Rio Tinto

Rössing Uranium Limited

Working for Namibia

Quality of Drinking-Water in the Erongo Region

Effective date	23/07/2015
Author	Gunhild von Oertzen
Reviewed by	Kelly Payne

Abstract

Drinking-water samples from the Swakopmund area (two samples from Swakopmund town, one from Mondesa, one from Arandis, and one from the Rössing Uranium mine site) and one from Walvis Bay were collected in April 2015 by Rössing Uranium employees and were analysed for their chemical and radionuclide content by a laboratory in Germany.

Water analysis results were compared against the WHO 'Guidelines for drinking-water quality' and Namibian 'Guidelines for the evaluation of drinking-water quality with regard to chemical, physical and bacteriological quality', in order to alleviate potential concerns that might be raised by the public about the quality of the drinking-water in Erongo Region (specifically where the quality relates to mining-related operations).

Most water samples met all of the World Health Organization (WHO) guideline values for drinking-water. There was only one exception where a guideline value was marginally exceeded.

The Namibian guidelines for drinking-water are based on the South African Water Act of 1956 and classify water into categories A (excellent), B (acceptable), C (low health concern), and D (not acceptable).

These guidelines remain in force since Namibian independence until new standards have been formulated. Most samples met the criteria for Category A, with a few exceptions where Category B was met.

Acronyms and abbreviations

The following acronyms and abbreviations are used throughout this report:

µg/L	–	micro-grams per litre, i.e. 10^{-6} g/L
µSv	–	micro-sievert, i.e. 10^{-6} sievert
µSv/a	–	micro-sieverts per annum
Bq	–	becquerel, disintegrations per second, unit for radioactivity
Bq/L	–	becquerels per litre (unit to quantify radioactivity concentration in water)
ICRP	–	International Commission on Radiological Protection
ISO	–	International Organization for Standardization
mBq/L	–	milli-becquerels per litre, i.e. 10^{-3} Bq/L
mg/L	–	milligrams per litre, i.e. 10^{-3} g/L
Sv	–	sievert, unit for radiation exposure dose
WHO	–	World Health Organization

Contents

1. Introduction

Historically, household water in the Erongo Region has been sourced from the Omaruru Delta (OMDEL) and Kuiseb aquifers, with water for Swakopmund, Arandis, and mines in the vicinity of these towns coming from the former and water for Walvis Bay coming from the latter.

Recently, the water supply from the OMDEL aquifer has been supplemented with desalinated water from the AREVA Desalination Plant at Wlotzkasbaken.

Despite household water being sourced from river aquifers or from the ocean – both of which have no contact with the uranium-bearing ores that are mined in Erongo Region – there remains some uncertainty in the community about the quality of the water available for drinking, and in particular about its radionuclide content.

Samples of drinking-water from some coastal locations and from the Rössing Uranium mine site were therefore analysed and the results compared with the drinking-water guidelines of the World Health Organization (WHO) [1] and with the Namibian drinking-water guidelines [2].

2. Method

Six separate water samples of 1 litre each were collected at the following locations:

Sample 1. Rössing Uranium mine site, drinking-water tap outside the Safety Building,

Sample 2. Mondesa (Swakopmund), household drinking-water tap,

Sample 3. Swakopmund, household drinking-water tap with water softener unit fitted ('soft water'),

Sample 4. Swakopmund, household drinking-water tap, no softener unit fitted ('hard water'),

Sample 5. Arandis, household drinking-water tap, and

Sample 6. Walvis Bay, household drinking-water tap.

These six samples were collected by Rössing Uranium employees on April 7th, 2015. Sample 1 was collected at the Rössing mine site while the remaining five samples were collected from the households of the employees tasked with collecting the samples at the various coastal sites.

The samples were collected in 1 litre sampling bottles, which were prepared with hydrogen chloride acidifier (a standard practice for the purpose of preserving the water samples). Because of the sample acidification it was not possible to measure pH values, conductivity values, or chloride content at the testing laboratory.

Samples were taken after first running the tap (on the cold water setting for mixer taps) for approximately five minutes before collecting the water. The water samples were then delivered to a local courier that sent them off for analysis at IAF - Radioökologie GmbH, Germany the following day. [1]

The water samples reached the laboratory on 13th April 2015 and the analysis results were submitted to Rössing Uranium on May 7th, 2015. The laboratory results are given in Appendix A (chemical analysis) and Appendix B (radionuclide analysis).

Each sample was analysed for a range of metals and metalloids as well as selected radionuclides from the uranium and thorium decay series.

The methods for measuring metals and metalloids included atomic emission spectrometry (aluminium, arsenic, barium, lead, boron, cadmium, chromium, iron, magnesium, manganese, sodium, nickel, strontium, titanium, uranium, zinc, tin) and atom absorption spectrometry (antimony, mercury, selenium, thallium).

Radionuclide concentrations of isotopes U-238, U-234, Ra-226, and Po-210 were analysed using alpha particle spectrometry, and concentrations of Pb-210 and Ra-228 were analysed using low-level beta measurement.

[1] IAF - Radioökologie GmbH is accredited under the DIN EN ISO/IEC 17025 standard.

3. Results

3.1. Metal content

The results of the chemical analysis are presented in Table 1 below. The guideline values of the WHO guidelines and of the Namibian guidelines for Category A water (i.e. for water of excellent quality) are also listed.

Where the values for Category A are exceeded, the values for Category B (acceptable quality) are also given for reference.

The values for Category C (low health risk) and Category D (not suitable) are not given as these were not exceeded in any of the samples.

Table 1: Chemical analysis: metal content of analysed samples

	Sample 1: Rössing Uranium mine	Sample 2: Mondesa	Sample 3: Swakop-mund (hard water)	Sample 4: Swakop-mund (soft water)	Sample 5: Arandis	Sample 6: Walvis Bay	WHO guideline for drinking-water [2]	Namibia Category A (excellent)	Namibia Category B (ac-ceptable)
Aluminium (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.9	0.15	n/a
Antimony (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.05	n/a
Arsenic (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.1	n/a
Barium (µg/L)	0.057	0.075	0.058	0.054	0.066	0.039	0.7	0.5	n/a
Boron (mg/L)	0.72	0.63	0.59	0.65	0.68	0.15	2.4	0.5	2
Cadmium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.01	n/a
Chromium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.1	n/a
Copper (mg/L)	0.024	0.039	0.017	0.052	0.058	0.51	2	0.5	1
Iron (mg/L)	0.092	0.28	0.042	0.046	0.072	0.35	nv	0.1	1
Lead (mg/L)	<0.01	0.016	<0.01	<0.01	<0.01	<0.01	0.01	0.05	n/a
Magnesium (mg/L)	16.8	17.6	17.7	18	16.6	32.7	nv	70	n/a
Manganese (mg/L)	0.004	0.002	0.002	<0.002	<0.002	0.004	nv	0.05	n/a
Mercury (µg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	6	5	n/a
Nickel (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.25	n/a
Selenium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.02	n/a
Sodium (mg/L)	199	180	179	195	197	119	nv	100	400
Strontium (mg/L)	0.68	0.66	0.67	0.69	0.67	0.46	nv	nv	n/a
Thallium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	nv	0.005	n/a
Tin (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	nv	0.1	n/a
Titanium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	nv	0.1	n/a
Uranium (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	1	n/a
Zinc (mg/L)	0.065	0.024	0.034	0.031	0.034	0.069	4	nv	n/a

[2] 'nv' denotes a quantity where no guideline value is given. This means that at the concentrations found in drinking-water, the reported element does not present a health concern.

3.1.1. WHO guidelines

The chemical analysis shows that the quality of the water sampled met all of the WHO guideline values (where these are quantified) with one exception (marked red in Table 1).

In particular, the concentrations for **aluminium, antimony, arsenic, barium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, uranium and zinc** were below the WHO guideline values for these elements for all the samples (these are marked green in Table 1). The only exception is the sample from Mondesa, which marginally exceeded the WHO guideline value for lead (0.01 mg/L) at 0.016 mg/L; this is likely due to lead being used in pipes or taps in this particular household.

For concentrations of **iron, magnesium, manganese, sodium, strontium, thallium, tin, and titanium**, no guideline values are given in the WHO guidelines as these elements are not regarded as a health risk at the concentrations found in drinking-water (these are also marked green in Table 1).

3.1.2. Namibian guidelines

The Namibian guidelines stipulate four categories, from Category A (excellent) to D (not acceptable). There was no sample that was found to exceed any of the Namibian guideline values for Category B water and hence to only satisfy conditions for Category C water (low health risk). For most samples and elements sampled, the quality of Category A (excellent) was reached.

In particular, Category A was met for all samples for concentrations of **aluminium, antimony, arsenic, barium, cadmium, chromium, lead, magnesium, manganese, mercury, nickel, selenium, thallium, tin, titanium and uranium**. In addition, all samples except Sample 6 (from Walvis Bay) met the Namibian Category A guideline values for **copper** (0.5 mg/L), while Sample 6 met the guideline value for Category B (1 mg/L) at 0.51 mg/L.

For the concentrations of **strontium and zinc**, no values are given in the Namibian guidelines.

The concentrations of **boron** exceeded the Category A guideline values for all samples originating from the OMDEL aquifer/AREVA Desalination Plant source (i.e. the Swakopmund, Arandis and Rössing mine site samples); for all of these, the guideline values for Category B (acceptable) were met. The relatively high boron concentrations can be ascribed to the water sourced from the desalination plant, from which boron is not completely removed. However, as explained in Section 3.1.1 above, the WHO standard was still met for all of these samples. For Walvis Bay, the boron values met the Category A standard.

The guideline values for Category A were also exceeded for **iron** (Mondesa and Walvis Bay), and **sodium** (all samples) but met the levels for Category B.

Table 2 provides a summary of those elements where the Namibian guideline value for Category A was exceeded for some of the samples.

3.2 Radionuclide analysis

The results of the radionuclide analysis are presented in Table 3 below. Table 3 shows that all the radionuclide values are significantly below the WHO drinking-water guidelines for radiological aspects.

Table 2: Elements where guideline values for Category A were not met for all samples. The relevant category (A or B) is given for each sample.

	Sample 1: Rössing Uranium mine	Sample 2: Mondesa	Sample 3: Swakopmund (hard water)	Sample 4: Swakopmund (soft water)	Sample 5: Arandis	Sample 6: Walvis Bay
Boron	B	B	B	B	B	A
Copper	A	A	A	A	A	B
Iron	A	B	A	A	A	B
Sodium	B	B	B	B	B	B

Table 3: Radionuclide analysis

	Sample 1: Rössing Uranium mine	Sample 2: Mondesa	Sample 3: Swakopmund (hard water)	Sample 4: Swakopmund (soft water)	Sample 5: Arandis	Sample 6: Walvis Bay	WHO guideline for drinking-water
U-238 (mBq/L)	119	108	104	132	102	114	**10 000**
U-234 (mBq/L)	156	150	154	171	143	223	**1 000**
Ra-226 (mBq/L)	10	12	19	11	78	<3	**1 000**
Ra-228 (mBq/L)	<30	<30	<30	<30	<30	<30	**100**
Pb-210 (mBq/L)	<11	<12	<12	<11	<11	<11	**100**
Po-210 (mBq/L)	2.4	<1.4	3.6	2.4	2.5	1.9	**100**

3.2.1 Interpretation of radionuclide analysis

In order to quantify the radiological implications of drinking water from these sources, an ingestion dose can be calculated. For each specific radionuclide, dose coefficients are given for its intake, by the International Commission on Radiological Protection (ICRP).

The coefficients differ according to the age of the member of the public, i.e. specific values are given for infants, for individuals aged 1 year, 5 years, 10 years, and 15 years, and for adults [3]. The difference in dose coefficients for individuals at different ages arises from the fact that biological sensitivity to radiation exposures depends on age.

Using the ICRP dose conversion coefficients for adults and for infants of age less than 1 year, it is possible to arrive at two representative ingestion doses from drinking water at these sites.

The assumption is made that adults consume 730 litres of water each year (2 litres a day), and that infants consume 150 litres per year.

Where radionuclide concentration results in Table 3 are indicated as an upper limit (e.g. <30 mBq/L), the assumption is also made that this upper limit is the measured value (i.e. representing a conservative estimate of the actual value, which will be lower).

The first five samples originated from the same source (OMDEL aquifer water mixed with desalinated water from the AREVA plant), hence the ingestion dose for the public from these samples can be averaged out.

Sample 6 is from Walvis Bay, and the resulting ingestion dose for the public is given separately for this source. The results are summarised in Table 4 below.

Table 4: Annual ingestion dose from consuming drinking-water, in micro-sieverts per annum

ADULTS:

Source nuclide	Sample 1: Rössing Uranium mine	Sample 2: Mondesa	Sample 3: Swakopmund (hard water)	Sample 4: Swakopmund (soft water)	Sample 5: Arandis	Sample 6: Walvis Bay
U-238	3.9	3.5	3.4	4.3	3.4	3.7
U-234	5.6	5.4	5.5	6.1	5.1	8.0
Ra-226	2.0	2.5	3.9	2.2	15.9	<0.6
Ra-228	<15.1	<15.1	<15.1	<15.1	<15.1	<15.1
Pb-210	<5.5	<6.0	<6.0	<5.5	<5.5	<5.5
Po-210	2.1	<1.2	3.2	2.1	2.2	1.7
Total dose, µSv/a	**<34.3**	**<33.7**	**<37.1**	**<35.5**	**<47.3**	**<34.7**
Average ingestion dose (µSv/a), upper limit			**<38**			**<35**

INFANTS (<1 year):

Source nuclide	Sample 1: Rössing Uranium mine	Sample 2: Mondesa	Sample 3: Swakopmund (hard water)	Sample 4: Swakopmund (soft water)	Sample 5: Arandis	Sample 6: Walvis Bay
U-238	2.5	2.3	2.2	2.8	2.1	2.4
U-234	4.0	3.8	3.9	4.4	3.6	5.7
Ra-226	8.6	10.3	16.2	9.4	66.7	2.6
Ra-228	<135	<135	<135	<135	<135	<135
Pb-210	<4.0	<4.3	<4.3	<4.0	<4.0	<4.0
Po-210	20.2	<11.8	30.2	20.2	21.0	16.0
Total dose, µSv/a	**<174.1**	**<167.4**	**<191.9**	**<175.7**	**<232.4**	**<165.6**
Average ingestion dose (µSv/a), upper limit			**<188**			**<166**

The calculated ingestion dose values represent upper limits, as for some radionuclides (such as Ra-228) only upper limits were available as measurement results. Using the upper limit values for the ingestion dose calculations, the average radionuclide ingestion doses in Swakopmund and Walvis Bay were found to be 38 and 35 micro-sieverts per annum respectively for adults. For infants of the age of under 1 year, the upper limit dose values are 188 and 166 micro-sieverts per annum. The results thus show that the average ingestion doses from radionuclides in the water from the two different sources are very similar.

The ingestion doses must be put into perspective by comparing them to the world average age-weighted ingestion dose from ingesting food and drink, which has been determined to be 140 micro-sieverts per annum (when considering only the uranium and thorium series radionuclides [4]).

More specifically, the annual dose for infants aged under 1 year from uranium and thorium ingestion is found to be 260 micro-sieverts per annum, and that of adults is 110 micro-sieverts per annum [4]. In this context, the values found for the ingestion of drinking water from the OMDEL aquifer/AREVA Desalination Plant source and from the Kuiseb aquifer are below the world average values.

This is to be expected as drinking water is not the only source of the ingestion dose (food being an additional source).

It must be cautioned that the ingestion dose values calculated here represent upper limits only; the actual dose can be significantly lower.

For a more detailed result, a single additional sample from Rössing mine site was sent to the same laboratory on June 24, 2015. The detailed radionuclide analysis report is given in Appendix C.

Table 5 summarises the public dose assessment that is based on the more detailed analysis.

Here it can be seen that upon more detailed analysis, the upper limit for the public dose from drinking water sourced from the OMDEL aquifer/AREVA Desalination Plant is reduced to 26 µSv/a for adults and to 118 µSv/a for infants under 1 year. The change is mainly due to any reduction in the upper limit of Ra-228, as this is the radionuclide with the largest contribution to the public dose.

Table 5: Annual ingestion dose from consuming drinking-water, in micro-sieverts per annum, for drinking-water sampled at the Rössing mine

Adults	**Sample 7: Rössing mine, radionuclide activity in mBq/L**	**Ingestion dose for adults in µSv/a**	**Ingestion dose for infants <1 year in µSv/a**
U-238	88	2.9	1.8
U-234	121	4.3	3.1
Th-230	1.8	0.3	1.1
Ra-226	<10	<2.0	<8.6
Pb-210	<10	<5.0	<3.6
Po-210	<1	<0.9	<8.4
U-235	3.9	0.1	0.1
Th-232	<1	<0.2	<0.2
Ra-228	<20	<10.1	<90
Th-228	<1	<0.1	<0.6
Total		**<25.9**	**<117.5**

4. Summary and conclusions

Drinking-water originating from the OMDEL aquifer/ AREVA Desalination Plant and from the Kuiseb aquifer was sampled.

The chemical analysis revealed the following characteristics:

- Drinking-water quality from all samples was similar, and generally of 'excellent' or 'acceptable' quality under the Namibian guideline's categories.
- For all samples, the WHO guidelines for drinking-water were met. The only exception was the sample from Mondesa, where the WHO guideline value for lead marginally exceeded the guideline value.
- All samples originated from the OMDEL aquifer/ AREVA Desalination Plant source exceeded the Namibian Category A values for boron, but met the Category B standard. This reflects the fact that desalinated water forms part of the mix, as this contains higher amounts of boron than water from the aquifers. All samples met the WHO standard for boron.

The radionuclide analysis revealed the following:

- All samples displayed radionuclide values significantly below the WHO standard guideline values for radiological properties of drinking-water. (No value is given in the Namibian standard for radionuclides.)
- The maximum possible ingestion dose from any of the samples was found to be 47 µSv per annum for adults and 220 µSv per annum for infants (Arandis, Sample 5).
- The average public dose over all samples from the OMDEL aquifer/AREVA Desalination Plant source was 38 µSv per annum for adults and 185 µSv per annum for infants (with upper limits assumed for values below the detection limit).
- The public dose for the sample from Walvis Bay was 35 µSv per annum for adults and 172 µSv per annum for infants (with upper limits assumed for values below the detection limit).

A more detailed radionulcide analysis of water from the Rossing mine site revealed a reduction in the public dose, from 34 to 26 µSv/a for adults, and from 174 to 118 µSv/a for infants. The change is mainly due to an improved accuracy on the content of Ra-228 in the water, thereby indicating a lower ingestion dose.

The age-weighted world average ingestion dose per annum (weighted over all age groups) from the uranium and thorium decay chains is 140 µSv per annum [4], which is consistent with the values found for water ingestion from these samples. Additional internal exposure will result from the ingestion of food and other sources of drink.

Both types of analysis demonstrate that the drinking-water in the region is of 'acceptable' to 'excellent' quality and that the ingestion dose from this water is low and of no concern, even for infants. The mining industry does not affect the quality of the drinking-water as the water originates from sources not affected by its operations.

5. References

[1] World Health Organization (2011): *Guidelines for Drinking-water Quality,* Fourth Edition.

[2] Ministry of Agriculture, Water and Rural Development, Department of Water Affairs: *The Water Act (Act 54 of 1956) and its requirements in terms of water supplies for drinking-water and for waste water treatment and discharge.*

[3] ICRP (2012): *Compendium of dose coefficients based on ICRP Publication 60*, ICRP Publication 119, International Commission on Radiological Protection, Elsevier.

[4] United Nations Scientific Committee on the Effects of Atomic Radiation, (UNSCEAR) (2000): *Report to the General Assembly.*

Appendix A: Laboratory report on chemical analysis

ERGO Umweltinstitut GmbH

IAC-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-14613-01-00

Akkreditiert nach DIN EN ISO/IEC 17025 - Die Akkreditierung gilt für die in der Urkunde aufgeführten Prüfverfahren. Messstelle nach § 26 Bundesimmissionsschutzgesetz (BImSchG)

Prüfbericht Nr. 15/0865.1

Ausstellungsdatum des Prüfberichtes: 01.06.2015
Gesamtseitenzahl des Prüfberichtes: 2 Seite(n)
Anlagenzahl des Prüfberichtes: 1 Anlage(n)

Auftraggeber (AG): IAF-Radioökologie GmbH

Frau Bertholdt
Wilhelm-Rönsch-Straße 9
01454 Radeberg

Kunden-Nr.: 12042

Auftrags-Nr. des AG: 150413-02
Bestell-Nr. des AG:
Objekt: Analyse von Wasserproben

Beschreibung des Prüfgegenstandes: Untersuchung von Proben

Prüfauftrag: Prüfung auf vorgegebene Parameter
Probenahme: durch AG

Probeneingang: 21.04.2015

Analysenmethoden:

Parameter	Probenvorbereitung	Verfahren	Methode
- Aluminium		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Antimon		DIN EN ISO 15586 (E4)	atomabsorptionsspektrometrisch
- Arsen		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Barium		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Blei		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Bor		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Cadmium		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Chrom-ges		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Eisen		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Kupfer		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Magnesium		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Mangan		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch

ERGO Umweltinstitut GmbH
Lauensteiner Straße 42
01277 Dresden
Telefon (0351) 33 68 60
Telefax (0351) 33 68 610
eMail info@ergo-dresden.de
Internet www.ergo-dresden.de

Handelsregister
Dresden HRB 320
Steuer-Nr. 203/108/08165
Ust-IdNr. DE140131094
Geschäftsführer
Dipl.-Chem. Michael Frind

Bankverbindungen
Deutsche Bank
BLZ 870 700 00
Kto 7701709 00
IBAN DE65 870 700 000 7701709 00
BIC/SWIFT DEUT DE 8CXXX

Commerzbank Dresden
BLZ 850 800 00
Kto 04 025 593 00
IBAN DE76 8508 0000 0402 5593 00
BIC/SWIFT DRES DE FF 850

ERGO Umweltinstitut GmbH 15/0865 Seite 2 von 2

Parameter	Probenvorbereitung	Verfahren	Methode
- Natrium		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Nickel		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Quecksilber		DIN EN ISO 12846	atomabsorptionsspektrometrisch
- Selen		DIN EN ISO 15586 (E4)	atomabsorptionsspektrometrisch
- Strontium		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Sulfat		DIN EN ISO 10304-1	ionenchromatografisch
- Thallium		DIN EN ISO 15586 (E4)	atomabsorptionsspektrometrisch
- Titan		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Uran		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Zink		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch
- Zinn		DIN EN ISO 11885 (E22)	atomemissionsspektrometrisch

nichtakkreditierte Prüfverfahren sind mit (*) gekennzeichnet

Prüfergebnisse: siehe Anlage(n) zum Prüfbericht 15/0865

Prüfdatum: vom 21.04.2015 bis 23.04.2015

Bemerkungen:
- Messwerte mit „<" entsprechen der Bestimmungsgrenze des angewendeten Analysenverfahrens.
- Die Proben werden, wenn nicht anders vereinbart, 3 Monate im Labor aufbewahrt. Die Aufbewahrungszeit für wässrige Proben beträgt nur 2 Wochen.
- Die Prüfergebnisse beziehen sich nur auf die untersuchte(n) Probe(n).
- Der Prüfbericht darf nicht ohne schriftliche Genehmigung des Prüflabors auszugsweise vervielfältigt werden.
- n. b.: Summe nicht berechnet, da alle Einzelergebnisse unterhalb der jeweiligen Bestimmungsgrenzen.

ERGO Umweltinstitut GmbH

i.V. Bernhardt

Michael Frind
Laborleiter

ERGO Umweltinstitut GmbH

Anlage zum Prüfbericht 15/0865.1
150413-02

			D-15-04-1267 Rössing mine	D-15-04-1268 Mondesa	D-15-04-1269 Swakopmund (head water)	D-15-04-1270 Swakopmund (soft water)	D-15-04-1271 Walvis Bay	D-15-04-1272 Arandis
Quecksilber	Mercury	[µg/l]	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20	< 0,20
Aluminium	Aluminium	[mg/l]	< 0,10	< 0,10	< 0,10	< 0,10	< 0,10	< 0,10
Arsen	Arsenic	[mg/l]	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Bor	Boron	[mg/l]	0,72	0,63	0,59	0,65	0,15	0,68
Barium	Barium	[mg/l]	0,057	0,075	0,058	0,054	0,039	0,066
Cadmium	Cadmium	[mg/l]	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001
Chrom-ges	Chromium, total	[mg/l]	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Kupfer	Copper	[mg/l]	0,024	0,039	0,017	0,052	0,51	0,058
Eisen	Iron	[mg/l]	0,092	0,28	0,042	0,046	0,35	0,072
Magnesium	Magnesium	[mg/l]	16,8	17,6	17,7	18	32,7	16,6
Mangan	Manganese	[mg/l]	0,004	0,002	0,002	< 0,002	0,004	< 0,002
Natrium	Sodium	[mg/l]	199	180	179	195	119	197
Nickel	Nickel	[mg/l]	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Blei	Lead	[mg/l]	< 0,01	0,016	< 0,01	< 0,01	< 0,01	< 0,01
Antimon	Antimony	[mg/l]	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Selen	Selenium	[mg/l]	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Zinn	Tin	[mg/l]	< 0,10	< 0,10	< 0,10	< 0,10	< 0,10	< 0,10
Strontium	Strontium	[mg/l]	0,68	0,66	0,67	0,69	0,46	0,67
Titan	Titanium	[mg/l]	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Thallium	Thallium	[mg/l]	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001
Uran	Uranium	[mg/l]	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Zink	Zinc	[mg/l]	0,065	0,024	0,034	0,031	0,069	0,034

i. V. Beuchert

Frind
Laborleiter

Appendix B – Laboratory report on radionuclide analysis

IAF - Radioökologie GmbH
Labor für Radionuklidanalytik | Radiologische Gutachten | Consulting
Wilhelm-Rönsch-Str. 9
01454 Radeberg
Tel.: +49- (0) 3528-48730-0
Fax: +49- (0) 3528-48730-22

DAkkS Deutsche Akkreditierungsstelle D-PL-11201-01-00
Durch die DAkkS nach DIN EN ISO 17025 akkreditiertes Prüflaboratorium.

Analysis of radionuclides

Test report:	150413-02
Contractor:	Rössing Uranium Mine Ltd. Mrs. Dr. G. von Oertzen 28 Hidipo Hamutenya Swakopmund Namibia
Date of order:	2015/04/08
Type of samples:	Water Samples
Number of samples:	6
Sampling by:	Client (Rössing Uranium Mine Ltd.)
Date of sampling:	not specified
Delivery of the samples:	2015/04/13
Date of performance:	2015/04/13 - 2015/05/04
Analytical methods:	Gamma-ray spectrometry (γ), Alpha-particle spectrometry (α), Low level beta measurement (LL)
Evaluation:	Measurement uncertainties and decision thresholds are determined according to DIN ISO 11929 (2011) with $k_{1-\alpha} = 1{,}645$, $k_{1-\beta} = 1{,}645$
General remarks:	none
Released:	2015/05/04
Number of pages:	2

Prof. L. Funke
Vice Head of Laboratory

The accreditation is valid for the methods mentioned in the certificate. Test results refer to the submitted test items. The test report may be forwarded to other parties provided that it is not changed in any way. Excerpts from the test reports require the prior, written permissio of IAF - Radioökologie GmbH.

Managing Director: Dr. rer. nat. habil. Hartmut Schulz
HypeVereinsbank Dresden IBAN: DE92 8502 0086 5360 1794 29 SWIFT (BIC): HYVEDEMM496
Trade register: HRB 9185,Amtsgericht (County court) Dresden , Sales tax identification number: DE15926879

IAF - Radioökologie GmbH

Labor für Radionuklidanalytik | Radiologische Gutachten | Consulting

DAkkS Deutsche Akkreditierungsstelle D-PL-11201-01-00

Durch die DAkkS nach DIN EN ISO 17025 akkreditiertes Prüflaboratorium.

Test report: 150413-02

Contractor: Rössing Uranium Mine Ltd.
Mrs. Dr. G. von Oertzen
28 Hidipo Hamutenya
Swakopmund Namibia

Type of samples: Water Samples

Reference date: 2015/05/04

Analysis results			ser. no. 1		ser. no. 2		ser. no. 3	
Sample description			Swakopmund (hard water)		Swakopmund (soft water)		Mondesa	
Nuclide		Units	Result	U [%]	Result	U [%]	Result	U [%]
U-238-series								
U-238	α	mBq/l	104	16	132	19	108	16
U-234	α	mBq/l	154	15	171	18	150	15
Ra-226	α	mBq/l	19	29	11	33	12	29
Pb-210	LL	mBq/l	< 12	-	< 11	-	< 12	-
Po-210	α	mBq/l	3,6	59	2,4	78	< 1,4	-
Th-232-series								
Ra-228	LL	mBq/l	< 30	-	< 30	-	< 30	-

Analysis results			ser. no. 4		ser. no. 5		ser. no. 6	
Sample description			Rössing mine		Arandis		Walvis Bay	
Nuclide		Units	Result	U [%]	Result	U [%]	Result	U [%]
U-238-series								
U-238	α	mBq/l	119	15	102	21	114	19
U-234	α	mBq/l	156	15	143	19	223	17
Ra-226	α	mBq/l	10	33	78	20	< 3	-
Pb-210	LL	mBq/l	< 11	-	< 11	-	< 11	-
Po-210	α	mBq/l	2,4	71	2,5	79	1,9	79
Th-232-series								
Ra-228	LL	mBq/l	< 30	-	< 30	-	< 30	-

U [%]: relative expanded measurement uncertainty with coverage factor k = 2.
Data with "<" are related to the decision threshold.

- End of the test report -

Appendix C: Laboratory report on additional radionuclide analysis at Rössing mine site

IAF - Radioökologie GmbH

Labor für Radionuklidanalytik | Radiologische Gutachten | Consulting
Wilhelm-Rönsch-Str. 9
01454 Radeberg
Tel.: +49- (0) 3528-48730-0
Fax: +49- (0) 3528-48730-22

DAkkS Deutsche Akkreditierungsstelle D-PL-11201-01-00
Durch die DAkkS nach DIN EN ISO 17025 akkreditiertes Prüflaboratorium.

Analysis of radionuclides

Test report:	150629-02
Contractor:	Rössing Uranium Mine Ltd. Mrs. Dr. G. von Oertzen 28 Hidipo Hamutenya Swakopmund Namibia
Date of order:	2015/06/25
Type of samples:	Water Sample
Number of samples:	1
Sampling by:	Client (Rössing Uranium Mine Ltd.)
Date of sampling:	not specified
Delivery of the samples:	2015/06/29
Date of performance:	2015/06/29 - 2015/07/22
Analytical methods:	Gamma-ray spectrometry (γ), Alpha-particle spectrometry (α), Low level beta measurement (LL)
Evaluation:	Measurement uncertainties and decision thresholds are determined according to DIN ISO 11929 (2011) with $k_{1-\alpha} = 1{,}645$, $k_{1-\beta} = 1{,}645$
General remarks:	none
Released:	2015/07/22
Number of pages:	2

Dr. H. Hummrich
Head of Laboratory

The accreditation is valid for the methods mentioned in the certificate. Test results refer to the submitted test items. The test report may be forwarded to other parties provided that it is not changed in any way. Excerpts from the test reports require the prior, written permissio of IAF - Radioökologie GmbH.

Managing Director: Dr. rer. nat. habil. Hartmut Schulz
HypeVereinsbank Dresden IBAN: DE92 8502 0086 5360 1794 29 SWIFT (BIC): HYVEDEMM496
Trade register: HRB 9185,Amtsgericht (County court) Dresden , Sales tax identification number: DE15926879

IAF - Radioökologie GmbH

Labor für Radionuklidanalytik | Radiologische Gutachten | Consulting

DAkkS Deutsche Akkreditierungsstelle D-PL-11201-01-00

Durch die DAkkS nach DIN EN ISO 17025 akkreditiertes Prüflaboratorium.

Test report: 150629-02

Contractor: Rössing Uranium Mine Ltd.
Mrs. Dr. G. von Oertzen
28 Hidipo Hamutenya
Swakopmund Namibia

Type of samples: Water Sample

Reference date: 2015/07/08

Analysis results			ser. no. 1	
Sample description			Drinking Water	
Nuclide		Units	Result	U [%]
U-238-series				
U-238	α	mBq/l	88	13
U-234	α	mBq/l	121	13
Th-230	α	mBq/l	< 1,8	-
Ra-226	γ	mBq/l	< 10	-
Pb-210	LL	mBq/l	< 10	-
Po-210	α	mBq/l	< 1,0	-
U-235-series				
U-235	α	mBq/l	3,9	47
Th-232-series				
Th-232	α	mBq/l	< 1,0	-
Ra-228	γ	mBq/l	< 20	-
Th-228	α	mBq/l	< 1,0	-

U [%]: relative expanded measurement uncertainty with coverage factor k = 2.
Data with "<" are related to the decision threshold.

- End of the test report -