need regular opportunities for information exchange with their peers and for updating their professional qualifications. Rössing Uranium works in collaboration with the Namibian Uranium Institute (NUI) to upgrade the professional skills of all radiation safety workers in the industry, including those in other operations that work with radioactive materials or where workers may be exposed to ionising radiation through their work. Rössing's designated Radiation Safety Officer (RSO) continues to provide expertise and advice to the training programmes offered via the NUI.

Both Radiation Protection Officers (RPOs) currently working in the Radiation Safety Section at Rössing Uranium, Colwyn Hoaeb and Nelao Endjala, have completed modules I, II and III of the Radiation Safety Officers' course, which are offered to radiation safety professionals at the NUI. In addition, both attended the second Winter School for radiation safety officers, which was offered at the NUI in 2014 and is now an annual event.

Both RPOs are undergoing on-the-job professional development to acquire further skills. Included in this coaching and training programme is experience gained by acting as the site's Radiation Safety Officer while the designated RSO is away from the office. Both RPOs were provided with the opportunity to act as RSO, while in constant email and phone contact with the RSO for support and information.

For the RSO, skills development includes experience in radiation protection at other sites. In 2014, the RSO provided support as external Health, Safety, and Environment auditor to two external Rio Tinto operations in their regular auditing and review programme: the Ranger Mine of Rio Tinto Energy Resources Australia, and QIT Madagascar Mineral Resources.

Skills development also includes providing external training to others: as part of the NUI training programme, the Rössing Uranium RSO provides training to the industry via the RSO training programme offered at the NUI. Regular interaction with radiation safety professionals broadens the experience of the RSO and deepens her understanding of the issues relating to radiation safety as they may arise at other sites.

3. Occupational exposure

3.1 Changes in the Monitoring Programme

At Rössing Uranium, the occupational hygiene management programme is based on the definition of 'similar exposure groups' (SEGs), and a thorough inspection of the workplace risks and hazards is performed every year.

Based on these annual assessments, the SEGs are defined and the workplace risks to a group of people working under similar conditions (i.e. having similar roles) are summarised. Each worker on site (including all full-time contractors) is assigned to a particular SEG, based on the role that the worker performs.

In 2014, five new SEGs were added to the fifteen that were defined previously, i.e. 'Mining Support', 'Processing Support', 'Logistics & Warehousing', 'Blasting & Grade Control' and 'Transport'. The creation of new SEGs was considered necessary mostly because of occupational hygiene risks other than radiation; therefore only one of the five new SEGs was included in the annual radiation monitoring programme.

Employees assigned to the other four new SEGs were allocated the dose for their previous SEG: in other words, employees in the new SEGs 'Mining Support' and 'Blasting and Grade Control' were allocated the average dose that was assigned to 'Pit Field'; and workers in the 'Processing Support' and 'Transport' groups were allocated the dose for 'Field Workers'. The group 'Logistics and Warehousing' was newly sampled in 2014.

3.2 Monitoring results for 2014

At Rössing Uranium, three radiation exposure pathways are monitored by personal measurement for each SEG. In 2014, 1,428 personal dose samples were collected. For each SEG and pathway, the minimum number of samples taken was 11, with an average per pathway and SEG of 30 samples.

All workers working on site are regarded as occupationally exposed workers, and every worker is assigned to one of the 20 SEGs according to work area and job specification.

For designated radiation workers, the external gamma dose is recorded continuously while the internal dose from inhalation of long-lived radioactive dust and from radon decay products is recorded randomly per SEG. For all other occupationally exposed persons (i.e. non-designated radiation workers) all SEGs are sampled randomly for internal and external exposure to radiation.

The results of the occupational exposure monitoring are communicated to the affected workers and the affected SEGs when the information becomes available.

At the end the year, a dose summary is communicated to all workers via the Rössing Uranium intranet. The personal dose results as they are recorded for each worker and communicated to the NRPA are available to each worker, also via the Rössing Uranium intranet (where each worker has access only to his or her own dose records).

Urine sampling records are also available to designated radiation workers and their supervisors via this avenue.

Radiation monitoring results, dose per person, by similar exposure group (SEG), 2014

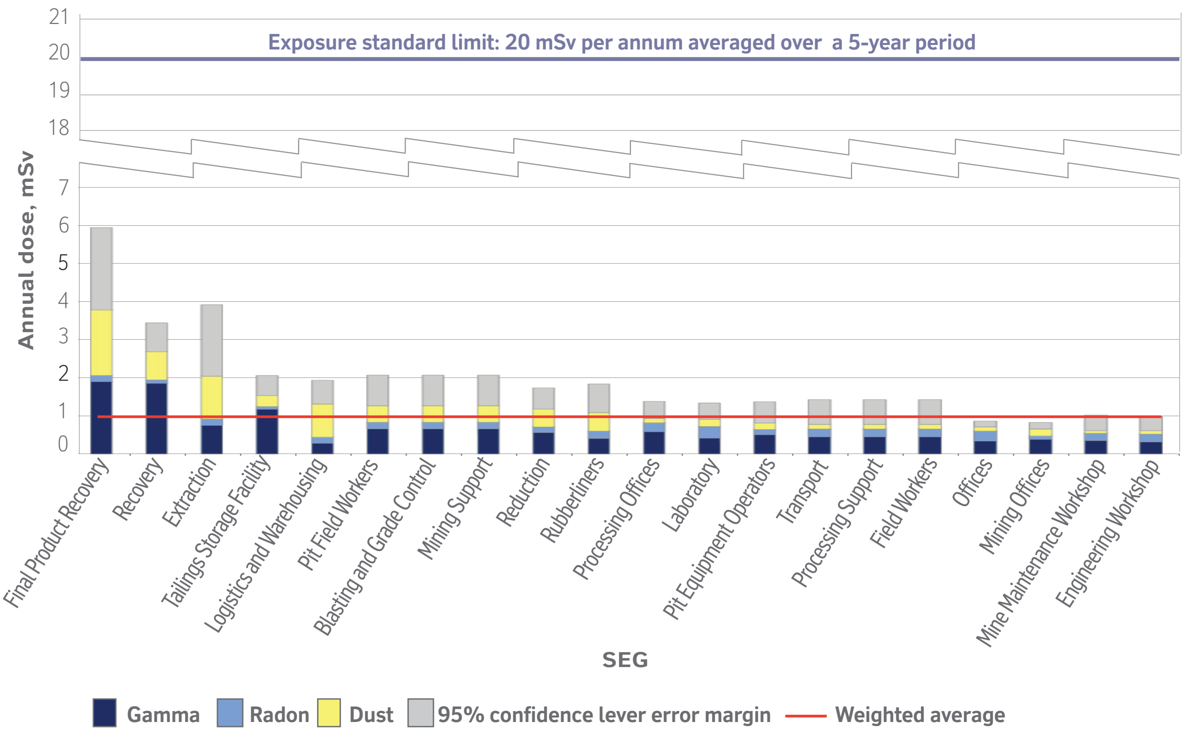

Figure 2: Average 2014 annual radiation exposure dose per worker in mSv/a, by SEGs

The exposure dose records for 2014 are summarised in Figure 2. The SEGs with the highest average doses are the Final Product Recovery workers (14 workers) with an average dose of 3.9 mSv/a, and the Recovery workers (31 workers) with an average dose of 2.7 mSv/a.

The average doses of the SEGs ‘Processing Office’, ‘Laboratory’, ‘Pit Equipment Operators’, ‘Transport’, ‘Field workers’, ‘Processing Support’, ‘Offices’, ‘Mining Offices’, ‘Mine Maintenance Workshop’ and ‘Engineering Workshop’ workers were all below 1.0 mSv/a, and the weighted average dose across all workers was exactly 1.0 mSv/a. The 95 per cent confidence level for the weighted average dose in 2014 was 2.0 mSv/a.

Although the radiation dose for each worker must be optimised according to the principle of ALARA[5], the collective exposures of all workers must also be optimised. The largest collective dose generally occurs in those groups of workers with the largest number of members – this principle has been summarised in Figure 3, where the total collective dose for all 907 employees for the year 2014, i.e. 928 mSv or roughly one sievert, has been distributed between the SEGs. The largest collective dose (15 per cent of total) is then seen to occur in the Pit Equipment workers, although the dose per person in the SEG is very low at 0.8 mSv per annum. The group with the lowest collective dose is that of Rubberliners, at 1 per cent of the total dose, with individual doses of 1.1 mSv/a in that group.

3.3 Radiation workers

For radiation workers[6], the direct pathway (gamma radiation) is monitored individually and continuously, using thermo-luminescent dosimeters (TLDs), with a wearing period of 12 weeks each. For some workers, the annual gamma dose was found not to be representative because the worker lost a TLD or was registered or de-registered partway through the year. In cases such as these the group average dose is assigned to the worker instead.

The highest deep dose recorded in 2014 was 8.7 mSv/a. This was due to a pro rata overexposure of 7.7 mSv in a 12-week wearing period for a worker in the ‘Engineering Workshop’ SEG. Extrapolated to the full year at the same conditions, this exposure would have resulted in an annual gamma dose of 33 mSv, exceeding the 5-year average dose limit of 20 mSv/a (but not the 1-year dose limit of 50 mSv/a). This pro rata overexposure was extensively investigated: electronic dose measurements in the work area for the worker concerned have indicated that the measurement was likely an error caused by placing the TLD in a high dose rate area, rather than it being worn continuously on the person (as it should

[5] As low as reasonably achievable.

[6] Radiation workers at Rössing Uranium are defined to be those workers who are potentially at risk of receiving an annual dose of 5 mSv or more, although in reality 5 mSv is rarely reached or exceeded by any one worker in a year.

Radiation monitoring results, dose per similar exposure group (SEG), 2014

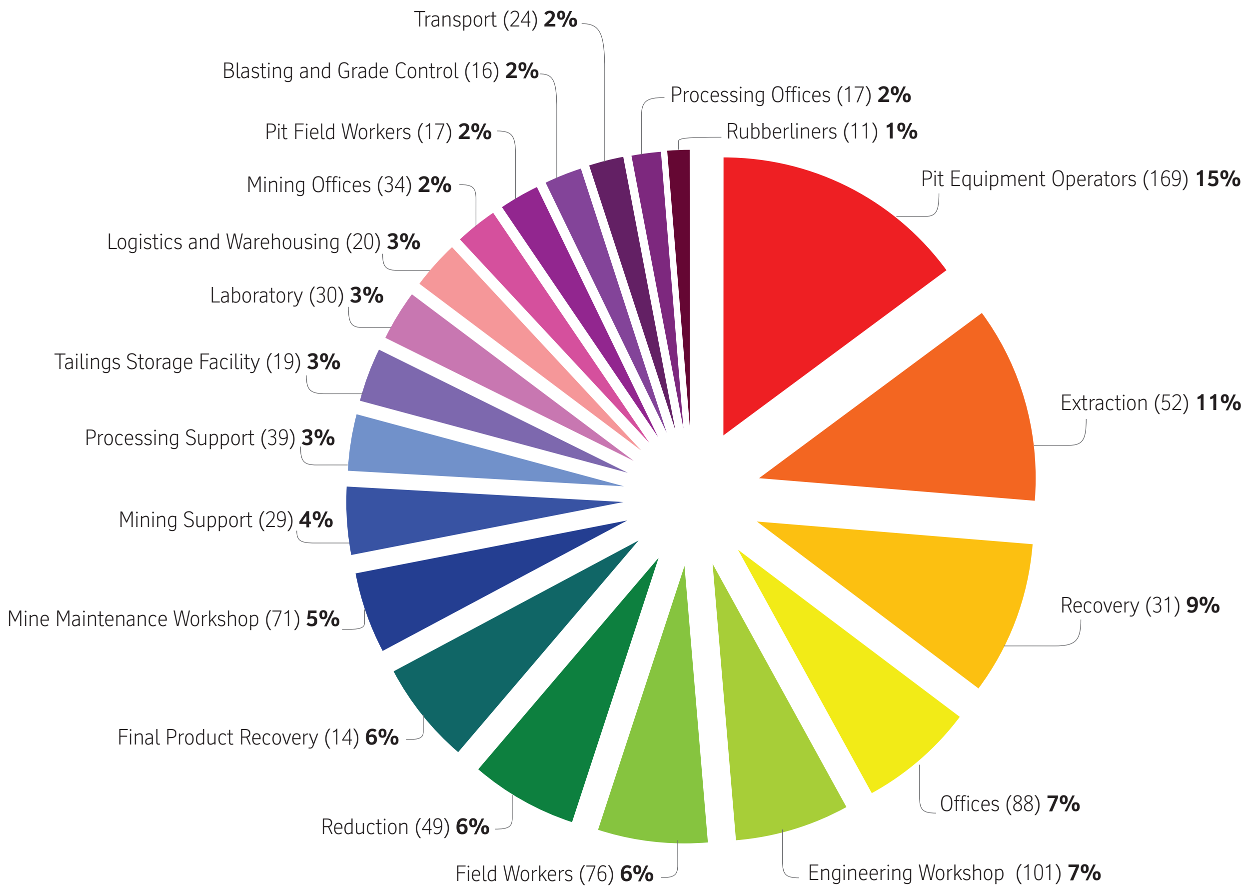

Figure 3: Collective radiation dose per SEG in the year 2014. The pie chart shows the dose per SEG by listing the name of the SEG, the number of workers in that SEG (in brackets) and finally percentage of the total collective dose for that SEG. The collective dose for all employees was roughly 1 Sv in 2014.

have been). The dose will be recorded against the worker however, because the inaccuracy of the result cannot be demonstrated beyond doubt. The recorded full dose for this worker, including all pathways and all wearing periods, was 9.0 mSv in 2014.

Only two more workers exceeded an annual dose of 5 mSv. Both are Final Product Recovery workers and in 2014 received full doses of 5.0 and 5.2 mSv respectively, including all three exposure pathways.

The average and maximum gamma doses for radiation workers are summarised in Table 1 by SEG.

The average and maximum dose records demonstrate that in all cases except the pro rata overexposure incident in the 'Rubberliners' SEG, gamma exposures were significantly below the 5 mSv/a that serves as the threshold level above which continuous monitoring is regarded as necessary.

Table 1: Average and maximum doses from gamma radiation in 2014 for radiation workers, per SEG

SEG	Average gamma dose, mSv/a	Maximum gamma dose, mSv/a
Final Product Recovery workers	1.9	3.3
Recovery workers	1.8	2.7
Rubberliners	1.6	8.7
Laboratory workers	1.1	1.8
Field workers	1.1	1.7

New TLD boards were introduced in 2014 for TLD display and storage in each workplace, as shown in Figure 4. These boards enable better control of TLD usage, particularly since:

- supervisors are able to see if workers are not using a TLD while on shift;
- colour stickers are used to display compliance with the monthly urine sampling requirement; stickers are colour coded for each month in order for supervisors to be able to quickly assess compliance every month; and
- when workers are not on shift, all their TLDs are stored at the same place, making data analysis more accurate as the same background dose is accumulated on each TLD while workers are not on duty.

All radiation workers are required to undergo monthly urine sampling to confirm that no uranium was ingested at the workplace. Workers have access to their urine sampling results via the Rössing Uranium intranet (workers can see only their own results, not those of their colleagues).

In 2014, 1,237 urine samples were collected and analysed at the Swakopmund Trace Element Analysis Laboratory (TEA-Lab cc), shown in Figure 5. None of these exceeded the warning or action level (20 and 40 µg/L respectively). Of these, 132 samples, or 11 per cent, reached the detection limit of 5 µg/L.

The regular sampling of urine is an important check on potential ingestion of uranium. The fact that about 11 per cent of the samples indicated a positive (non-zero) result indicates that some minimal ingestion takes place and further optimisation in this regard is possible and necessary.

Female radiation workers, of whom there were twelve in 2014, have to undergo monthly pregnancy testing in addition to other monitoring. This measure was introduced in 2011 in order to ensure that the public dose limit of 1 mSv/a is complied with for all pregnant workers.

Eighty-three pregnancy tests of female radiation workers were performed in 2014, as well as 96 voluntary pregnancy tests of non-designated female workers (there were in total 12 no-shows for testing of radiation workers, or an average no-show percentage of 10 per cent). Of course, pregnancy testing is not a requirement for workers that are already pregnant. No-shows are regularly communicated to supervisors, who are required to ensure compliance with this testing request. Six of the pregnancy tests were positive, resulting in reassignment of these workers into low risk working environments where necessary. As at the end of 2014, four of the twelve female radiation workers (i.e. one in three) were pregnant, attesting to the relevance of this testing procedure for optimised control of radiation exposures.

Figure 4: TLD boards for radiation workers, with Field worker Denzel Xoagub

Uranium density (µg/L), 2014

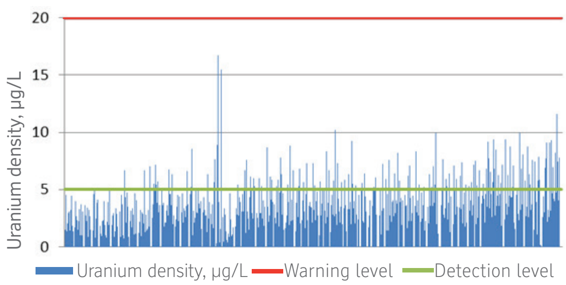

Figure 5: Uranium in urine samples 2014, with red line indicating warning level (never exceeded) and green line indicating detection level.

3.3 Radiation awareness

Radiation awareness training is an important ongoing activity, in order to ensure that workers are aware of the potential risks of exposure to radiation but are not unduly alarmed about them. In 2014, the need for information was highlighted by several sensationalist reports about the alleged health issues of Rössing Uranium workers associated with radiation. These reports appeared in the press but were not based on scientific evidence or fact.

The need for a scientific study on the potential health effects on workers from mining uranium has long been acknowledged by Rössing Uranium, and in recent years a scientific epidemiological study has been started.

By the end of 2014, the scoping of the study had been completed [7] and a scientific team had been assigned to lead the study, which will be completed by 2016.

Information about radiation exposures and risks at Rössing Uranium forms part of regular awareness training at the mine. Every worker is required to attend, as a minimum, a one-hour training session about radiation every year. In 2014, full compliance with this requirement was achieved.

4. Medical exposure

Not applicable.

5. Public exposure protection

5.1 Background

The public exposure limit of 1 mSv/a requires an indirect measurement of the mining-related public dose, as the natural background radiation exposure of the public significantly exceeds the mining-related dose. Public exposure controls are designed to ensure compliance with this public dose limit, and the Rössing Uranium public dose assessments quantify the expected dose to critical groups along the identified pathways, as explained in the Rössing RMP and the public dose assessments referred to therein.

Compliance with the public dose limits is confirmed through monitoring of seepage water (Section 5.2); monitoring of PM_{10} (particulate matter smaller than 10 microns in diameter) dust at selected receptor locations (Section 5.3); and monitoring of radon concentrations close to the mine (Section 5.4). Monitoring results can then be used for a public dose assessment, confirming compliance with the public dose limit.

5.2 Water quality

A series of seepage recovery boreholes is used to collect seepage water from the areas surrounding the Tailings Storage Facility (TSF). As explained in more detail in the RMP, the ratio of the uranium radionuclides in the uranium chain, i.e. U-234 and U-238, can be used to assess if the water monitored is predominantly naturally occurring or results from seepage from the TSF. A collection of more than twenty boreholes is sampled at least annually (sometimes two samples are collected in a year) and the ratio of radionuclides is determined to enable this assessment.

The radionuclide activity ratio is obtained by dividing the activity of U-234 in the sampled water by that of U-238 in the same water. Generally, this activity ratio in hard rock unaffected by leaching is close to 1, as the two radionuclides are roughly in secular equilibrium. An activity ratio of U-234 to U-238 significantly exceeding 1 is typically characteristic of natural sediments that have come into contact with water over extended periods; a ratio of less than or equal to 1 typically indicates an origin of uranium which has recently been extracted from solid rock.[8] The principles underlying the relationship between radionuclides are complex, but are explained in more detail in the Rössing Uranium RMP.

A map of the mining area indicating the monitoring borehole positions and the outcome of the radionuclide sampling in 2014 is shown in Figure 6, with green dots indicating predominantly natural occurrence of uranium, and red dots indicating influence by seepage from the TSF. The detailed radionuclide monitoring results are summarised in Table 2.

[7] SENES Consultants, Scoping Study to Recommend Possible Health Studies of Workers Employed at the Rössing Uranium Mine, August 2014. (A copy of the scoping document has been provided to the NRPA.)

[8] Note: In the RMP, this concept is explained by using the reverse ratio, i.e. the activity ratio of U-238 to U-234 (U-238/U-234). Following the same argumentation, a ratio of U-238/U-234 exceeding a value of 1 is characteristic of freshly extracted uranium, while a value of less than 1 signifies naturally occurring sediments that have come into contact with water. The characteristics are best summarised in a table:

	U-234/U-238 (this report, 2013 report)	U-238/U-234 (RMP)
Freshly extracted uranium or uranium in ore	≤1	>1
Sediments in riverbeds and aquifers that have been in contact with water	>1	<1

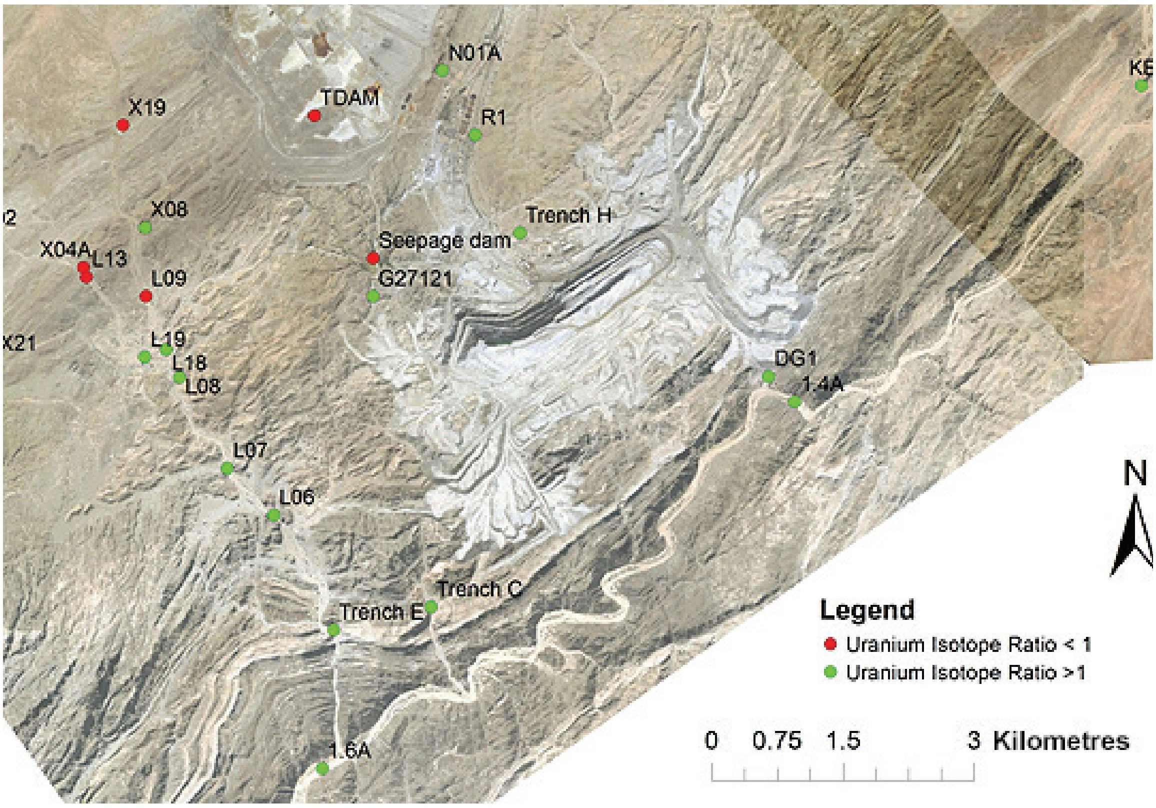

Figure 6: Seepage contamination plume at Rössing Uranium, January 2015.[9] An isotope ratio U-234/U238 exceeding the value 1 is indicated in green, and a value less than or equal to 1 is indicated in red.

All the boreholes in the Khan River and at the barrier or cut-off trenches display a U-234/U-238 ratio in excess of 1 (indicated by green dots in Figure 6), indicating a predominantly natural occurrence of uranium in the water. For the two boreholes north of the TSF, a ratio indicating natural occurrence of uranium was reported in 2013; one of these, T1, now indicates seepage from the TSF.

Water in Panner Gorge displayed variable ratios, with some boreholes indicating seepage but others indicating natural uranium in the water.

In order to better assess the variations in these boreholes, the changes in ratios over the last 10 years were examined more closely, as discussed in the following and displayed in Figures 7 to 10.

In Figure 7, the isotope ratios in the two boreholes situated to the north of the TSF are plotted from 2004 to 2015. For borehole T1, the ratio seems to be variable but mostly in excess of 1. There appears to be a downwards trend for borehole L01, leading to a value below 1 on one occasion in 2011 and 2012 respectively, and again in 2014.

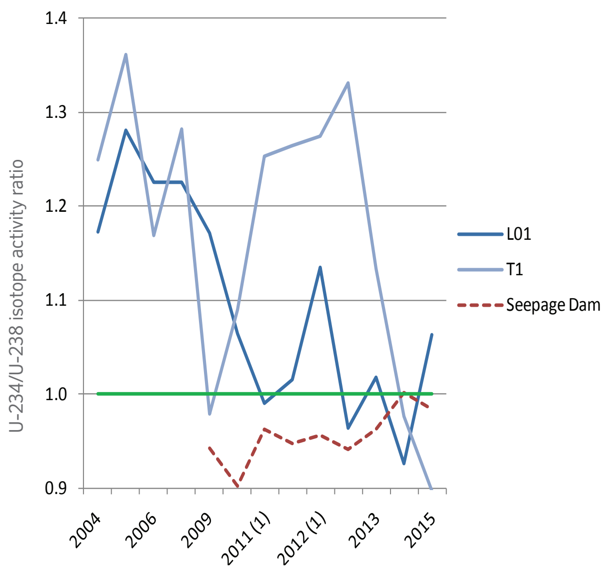

Figure 7: Isotope ratio U-234/U-238 north of the Tailings Storage Facility, 2004 to January 2015

[9] Note: The most recent borehole sampling analysis is dated January 2015, but the actual sampling was done in September 2014, and hence these results are incorporated in this report for the year 2014.

Table 2: Radionuclide sampling analysis for Rössing Uranium monitoring boreholes, as of January 2015 (i.e. sampling of September 2014)

Borehole code	U-234 activity concentration, mBq/L	U-238 activity concentration, mBq/L	Activity ratio U-234/U-238	Comment on location of borehole
1.4A	2,120	1,760	1.20	Khan River and seepage barrier trenches
1.6A	916	748	1.22	Khan River and seepage barrier trenches
DG1	6,760	5,310	1.27	Khan River and seepage barrier trenches
Trench C	11,600	9,950	1.17	Khan River and seepage barrier trenches
Trench E	423	148	2.86	Khan River and seepage barrier trenches
Trench H	41,900	41,500	1.01	Khan River and seepage barrier trenches
Seepage Dam	11,900	12,100	0.98	surface water, freshly extracted uranium
TSF	408,000	425,000	0.96	surface water, freshly extracted uranium
G27121	380	349	1.09	upstream of SJ Pit
T1	58	64	0.90	North of TSF
L01	337	317	1.06	North of TSF
N01A	10,100	10,100	1.00	East of TSF
Kem03	3,710	2,950	1.26	Dome area
N08	1,060	995	1.07	Panner Gorge
L06	7,450	6,410	1.16	Panner Gorge
L07	7,330	6,490	1.13	Panner Gorge
L08	8,950	7,480	1.20	Panner Gorge
L18	320	274	1.17	Panner Gorge
L19	5,880	5,120	1.15	Panner Gorge
X21	131	54	2.44	Panner Gorge
J	3,290	3,460	0.95	Panner Gorge
L13	4,920	5,110	0.96	Panner Gorge
L09	26,100	27,100	0.96	Panner Gorge
X19	32,800	33,400	0.98	Panner Gorge
X04A	3,780	3,940	0.96	Panner Gorge
X02	1,160	1,280	0.91	Panner Gorge

In this location however, the direction of water flow is towards the south, passing underneath the TSF and therefore not impacting the aquifer in the Khan River.

As expected, the isotope ratio in the trenches and in the Khan River significantly exceeds 1 in all cases, as shown in Figure 8, although there is an exception in Trench H in the years 2010 and 2011. Trench H is located to the north of the SJ Pit with a flow direction towards the pit, however, so there is no potential for seepage water to reach the Khan River as the flow is cut off by the open pit.

Another exception is an isotope ratio below 1 for borehole DG1 in the year 2011, in which rainfalls were higher than normal. This borehole is likely affected by the waste rock dumps close to it and may be affected by rainwater seasonally. This occurrence is, however, represented by a single measurement and is therefore clearly not a result of seepage of water from the TSF.

Isotope ratios in the monitoring boreholes in Panner Gorge are shown in Figure 9. The flow from these boreholes is intercepted at Trench C and Trench E,

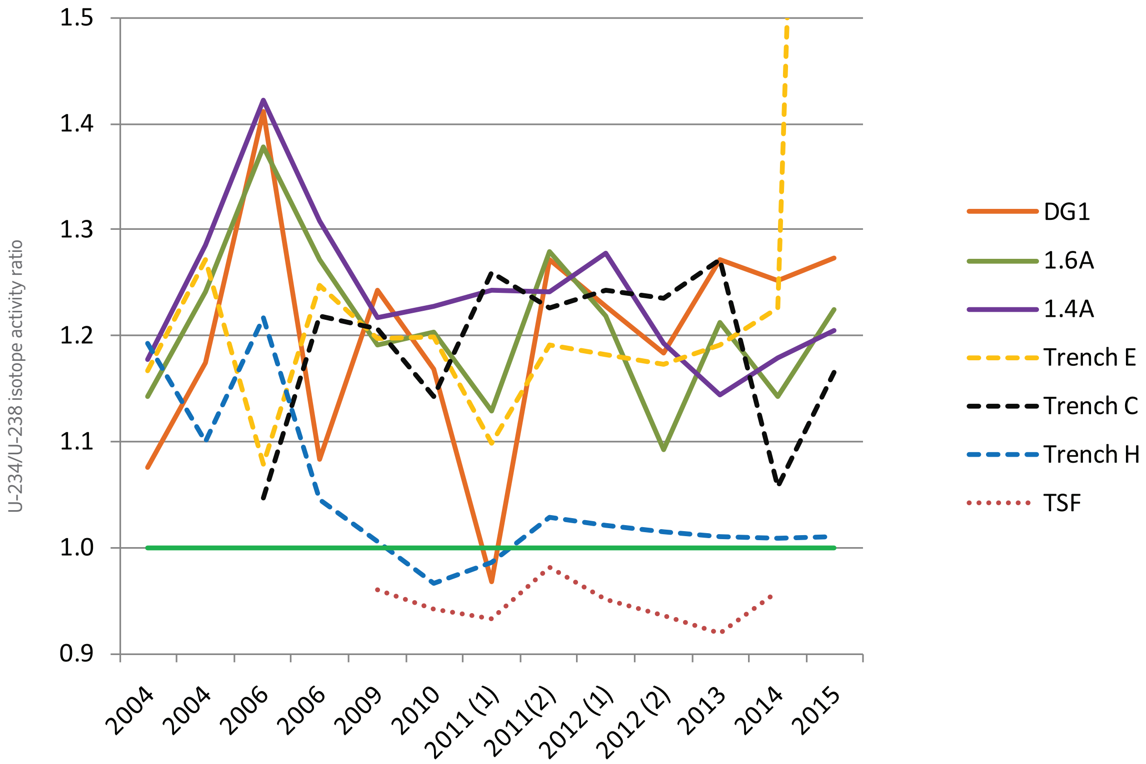

Figure 8: Isotope ratio in Khan River and cut-off trenches, 2004 to 2015

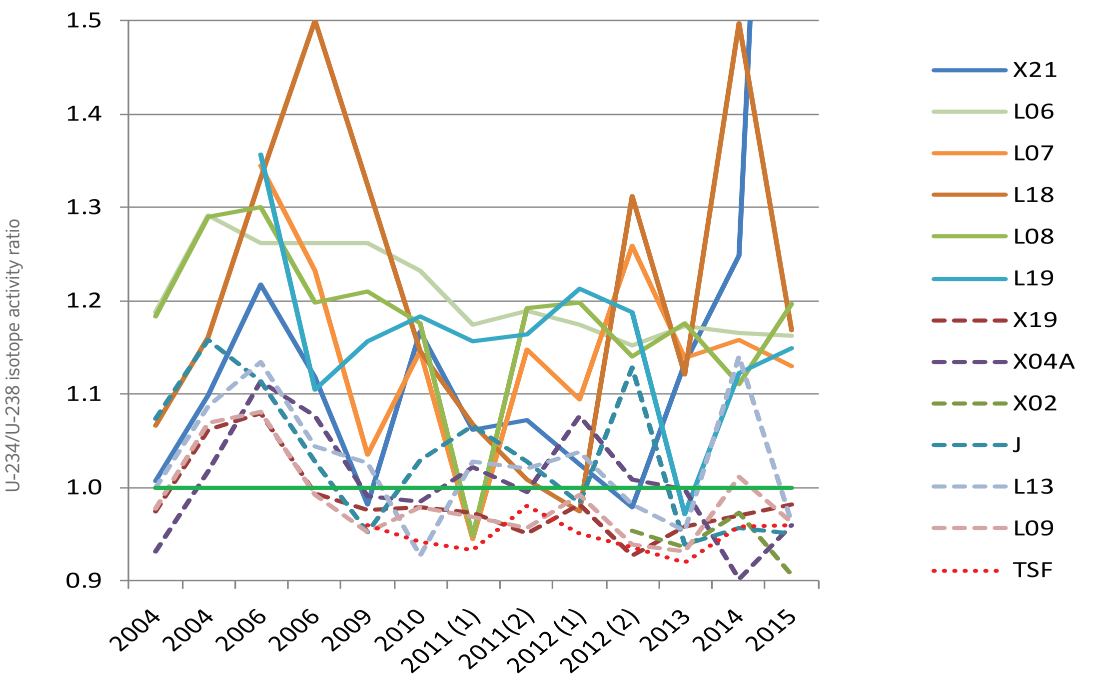

Figure 9: Isotope ratio in monitoring boreholes in Panner Gorge, 2004 to 2015

providing a barrier to seepage into the Khan River. Some of the boreholes in Panner Gorge are affected by seepage. For some of the boreholes, the isotope ratio alternates between values predominantly indicating seepage and those indicating natural occurrences. The successful prevention of seepage into the Khan River is however demonstrated by the isotope ratio in trenches E and C, indicating naturally occurring uranium in the water.

Finally, the monitoring of boreholes to the south and east of the TSF is summarised in Figure 10. A slight downwards trend in isotope ratio can be discerned for borehole N01A; for borehole R1, this trend is significant. The flow from all of these boreholes, however, is towards the open pit (SJ Pit) and seepage into the Khan River aquifer is therefore not a risk.

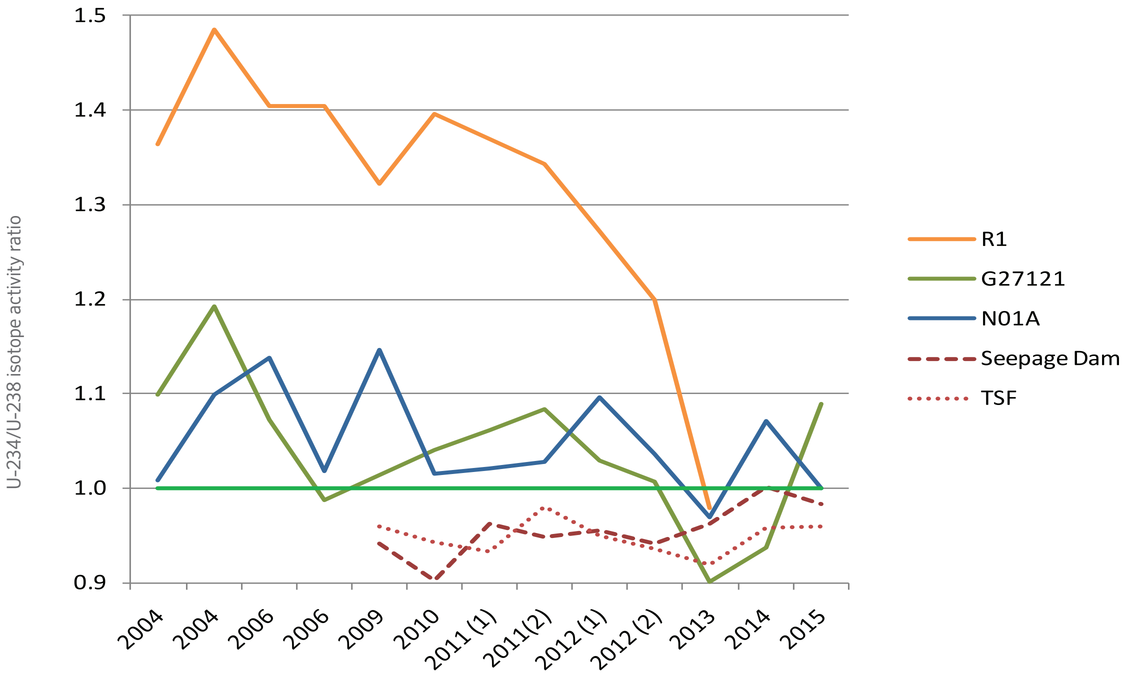

Figure 10: Borehole monitoring results for various boreholes in the immediate vicinity of the Tailings Storage Facility, 2004 to 2015

5.3. Dust monitoring

A public dose assessment on the inhalation dose from radioactivity in dust is dependent on knowing the amount of dust in the air that is breathed by the critical groups, and the radioactive content of the dust.

For the critical group at Arandis, a dust sample was carefully collected from within an outdoor enclosure where wind-blown dust had settled. The fraction of particles smaller than 10 µm (the inhalable fraction of the dust) was analysed for the radionuclides it contained. The analysis was carried out by IAF Radioökologie GmbH, and the results are reproduced in Table 3.

Table 3: Radionuclide analysis results of inhalable fraction of dust at Arandis, November 2014

Nuclide	Dust sample fraction smaller than 10 µm: activity in Bq/kg
U-238	494
Ra-226	756
Pb-210	7,770
U-235	<34
Ac-227	<100
Ra-228	220
Th-228	200
K-40	984

The quantity of dust collected was small (roughly 11 g), so that an analysis for all elements of the three decay chains was not possible. The results given, however, are sufficient to determine the correct dust conversion coefficient from the uranium, thorium and actinium decay chains for this dust, calculated to be 3 μSv/Bq.[10]

The grade of the dust collected at Arandis was measured to be 26 ppm for the total sample but was determined as 40 ppm for the inhalable fraction. Together with the average concentration of PM_{10} dust at Arandis, 11 μg/m^3, this uranium content in the inhalable dust may then be used to calculate the dose from inhalation of dust for the critical group at Arandis.

The PM_{10} concentration at Arandis is measured hourly (see Figure 11, and a summary by month in Figure 12). The total inhalation dose from this dust concentration is then calculated as 78 μSv/a, using the assumption that all inhaled dust contains the radionuclides as measured in the dust analysis shown in Table 3. Nevertheless, most the dust inhaled at this location will not originate from the Rössing mine site but will be background dust from the vicinity of the town.

To determine the contribution of mining-related dust to this dose, the wind direction at Arandis must be correlated with the direction in which the mine is located from Arandis, as demonstrated in Figure 13. When this was done, it emerged that the wind was blowing from the mine site towards Arandis 19 per cent of the time in 2014, and in directions away from the mine site (or not at all) the rest of the time.

When this difference in wind directions was taken into account, the public dose at Arandis due to mining operations at Rössing Uranium was found to be 16 μSv/a, which represents a trivial public dose when compared with the public dose limit of 1,000 μSv/a.

PM_{10} dust concentration, Arandis, hourly intervals, 2014

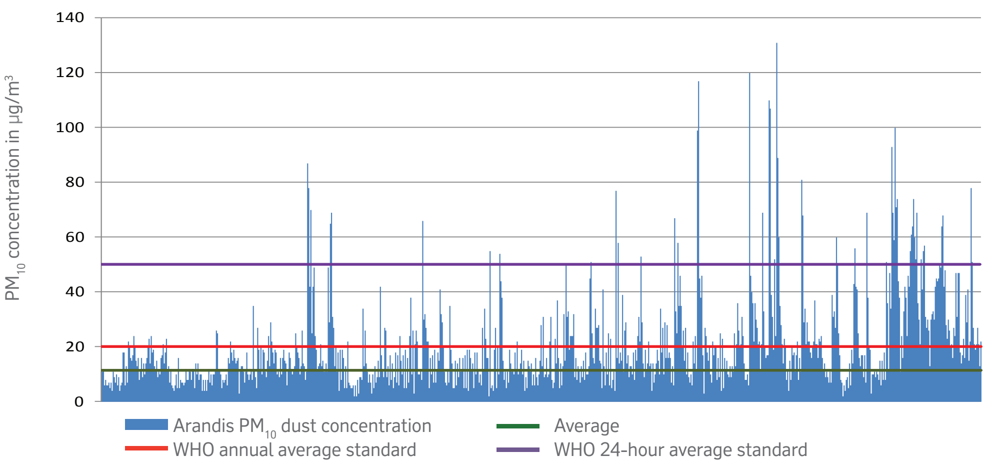

Figure 11: 2014 PM_{10} dust concentrations at Arandis in hourly intervals. The red line indicates the World Health Organisation (WHO) standard for the annual average outdoor PM_{10} air quality, the purple line indicates the WHO standard for 24-hour average in outdoor PM_{10} air quality , and the green line indicates the annual average of the concentrations measured.

PM_{10} dust concentration, Arandis, monthly average, 2014

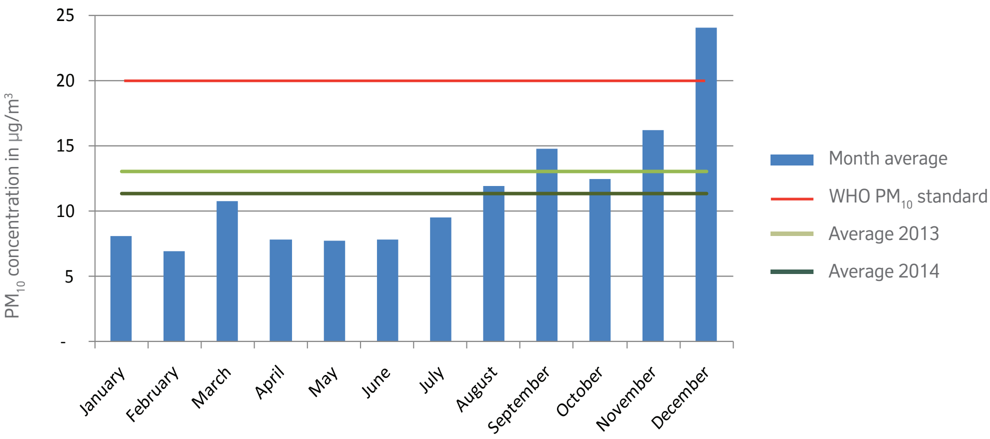

Figure 12: 2014 PM_{10} dust concentrations at Arandis - monthly averages . The red line indicates the WHO standard for outdoor air quality, when averaged over one full year of PM_{10} measurements.

[10] Note that the dust collected contains a significant portion of K-40, which was not considered in the dust dose conversion coefficient as potassium is not part of the ore mined at Rössing Uranium and hence constitutes a source of natural background radiation exclusively.

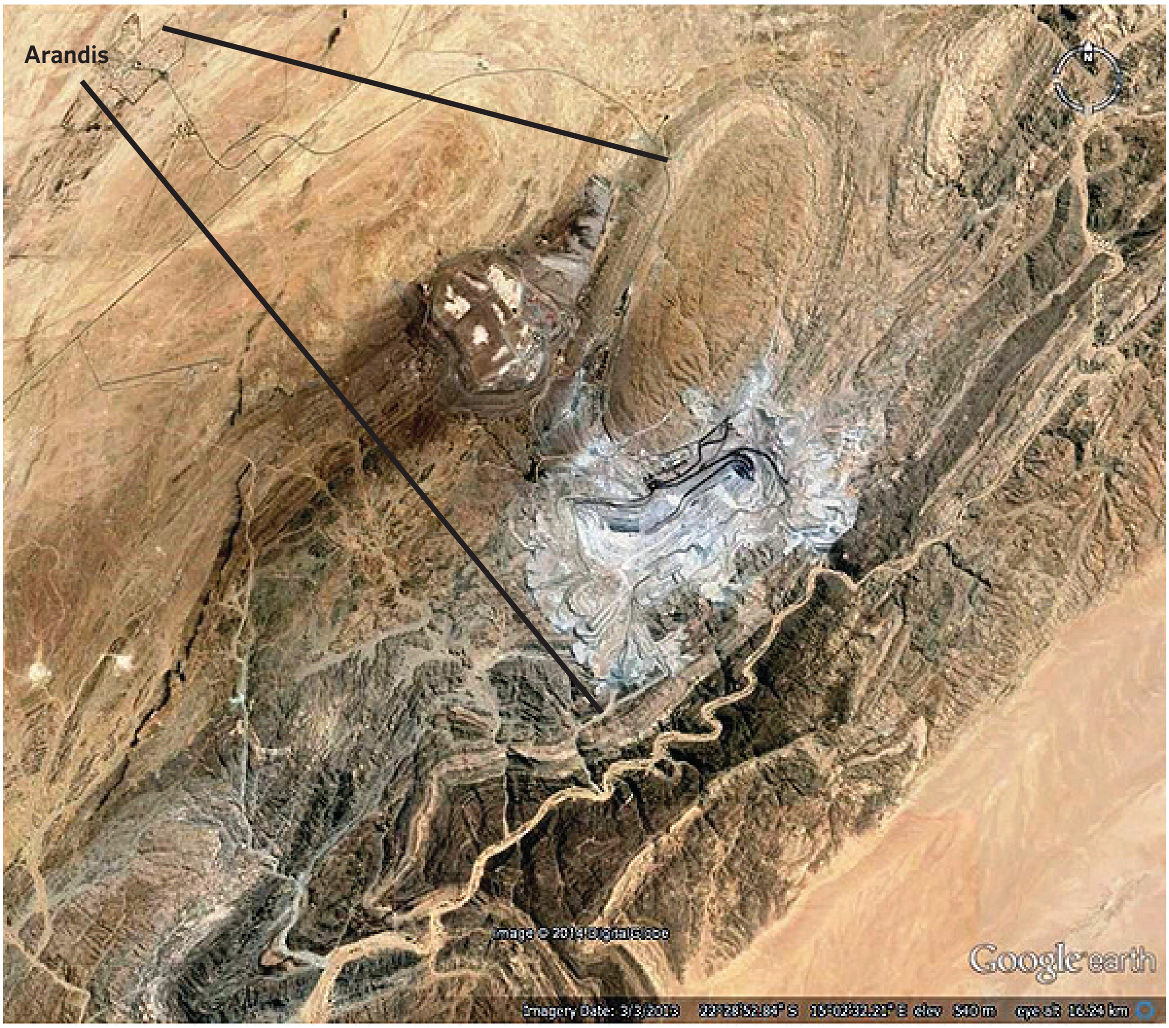

Figure 13: Satellite image of the Rössing mine site and Arandis, with wedge indicating wind directions that would result in mining-related dust being blown towards Arandis.

5.4. Radon survey

A radon survey was completed across the Rössing Uranium mine site and surrounding areas in 2013.[11] The survey results are available on the Rössing Uranium website.

Furthermore, a Saphymo™ AlphaGUARD Radon monitor located at the NamWater reservoir at Arandis, operated by the Namibian Uranium Institute and Namibia's Geological Survey, measures radon concentrations some 6 m above the ground at intervals of 10 minutes. A similar approach to that taken for the PM_{10} dust measurements at Arandis is used whereby the wind direction from the mine site is correlated with radon measurements. (Radon concentration measurements are available from 2011, with some gaps in the data.)

When this was done, it emerged that the radon concentration in the years 2013 and 2014 was anti-correlated with the wind direction from the mine site, i.e. the radon concentrations at Arandis were on average lower during periods when the wind blowing from the mine site than when the wind was blowing in other directions (or not at all). In the years 2011 and 2012, a small correlation could be found, leading to a public dose at Arandis of 27 μSv/a in 2011 and of 3 μSv/a in 2012. When weighted over all of the months from 2011 until December 2014 when data were available, and correlating for wind direction, the weighted public dose at Arandis as a result of the inhalation of radon was found to be 6 μSv/a, a trivial dose compared with the 1,000 μSv/a public dose limit and one that can be disregarded since it is statistically insignificant.

[11] Gunhild von Oertzen: *Baseline and Mining-related Radon Concentrations in the Rössing Mining Area*, 2013

6. Safety and security of sources

6.1. Sealed source register

No new radiation gauges or other radioactive sources were obtained in 2014. The sealed sources inventory was therefore unchanged, consisting of the four Cs-137 sources that are used in operations in the Primary Crushing Plant area of the mine. Furthermore, ten Cs-137 sources are in storage at the Radiation Source Bunker. Two of these are redundant while the remainder may be used again in operations at a later stage.

In addition, two small calibration sources are kept in a secure safe in the Radiation Safety Section Laboratory: a Cs-137 (3 kBq) source and a Th-230 (1 kBq) source, see Table 5.

Two X-ray fluorescence machines are in use at the Chemical Laboratory.

The source inventory — with the relevant source activities and most recent integrity tests — is detailed in the reporting spreadsheet supplied to the NRPA[12] together with this 2014 narrative report, and as reproduced in Table 4.

Source integrity testing is performed monthly for sources that are used in the mine's operations and six-monthly for sources kept in the Radiation Store Bunker.

All sealed radiation sources kept at the Rössing mine site are registered by the NRPA and a licence for their use has been issued.

Table 4: List of sealed sources at Rössing Uranium (radionuclide of all sources is Cs-137), December 2014

Name of manufacturer/ supplier	Serial number	Activity (GBq)	Location	Use	Comment
NTP Radio-isotopes	2725 GN	44	No. 1 Rock Box Primary Crushers (PC)	Level	In operation – new source
	004/12	35	No. 2 Rock Box PC	Level	In operation
	2770	15	Lube Room PC	Level	In operation
	005/12	34	Lube Room PC	Level	In operation
	70682	0.17	Radiation Source Bunker	Level	Not in use
	2771	15	Radiation Source Bunker	Level	Redundant
	PA 304	0.3	Radiation Source Bunker	Density	Not in use
	PA 299	0.3	Radiation Source Bunker	Density	Not in use
	PA 301	0.3	Radiation Source Bunker	Density	Not in use
	PA 302	0.3	Radiation Source Bunker	Density	Not in use
	PA 298	0.3	Radiation Source Bunker	Density	Not in use
	PA 297	0.3	Radiation Source Bunker	Density	Not in use
	2772	15	Radiation Source Bunker	Level	Redundant
	4084 GN	42	Radiation Source Bunker	Level	New source

Table 5: List of calibration sources at Rössing Uranium

Nuclide	Type of Source	Half-life (years)	Initial activity (kBq)	Date of manufacture	Time elapsed (years)
Cs-137	Beta	30	3	2011/12/13	3
Th-230	Alpha	75,380	1	2011/12/16	3

[12] Note: the spreadsheet is supplied to the NRPA as a legal requirement. It is not made publicly available because it contains personal dose records of workers which constitutes information subject to privacy considerations.

6.2. Sealed source checks

Integrity checks of sealed sources in operation are performed monthly. Sealed sources in storage in the Radiation Source Bunker are checked at six-monthly intervals only as there is no regular activity at the bunker.

6.3. X-ray generating equipment

The Rössing Uranium Chemical Laboratory makes use of two analytical x-ray units, as per its registration and licence, which expires in 2015.

7. Transport of radioactive material

7.1. Transport and export of uranium oxide concentrate

A total of nine shipments of uranium oxide were exported from Walvis Bay in 2014. The consignments are summarised in Table 6. A total quantity of 1,492,073.318 kg of uranium oxide concentrate (UOC) was exported, containing a total of 1,265,278.174 kg of natural uranium.

During an International Atomic Energy Agency (IAEA) inspection under the Safeguards Agreement, the IAEA delegation, accompanied by officials from the Ministry of Mines and Energy and the NRPA, obtained a sample of uranium oxide (3.9 g of U contained in the sample of 4.6 g) and a sample of ore slurry (0.01 g of U contained in roughly 33 g). Ownership of the sample material was transferred to the IAEA, which obtained the necessary permits for transporting this sample to Vienna.

Table 6: List of UOC shipments from Rössing Uranium in 2014

Date of consignment	Country of final destination	Total weight of UOC in shipment (kg)	Total weight of contained U element (kg)
19 January 2014	Canada	71,941.333	61,006.250
8 April 2014	USA	246,882.006	209,355.941
26 May 2014	USA	251,307.032	213,108.363
6 October 2014	China	302,365.796	256,406.195
1 November 2014	Canada	139,264.631	118,096.407
3 November 2014	China	250,807.080	212,684.404
13 November 2014	France	51,946.507	44,050.638
7 December 2014	Canada	141,453.986	119,952.980
21 December 2014	France	36,104.947	30,616.995

7.2. Transport of other source material

With the adoption of the 2012 edition of the IAEA *Transport Regulations,*[13] transport of radioactive sample material has become greatly simplified because ore samples not exceeding a grade of 800 ppm of uranium in ore are not considered radioactive for transport and therefore permits do not have to be obtained for these samples. As no samples with an ore grade exceeding 800 ppm were transported, no permits were required in 2014.

7.3. Radiation exposure of workers during transport

As described in the Rössing Uranium RMP, Rössing Uranium's UOC is transported by rail to the port at Walvis Bay. As has been confirmed with individual dose monitoring via electronic dosimeter, the exposure dose to transport workers as a result of activities related to transporting UOC from the mine site to the port at Walvis Bay is negligible.

Those radiation safety and quality control workers who accompany the transports to the port and supervise the handling of containers to ships are designated as radiation workers. As such, the exposure to penetrating radiation is monitored continuously via TLD devices and additional monitoring is therefore not regarded as necessary.

[13] Regulations for the Safe Transport of Radioactive Material, 2012 Edition, Specific Safety Requirements, No. SSR-6, International Atomic Energy Agency, Vienna, 2012

8. Emergency response and preparedness

A uranium spill drill was held in the container yard at the Rössing Uranium mine site on 18th December 2014.

The drill procedure — and communication with employees about the mock drill — followed Rössing's *Business Resilience and Recovery Programme.*

9. Disposal of radioactive waste

9.1. Disposal of radioactively contaminated waste

Waste that is radioactively contaminated is disposed of on the TSF. Before disposal, a trench is prepared for receiving the contaminated waste. Immediately after disposal, the waste is covered with tailings sand in order to prevent the loss or diversion of material from the disposal site.

Rössing Uranium disposed of a total of 685 tonnes of contaminated waste on the TSF in 2014.

In addition, 66 tonnes of radioactively contaminated hydrocarbons are stored in a designated storage area on site until a disposal method that is safe to the environment can be found.

9.2. Mineral waste

Mineral waste is deposited in the form of tailings material on the TSF and in the form of waste rock on the Waste Rock Dumps.

In 2014, a total of 7 million tonnes of tailings were deposited on the TSF, and 16 million tonnes of waste rock were deposited on the Waste Rock Dumps.

10. Changes and revision status

First Issue	Issue date	Prepared by	
2.0	10 March 2015	G. von Oertzen	
Version number	**Revision date**	**Revised by**	**Reason for change**
2.1	30 March 2015	G. von Oertzen	Layout for internet, update of TLD dose records (Table 1) with results that were still outstanding.