# Developments in radiation protection affecting zircon and zirconia industry

ZIA Annual Conference – Istanbul, September 2023

ZIRCON INDUSTRY ASSOCIATION

CALYTRIX CONSULTING PTY LTD

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## Presentation contents

1. The myth of “500 ppm U+Th”, its irrelevance from the point of view of radiation protection and could anything be done about it.

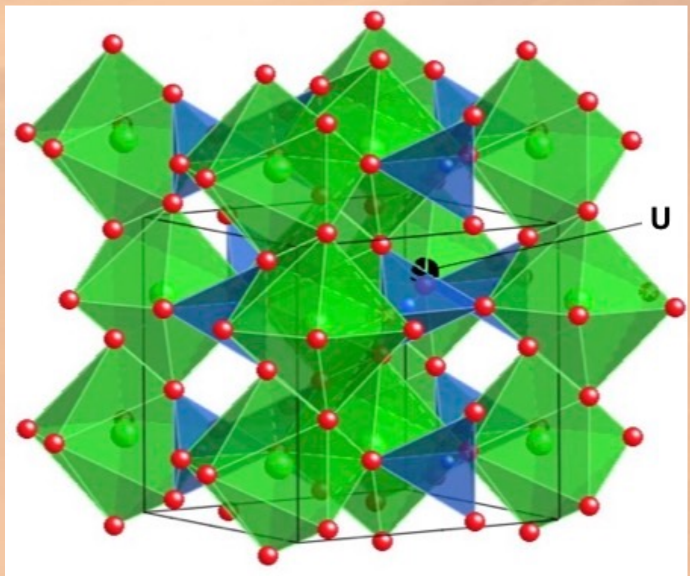
2. New internal radiation exposure dose coefficients and their potential impact on the industry.

3. The second stage of the IAEA Coordinated Research Project on Radiation Detection Systems used in border control and the need to re-confirm (or otherwise) the “10-times” exemption factor for transport of NORM.

4. Other relevant issues.

# Introduction

# Refresher: Let's see what the issue is

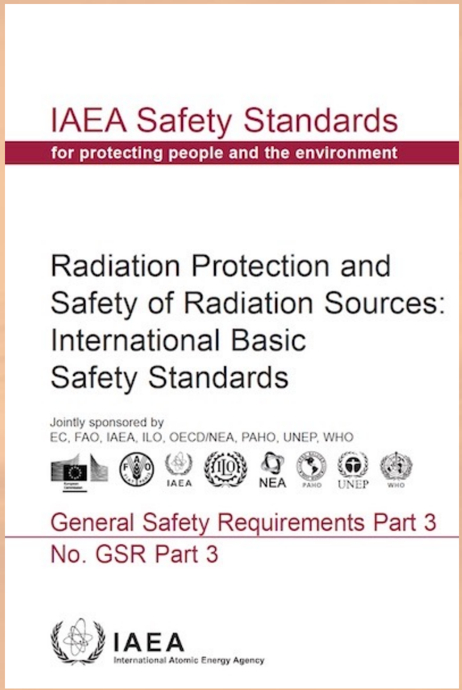


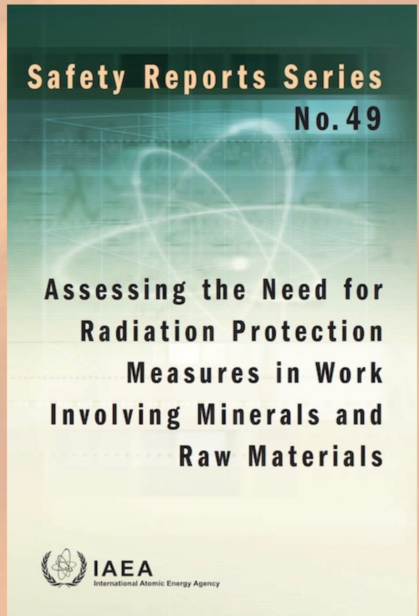

Uranium and thorium atoms are firmly locked within the crystal lattice.

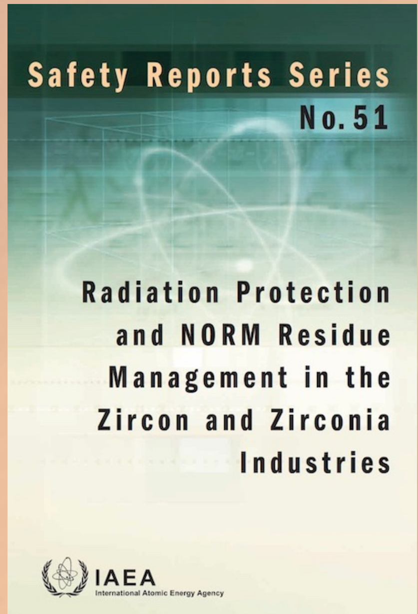
Therefore, there is no physical possibility for a radioactive atom to 'fall out' from a sand grain and contaminate the environment.

As radioactive decay of uranium and thorium occurs, these atoms disintegrate and the decay products (such as radium, etc) typically cannot escape the crystal lattice and only microscopic damage occurs within the mineral grain (metamict zircon). However, slightly elevated radiation levels can be detected in the proximity of relatively large volumes of the minerals.

# Concentrations of uranium and thorium



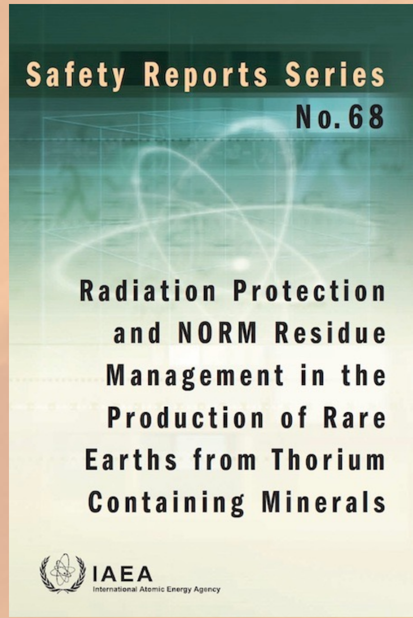




TABLE I.3. LEVELS FOR CLEARANCE OF MATERIAL: ACTIVITY CONCENTRATIONS OF RADIONUCLIDES OF NATURAL ORIGIN

| Radionuclide | Activity concentration (Bq/g) |
|---|---|
| K-40 | 10 |
| Each radionuclide in the uranium decay chain or the thorium decay chain | 1 |

- Typical range for zircon is 2.5-6.0 Bq/g,
- Mineral with < 1 Bq/g is not known to exist, lowest ~1.5 Bq/g
- Highest > 25 Bq/g (most likely due to incomplete separation from monazite), up to 150 Bq/g in tin mining residues (amang)

→ <u>All zircon is subject to radiation protection regulations</u>

# 1. The myth of 500 ppm U+Th

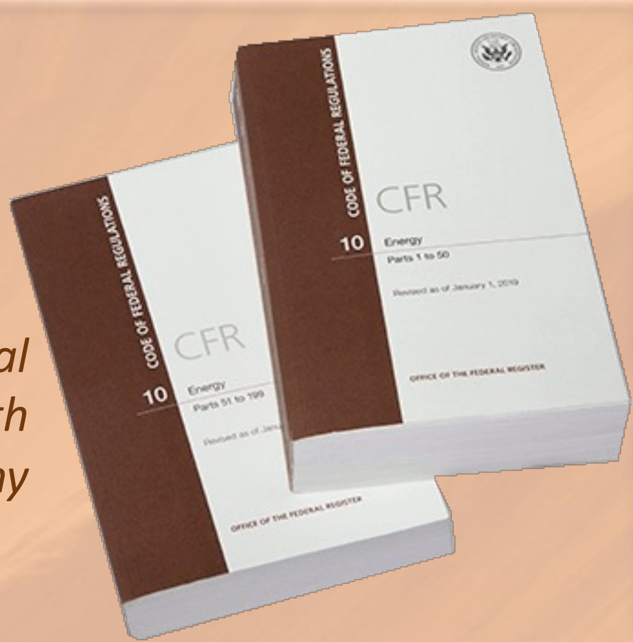
# The myth of “500 ppm U+Th”

<u>This value has no relevance to radiation protection whatsoever</u>

Introduced in March 1947 in the USA

***Source Material*** *means*

*(1) Uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores which contain by weight one twentieth of one percent (0.05%) or more of: (i) uranium, (ii) thorium or (iii) any combination thereof.*




U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
*Protecting People and the Environment*

*“At that time, the basis for the exemption was that the quantity of source material present in the exempted materials was not of significance to the common defence and security.”*

The “technological” value was picked up by numerous government departments in many countries and it is still used today, sometimes with variations.

# The myth of “500 ppm U+Th”

**UK** (The Nuclear Safeguards (EU Exit) Regulations 2019):

*(a) 0.1% or more uranium, in the case of uranium bearing ores*
*(b) 3% or more of thorium, in the case of thorium bearing ores, other than monazites*
*(c) 10% or more of thorium or 0.1% or more of uranium, in the case of monazites*

**Canada** (Nuclear Non-proliferation Import and Export Control Regulations 2000):
*…in which the concentration of source material is greater than 0.05 weight %*

**Australia** (Customs (Prohibited Exports) Regulations 1958):
*…controlled ores or concentrates containing 500 ppm or more of uranium and thorium combined*

**Appears not to make any sense where radiation risk is concerned**

# The myth of “500 ppm U+Th”

The threshold of 0.05% is a technology-related value and is not based on any potential radiation risk from the material.

Therefore, all it means is that if your material has more than 500 ppm U+Th – you will need to have additional export and/or import licenses for your product.

IAEA

**The Statute of the IAEA**

ARTICLE XX: Definitions

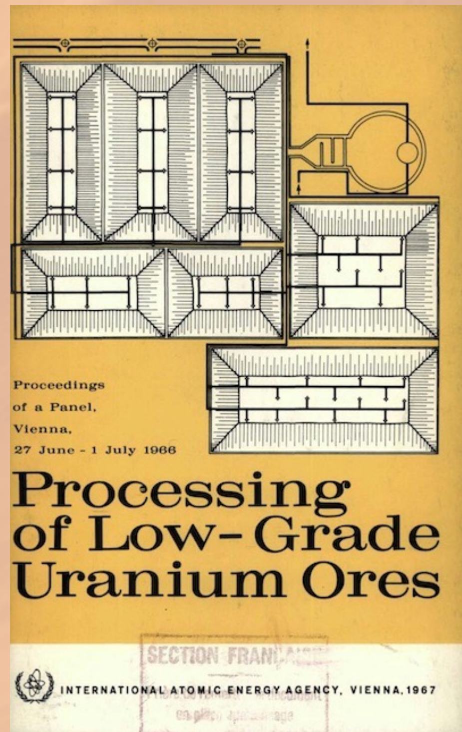
*3 . The term "source material" means uranium containing the mixture of isotopes occurring in nature; uranium depleted in the isotope 235; thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate; any other material containing one or more of the foregoing in such concentration as the Board of Governors shall from time to time determine; and such other material as the Board of Governors shall from time to time determine.*

# The myth of “500 ppm U+Th”

- On one hand, the value of 0.05% of U+Th makes no sense when we consider the radiation exposure of workers, public and the environment.
- On the other hand, there are technologies that allow the economical processing of uranium ores down to 0.02% and even to 0.01% of uranium.


0.03% $U_3O_8$ (~250 ppm U) mine, Africa, 2015

1967(!) IAEA Technical Report described processing of the ore at 0.01% $U_3O_8$ (~ 85 ppm U) in the Czech Republic



## The myth of “500 ppm U+Th”

Is anything can be done about this “0.05% U+Th” thing?

Theoretically, yes, but…

Could we make the situation worse?

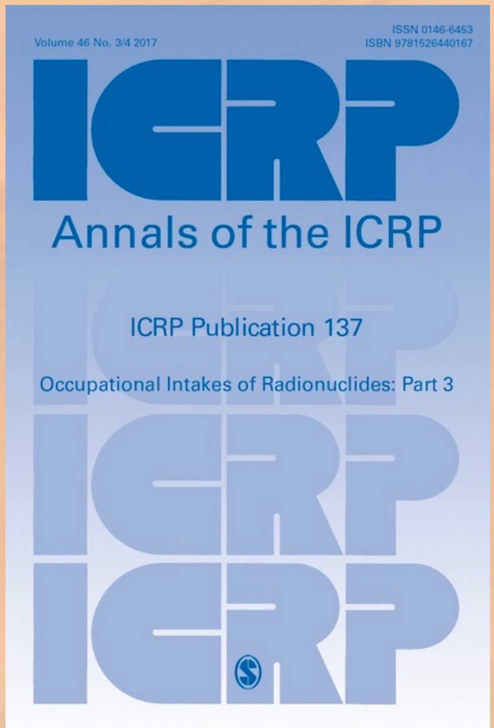
What are the chances that the limit will go down instead, to 0.03 or 0.02%…?

# 2. New dose coefficients and potential impact on the industry

# Increase in internal radiation exposure dose coefficients

Radiation exposure in mining, processing, separation, transport, storage and use of zircon occurs not only due to the exposure to the *external* gamma radiation. Another "pathway of exposure" is the *internal* one, inhalation of dust, radon and its decay products.

→ Recent: a VERY significant increase in dose coefficients, doubling and tripling internal exposures.



Volume 46 No. 3/4 2017

ISSN 0146-6453
ISBN 9781526440167

ICRP

Annals of the ICRP

ICRP Publication 137

Occupational Intakes of Radionuclides: Part 3

IOP Publishing | Society for Radiological Protection — Journal of Radiological Protection

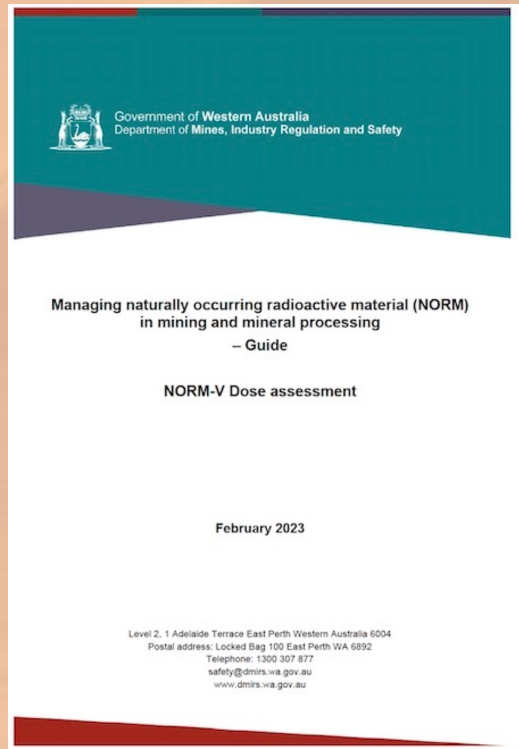
J. Radiol. Prot. 40 (2020) 1457–1475 (19pp) — https://doi.org/10.1088/1361-6498/abb039

Practical Matter Article

**Impacts of revised dose coefficients for the inhalation of NORM-containing dusts encountered in the Western Australian Mining Industry**

Martin I Ralph[1], Nick Tsurikov[2] and Marcus Cattani[1]

http://calytrix.biz/papers/19.Revised_dose_factors.pdf



Government of Western Australia
Department of Mines, Industry Regulation and Safety

Managing naturally occurring radioactive material (NORM) in mining and mineral processing
– Guide

NORM-V Dose assessment

February 2023

Level 2, 1 Adelaide Terrace East Perth Western Australia 6004
Postal address: Locked Bag 100 East Perth WA 6892
Telephone: 1300 307 877
safety@dmirs.wa.gov.au
www.dmirs.wa.gov.au

# Increase in internal radiation exposure dose coefficients

Th-232 decay series: default 5 µm dust particle size

| | |
|---|---|
| NEW DCF= | **0.0167** |
| OLD DCF= | 0.0080 |

**Increased by 2.1 times**

U-238 decay series: default 5 µm dust particle size

| | |
|---|---|
| NEW DCF= | **0.0084** |
| OLD DCF= | 0.0035 |

**Increased by 2.4 times**

Radon (Rn-222) from uranium decay chain

**Increased by 2.2 times**

Thoron (Rn-220) from thorium decay chain

**Increased by 3.1 times**

# Increase in internal radiation exposure dose coefficients – summary

**Internal dose coefficient for the default (5 µm) zircon dust**

**Previous – 0.0044 mSv/Bq**
**New – 0.0101 mSv/Bq**

**Increased by 2.3 times**

The typical radiation doses of workers in the industry are very low and were not expected to exceed the annual limit of exposure for the members of the general public (1 mSv/y).

However, with the increase in *internal* dose coefficients, these doses would also increase:

- Unlikely to get close to 5 mSv/year
- Possibly exceed 1 mSv/year

Changing calculation parameters will increase actual doses.

## Increase in internal radiation exposure dose coefficients – summary

The following measures are suggested:

1. Consult with the Regulatory Authority in your jurisdiction to ascertain when (and if) the new ICRP internal dose coefficients will be in force.

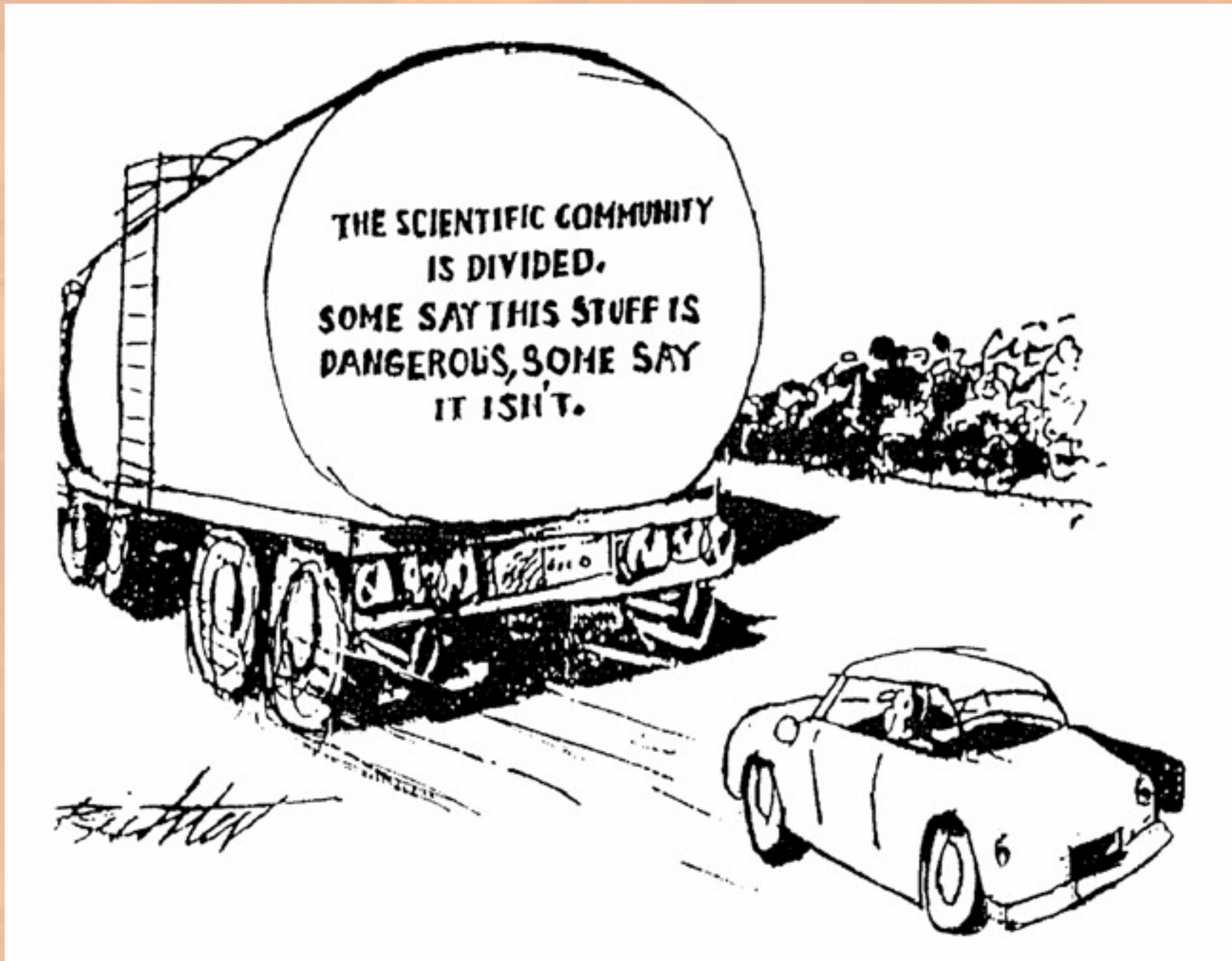
2. Re-evaluate controls that you have over dust and see if there is anything “reasonably achievable” to reduce its concentrations.

3. Undertake radon/thoron measurements in the areas that are used for storage of feedstock and products and re-evaluate the need for ventilation of these areas.



# 3. Transport of zircon and zirconia – IAEA Co-ordinated Research Project and the NORM exemption factor of 10

# What the placard on the shipments of zircon/zirconia should look like



# IAEA Co-ordinated Research Project

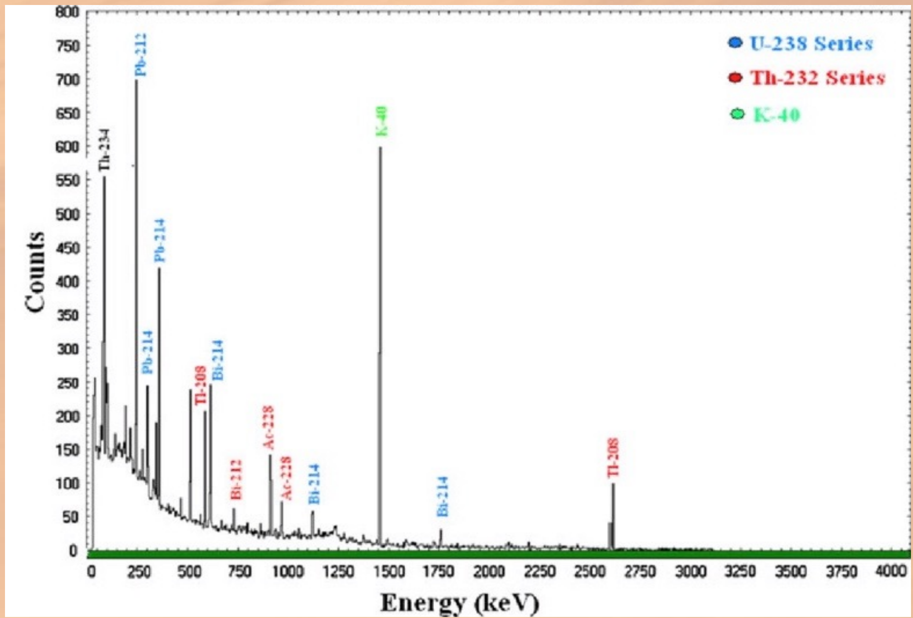
**Facilitation of safe and secure trade using nuclear detection technology, detection of radionuclides and other contraband**

Purposes of the project are:

1. Collect the spectroscopic data about NORM shipments
2. Obtain data for inclusion in the IAEA “TRACE” application

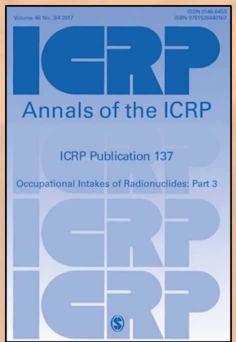

# IAEA Co-ordinated Research Project

3. Radiation monitoring data associated with transport will also be very useful.
4. Additional information is needed regarding gamma-spectra for different NORM for "front-line officers".




## The possible need to lower the exemption factor of 10


IAEA TECDOC-1728, 2013: Based on ten reports, exemption factor of 10 (§107(f) of IAEA SSR-6) was appropriate for NORM shipments.




ICRP Publication 137, 2017: Dose coefficients for NORM dusts and $^{222}Rn$ doubled, for $^{220}Rn$ – tripled.

All reports on which the TECDOC-1728 was based were re-assessed using new ICRP dose coefficients. For transport workers not to be "occupationally exposed":

- The factor of 10 is still valid for *packaged* NORM (drums, containers) and may be even increased to 15 or 20 (study from tantalum/niobium industry);
- The correct factor for the *bulk* NORM shipments is between 6 and 8.

# The possible need to lower the exemption factor of 10 – dust

Potential internal exposures: loading/unloading of bulk minerals, cargo hold inspection / cleaning

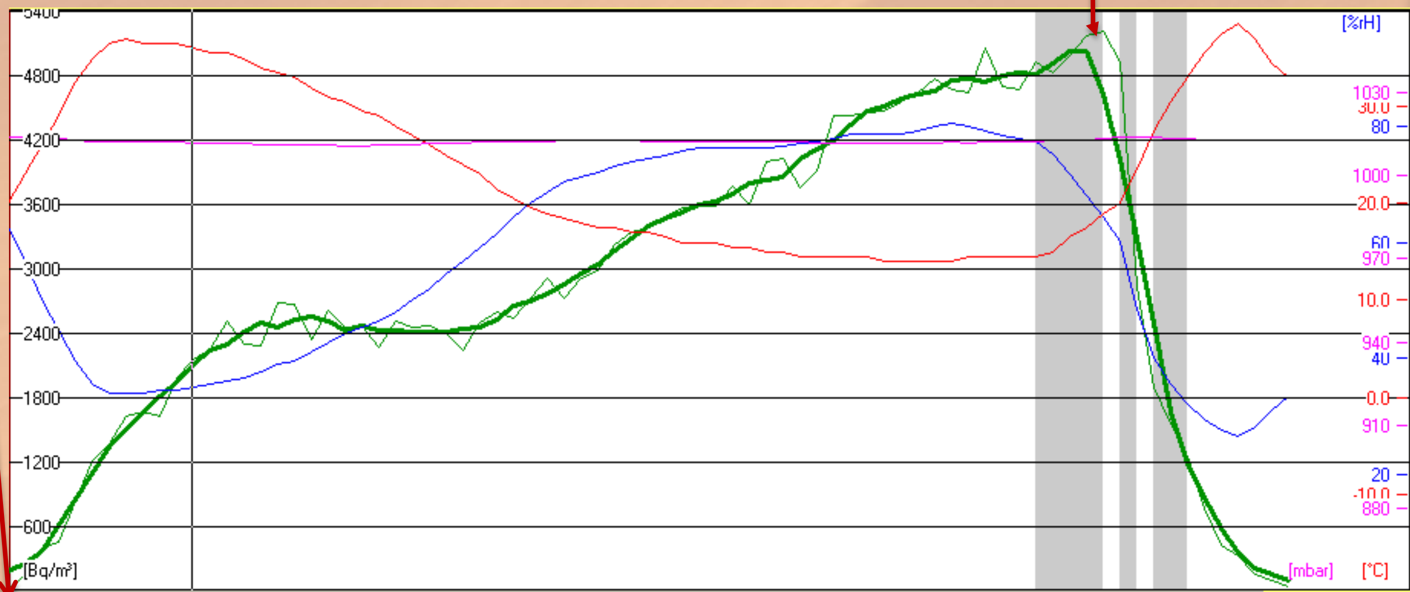

# The possible need to lower the exemption factor of 10 – radon

When minerals are transported in bulk or in bags, uranium and radium contained in minerals may cause significant concentrations of radon inside the sealed shipping containers and in the hulls of ships, up to and above 10,000 Bq/m$^3$ of radon.

Marginally ventilated shed with zircon >1,000 Bq/m$^3$, sealed container with zirconia > 5,000 Bq/m$^3$

Container doors closed

Container doors opened in 24 hours




1,000 Bq/m$^3$:
> 1 mSv/year in 150 hours

5,000 Bq/m$^3$:
> **<u>1 mSv/year in 30 (!) hours</u>**

## The possible need to lower the exemption factor of 10

Reason why radiation monitoring data for transport of industry products is needed:

- The exemption factor of 10 was introduced in 1996 and is still applicable,
- Ten years after this, the IAEA coordinated research project (2007-2010) looked at the factor of 10 and confirmed its validity,
- As another ten years have now passed (and new regulations were issued by the IAEA), it may be a good time to look at the possible exposures of transport workers once again.
  1. On one hand, some studies, specifically by Tantalum-Niobium Study Centre, indicate that the ’10-times’ exemption factor is too low and may be raised to around ’30-times’ (at least for containerised maritime transport). This, possibly, would be the case for the transport of zircon and rare earth concentrates in containers as well.
  2. On the other hand, due to the introduction of new internal exposure dose coefficients by the ICRP, the ’10-times’ exposure factor appears to be too high and may need to be lowered to around “6-8 times” (possibly 5) for the bulk shipment of NORM.

## The possible need to lower the exemption factor of 10

Discussions held with IMO (International Maritime Organisation) confirm that for purposes of exemption in practical situations in ports, it will be impossible to distinguish between NORM in different configurations – bulk or containers.

Some studies of radon emanation from zircon, zirconia and other industry products, such as ceramics have been carried out previously. It was found that the levels are too low for any "regulatory concern". With the increase in the internal radiation exposure dose coefficients, however, it is no longer the case.

It is hoped, that the additional data will prove that "on the balance between bulk and packaged" shipments the exemption factor of 10 can be retained in the future, especially if the newly-calculated exemption factor for bulk shipments would be below 10 by only a small margin.

In the absence of actual data, the modelling of exposures will need to be carried out, which usually is a significant over-estimation.

# Modelling of transport-associated worker exposures

**Computer modelling – are we making a new generation of professionals stupid?**

Nick Tsurikov

CALYTRIX CONSULTING PTY LTD

NORM-IX, Denver, 2019

**NEVER HAPPENS**

## EXAMPLES OF MODELLING

The examples of the use of models on the following slides are graded on a following scale:

**Stupid**

**Silly**

**Adequate**

**Ridiculous**

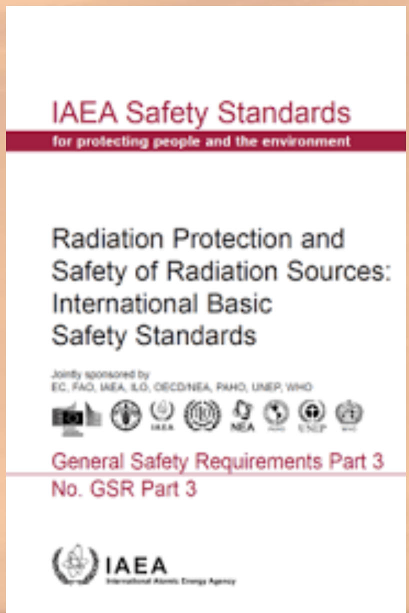
**Ludicrous**

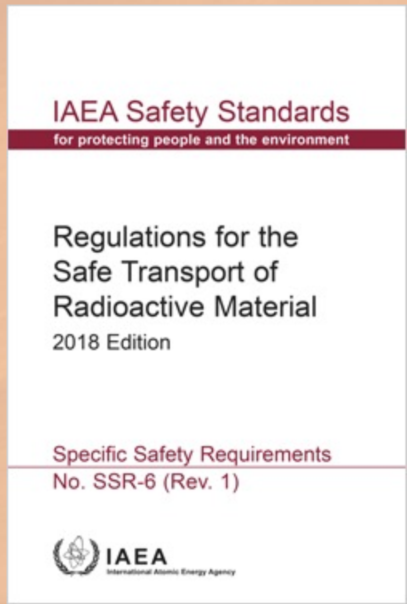
*Computer modelling – are we making a new generation of professionals stupid?* 13

# IAEA – an additional complication

The concept of $U_{(nat)}$ and $Th_{(nat)}$, on which the assessment of the applicability of all Regulations relevant to the industry was based has been removed in the latest edition of the IAEA Basic Safety Standards (BSS).

It is not yet known which approach would be taken in the future in regards to the limits for natural radionuclides for transport and the 'NORM Working Group' of the IAEA TRANSCC (relevant safety committee) is yet to re-convene.

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Any information that ZIA Member Companies can share in regards to radiation exposures during transport will be very much appreciated

# 4. One relevant issue

## Developments in the USA

Radiation safety in zircon/zirconia industry in the USA is typically governed by State Regulations, which (in most cases) are based of the SSR (Suggested State Regulations – part N for TENORM), developed by the CRCPD (Conference of Radiation Protection Program Directors).

In late 1990’s a lot of research was carried out in the USA, South Africa and Australia (coordinated by Zirconium Environmental Committee in the USA) and the specific exemption from regulations was obtained.

No additional research was carried out since late 1990’s, review of Part N commenced in 2014…

**Developments in the USA**

Development of the new Part N regulations (now a final draft):

<u>Current</u> (Rationale for Part N):

*"The optional exemption for zircon, zirconia and zircon products was added after evaluation of information submitted demonstrated that the dose criteria specified in N.4f. would not be exceeded. The zircon exemption was added as a new N.4d."*

<u>New</u>:

<u>No "industry-wide" exemptions</u> (applies to phosphate industry as well).

**Development of a Regulatory Framework for Naturally Occurring Radioactive Material in the United States**

**Developments in the USA**

Typical zircon would contain 1-1.5 Bq/g of thorium and 3-4 Bq/g of uranium.

New Part N *Registration screening levels*:

- Thorium 0.06 Bq/g (1.6 pCi/g), uranium 0.11 Bq/g (3.0 pCi/g)

New Part N *Concentrations requiring controls for worker exposure:*

- Thorium 0.89 Bq/g (24 pCi/g), uranium 3.26 Bq/g (88 pCi/g)

If your operations are in the USA, it is suggested to:

(a) Check if your State Regulations follow the SSR from the CRCPD, and if yes

(b) Find out when the new Part N could be in force in your State and how they will affect your operation.


Thank you for your attention!