Rössing Uranium Limited
Working for Namibia

Water quality monitoring at the Rössing Uranium mine, using isotope techniques (non-technical report)

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Contents

Acronyms and abbreviations

The following acronyms and abbreviations are used in this report:

Bq	–	becquerel, disintegrations per second, unit of radioactivity
FUSRAP	–	Formerly Utilized Sites Remedial Action Program
TSF	–	Tailings Storage Facility
U-238	–	Uranium-238, uranium isotope with 92 protons and 146 neutrons
Th-234	–	Thorium-234, direct decay product (daughter) of U-238
Pa-234	–	Protactinium-234, daughter of Th-234
U-234	–	Uranium-234, isotope with 92 protons and 142 neutrons, daughter of Pa-234

1. Introduction

Rössing Uranium Limited is an open pit uranium mine located in the Namib Desert, about 60 km inland from the coastal town of Swakopmund and about 10 km from the town of Arandis. The mine has a footprint of 2,300 ha, with the tailings storage facility (TSF) covering an area of about 750 ha.

The TSF, while mostly dry on the surface, locks in considerable quantities of water. This water can seep along the underlying drainage routes into the nearby Khan River if not controlled.

Figure 1 shows an aerial view of the Rössing Uranium mine site: water drainage systems are shown as solid yellow lines, or as broken yellow lines where the water flow is now interrupted because of a change of the terrain due to mining activities.

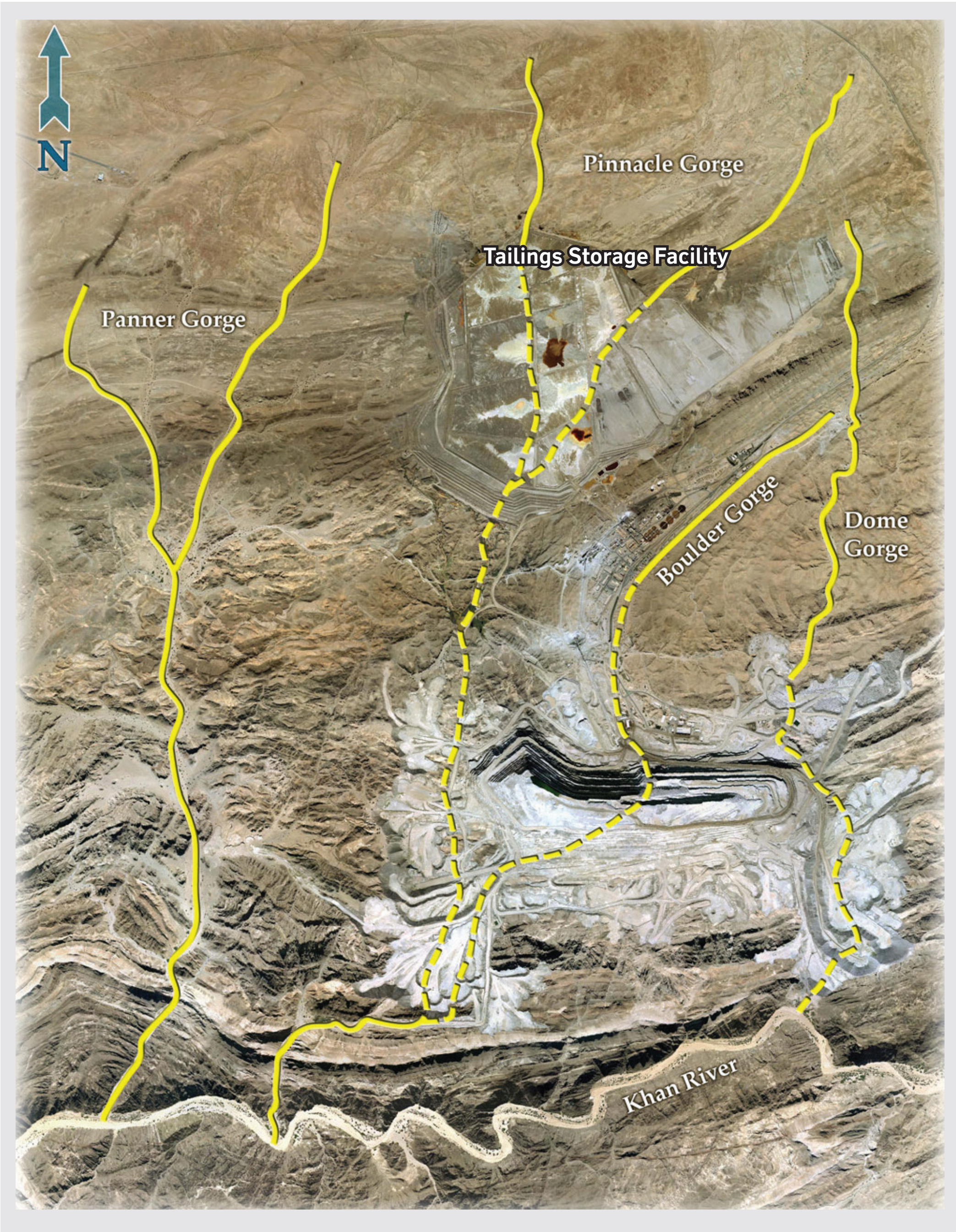

Figure 1: Footprint of Rössing Uranium mine, showing groundwater drainage systems into the Khan River aquifer.

Rössing Uranium operates a series of de-watering boreholes and cut-off trenches, designed to re-pump and recycle any seepage water into the processing stream. In addition, a series of monitoring boreholes is used for monitoring purposes – water quality in these boreholes is measured annually in order to detect any potential seepage of contaminated water before it reaches the Khan River aquifer.

The ratio between two uranium isotopes (different atom forms of the same chemical element) in the uranium decay chain is used to assess the origins of borehole water – i.e. due to natural groundwater or due to seepage from the TSF – making use of the principle of alpha recoil, as described in Sections 2 and 3.

2. Alpha recoil explained

Uranium occurs naturally in the environment. Three natural isotopes of uranium occur in nature, U-238, U-234, and U-235. [1]

When uranium decays (i.e. when the atom's nucleus breaks apart), many of its decay products are also radioactive. For example, decay of U-238 is followed by a series of 13 further decays until the stable isotope of lead, Pb-206, is reached. [2] The fourth element in this decay chain is U-234.

Because U-234 is a decay product of U-238, it forms at a rate commensurate with that at which U-238 decays.

Over long periods of time, equilibrium between the radio-isotopes in the decay chain is established; this is called 'secular equilibrium' and means specifically that the amount of U-238 radioactivity in a piece of rock is exactly the same as that from U-234.

For example, 1 g of rock with a 1 per cent content of natural uranium displays a radioactivity of 124 decays per second (referred to as becquerels, Bq) from the U-238 within it, and exactly the same activity of 124 Bq from the U-234 isotopes within it. [3]

Deep within a rock (i.e. some distance away from its surface), the isotope activity ratio of U-234 to U238 (U-234/U-238), is therefore equal to 1.

When U-238 decays, it emits an alpha particle: this process causes the U-238 atom (which is now in the process of decaying into a U-234 atom [4]) to spring back, or 'recoil' – much like the recoil of a gun when a bullet is fired from it. Sometimes, if the U-238 atom is located close to the surface of the substrate (grain of sand or piece of rock), the recoil can be strong enough to dislodge the decaying U-238 atom from the substrate.

If the substrate is in contact with water, the decay product will end up in the water. Many of these recoils will happen over time and as a consequence the decay products of U-238 (including U-234) will end up in the water that is in contact with the substrate.

When this happens, a dis-equilibrium occurs, with the ratio U-234/U-238 in the water now exceeding 1 [2]. (On the substrate's surface a dis-equilibrium will also occur, with the U-234/U-238 ratio now less than 1. Since the substrate particles are usually big, however, beyond the actual surface there will generally still be secular equilibrium.)

We can use this fact of physics to determine if any uranium found in water has dissolved into the water over a very long time (i.e. over thousands of years), or if it is freshly extracted uranium that is dissolved in the water.

This is because freshly extracted uranium displays an isotope ratio U-234/U-238 of 1 or less than 1, whereas uranium occurring naturally in the water displays a ratio of more than 1. [5]

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[1] Isotopes of an element are chemically identical. They differ only by the number of neutrons in the atomic nucleus.
[2] This decay sequence is called the uranium decay chain; for an overview, see reference [1].
[3] Under conditions of secular equilibrium, the same 1 g of rock with 1% uranium content also displays 124 Bq from each of the other 12 radio-isotopes in the uranium decay chain, as well as additional radioactivity from the actinium and thorium decay chains.
[4] This decay occurs in three steps via Th-234 and Pa-234.
[5] For more details on the alpha recoil process, the reader is referred to the technical version of this report, 'Using Alpha Recoil as a Tool for Contamination Control in the Khan River Aquifer', which can be found under 'Reports and Research' on the Rössing website, www.rossing.com.

3. Water monitoring and radionuclide analysis at Rössing Uranium

The water monitoring programme at Rössing Uranium comprises annual sampling of some 20 monitoring boreholes (as well as surface water from the TSF and seepage dams) and radionuclide analysis of the water samples.

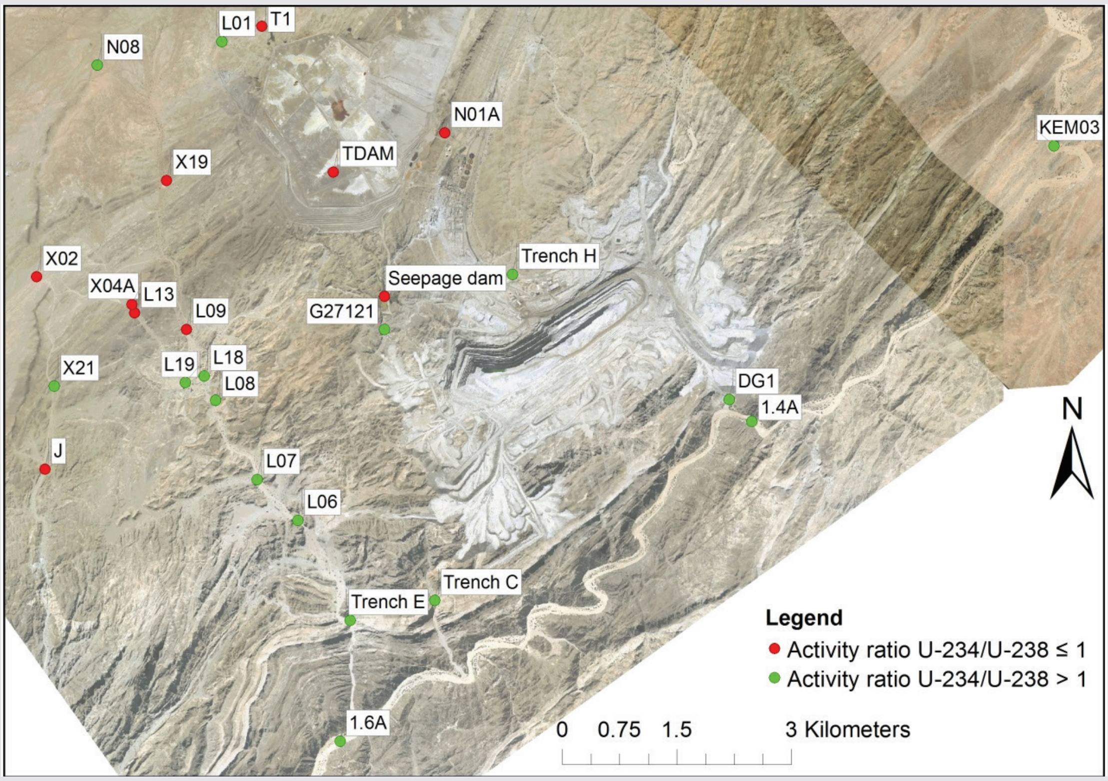
The uranium isotopes U-238 and U-234 from the uranium decay chain are sampled during this process. The ratio between U-234 and U-238 isotopes in the borehole water allows an assessment of the source of the water (as described above).

A representative result is shown in Figure 2. Sampling locations are shown in colour on a satellite image of the Rössing Uranium mine site: a red dot indicates a site with a radionuclide ratio U-234/U238 equal to or less than 1 (i.e. aquifer water mixing with process solution seeping from the TSF); a green dot indicates a site with a radionuclide in excess of 1, or due to naturally occurring uranium in the aquifer.

The key sites showing an absence of groundwater contamination are the cut-off trenches (trenches C, E and H in Figure 2), and the boreholes in or close to the Khan River: 1.4A, 1.6 A and DG1. All these sites (green dots on the map) display an isotope ratio indicating a natural occurrence of environmental uranium.

The boreholes indicating the occurrence of seepage (red dots on the map) are all located upstream of natural or artificial barriers that prevent water containing seepage from the TSF reaching the Khan River. For example, the flow direction of boreholes X04A, L13 and L09 is down Panner Gorge, where eventually the flow is stopped by Trench E, thus preventing contamination of the Khan River.

Figure 2: Seepage contamination at the Rössing Uranium mine site, January 2015. Positions are colour coded for activity ratio for uranium chain isotopes based on 2014 monitoring results: red for sites affected by process solution; green for naturally occurring uranium.



4. Frequently asked questions

4.1. How is seepage prevented at Rössing Uranium?

A series of de-watering boreholes is used to continuously pump out water from places where it has seeped from the TSF into the environment. This water is then recycled into the uranium extraction process, thus reducing the mine's use of freshwater and preventing environmental contamination.

Further control is achieved by interrupting the potential underground flow of seepage water with a series of cut-off trenches that prevent the downstream flow of contaminated water.

4.2. What does this mean for water in the Khan River?

The isotope analysis of monitoring borehole water demonstrates that there is no seepage of contaminated water from the Rössing TSF into the Khan River aquifer.

4.3. What authority checks these results?

The results from isotope analysis of monitoring borehole water are reported annually to the National Radiation Protection Authority (for an example see [3]).

4.4. What will happen after the Rössing Uranium mine is closed?

Pumping water from de-watering boreholes will continue until this practice is no longer necessary, i.e. until seepage has stopped.

4. References

[1] Von Oertzen, G. and von Oertzen, D. (2012): *Questions Answered About Uranium and Radiation*, Chamber of Mines Uranium Institute.

[2] Frederick, W.T., Keil, K.G., Rhodes, M.C., Peterson, J.M. and MacDonell, M.M.: *Utilizing uranium isotope ratios in groundwater evaluations at FUSRAP sites*, Proceedings of Waste Management Conference WM'07, Tucson, AZ, 2007.

[3] Rössing Uranium Limited (2013): *Implementation of Radiation Management Plan*, Annual Report for Rössing Uranium Limited.