Rio Tinto

Rössing Uranium Limited
Working for Namibia

Implementation of Radiation Management Plan

2016 Annual Report

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 deposit in 1966. Ten years later, in 1976, Rössing Uranium, Namibia's first commercial uranium mine, began operating and celebrated its 40th year of production in 2016.

Today, Namibia has two significant uranium mines, which together provide just more than 5 per cent of the world's uranium oxide mining output; Rössing Uranium produces about 2.5 per cent of the world's output.

The mine has a nameplate capacity of 4,500 tonnes of uranium per year and, by the end of 2016, had supplied a total of 130,500 tonnes of uranium oxide to the world.

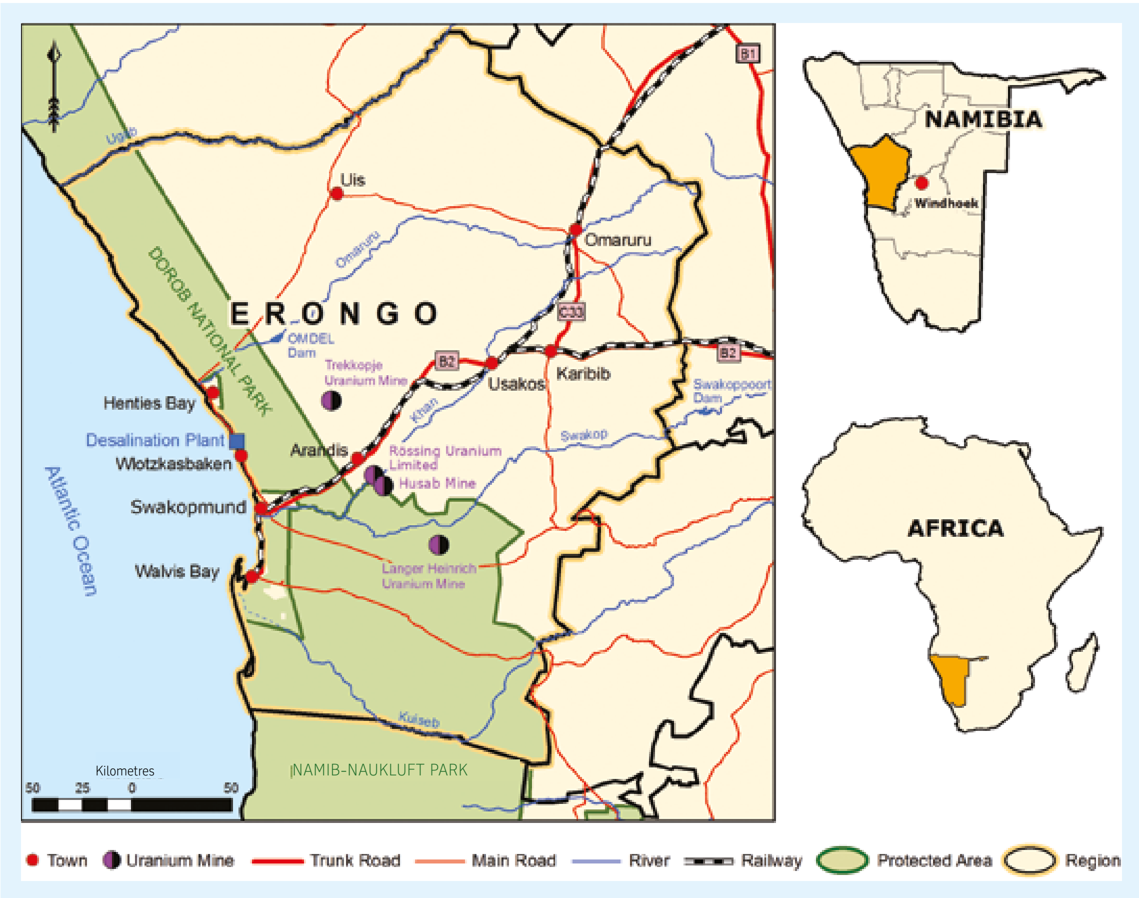
The mine is located 12 km from the town of Arandis, which lies 70 km inland from the coastal town of Swakopmund in Namibia's Erongo Region. Walvis Bay, Namibia's only deep-water harbour, is located 30 km south of Swakopmund.

The mining operation is located in a hyper-arid environment. Insolation at Rössing Uranium is high, and as a result, daytime temperatures ranges are wide, especially during May and September, when the difference between minimum and maximum temperatures exceeds 20°C daily.

The lowest temperature is normally recorded during August, but frost is rare. The highest temperature is normally recorded in the late summer, particularly in 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, waste disposal and processing.

Mining is done by blasting, loading and hauling from the main 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.



Contents

JK85/RMP/004

HSE MS Element 4

Effective date	10/08/2017
Version no.	1.1
Status	Revision
Author	G. von Oertzen

Acronyms and abbreviations

The following acronyms and abbreviations are used throughout the report:

Bq	becquerels, decays per send, unit for measuring radioactivity
g	gram
HSEC	Health, Safety, Environment and Communities
kBq	kilo-becquerels, 1,000 Bq
LLRD	Long Lived Radioactive Dust
mBq/L	milli-becquerels per litre, 10^{-3} Bq per litre
mSv	milli-sieverts, sieverts/1,000
µSv	mico-sieverts, sieverts/1,000,000
µSv/a	µSv per annum
mSv/a	mSv per annum
mg/m^3	milligrams per cubic metre, 1/1,000th of a gram per cubic metre
µg/m^3	micrograms per cubic metre, 1/1,000,000th of a gram per cubic metre
µg/L	micrograms per litre, 10^{-6} grams per litre
NRPA	National Radiation Protection Authority
ppm	parts per million
PM10, PM_{10}	Particulate matter with particle size below 10 microns
RUL	Rössing Uranium Limited
RMP	Radiation Management Plan
RPO	Radiation Protection Officer
RSO	Radiation Safety Officer (statutory role)
SEG	Similar exposure group
TLD	Thermo luminescent dosimeter
TEA Lab	Trace Element Analysis Laboratory
TSF	Tailings Storage Facility
UI	Namibia Uranium Association Uranium Institute
UOC	Uranium oxide concentrate
WHO	World Health Organization
XRF	X-ray fluorescence

1. Introduction

Background

Under the Radiation Protection Regulations[1], an annual narrative report to the National Radiation Protection Authority (NRPA) about the implementation of the site Radiation Management Plan (RMP) is a requirement.

Rössing Uranium hereby presents the fourth narrative report since the implementation of this requirement. The previous reports (2013 to 2015) are publicly available on the Rössing website, http://www.rossing.com/reports-research.htm.

2. Organisational arrangements

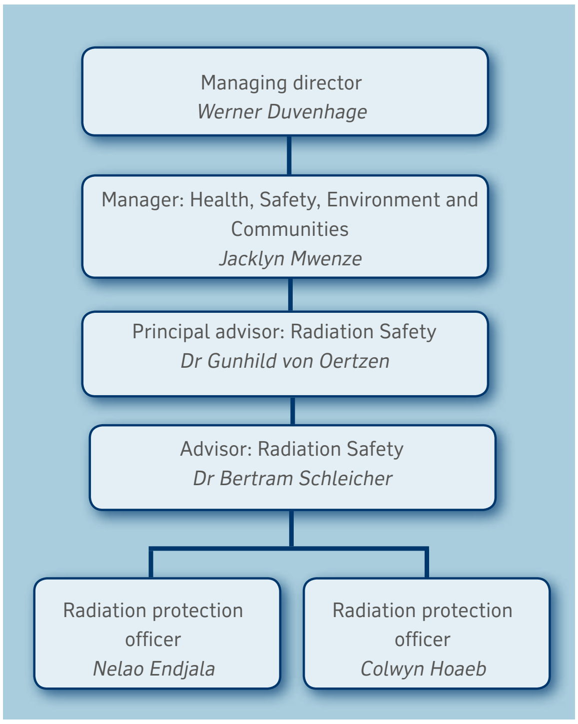
2.1 Organisational structure

The organisational structure relating to Radiation Safety in 2016 is shown in Figure 1.

The reporting structure remains unchanged from 2015, with the newly-created position of Advisor: Radiation Safety having been filled since May 2016 by Dr Bertram Schleicher. Dr Schleicher has a scientific background in applications ranging from characterisation of nano aerosol particles to oil technology and is amply qualified as an analyst for radiation physics applications.

With this recruitment, the team capacity is increased significantly, hence reducing any risk to the radiation safety programme from potential resignations in the team.

Figure 1: Organisational structure for Radiation Safety Section, 2016



2.2 Capacity building

In 2016, the International Radiation Protection Association (IRPA), which is the overarching Association of individual National or Regional Radiation Protection Associations, held its 14th International Conference in Cape Town, South Africa.

The proximity of the conference location was an ideal opportunity to participate. Principal advisor: Radiation Safety, Dr Gunhild von Oertzen, presented a paper titled "Public dose assessments for atmospheric pathways at Rössing Uranium mine, utilising direct monitoring data", summarising and explaining the approach we are taking for evaluating the public dose at nearby town, Arandis. The conference was also a unique opportunity to catch up with the latest development in international radiation safety.

In order to reinforce the importance of radiation protection and the skills base needed for a comprehensive radiation protection programme, Rössing Uranium continues to support and contribute towards the training programme for Radiation Safety Officers (RSOs) offered at the Uranium Institute.

During 2016, several training courses were offered for RSOs, including two one-week introductory RSO courses and the popular annual two-day RSO refresher workshop aimed at bringing experts of the industry together to learn about contemporary issues in radiation safety.

The annual RSO refresher workshops focus on different topics each year. In 2016 we developed some scenarios relative to radiation safety via role play in working groups, and each candidate gave a presentation about a topic from his or her own work experience in radiation safety to the group. Six professionals from Rössing Uranium participated in the RSO refresher workshop, including all four team members from Radiation safety and two from the Health management team.

[1] Radiation Protection and Waste Disposal Regulations: Atomic Energy And Radiation Protection Act, 2005 (Act No. 5 of 2005)

3. Occupational exposure protection

3.1 Radiation dose monitoring results for 2016

At the beginning of each year, we re-examine the assignments of similar exposure groups (SEGs) and people. This helps to ensure that people assigned to a SEG have similar exposures to occupational risks, as the term 'similar exposure group' implies, and that we understand and adjust for important deviations from this assignment.

In 2016 we had 22 SEGs, one of which is not relevant to radiation protection as it pertains to workers working off-site. We monitored each of the remaining 21 SEGs as follows:

- All workers in the SEGs "Recovery" and "Final Product Recovery" are designated "radiation workers", which means that they could potentially be exposed to 5 mSv per year or more. Therefore, the penetrating (gamma) radiation dose of these workers is monitored continuously using TLD badges which are issued for 12 weeks at a time. At present, there are 45 workers in this category.
- All other workers are regarded as "occupationally exposed", but not significantly so, as their annual dose is similar to background radiation. Hence, monitoring of people in this category is randomly by SEG. This means that the exposure dose of a number of people in each SEG is measured over a few days. The average dose for the group is then extrapolated to an annual dose, based on a 2,000-hour working year and without subtracting any background radiation. In order to ensure statistical validity, we compare this result with that from previous years and repeat the measurement if significant differences in outcome are observed. This average SEG dose is then assigned to each worker in the SEG. The approach is valid as the dose per worker is not significantly different from background radiation, and substantially below the annual dose limit of 20 mSv.
- The random personal monitoring programme stretches over all SEGs (even "Recovery" and "Final Product Recovery"). It covers three pathways: external exposure from gamma radiation, internal exposure from the inhalation of long-lived radioactive dust, and from radon and its decay products. Each of these pathways is monitored personally, using customised personal dosimeters designed for the purpose.

The outcome for 2016 is summarised in Figure 2.

We find that when averaged over the dose records of all workers on the mine, the average dose is close to 1 mSv/a, as has been confirmed for the past four years. The mine-wide weighted average dose this year was found to be 1.1 mSv per annum, when assuming 2,000 hours of working time in the year. There was only one person whose total dose exceeded 5 mSv per annum, with the maximum value recorded as 6.0 mSv.

3.2 Urine bioassays

Each worker who is classified as a "radiation worker" is required to provide a monthly urine sample. In the Final Product Recovery (FPR) area, the sampling is more frequent at two-weekly. Samples are analysed at the Trace Element Analysis Laboratory in Swakopmund for their uranium contents.

In 2016, one sample was found to exceed the action level of 40 µg/L of uranium in urine. The worker was removed from the workplace pending the conclusion of the investigation into the incident, and until urine sampling returned a normal value. The investigation of the incident unveiled the fact that the density of this sample was almost identical to that of water, or below the reference range for urine samples. It was therefore concluded that the sample was accidentally diluted with water and was not a valid sample.

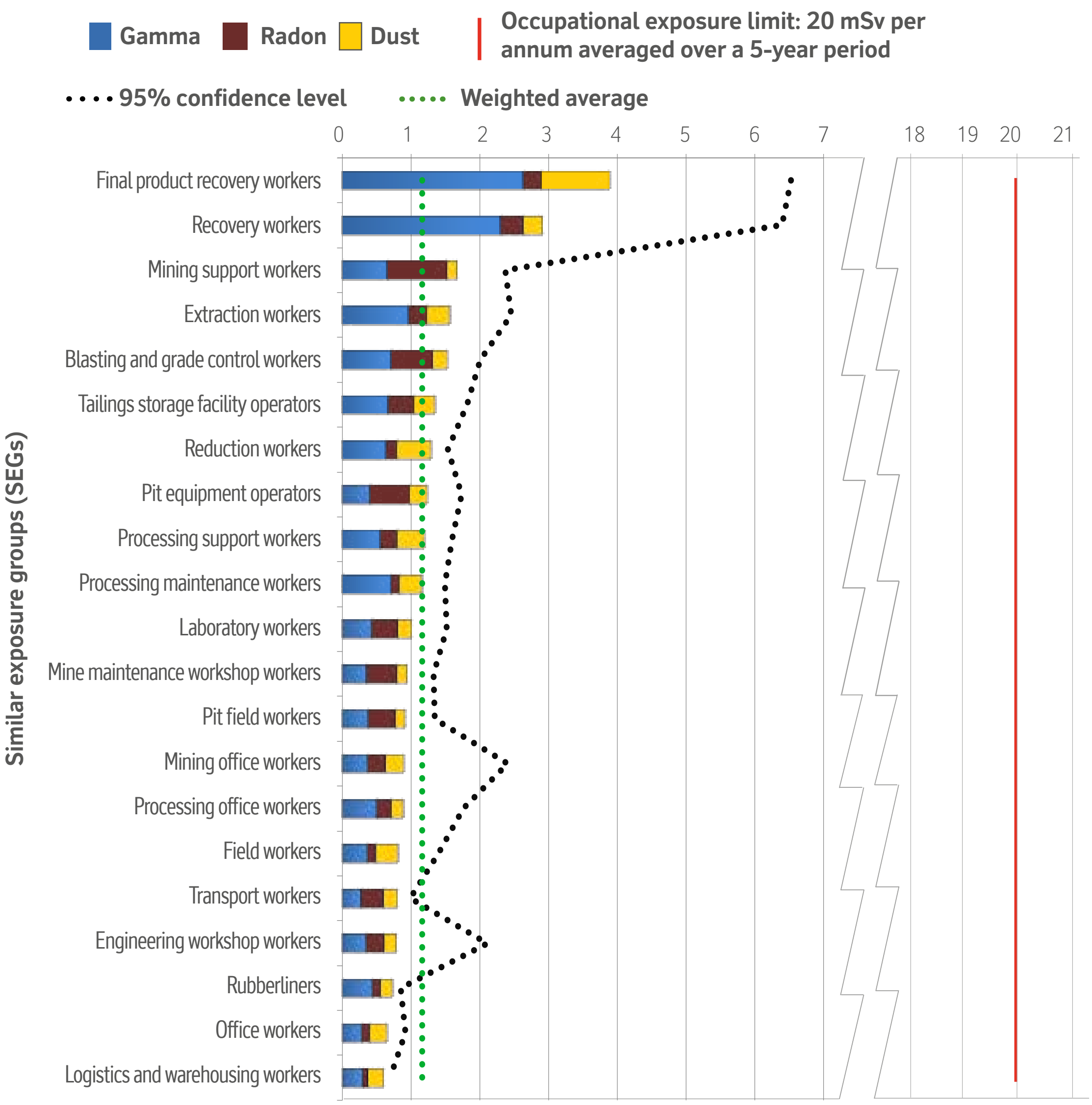
An investigation of the workplace habits of the affected worker was unable to detect any potential for accidental ingestion of uranium, particularly as the worker worked in the Solvent Extraction area, where ingestion of uranium is highly unlikely.

The subsequent urine sample of the affected worker came up with a uranium content below the detection limit, hence confirming the conclusion that the initial test result was erroneous.

A total of 1,057 samples were taken in 2016, with no other exceedances of either the warning (20 µg/L) or the action (40 µg/L) levels. Only nine samples exceeded the limit of detection, which is less than 1 per cent of all samples.

Figure 2: Average doses recorded by pathway and SEG, in 2016

Figure 2: Personal radiation exposure dose by similar exposure group (SEG), 2016

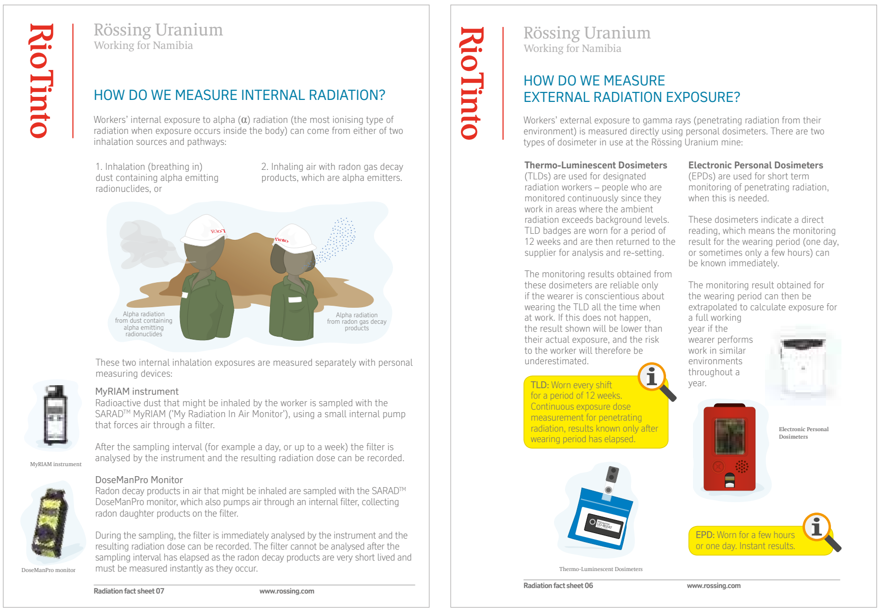


3.3 Radiation awareness training

Apart from awareness sessions about radiation that are offered to each section on demand or if a need for such a session has been determined, radiation awareness training forms part of the Health, Safety and Environment (HSE) training requirements for workers, compliance with which is logged electronically and followed up continuously. Each worker attends a two-hour induction about radiation safety when he or she commences working at the mine, and attends a refresher at least every two years thereafter.

In addition to interactive sessions, the Rössing Uranium intranet provides information about radiation with 100 fact sheets and/or toolbox topics about radiation, which workers or leaders can access on demand. Topics include workplace radiation protection, typical concerns about radiation, background information about radiation and its possible effects on people and the environment, occupational exposure controls and occupational exposure statistics for Rössing Uranium workers. Two examples of typical radiation fact sheets are displayed in Figure 3.

Figure 3: Examples of fact sheets about radiation on Rössing Uranium's intranet



3.4 Communication of monitoring outcomes to employees

After each week of personal radiation exposure monitoring, a group report is prepared, summarising and explaining the monitoring outcome. This report is shared with the affected team during team discussions.

Urine sampling results are communicated to individuals only if an exceedance of the warning or action levels has occurred.

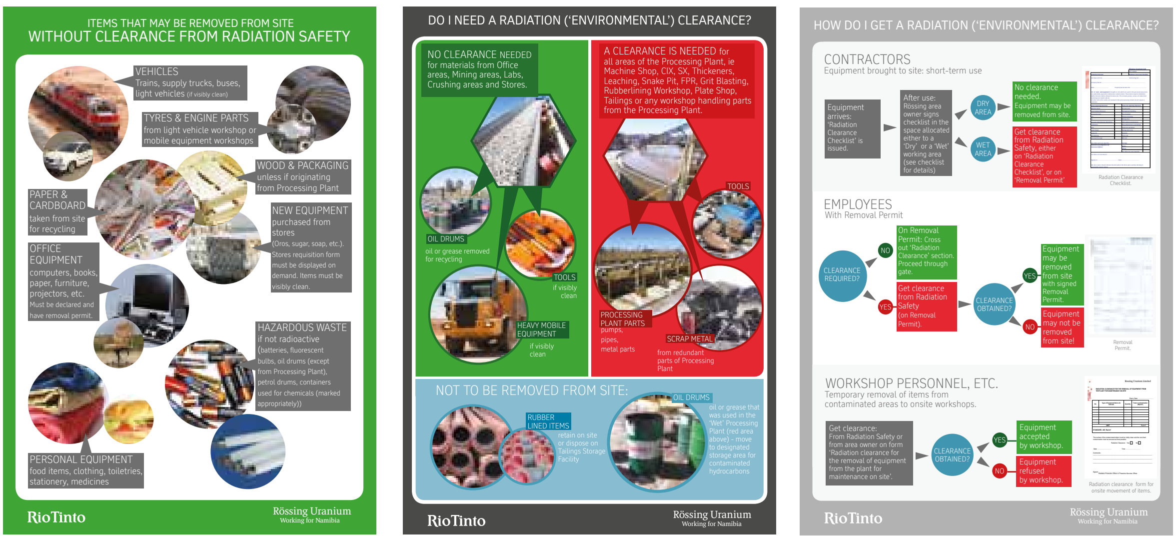
All personal exposure dose results and urine sampling results are available to employees via the Rössing Uranium intranet.

The results displayed are only those of the person logged on to the computer, not of anyone else, hence ensuring confidentiality of the results. All Rössing Uranium workers have access to computers in their working areas.

3.5 Signage

Because of the potential for contamination with radioactive materials at the mine, any item that is removed from the site needs to be confirmed to be free of any radioactive contamination. The process for obtaining clearances from Radiation Safety department for removing items has created confusion in the past, leading to inefficiencies in the workplace.

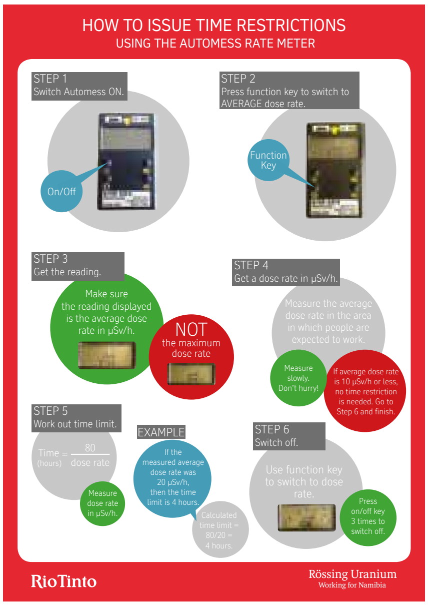
Figure 4: Signs explaining the process for obtaining clearances from Radiation Safety



In 2016, we created a series of signs explaining the process, and provided each working area with the appropriate signage around the clearance process. This has significantly improved the waiting time associated with clearances, and has equipped workers with an improved awareness of the necessary steps to obtain these clearances. Signs explaining the process are displayed in Figure 4.

We also introduced signage explaining the process of time restrictions in areas with elevated dose rates: in areas where the average dose rate exceeds 10 μSv/h, time restrictions on working in that area apply, such that a daily reference level of 80 μSv is not exceeded for any worker. A sign explaining the process is displayed in Figure 5.

Figure 5: Poster explaining how to issue time restrictions



3.6 Dust levels in FPR area

Levels of dust in the FPR area have been a concern in the recent past. Rössing Uranium has therefore introduced several changes to the area:

- We have created a physical separation between the drum filling machine and the remainder of the building, hence separating potentially dusty areas from areas in which people are working.
- We have introduced a level measuring source into the drum filling process in order to prevent overfilling of drums and in the process creating additional dust (see Figure 6).
- We have procured a new drum filling and drum washing unit, which will be installed in 2017 and should significantly further reduce any issues with dust in the area.

In 2016, the average dust inhalation dose rate recorded in the FPR area was 6 μSv/h, without taking the protective effect of wearing respirators into account.

The measures have already significantly reduced the levels of dust in the FPR area, which will improve more when the new unit is installed towards mid 2017.

Figure 6: New sealed source for measuring drum filling levels in Final Product Recovery area

4. Medical exposure

Not applicable.

5. Public exposure protection

5.1 Background

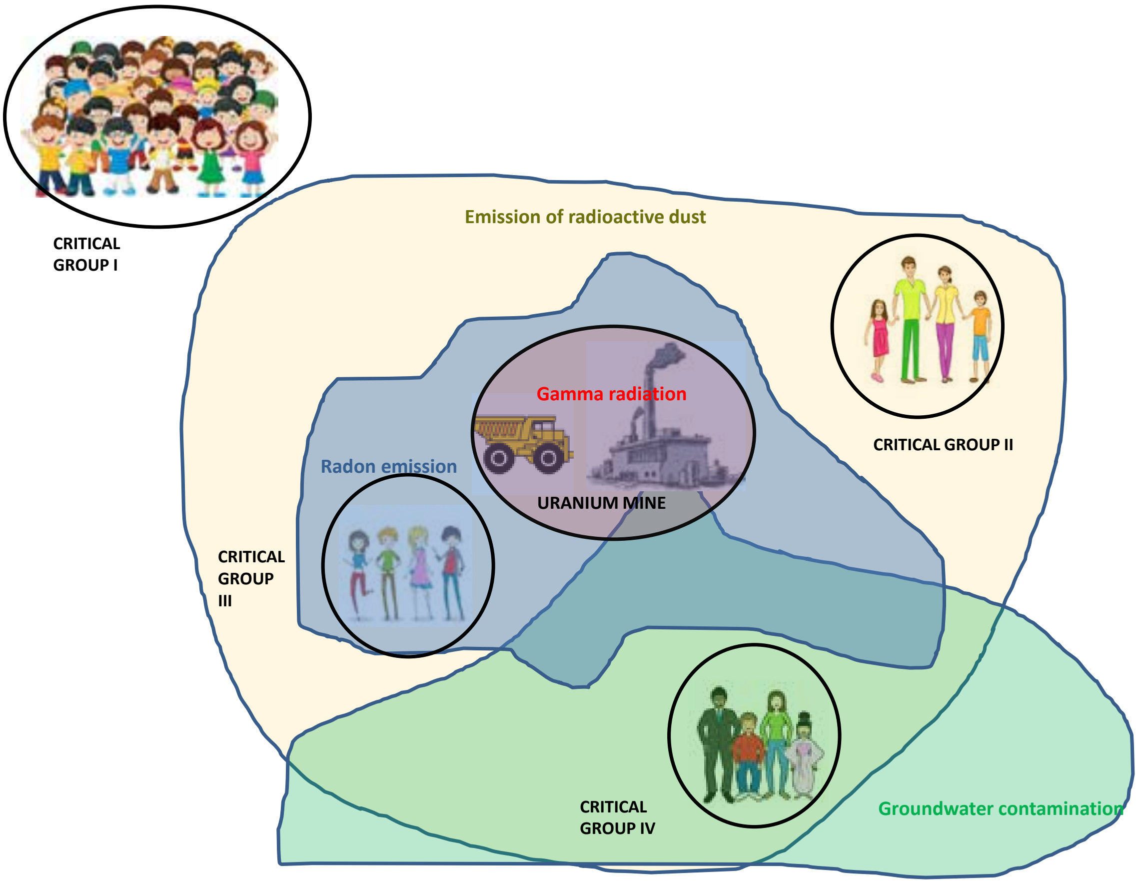
The dose limit for public exposure resulting from mining activities at Rössing Uranium is 5 mSv over a defined 5-year period, or 1 mSv per year on average. This dose limit does not include background sources, be they natural or man-made.

The natural background radiation in the Erongo Region is approximately 1.8 mSv/a, while the additional dose from mining activities to critical groups in the public is generally very low to negligible. It is therefore not possible to measure the public dose[2] directly — it must be calculated from first principles, after determining the factors potentially contributing to this public dose.

This principle is illustrated schematically in Figure 7: the potential public exposure pathways include the emission of radioactive dust, the emission of radon emitted as a result of the mining process and potential groundwater contamination.

Each of these pathways can potentially reach a different public group. In some cases, there can be overlaps between pathways, such that the same critical group is exposed to radiation from several distinct pathways.

Figure 7: Schematic summary of pathways and critical groups contributing to potential public exposure doses



[2] The additional dose to the public due to mining related activities is referred to as the "public dose", and this explicitly excludes background related sources of radiation exposure dose.

Hence, the exposure along each pathway needs to be quantified for each critical group (the group that would receive the maximum possible dose from a particular scenario).

Where a group is exposed to radiation from several pathways, the total dose to that group from all pathways combined must not exceed the public dose limit. With no members of the public living on the mine site, the public dose from gamma radiation, which is localised to the mine, can be disregarded.

In the hypothetical example shown in Figure 7, critical group I is not exposed to any radiation from the mine; group II is exposed only to inhalation of radioactive dust; group III is exposed to dust and radon originating from the mine; and group IV is exposed to drinking groundwater potentially contaminated by mining activities, as well as to the inhalation of radioactive dust.

At Rössing, the critical group relevant to the inhalation of radon coincides with that for the inhalation of radioactive dust and is comprised of the people of Arandis.

For potential groundwater contamination, there is currently no critical group that can be affected through this pathway, as the direction of water flow from the mine is to the south, towards the Khan River. Nevertheless, groundwater contamination is well controlled with no impact on the groundwater in the immediate environment.

5.2 Water monitoring

Exposure through the aquatic pathway could result from the potential seepage of contaminated water from the Tailings Storage Facility (TSF) into the Khan River aquifer.

Tailings from the processing of uranium ore at Rössing Uranium are stored in a single TSF. The tailings impoundment has an existing footprint of about 750 ha and a maximum wall height of around 100 m.

The ultimate footprint for the life of mine configuration in 2025 is planned to stay at about 750 ha with an increased wall height and a total storage capacity of 600 million dry tonnes.

Fine tailings are pumped and coarse tailings conveyed to the facility where they are mixed and hydraulically deposited into an active paddock. Decant water from the facility is recycled back to the process plant.

Surface seepage from the TSF is captured in a down-gradient seepage collection dam. This water is recycled back to the Processing Plant. Process water in the decant ponds on the TSF typically has a pH of 2, contains some dissolved uranium and has a total dissolved solids concentration of about 25 g/L, reaching up to 70 g/L. Percolation towards the base of the TSF results in neutralisation and precipitation of contaminants.

A system of monitoring boreholes surrounds the TSF and water quality is measured bi-annually. In the past, water samples were analysed for their radionuclide content, in particular the ratio of radioactivity of the isotopes U-234 and U-238 was determined. The isotope ratio allows a determination of the origin of water resources as either naturally occurring, or resulting from seepage from the TSF[3].

In 2016, the borehole monitoring programme was systematically reviewed. The delineation of the current seepage plume around the TSF is influenced by the chemical content and flow direction of the tailings fluids in the geohydrological environment.

In Figure 8, the current seepage plume is indicated together with boreholes close to the edge of the plume. Boreholes close to the edge, but outside the plume are monitored regularly; this will be sufficient to obtain information on the potential advancement of the plume.

Boreholes within the plume need not be monitored, as it is already known that they are affected by seepage. The plume outline found in this way is broadly consistent with the radionuclide analysis methods used in earlier years to delineate the area affected by seepage.

[3] The principles behind alpha recoil and its potentials for monitoring are explained in the RMP, and in the articles *Water quality monitoring at Rössing Uranium mine using isotope techniques*, and *Using alpha recoil as a tool for contamination control in the Khan River aquifer*. All of these are available on the Rössing Uranium website, http://www.rossing.com/reports-research2.htm.

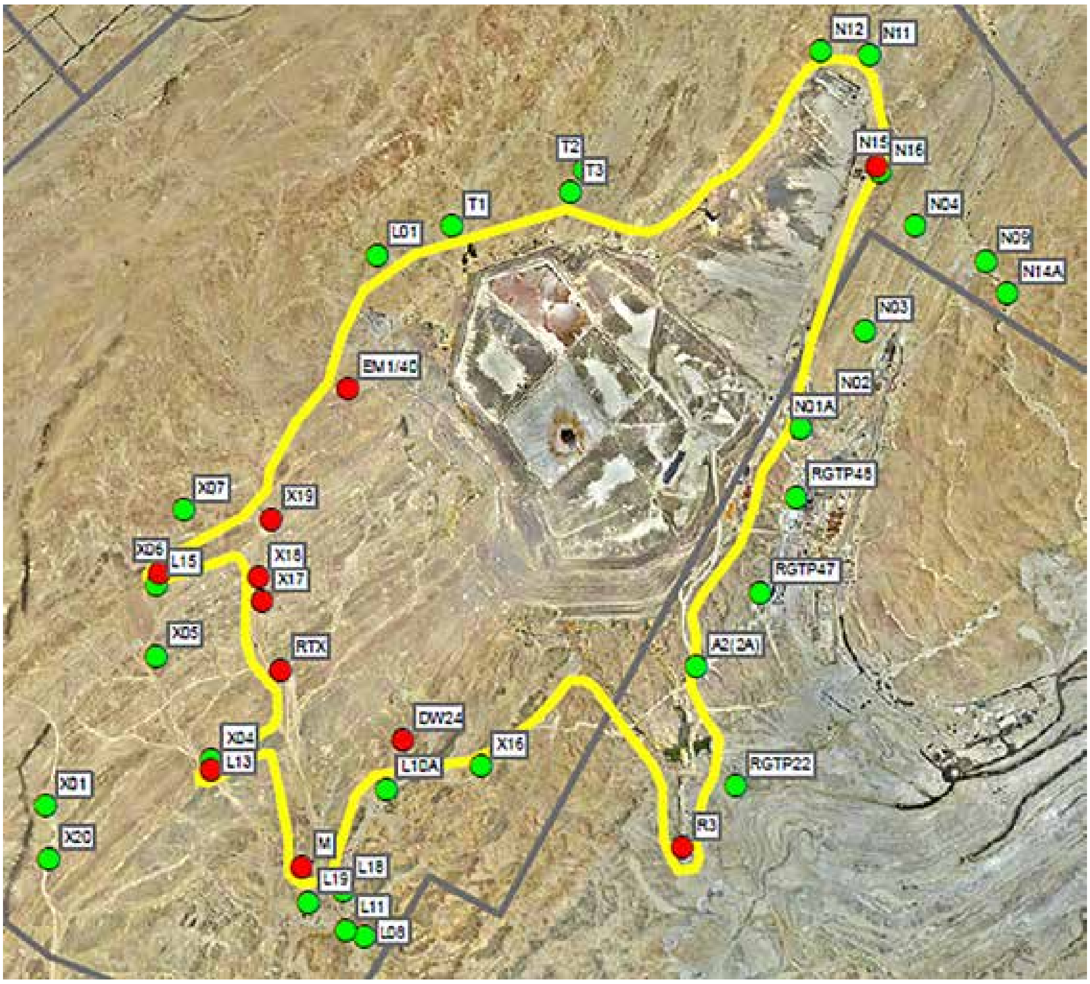


Figure 8: Delineation of the seepage plume surrounding the tailings storage facility (yellow line). Affected bores close to the seepage front are indicated with red circles; unaffected bores with green circles.

5.3. Dust monitoring

The public dose from the inhalation of dust can be assessed via measurements of the concentration of dust in the air breathed. The size of particles inhaled is directly linked to their potential for causing health risks. Small particles less than 10 micrometres in diameter pose the greatest risk, because they can get deep into the lungs, and some may even get into the bloodstream.

Several dust monitoring stations are placed in strategic locations around the mine site, where the concentration of dust particles smaller than 10 microns is measured in 15-minute intervals. This dust is referred to as particulate matter smaller than 10 microns, or PM_{10} in short.

The locations of the PM_{10} stations include one at Arandis, one at the Rössing Uranium TSF, one at the Communications Management Centre (CMC) and one at the western mine boundary. The location of these monitoring stations is shown in Figure 9, along with the positions of dust fallout monitors and multi-vertical samplers.

The PM_{10} sampler at Arandis provides the PM_{10} dust concentration, wind speed and wind direction in intervals of 15 minutes. This allows the allocation of a dust concentration as mining related (if the wind blows from the mine) or background (when the wind is blowing in any other direction). This principle is illustrated in Figure 10.

In 2016, we found that the wind was blowing towards Arandis 14 per cent of the time, and towards other directions for the remainder of the time (Figure 11). The PM_{10} dust concentration measured in 15-minute intervals is summarised in Figure 12.

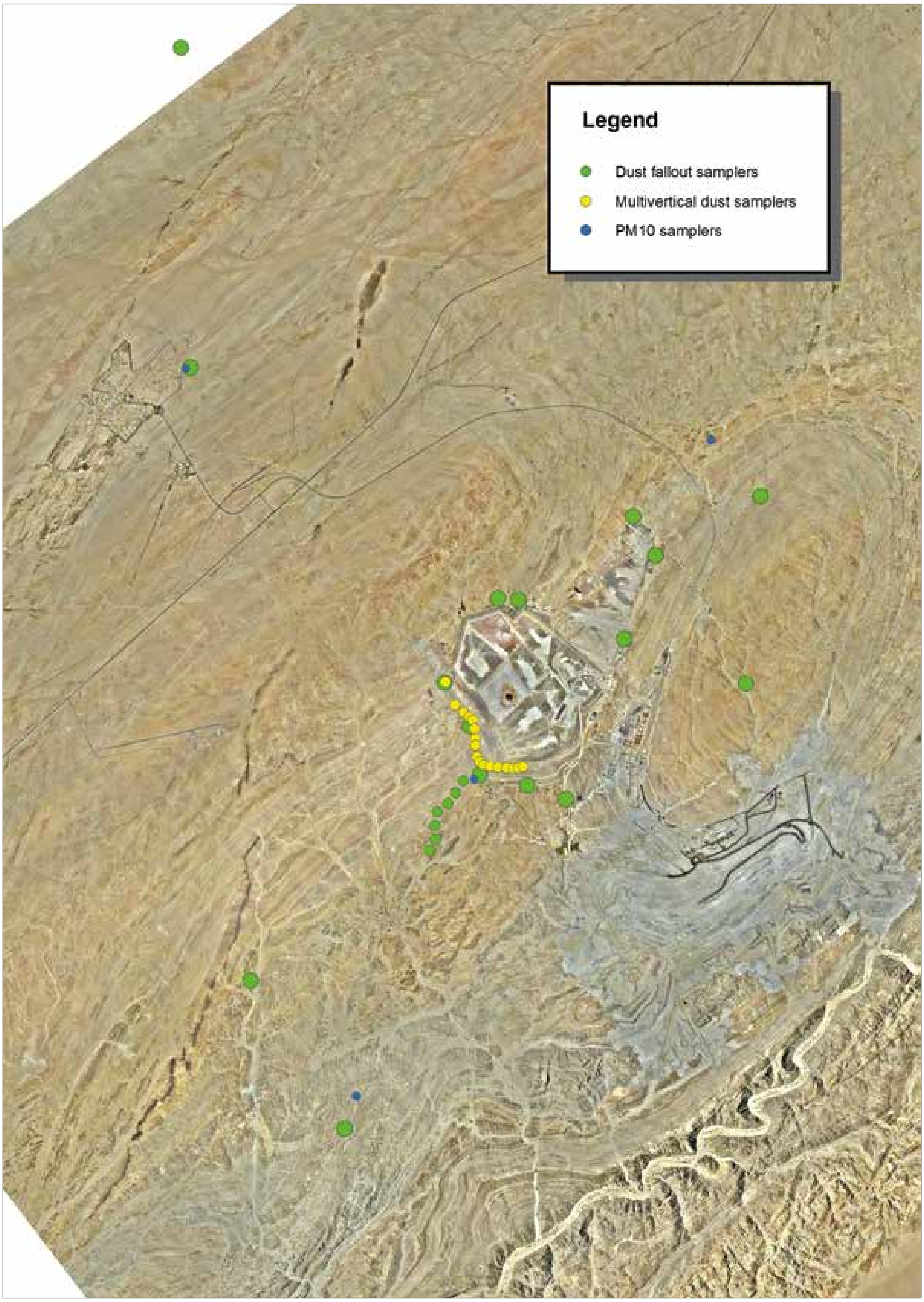


Figure 9: Air quality monitoring network at Rössing Uranium, with locations of dust fallout samplers (green), multi-vertical dust samplers (yellow) and PM10 monitoring stations (blue) indicated.

Figure 10: A satellite image showing those wind directions that could result in dust exposure at Arandis as a result of activities at the mine.

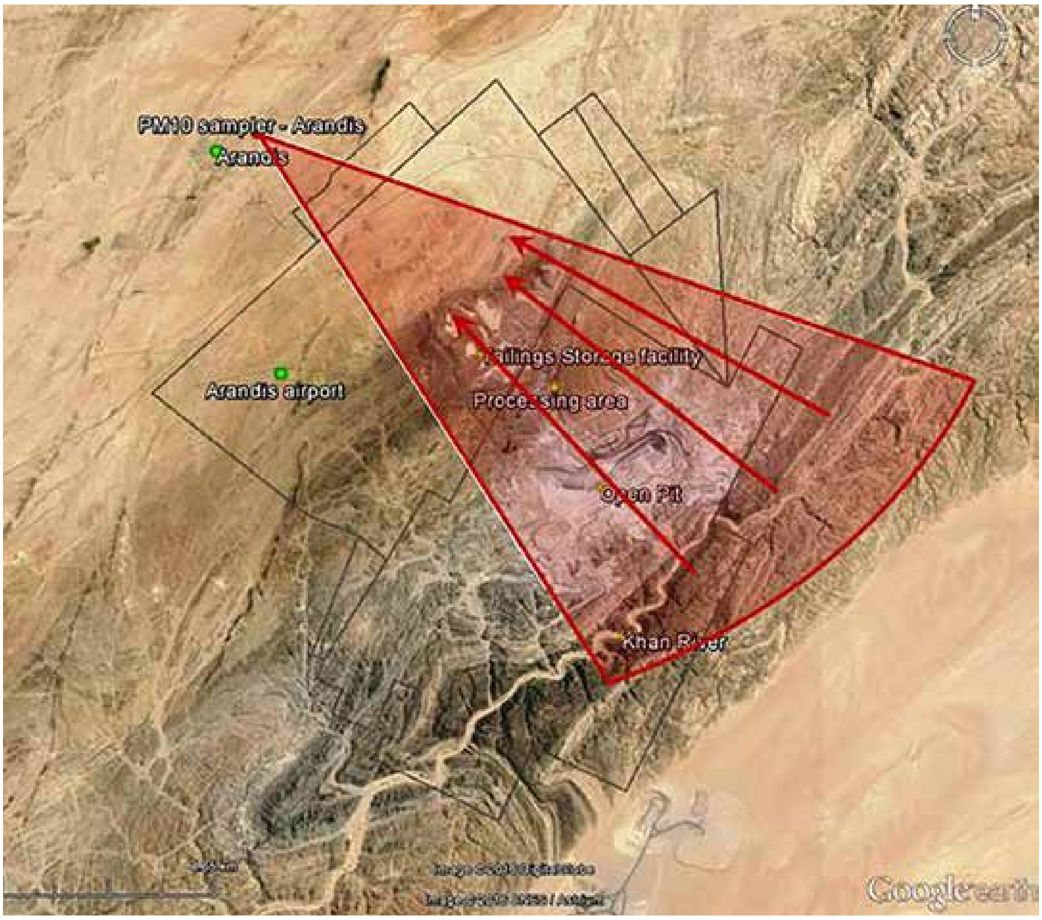


Figure 11: Fraction of wind directions, with mining related wind directions in dark blue

Faction of wind direction at Arandis, 2016

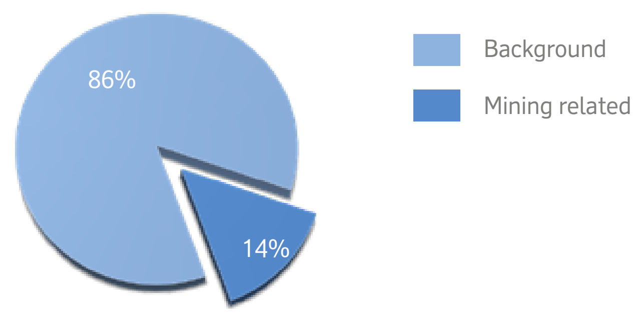
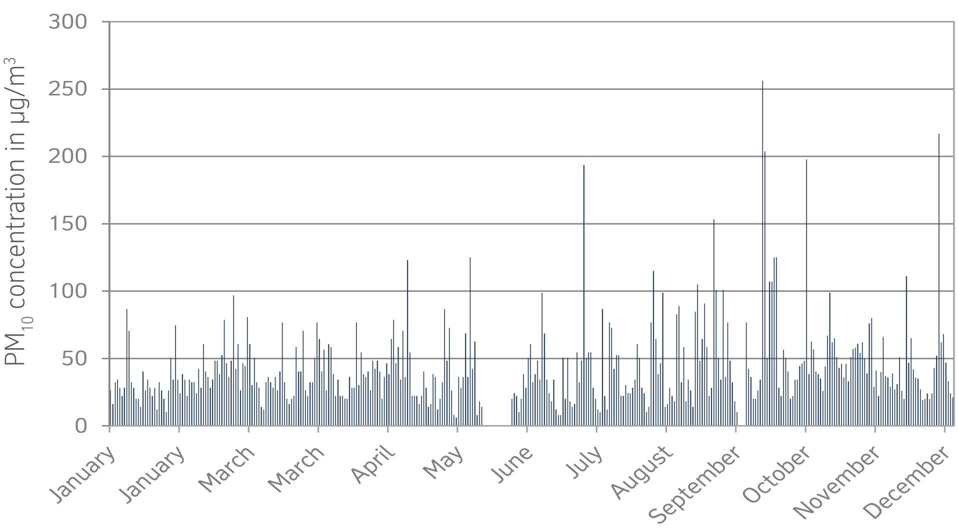


Figure 12: PM_{10} concentration at Arandis, measured in intervals of 15 minutes

PM_{10} dust concentration, Arandis, 2016



The overall average PM_{10} dust concentration measured was 16 µg/m³, which is below the World Health Organization (WHO) guideline value for outdoor air quality of 20 µg/m³ when averaged annually. The concentration measured in directions from the mine was 19 µg/m³ and the average not related to mining actitivies was also 16 µg/m³.

Based on the composition of all dust found at Arandis[4], the total inhalation dose at Arandis due to the inhalation of all dust is 6 µSv per annum, which is a trivial dose[5]. The mining-related contribution, ie the public dose, is only 1 µSv per annum, ie 0.001 mSv per annum.

In 2016, at the south-western boundary PM_{10} station, the wind was blowing in a direction from the mine 23 per cent of the time (Figure 13).

The relevant measured dust concentrations are shown in Figure 14.

The total average PM_{10} concentration at the south-western boundary station was found to be 32 µg/m³. The PM_{10} concentrations measured down- and upwind of the mine were 33 and 32 µg/m³ respectively.

If one assumes as a worst case the dust downwind of the mine to be pure ore dust from the Rössing Uranium crushers, then this would result in a theoretical mining related public dose of 12 µSv/a (0.012 mSv per annum) at this location, which is still a very low dose, even though it is larger than at Arandis.

Figure 13: Wind directions at the south-western mine boundary, 2016

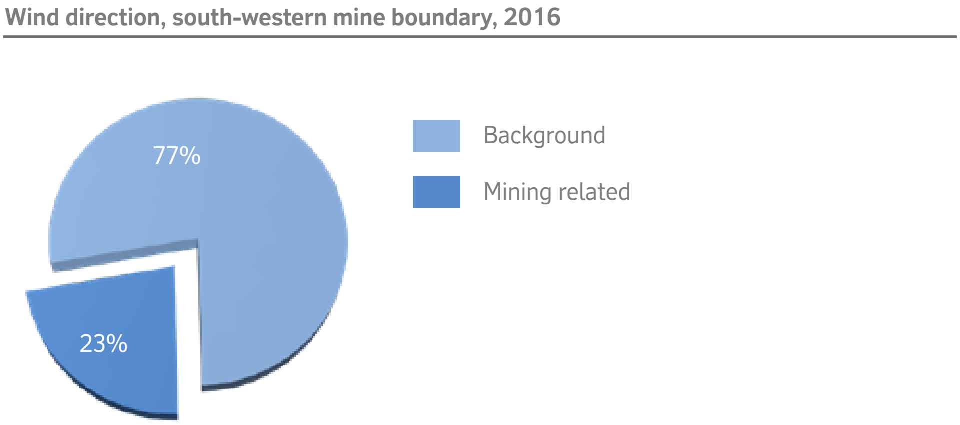
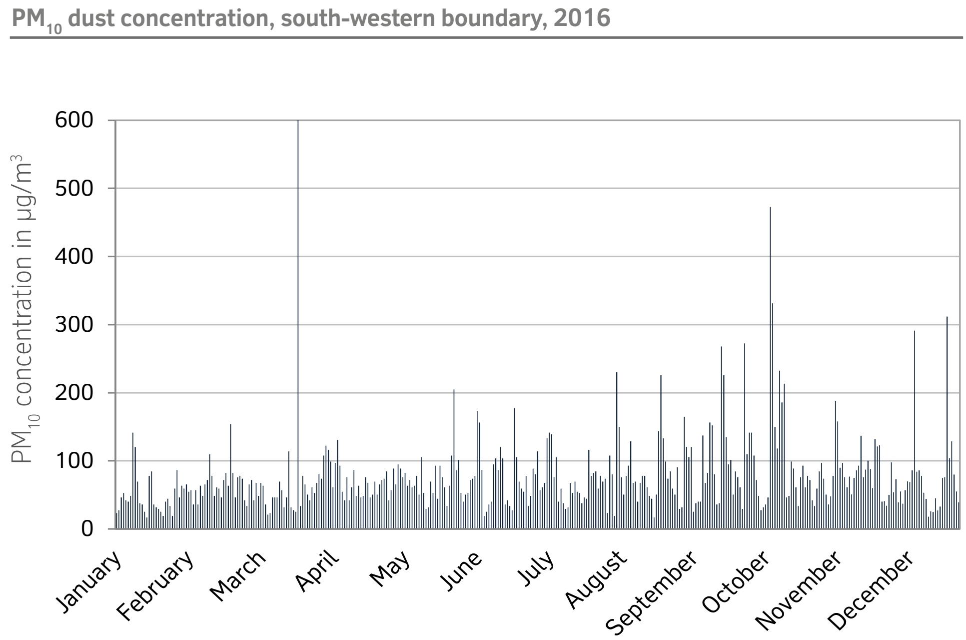


Figure 14: Measured PM_{10} concentrations at south-western mine boundary, in intervals of 15 minutes



[4] See for example 2015 Implementation of Radiation Management Plan, downloadable at www.rossing.com.
[5] A public dose of less than 10 µSv per year from any activity is generally regarded as trivial by the International Commission on Radiological Protection (ICRP).

5.4. Radon monitoring

As there have been no changes to the mining operations that could result in a measurable increase of the radon emitted from the site, no new radon measurement were performed in 2016.

The average radon concentration at Arandis is measured at the radon station operated by the Uranium Institute and owned by the National Radiation Protection Authority. The station is located at the Arandis NamWater reservoir some 6 m above ground level. Between 2011 and 2014, the average radon concentration measured there was found to be 21 Bq/m3, consistent with background radon concentrations found in the 2011 Strategic Environmental Assessment report[6].

The radon concentration data available from the station at Arandis are incomplete as there are data gaps of several months for most years; the most complete set of data is from the year 2013.

At the radon monitoring station, the relevant wind directions from the mine range between 113 and 203 degrees. Atmospheric radon concentrations are measured in 10-minute intervals, and can be classified as mining or non-mining related, based on the wind direction at the time of measurement, as demonstrated in Figure 15.

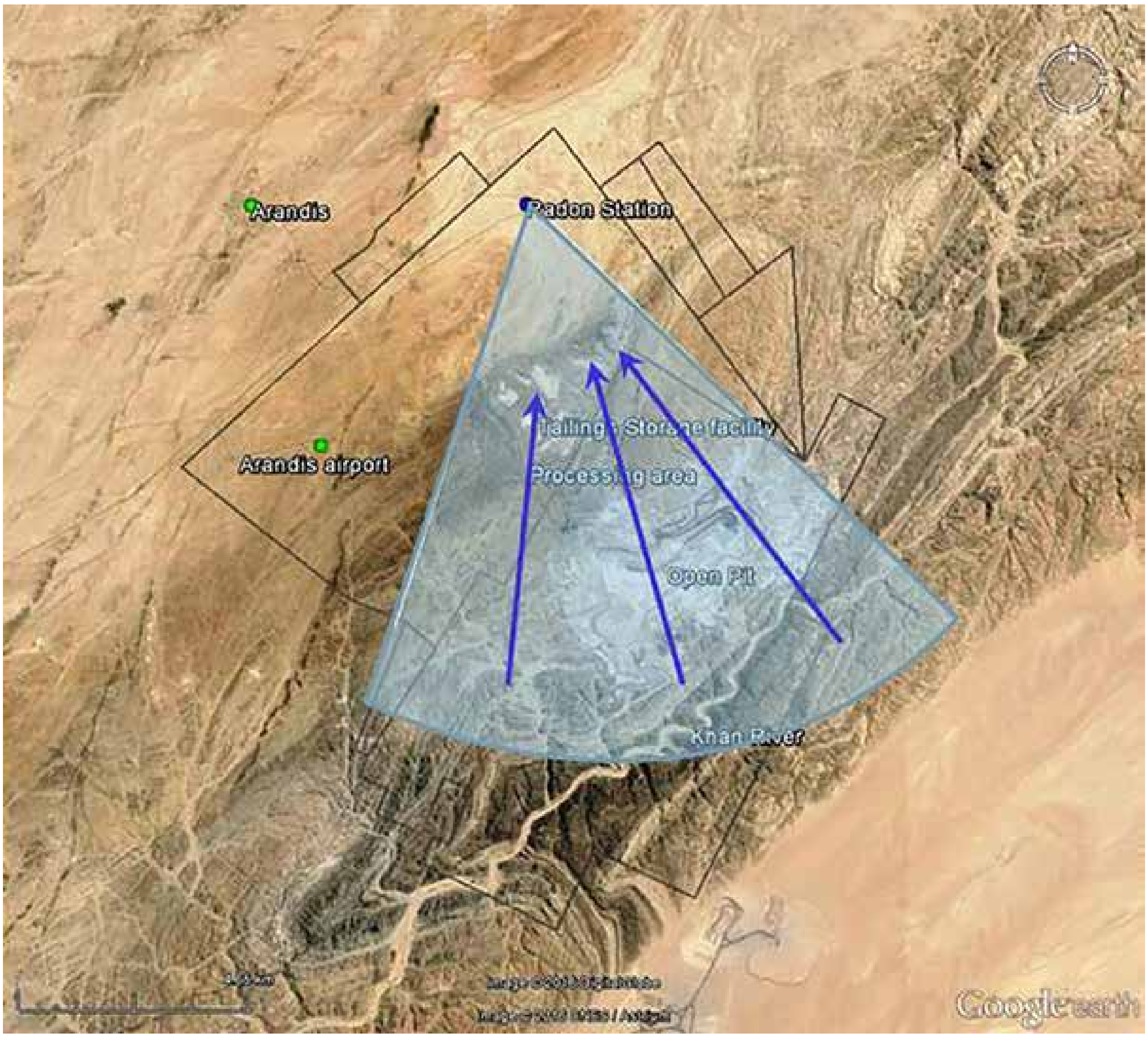


Figure 15: Satellite view of Rössing mine, with radon station indicated as a blue dot. The wind directions relevant to mining related radon are indicated as a blue wedge.

[6] H Liebenberg-Enslin, J van Blerk, ID Kruger, Strategic Environmental Assessment (SEA) for the Central Namib 'Uranium Rush' Radiation and Air Quality Theme Report, 2010.

The wind directions and radon concentration measurements are summarised in Figure 16 and Figure 17 for the year 2013.

The measured concentrations and respective calculated doses are collected in Table 1.

At the location of the radon station a definite excess of radon concentration is measured compared to background radon levels. The average concentration results in an exposure dose of 0.8 mSv/a, which includes background as well as mining-related sources of radon.

Although the excess is due to the nearby mining operation, during the year, the wind only blows from the direction of the mine 11 per cent of the time. For this reason the resulting mining-related public exposure dose (0.1 mSv/a) is only 16 per cent of the total radon inhalation dose at the location of the radon monitoring station (0.8 mSv/a). The remaining radon exposure, 0.7 mSv/a, is due to background sources of radon.

Figure 16: Wind directions at Arandis radon station, 2013

Wind direction, Arandis radon station, 2013

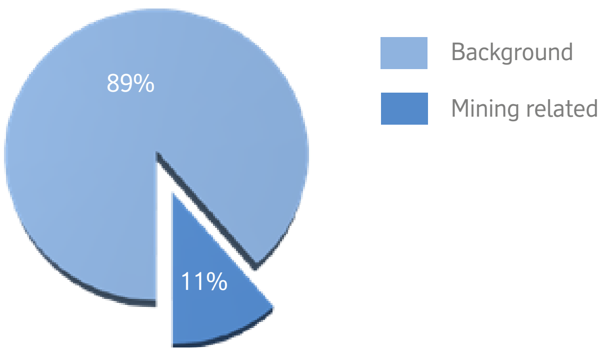


Figure 17: Radon concentrations at the radon monitoring station, for the year 2013.

Radon concentrations, Arandis, 2013

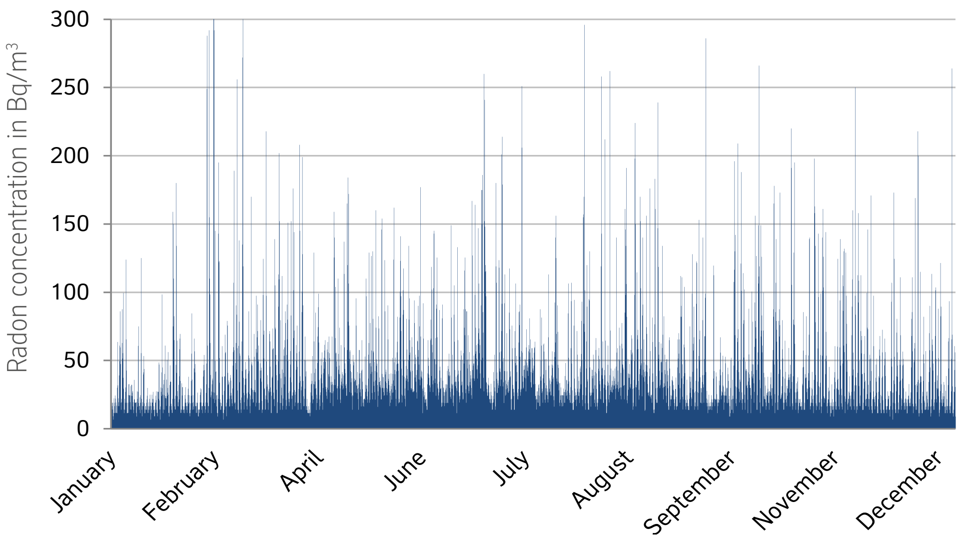


Table 1: Measured radon concentrations correlated by wind direction, equilibrium factor and calculated annual dose from background and mining origin respectively, for the year 2013.

	Rn concentration (Bq/m^3)	Fraction of time measured	Equilibrium factor (measured)	Resulting dose (mSv/a)
Average	22	100%	0.7	0.8
Non-mining	21	89%	0.7	0.7
Mining	32	11%	0.7	0.1

6. Safety and security of sources

6.1. Sealed source register

Only five sealed sources are currently being used. Four of them are used as level-measuring devices in the two Primary Crushers. Each crusher is equipped with two sealed sources, one respectively for the bottom and the top of the rock box of each crusher.

A fifth source was purchased in 2016, with the intention of using it as a level-measuring device for the drum filling process in the FPR area (license SSL/113/01/16). All other sources on site are being stored in the Radiation Source Bunker, as summarised in Table 2. The license issued for use and operation of all other sources is SSL/113/16-01.

In addition, two low activity calibration sources are kept at the Radiation Safety Laboratory (Table 3).

Table 2: List of sealed sources at Rössing Uranium (radionuclide of all sources is Cs-137)

Serial number	Activity (GBq)	Location	Use	Comment
27525 N	40	Rock Box Primary Crusher No 1	Level	In operation
004/12	34	Rock Box Primary Crusher No 2	Level	In operation
H500081140	41	Lube Room Primary Crusher No 1	Level	In operation
005/12	32	Lube Room Primary Crusher No 2	Level	In operation
B278	0.03	FPR (Automated Drum Filling)	Level	In operation
70682	0.2	Radiation Store	Level	Not in use
2771	14	Radiation Store	Level	Redundant
PA 304	0.3	Radiation Store	Density	Not in use
PA 299	0.3	Radiation Store	Density	Not in use
PA 301	0.3	Radiation Store	Density	Not in use
PA 302	0.3	Radiation Store	Density	Not in use
PA 298	0.3	Radiation Store	Density	Not in use
PA 297	0.3	Radiation Store	Density	Not in use
2772	14	Radiation Store	Level	Redundant
2770	14	Radiation Store	Level	Redundant

Table 3: 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	5
Th-230	Alpha	75380	1	2011/12/16	5

6.2. Sealed source checks

Leak tests of sources in operation are performed two-monthly, while sources not in use are only tested at six-monthly intervals. As these sources are stored in the Radiation Source Bunker, which is access restricted, no risk is posed by moving the leak test out to once in six months.

6.3. X-ray generating equipment

The Rössing Uranium chemical laboratory is making use of two analytical x-ray units, as per registration and license EPL/113/01/15, which expires in 2018.

7. Transport of radioactive material

7.1. Transport and export of uranium oxide concentrate

Under the authorisations TRM/113/01/15/ET and TRM/113/01/16/ET, which authorise Rössing Uranium to transport uranium oxide to overseas converters, 1,685 tonnes of uranium oxide of chemical composition U_3O_8 (with a content of 1,429 tonnes of uranium) were exported in 2016, as summarised in Table 4.

Table 4: List of UOC shipments from Rössing Uranium in 2016

Date of consignment	Country of Final Destination	Total weight of UOC in shipment (kg)	Total weight of contained U element (kg)
23 JANUARY 2016	CANADA	86,864.729	73,661.290
9 FEBRUARY 2016	FRANCE	107,567.304	91,217.074
22 MARCH 2016	USA	143,036.969	121,295.350
22 MARCH 2016	CANADA	54,202.324	45,963.571
1 MAY 2016	USA	127,634.007	108,233.638
30 APRIL 2016	FRANCE	108,693.632	92,172.200
19 JUNE 2016	USA	90,721.071	76,931.468
12 JUNE 2016	FRANCE	106,415.906	90,240.688
11 JULY 2016	FRANCE	72,383.244	61,380.991
24 AUGUST 2016	FRANCE	53,967.498	45,764.438
25 SEPTEMBER 2016	CHINA	139,428.939	118,235.740
27 SEPTEMBER 2016	CANADA	90,457.493	76,707.954
27 SEPTEMBER 2016	USA	73,090.566	61,980.800
8 OCTOBER 2016	CHINA	140,115.585	118,818.016
6 NOVEMBER 2016	FRANCE	199,031.454	168,778.673
16 DECEMBER 2016	FRANCE	91,552.024	77,636.116
Total		1,685,162.745	1,429,018.008

7.2. Transport of other source material

Under the authorisations TRM/113/15/03/T and TRM/113/16/02/T, which authorise Rössing Uranium to transport uranium-bearing ore and leach feed samples to laboratories in South Africa, six consignments to laboratories in South Africa were made in 2016, summarised in Table 5.

None of these consignments had a radioactivity concentration exceeding 10 Bq/g, and hence under the IAEA Transport Regulations[7], these materials are not regarded as radioactive for transport.

[7] IAEA, Regulations for the Safe Transport of Radioactive Material, 2012 Edition, *Specific Safety Requirements for protecting people and the environment*, No. SSR-6

Table 5: Sample materials exported to laboratories in South Africa in 2016

Date 2015	Material exported	Mass	Total radioactivity of exported material (MBq)	Purpose of consignment	Consignee of exported material	Mode of transport
12 January 2016	Rock sample	4,000 kg	< 20 MBq	Ore-sorting tests	Mintek	Road transport by Wesbank Transport
22 January 2016	rock samples	350 kg	< 1 MBq	Ore-sorting tests, mineralogy tests	Mintek, South Africa	Road transport by Wesbank Transport
21 January 2016	Rock samples	3,000 kg	< 11 MBq	Comminution test work	SGS Laboratories, South Africa	Road transport by Wesbank Transport
1 February 2016	Ore samples	240 kg	< 1 MBq	Tri-axial tests	Geostrada Laboratories, South Africa	Road transport by Wesbank Transport
8 June 2016	Ore samples	7 kg	< 20 MBq	Chemical analysis	Set Point Laboratories, Johannesburg, South Africa	Road transport by Wesbank Transport
27 September 2016	pulp samples	5 kg	< 1 MBq	leaching studies	Set Point Laboratories, Johannesburg, South Africa	Road transport by Wesbank Transport

All sample residues are to be returned to the mine after analysis is completed.

8. Emergency preparedness and response

The Rössing Uranium emergency response to uranium spills, as outlined in the procedure *JK60/PRD/009-Uranium Oxide Spillage*, was rehearsed as a desktop exercise on 22 September 2016.

The drill scenario was that of a train transporting the containers of U_30_8 derailing in the vicinity of the Rössing Mountain, with one container damaged resulting in some U_30_8 drums being damaged and about 400 kg of uranium oxide being spilled from container.

No injuries were reported, but vehicles reported to block the road with spectators crowding the scene.

9. Disposal of radioactive waste

9.1. Disposal of contaminated waste

Contaminated waste is deposited on the TSF, which in itself is a contaminated waste site. In 2016, a total of 397 tonnes of contaminated waste was deposited on the TSF.

9.2. Mineral waste

Both tailings material and waste rocks deposited without processing are regarded as mineral waste.

In 2016, we have deposited 9,194,439 tonnes of tailings onto the TSF, which now holds the cumulative amount of roughly 418 million tonnes of tailings material.

We have deposited 16,467,097 tonnes of waste rock onto the Waste Rock Dumps, bringing the cumulative total of waste rock material deposited to date to roughly 940 million tonnes of material.

10. Research

We started in 2014 to conceptualise a study to establish whether there are any potential links between workforce exposure to occupational risks, notably radiation exposure, and health effects.

In 2015 the Centre for Occupational and Environmental Health, Centre for Epidemiology, Institute of Population Health, Faculty of Medical and Human Sciences at The University of Manchester in the United Kingdom was selected to perform the study based on their extensive experience and expertise in the field of epidemiological studies, in particular given the radiological risk that is being researched. The research team members visited the mine in 2015 to commence with the study.

The protection of personal information during all stages of the study is of paramount importance; hence any information used for the study is anonymised before it is shared with the research team or other external stakeholders.

The research project has been approved by the Namibian Ministry of Health and by the Namibia Cancer Registry. An independent External Advisory Committee — consisting of delegates from the Mineworkers Union of Namibia, the Ministry of Health and Social Services, the Ministry of Mines and Energy, former Rössing Uranium workers and the Namibian Atomic Energy Board — is providing ethical oversight for the Project. Both The University of Manchester and the South African Cancer Registry have approved the project after submission to their respective ethics commissions.

The findings from the project will be presented for publication in the internationally peer-reviewed scientific literature. A final report is expected in mid-2018.

In 2016, we have worked unabatedly to collect all the needed anonymised information about current and former Rössing Uranium workers, such as gender, age and the time each person worked at the mine, and what position he or she occupied.

We have collaborated with the Namibian Cancer Registry to help identify any cancer cases that have been reported to them, and we have started on a similar collaboration with the South African Cancer Registry. We are proceeding to quantify occupational exposures of people for the study, such as the exposures to radiation, silica dust, acids mist, diesel and welding fumes and such like.

More information and updates on the Rössing Uranium health study are published on the website, http://www.rossing.com/reports-research2.htm. This site is also used to share more detailed information on Rössing Uranium's performance with the public.

Environmental impact assessments and closure plans, environmental and biodiversity management plans and discussion of some frequently asked questions about the mine's management of health and environment are also published on the website. In addition, Rössing Uranium's RMP and its annual reports to the NRPA are presented there for public information.

11. Conclusion

The Radiation Safety team has been strengthened by the arrival of the Advisor: Radiation Safety, leaving team members better equipped to shoulder their work load.

Further improvements on time efficiency were achieved by improved signage on-site on clearance procedures, which has significantly streamlined this particular compliance process.

An audit by the NRPA of the RMP implementation at Rössing Uranium was held in August 2016. No significant non-compliances were reported in the audit.

For the coming year, our focus areas will include:

- succession planning, training, and performing an understudy program for one of the officers;
- reducing levels of uranium dust in the FPR area further; and
- completing the collection of all relevant data for the Rössing Uranium health study.

Awareness on radiation risk remains a focus, and awareness sessions by suitably trained experts with all workers remain an important deliverable. In 2017, we aim to focus our staff training efforts towards improving the communication skills of our staff members for interacting with workers and with the public relating to radiation issues.

Once again, the monitoring results attest to the fact that radiation exposures at Rössing Uranium are very low indeed, and our controls are therefore a successful implementation of our vision of zero harm to people and to the environment.

We will continue making relevant information available to the public, in order to empower our communities with the knowledge to successfully put the risks relating to radiation safety into perspective.

12. Changes and revision status

First Issue	Issue date	Prepared by	
1.0	14 February 2016	G. von Oertzen	
Version number	**Revision date**	**Revised by**	**Reason for change**
1.1	10/08/2017	G. von Oertzen	Update for website