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## Journal Office Bearers

# EDITORIAL

ARPS Executive and ARPAB have been discussing a number of issues over the last several months, well maybe a year or two. I certainly have been raising some of these issues for some time. The two issues I am "spruking" are certification of training packages and trainers by ARPAB, and the second issue is the few numbers of young people coming into our profession.

A number of you ARPS members are aware that I have been trying to sell my business and retire for the last few years without much success. I have had two prospective buyers, one local and one from overseas – the first didn't come to fruition as their Health Physicist was head-hunted and enticed away by a government body. Since then that company has not been able to entice a new health physicist to join (I will detail that later); the second company offered such ridiculous reward and conditions that I had no option but to walk away. I am concerned for my current clients.

Why cant companies get health physicists to join them and why cant I find a buyer? My opinion and that of the first company is that fresh young graduates expect large incomes from the start, consider that they don't need to gain experience, further knowledge and ability, and don't want "to get their hands dirty". Part of my company's capabilities is environmental radiation surveys (as was the intent of the first company), yet no young health physicist or physicist is interested in doing the field work – I find the field work really enjoyable and enlightening, maybe that is because I am a biologist and ecologist by original qualifications.

I, and I am sure that a few others were mentored by senior members of ARPS. That was a means of gaining experience as well as learning new aspects of the profession (environmental radiation was what I was mentored). Is mentoring happening now and if not why not? Why arent we getting younger new members, ARPS will slowly fade away if we don get new younger members. Having ARPAB certification available for RPAs, Experts and trainers would be an excellent incentive. Maybe the new Student Membership policy that has been under review recently may improve the situation. Also ARPS in all States must get involved with schools (counselling and advising on careers) as well as being involved in Science Week would certainly improve our visibility.

On another topic, I am still wanting members to submit articles for publication in RpiA. I received one excellent article on transport of NORM just after going to print of Issue 1. Surely there are more articles and technical pieces out there among our members.

Enjoy!

***William Bartolo***
editor

# Application of Transport Regulations to NORM: Practical Guide

by
**Nick Tsurikov[1], and Paul John Hinrichsen[2]**

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**Abstract**

This paper provides an update on the issues associated with the transport of naturally occurring radioactive materials (NORM) in the mining and mineral processing industry and is an update of the earlier publication on the same topic, prepared by two of the authors from the original 2007 paper[1]. The update is required due to regulatory changes and several identified inaccuracies in the earlier publication.

The arguments in the 2007 publication were based on the 2005 IAEA Regulations for the Safe Transport of Radioactive Material [2] and the 2002 Advisory Material for the Regulations [3].

In the interim, both the International Regulations and the Advisory Material were re-issued several times [4–9], with documents [6] and [9] being currently applicable. Also, since the time of publication of the previous version of this paper, the regulations in Australia have also changed three times [10–13], with document [13] being currently applicable.

A preliminary assessment of the applicability of the current Transport Safety Regulations [6,9] to NORM was carried out by Calytrix Consulting in 2016-2019 and an informal technical reference note was published online in August 2019, together with the calculator created in MS Excel [14].

## 1. INTRODUCTION AND GENERAL CONSIDERATIONS

In many cases there is an insufficient level of communication in regards to the legal requirements between the supplier/exporter and consumer/importer of a mineral concentrate containing naturally occurring radioactive materials (NORM) and the relevant Regulatory Authorities. The lack of communication between logistics companies and government departments in different countries (and between the States within one country), combined with frequent misinterpretations of different legislative acts, regulations and guidelines very often results in serious challenges, both for the regulators and for the minerals industry.

The issue becomes much more complex if we consider the fact that International Transport Safety Regulations [6] are not adopted simultaneously across the world, and different requirements may apply in different jurisdictions.

It is essential that any mining and mineral processing company, and relevant logistics operators carefully examine all applicable legislation, to fully understand how radioactive material is defined within the respective jurisdictions where NORM is proposed to be transported, so as to be absolutely clear about which controls will apply to a specific material. It is also advisable that discussions are held with the local regulator to ensure a common understanding of interpretations and requirements.

The Definition of naturally occurring radioactive material (NORM) is given in the IAEA Safety Glossary [15] as follows:

*Radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides.*

- *The exact definition of 'significant amounts' would be a regulatory decision.*
- *Material in which the activity concentrations of the naturally occurring radionuclides have been changed by a process is included in naturally occurring radioactive material (NORM).*
- *Naturally occurring radioactive material or*

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*NORM should be used in the singular unless reference is explicitly being made to various materials.*

There are 24 industries (listed in Table 1) where the management of NORM may be required. The situations where at least some items or materials may require an assessment of the applicability of transport safety regulations are highlighted in **bold blue font.**

## 1.2. Different modes of transport and types of packaging

In the consideration of the radiation safety measures to be applied to the transport of NORM the mode of transport is as important as its activity concentrations, in some cases even more important, as illustrated by an example below.

If NORM is packed in appropriate bags and placed inside containers, at the point of origin the only radiation exposure workers would receive will be from gamma radiation. There is, however, a significant concern for workers who would be opening the containers at their destination; the concentrations of radon ($^{222}Rn$) inside containers could be extremely high (in order of 10,000 Bq/ $m^3$) and the containers may need to stay opened for several hours, to allow for the reduction of radon concentrations through natural ventilation. This applies to the transport of any mineral concentrate containing uranium, irrelevant of the applicability of the Regulations, and to the transport of contaminated equipment from oil and gas, titanium pigment, geothermal energy generation, and other relevant industries.

If, however, NORM is transported in bulk, at the point of origin the dose for workers from dust and radon inhalation also needs to be considered, and in case of a marine shipment, where the same considerations for radon (as in the paragraph above) will apply to opening a ship's hull at a destination port.

**Table 1. The list of NORM**

| | |
|---|---|
| **Bauxite/aluminium** | **Phosphoric acid production** |
| Building industry | **Titanium pigment** |
| **Cement, clinker ovens** | **Thermal phosphorus** |
| Coal-fired power plants | **Rare earths** |
| **Geothermal energy** | **Scrap metal recycling** |
| **Hydraulic fracturing** | **Tantalum** |
| Iron and steel | **Thorium compounds/products** |
| **Mining ores other than uranium** | **Tin, copper** |
| **Niobium, ferro-niobium** | Tunnelling |
| **Oil and gas production** | Water treatment |
| **Paper and pulp production** | **Zinc, lead** |
| **Phosphate fertilisers** | **Zircon and zirconia** |

## 1.1. Material on a mining/processing site

The first step is to establish if the Regulations [6, 13] apply to the movement of potentially radioactive material. If the transport is within the boundaries of an authorised mining/processing site, the Regulations are not applicable, in accordance with §107(b):

*107. The Regulations do not apply to:*

…

- *(b) Radioactive material moved within an establishment that is subject to appropriate safety regulations in force in the establishment and where the movement does not involve public roads or railways.*

Despite the fact that such shipment does not need to comply with the Regulations, good radiological practice should nonetheless be followed during the transport on the authorised site.

If, however, there is a need to use a public road, railway or waterway, the requirements of the Regulations must be complied with.

### 1.3. Differences between 'natural uranium' and U (natural)

These two terms are not equal and, in many cases, the differences may need to be taken into account.

§247 of the Regulations [6] defines "natural uranium" as follows:

*Natural uranium shall mean uranium (which may be chemically separated) containing the naturally occurring distribution of uranium isotopes (approximately 99.28% uranium-238 and 0.72% uranium-235, by mass).*

This definition describes "chemically-separated uranium", which means that the uranium decay chain may be disrupted, but the uranium nuclide mixture ($^{238}U$ to $^{235}U$ ratio) is undisturbed (the uranium is not enriched in the $^{235}U$ isotope).

"**U(natural)**" is not the same as "natural uranium". Whilst "natural uranium" refers to the non-enriched but possibly chemically separated uranium, "U(nat)" refers to chemically undisturbed uranium in secular equilibrium with its decay products.

Therefore, in almost all cases of NORM transport the material which has not been subjected to any chemical or thermal processing may be considered as "U(nat)". Additional information on this issue is presented in [16].

This same argument applies to thorium ores, which have not been chemically- or thermally-processed and are classified as Th(nat).

### 1.4. Expected removal of U (natural) and Th(natural) concepts from the Regulations

It should be noted that the concept of U(nat) and Th(nat) has been removed in the latest edition of the International Basic Safety Standards (BSS) [17]. It is possible that the definitions and corresponding limiting values for U(nat) and Th(nat) will be removed from the subsequent edition of the International Transport Regulations as well, as they need to be aligned with the IAEA BSS.

It is not yet known which approach will be taken in the future in regards to the limits for natural radionuclides. Table I.1 of the BSS [17] contains the values for $^{232}Th$ and $^{238}U$, but these exemption levels are:

(a) For "moderate amounts of materials", the footnote to the Table I.1 clearly states, *the calculated values apply to practices involving small scale usage of activity where the quantities involved are at the most of the order of a tonne*. Therefore, these values cannot apply to the shipments of materials in mining and mineral processing industry, due to the fact that those always exceed the amount of one tonne.

(b) For $^{232}Th$ do not include any of the decay products (all of them are included in the case for Th(nat)), for $^{238}U$ only include two immediate decay products, not all of them, as is the case for U(nat).

Table I.2 of the IAEA BSS [17] is irrelevant for mining and mineral processing industry, as it addresses only artificial radionuclides.

The only relevant Table in the BSS [17] is I.3, which is *Levels for clearance of material: activity concentrations of radionuclides of natural origin*, which contains a single value, 1 Bq/g for *each radionuclide in the uranium decay chain or the thorium decay chain*.

If the same "10-times" exemption from the application of Transport Regulations applicable to NORM, described in section 2.1 below is maintained, nothing is expected to change for shipments of materials where $^{238}U$ and $^{232}Th$ decay chain radionuclides are in the state of secular equilibrium.

The Transport Safety Standards Committee of the IAEA is currently looking into this matter and will advise in due course.

## 2. CORRECT APPROACH TO THE TRANSPORT OF NORM AND CALCULATIONS

### 2.1. Definitions, determination of activity concentration and exemptions

If it is established that compliance with Regulations may be necessary, the next step is to determine the activity concentration of the material to be transported and compare it with the appropriate limits.

The Regulations[6] in Table 2, Basic Radionuclide Values specifies the values for Th (nat) and U (nat) at 1.0 Bq/g each.

The exemption for NORM is provided in §107(f) of the IAEA Regulations:

*107. The Regulations do not apply to:*
*(f) Natural material and ores containing naturally occurring radionuclides, which may have been processed, provided the activity concentration of the material does not exceed 10 times the values specified in Table 2, or calculated in accordance with paras 403(a) and 404–407. For natural materials and ores containing naturally occurring radionuclides that are not in secular equilibrium the calculation of the activity concentration shall be performed in accordance with para. 405.*

It is important to note that the '10-times' factor applies only to the activity concentrations, not to the 'total activity of the consignment'.

The justification for the factor of 10 is provided in §107.4 of the Advisory Material [9],

*A factor of 10 times the exemption value for activity concentration was chosen as providing an appropriate balance between the radiation protection concerns and the practical inconvenience of regulating large quantities of material with low activity concentrations of naturally occurring radionuclides.*

Therefore, the actual limits for the minerals and associated products are raised to 10 Bq/g for Th (nat) and U (nat). Please note that the value of 10 Bq/g refers to the aggregate activity concentration of $^{232}$Th and $^{238}$U in equilibrium with their decay products, not to each element separately.

If the aggregate activity of U(nat) and Th(nat) in the material to be transported exceeds 10 Bq/g, there is still one more factor that needs to be considered, the Activity limit for an exempt consignment. These values are also provided in Table 2 of the Regulations [6].

In accordance with §236 of the Regulations,

*Radioactive material shall mean any material containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values specified in paras 402–407.*

The total activity will always be exceeded in case of transport of tens of tonnes of minerals; however, this may not be the case when small packages are transported to and from laboratories.

For example, if a mineral concentrate containing 15 Bq/g of Th(nat) is to be transported, two limits will apply to its shipment:

- Activity concentration limit for exempt material, 10 Bq/g for Th(nat), and
- Activity limit for an exempt consignment, 1,000 Bq for natural thorium (the 10-times exemption factor for natural materials does not apply to the total activity limits).

The first limit is clearly exceeded (15 Bq/g > 10 Bq/g), but if the total mass of the package is less than 66 grams – the shipment will not fall under the provisions of transport safety regulations and will not need to be signposted or labelled.

The above consideration is particularly important for transporting small mineral samples to and from analytical laboratories.

### 2.2. Two different types of materials requiring different calculation methods

Radionuclides in $^{238}$U and $^{232}$Th decay chains in the material may or may not be in the state of secular equilibrium. "Secular equilibrium" means that the thorium and uranium decay chains in NORM have not been disturbed, no chemical or thermal processing took place. This applies to materials such as zircon and ilmenite sand, rare earth, tin and tantalum concentrates, where only physical processing (gravimetric, magnetic, etc) was carried out.

The complete data on the disruption of the secular equilibrium during processing is typically not available for many mineral products, but it is prudent to assume that this disruption may occur in cases of:

- Any chemical processing of the material, such as leaching or adding flotation agents to the process;

- Any thermal processing of the material. Due to the variety of different materials and methods used in their treatment it is impossible to establish a universal ‘cut-off’ point for the temperature, at which some radionuclides can volatilise and disrupt the equilibrium; the value of 250-300oC is suggested as a general guide at which additional analysis of the material may be required.

### 2.3. Transport of NORM in secular equilibrium

If thorium and uranium decay chains in a specific NORM are in equilibrium, both $^{232}Th$ and $^{238}U$ have much longer half-lives than any other nuclide in the respective decay chains; therefore, only Th(nat) and U(nat) concentrations (usually available in parts per million, ppm) are used in the calculations:

$$C(^{Bq}/_{g}) = \frac{Th\ (ppm) \times 4.055 + U\ (ppm) \times 12.859}{1000}$$

The factor for U(nat) of 12.859 takes into account the contributions from both U-238 and U-235.

If the result is less than 10, the material is exempt from Transport Safety Regulations [6].

It is important to note that the laboratories typically provide the values for the concentrations of uranium and thorium in the form of oxides, $ThO_2$ and $U_3O_8$. In this case the following coefficients must be used for the correct application of the equation above:

- 1 ppm of ThO2 equals to 0.879 ppm of Th,
- 1 ppm of U3O8 equals to 0.848 ppm of U.

**Practical example 1**

Mineral concentrate in secular equilibrium contains 250 ppm $ThO_2$ and 40 ppm of $U_3O_8$.

- Th(nat) = 250 x 0.879 = 220 ppm, U(nat) = 40 x 0.848 = 34 ppm,
- Activity concentration = (220 x 4.055 + 34 x 12.589)/1000 = 1.33 Bq/g,
- 1.33 Bq/g < 10 Bq/g, this mineral concentrate is exempt from Transport Safety Regulations [6].

### 2.4. Transport of NORM containing “non-series” radionuclides

In some circumstances the concentrations of the radionuclides that are not part of $^{232}Th$, $^{238}U$ and $^{235}U$ decay chains may also need to be considered. The following applies to the transport of spodumene/lithium concentrates and products containing significant concentrations of potassium such as fertilisers or fruit juice concentrates.

These materials typically contain uranium and thorium in concentrations of less that 0.1 Bq/g, therefore these can be disregarded. However, the concentrations of the naturally occurring radionuclides such as $^{40}K$ and $^{87}Rb$ may be relatively high and needs to be considered before transport of some materials.

The limiting concentrations in the Regulations [6] are as follows:

- $^{40}K$ – 100 Bq/g (1,000 Bq/g for NORM), and
- $^{87}Rb$ – 10,000 Bq/g (100,000 Bq/g for NORM).

As in case of uranium and thorium, the laboratories typically provide the results for the oxides, $K_2O$ and $Rb_2O$ and there is also a need to consider that only a fracton of total potassium and rubidium are radioactive isotopes.

The following coefficients must be used to convert the concentrations of oxides to concentrations of metals:

- 1 ppm of $K_2O$ equals to 0.830 ppm of K
- 1 ppm of $Rb_2O$ equals to 0.914 ppm of Rb

The specific activity of $^{40}K$ is 265,267 Bq/kg, but as only 0.012% of potassium is $^{40}K$, when converted from K(ppm) value the value is 32 Bq/kg.

The specific activity of $^{87}Rb$ is 3,099 Bq/kg, but only 28% of rubidium is $^{87}Rb$, therefore, when converted from Rb(ppm) value is 868 Bq/kg.

It is important to note that it is extremely unlikely that NORM containing only potassium and rubidium will ever be a subject to the Transport Safety Regulations and the data is provided for information only, for very rare cases when $^{40}K$ and $^{87}Rb$ may need to be considered in the fractions equation (part 2.6 below), alongside radionuclides from thorium and uranium decay chains.

**Practical example 2**

Mineral concentrate in secular equilibrium contains 7% of $K_2O$ and 0.5% of $Rb_2O$.

- K = 70,000 x 0.830 = 58,100 ppm, Rb = 5,000 x 0.914 = 4,570 ppm,
- $^{40}$K activity concentration = 58,100 x 0.032/1000 = 1.86 Bq/g
- $^{87}$Rb activity concentration = 4,570 x 0.868/1000 = 4.00 Bq/g,
- The values are significantly less than the transport limits (1,000 Bq/g for $^{40}$K and 100,000 for $^{87}$Rb) and it is clear that this mineral concentrate is exempt from Transport Safety Regulations.

### 2.5. Transport of NORM not in secular equilibrium, general considerations

As noted in part 2.2 above, for many materials and mineral concentrates the analysis of only uranium and thorium is not sufficient.

**Correction Note 1:** The calculations for the materials where the radionuclides in thorium and uranium decay chains are not in secular equilibrium were incorrect in the previous version of this paper [1]. It was previously assumed that the concentrations of all radionuclides (even very short-lived ones) need to be considered.

However, in accordance with §404 of Transport Safety Regulations [6], this is not correct:

*In the calculations… a single radioactive decay chain in which the radionuclides are present in their naturally occurring proportions, and in which no daughter nuclide has a half-life either longer than 10 days or longer than that of the parent nuclide, shall be considered as a single radionuclide.*

*In the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than 10 days or longer than that of the parent nuclide, the parent and such daughter nuclides shall be considered as mixtures of different nuclides.*

**Correction Note 2:** The 'mixtures' equation from the §405 of the Regulations [6] applies to the materials where the decay chains are not in secular equilibrium. §I.81 in Advisory Material to the Regulations [9] repeats this equation, but §I.80 in [9] contains the old calculation method ("ratio"), which is much simpler to use. It should be noted that the same results are achieved when using one or another method of the calculation.

The following steps are suggested for the accurate estimation of the applicability of the Regulations [6] to the transport of NORM, where it is suspected that secular equilibrium between radionuclides in $^{238}$U and/or $^{232}$Th decay chains may have been disrupted by processing.

A. If both the producer/transporter and the regulatory authority agree that $^{238}$U and $^{232}$Th are in equilibrium, the analysis is to be performed only for U and Th.

B. If it is suspected that one or both of the decay chains may be in disequilibrium, the analysis is performed only for the limited set of radionuclides, after the consultation with the regulator:

- $^{232}$Th decay chain: $^{232}$Th, $^{228}$Ra, $^{228}$Th;
- $^{238}$U decay chain: $^{238}$U, $^{234}$U (no analysis needed, assumed to be equal to $^{238}$U), $^{230}$Th, $^{226}$Ra, $^{210}$Pb;
- $^{235}$U decay chain: Usually not required.
- If it is confirmed that both $^{232}$Th and $^{238}$U decay chains are in equilibrium – return to step A for all subsequent analyses (part 2.3 above, just U(nat) and Th(nat));
- If the disequilibrium is confirmed – proceed to step C.

C. Analyse for the following radionuclides to determine the applicability of Regulations [6] to the specific material (full set):

- $^{232}$Th decay chain: $^{232}$Th, $^{228}$Ra, $^{228}$Th;
- $^{238}$U decay chain: $^{238}$U, $^{234}$Th, $^{234}$U, $^{230}$Th, $^{226}$Ra, $^{210}$Pb, $^{210}$Po;
- $^{235}$U decay chain: only if required by a customer/transporter or requested by the Regulatory Authority: $^{235}$U, $^{231}$Pa, $^{227}$Ac, $^{227}$Th, $^{223}$Ra.

The footnote (b) to the Table 2 of the Regulations [6] states that the concentration of one isotope may be considered to include the concentrations of its decay products. For example, this footnote states that $^{226}Ra$ may "cover" the remainder of the $^{238}U$ decay chain. It is important to note that may not be correct for the processed NORM in many circumstances, as during processing of minerals radium and lead/polonium usually behave in different ways.

It is, therefore, essential that in cases where disequilibrium has been clearly established, the analysis for the full set of radionuclides listed in "C" above be carried out.

Without the data for all of the above ten radionuclides from $^{232}Th$ and $^{238}U$ decay chains (and, where required, the data for five more radionuclides from the $^{235}U$ decay chain) it is impossible to determine if material is classified as 'radioactive' for transport or not. In some circumstances the data may also be required for other radionuclides such as $^{40}K$ and $^{87}Rb$ (part 2.4 above).

It is very important to remember the following:

a. Prior to undertaking a complete analysis (step C above), the measurements of the concentrations of seven radionuclides (step B in this part) should be carried out to initially assess the secular equilibrium of the decay chains.
b. The regular analysis for all radionuclides (i.e., for each shipment) should not be required (a confirmation from the local regulator would be needed); the analyses will only need to be repeated if the feedstock changes, the processing method changes, of both of those change.

### 2.6. Transport of NORM not in secular equilibrium, calculations when data is available

The equation that is given in the Regulations [6] is:

$$X_m = \frac{1}{\sum_i \frac{f(i)}{X(i)}}$$, where:

**f(i)** is the fraction of activity concentration of radionuclide ***i*** in the mixture,

**X(i)** is the appropriate activity concentration limit for exempt material as appropriate for the radionuclide i, which needs to be multiplied by 10 (exemption factor for NORM), and

$\mathbf{X_m}$ is the derived value of activity concentration limit for exempt material.

Instead of detailed and relatively complex explanations on how the Mixtures method is used in calculations, it was considered that the presentation of an actual practical example that can be easily used by the industry and/or regulators will be much more appropriate.

**Practical example 3**

Mineral concentrate was treated using chemicals and dried in the kiln; it is, therefore, suspected that the secular between radionuclides in $^{232}Th$ and $^{238}U$ decay chains has been disrupted. The disruption of secular equilibrium has been confirmed and the concentrations of radionuclides were measured as follows:

| Radionuclide | Concentration (Bq/g) | |
|---|---|---|
| $^{232}Th$ | 6.44 | $^{232}Tn$ decay chain is not in equilibrium |
| $^{228}Ra$ | 3.12 | |
| $^{228}Th$ | 6.04 | |
| $^{238}U$ | 5.33 | $^{238}U$ decay chain is not in equilibrium |
| $^{234}Th$ | 7.05 | |
| $^{234}U$ | 4.28 | |
| $^{230}Th$ | 5.21 | |
| $^{226}Ra$ | 6.73 | |
| $^{210}Pb$ | 2.15 | |
| $^{210}Po$ | 1.18 | |

First step is to determine which activity concentration limits apply to individual radionuclides, from Table 2 of the Regulations [6] (taking into account the factor of 10 for NORM), sum up the concentrations and update the table, by adding one more column to the right:
*see over page*

In the second step, we calculate the fraction of the activity, which each radionuclide contributes to the total. For example, $^{232}Th$ concentration is 6.44 Bq/g. Dividing this value by the sum (47.53 Bq/g) gives the result of 0.135, which is the fraction for $^{232}Th$.

| Radionuclide | Concentration (Bq/g) | *Concentration limit (Bq/g)* |
|---|---|---|
| $^{232}Th$ | 6.44 | *100* |
| $^{228}Ra$ | 3.12 | *100* |
| $^{228}Th$ | 6.04 | *10* |
| $^{238}U$ | 5.33 | *100* |
| $^{234}Th$ | 7.05 | *1000* |
| $^{234}U$ | 4.28 | *100* |
| $^{230}Th$ | 5.21 | *10* |
| $^{226}Ra$ | 6.73 | *100* |
| $^{210}Pb$ | 2.15 | *100* |
| $^{210}Po$ | 1.18 | *100* |
| *SUM* | *47.53* | |

Similarly, if we divide 3.12 Bq/g for $^{226}Ra$ by the same 47.53 Bq/g, we have the value for the fraction of $^{226}Ra$, which is 0.066. This is done for each radionuclide and the table is further updated, by adding one more column:

| Radionuclide | Concentration (Bq/g) | *Fraction* ***f(i)*** | Concentration limit ***X(i)*** (Bq/g) |
|---|---|---|---|
| $^{232}Th$ | 6.44 | *0.135* | 100 |
| $^{228}Ra$ | 3.12 | *0.066* | 100 |
| $^{228}Th$ | 6.04 | *0.127* | 10 |
| $^{238}U$ | 5.33 | *0.112* | 100 |
| $^{234}Th$ | 7.05 | *0.148* | 1000 |
| $^{234}U$ | 4.28 | *0.090* | 100 |
| $^{230}Th$ | 5.21 | *0.110* | 10 |
| $^{226}Ra$ | 6.73 | *0.142* | 100 |
| $^{210}Pb$ | 2.15 | *0.045* | 100 |
| $^{210}Po$ | 1.18 | *0.025* | 100 |
| SUM | 47.53 | | |

Now we are at the third step, where we are ready to use the equation from §405 of the Regulations [6], cited above.

The values of f(i) are now available, as well as the values of X(i) for each radionuclide.

To calculate the value of Xm, which is the derived value of activity concentration limit for this specific mix of radionuclides, we divide f(i) by X(i) for each radionuclide and sum all of them, that is the denominator in the equation, where the 1 is the numerator.

The resulting table is as follows:

| Radionuclide | Concentration (Bq/g) | Fraction ***f(i)*** | Concentration limit ***X(i)*** (Bq/g) | *The limit for* *<u>this</u>* *mixture* |
|---|---|---|---|---|
| $^{232}Th$ | 6.44 | 0.135 | 100 | $X_m = \frac{1}{\sum_i \frac{f(i)}{X(i)}}$ |
| $^{228}Ra$ | 3.12 | 0.066 | 100 | |
| $^{228}Th$ | 6.04 | 0.127 | 10 | |
| $^{238}U$ | 5.33 | 0.112 | 100 | |
| $^{234}Th$ | 7.05 | 0.148 | 1000 | |
| $^{234}U$ | 4.28 | 0.090 | 100 | |
| $^{230}Th$ | 5.21 | 0.110 | 10 | |
| $^{226}Ra$ | 6.73 | 0.142 | 100 | |
| $^{210}Pb$ | 2.15 | 0.045 | 100 | |
| $^{210}Po$ | 1.18 | 0.025 | 100 | |
| SUM | 47.53 | | | *33.52* |

The last step is to compare the value of the limit for this mix of radionuclides in the specific material to the total calculated in the first step:

47.53 Bq/g > 33.52 Bq/g

Therefore, this material is not exempt and the Regulations [6] apply to its transport.

### 2.7. Transport of NORM not in secular equilibrium, calculations when data is not available

This method is very inadvisable, but can be used when the detailed information about the concentrations of radionuclides in the material is not available and it is also unknown if both thorium and uranium chains are in secular equilibrium.

Table 3 in §407 of the Regulations [6] suggests the values that should be used in these circumstances.

As the limit for 'total activity' in Bq will always be exceeded in case of a bulk shipment of the material, the attention must be paid to the third column of the Table 3 (*Activity concentration for exempt material*), which has three lines:

*Only beta or gamma emitting nuclides are known to be present (10 Bq/g)*
*Alpha emitting nuclides, but no neutron emitters, are known to be present (0.1 Bq/g)*
*Neutron emitting nuclides are known to be present or no relevant data are available (0.1 Bq/g)*

Please note that the exemption factor of 10 for NORM applied only to the radionuclide concentrations in Table 2, not to the values in Table 3.

As it would be very rare that a mineral to be transported contains only beta and gamma emitting radionuclides nuclides the value of 10 Bq/g should only be used when the absence of alpha emitting nuclides has been conclusively proven. For all other practical purposes that value of 0.1 Bq/g will be applicable.

**Practical example 4**

The same material as in the practical example 1 above is ready for shipment. The data for the concentrations of radionuclides is not available, the only known value is the concentration of $U_3O_8$, 40 ppm (34 ppm of uranium). The activity concentration that corresponds to 34 ppm of uranium is 0.42 Bq/g, which is above 0.1 Bq/g, the limiting value specified in Table 3 in §407, the material will not be exempt from Regulations [6].

Which leads to an absurd situation, where the material may be exempt from general radiation protection regulations [17], as the activity concentration is below 1 Bq/g, but will be a subject to the transport safety regulations [6].

A note on practical examples 1 and 4

The cost and the length of time associated with obtaining full radionuclide-specific information for a material should be weighed against the disadvantages of the potentially incorrect classification of this material as radioactive for transport. The suggested approach is to use the partial data (step B in part 2.5 above) and, if it appears that a material is not exempt, carry out the detailed analysis (step C in part 2.5 above).

If the laboratory analysis shows that activity of the material to be transported is very close to the limit (above 9 Bq/g for NORM in secular equilibrium, or the sum of activity concentrations calculated in practical example 3 is above 90% of the limit calculated for this specific mixture of radionuclides, it is always prudent to take additional samples to ensure that at no time the limits are exceeded.

### 2.8. A note on radionuclides from $^{235}U$ decay chain

The analysis of the material for the nuclides of 235U decay chain is typically not required for NORM, for the following reasons:

- As natural abundance of $^{235}U$ is only 0.72%, the values are usually not very important in the determination of the applicability of the regulations;
- Smaller laboratories (at mining and processing sites) would provide the data as

'total uranium' in parts per million for $U_3O_8$ (without any isotopic analysis), and the small proportion that $^{235}U$ represents is very often within the margin of typical laboratory errors/ variance.

In some cases, however, measurements of concentrations of $^{235}U$ decay chain nuclides may be needed. Then (as noted in step C of part 2.5 above) the analysis will be required for the following radionuclides: $^{235}U$, $^{231}Pa$, $^{227}Ac$, $^{227}Th$, $^{223}Ra$.

<u>**Correction Note 3:**</u> The previous version of the paper stated that the concentration of $^{235}U$ could be estimated by multiplying the value of $^{238}U$ by 0.01, which was incorrect and this method should not be used.

An explanation of correct estimation of $^{235}U$ concentration based on $^{238}U$ value is as follows:

The specific activity of $^{238}U$ is 12,384 Bq/g and $^{235}U$ – 80,170 Bq/g.

100 grams of uranium contain:

- 99.68 g of $^{238}U$ and 0.72 g of $^{235}U$, and
- 1,234.4 kBq of $^{238}U$ and 57.7 kBq of $^{235}U$.

Therefore, an activity ratio $^{235}U$:$^{238}U$ is 4.7%, not 1% and the combined specific activity of U-238 and U-235 is 12.859 Bq/g. If there is a need to theoretically estimate the activity concentration of $^{235}U$ in NORM and the value is available only for U-238 (not for the U(nat)), the activity concentration of $^{238}U$ needs to be multiplied by 0.047, not by 0.01.

### 2.9. Materials with no 232Th or 238U, where only parts of decay chains are present

There are also several cases when there is no thorium and/or uranium in NORM, and only a part of decay chain or individual natural radionuclides may be present in the material that is transported, the examples are:

a. Waste/sludge/scale from oil and gas production, paper/pulp production, geothermal energy generation, water treatment, etc. (where the decay chains start from $^{226}Ra$ and/or $^{228}Ra$);

b. Films from internal surfaces of the gas processing and storage equipment, containing $^{210}Pb$;

c. Dust from electrostatic precipitators and filters at coal, iron, copper, etc. smelters, in which $^{210}Pb$ and $^{210}Po$ may accumulate in significant concentrations.

In these cases, the limits applicable for individual radionuclides should be used and both a consultation with the Regulatory Authority and specialist advice are highly advisable.

Several examples of the calculations for the three cases above are given below. These calculations are similar to those presented in practical example 3 above.

### Practical example 5

The old scale packaged in drums, containing $^{226}Ra$ at 90 Bq/g, $^{210}Pb$ at 50 Bq/g and $^{210}Po$ at 40 Bq/g.

Step 1. Sum the activity concentrations in the mixture for all radionuclides nuclides to obtain the total activity concentration in the mixture: the sum is 180 Bq/g.

Step 2. For each nuclide ***i*** divide the activity concentration, measured for that nuclide, by the sum from Step 1 above, to obtain the fraction of the nuclide ***i*** in the mixture: $^{226}Ra$ ***f(i)*** = 0.5, $^{210}Pb$ ***f(i)*** = 0.28, $^{210}Po$ ***f(i)*** = 0.22.

Step 3. Divide the ***f(i)*** derived above, by the ***X(i)*** – the appropriate limit for this radionuclide from Table 2 of the Regulations [6] (multiplied by the factor of 10, as allowed for NORM): $^{226}Ra$ = 0.0050, $^{210}Pb$ = 0.0028, $^{210}Po$ = 0.0022.

Step 4. Calculate the ***Xm*** value for this particular mixture: ***Xm*** = 100 Bq/g

Step 5. Compare the calculated ***Xm*** value with the measured total activity concentration, calculated in step 1:

Outcome:180 Bq/g > 100 Bq/g – the material is classified as 'radioactive' for transport.

### Practical example 6

A box (~15 kilograms) of "fresh" $^{210}Pb$ films removed from the internal surfaces at a gas storage facility. It is assumed that the levels of radon in natural gas were very high and an additional non-scheduled cleaning activity was undertaken. Thus, due to a relatively short time since previous clean up (~1 month), no ingrowth of $^{210}$Po in concentrations requiring assessment is assumed to have taken place and we consider that the material in the box contains exclusively $^{210}$Pb at 140 Bq/g.

No use of any equations is required in this case – instead the values given in Table 2 of the Regulations for 210Pb are used in the assessment:

- The activity concentration limiting value is 100 Bq/g, taking into account that the material is NORM,
- The activity limit for the exempt consignment is 10,000 Bq (the factor of 10 does not apply to limits for total activity)

Both limits have to be exceeded for the material to be classified as 'radioactive' for transport: the Regulations apply in this case, as –

- 140 Bq/g > 100 Bq/g, and
- 140 Bq/g  15,000 g = 2,100,000 Bq > 10,000 Bq.

However, as the gamma radiation level from the surface of package is low was (was measured at 1.8 μSv/hour), the box can be transported as an *excepted* package, without radiation labels or placards on the outside surfaces (please see part 2.10 below).

**Practical example 7**

Several drums of dust collected from electrostatic precipitators and 'bag houses', containing $^{210}$Pb at 120 Bq/g and $^{210}$Po at 40 Bq/g.

Step 1. Sum the activity concentrations in the mixture for all radionuclides nuclides to obtain the total activity concentration in the mixture: the sum is 160 Bq/g.

Step 2. For each nuclide ***i*** divide the activity concentration, measured for that nuclide, by the sum from Step 1 above, to obtain the fraction of the nuclide ***i*** in the mixture: $^{210}$Pb ***f(i)*** = 0.75, $^{210}$Po ***f(i)*** = 0.25.

Step 3. Divide the ***f(i)*** derived above, by the ***X(i)*** – the appropriate limit for this radionuclide from Table 2 of the Regulations [6] (multiplied by the factor of 10, as allowed for NORM): $^{210}$Pb = 0.0075, $^{210}$Po = 0.0025.

Step 4. Calculate the ***Xm*** value for this particular mixture: ***Xm*** = 100 Bq/g

Step 5. Compare the calculated ***Xm*** value with the measured total activity concentration, calculated in step 1:

Outcome: 160 Bq/g > 100 Bq/g – the material is classified as 'radioactive' for transport.

## 2.10. Excepted packages

There is a possibility that the NORM shipment can be classified as ***excepted*** package (please note the difference with ***exempted*** package, when the Regulations do not apply at all).

The main criterion for the determination of the excepted package is given in the §516 of the Regulations:

*The radiation level at any point on the external surface of an excepted package shall not exceed 5 microSv/h.*

Please note that the measurement is taken on the surface, not at a distance of 1 metre.

The second criterion is adherence to Table 4 of the Regulations and this cannot be ignored. This Table contains activity limits for *excepted* packages and where NORM is concerned, the applicable values are:

- For special form materials $10^{-3}$ of $A_1$ value,
- For other form materials $10^{-3}$ of $A_2$ value.

The $A_1$ and $A_2$ values for different radionuclides are provided in the Table 2 of the Regulations – Basic radionuclide values, where the concentrations and total activity limits are obtained for calculations.

For U(nat) and Th(nat) $A_1$ and $A_2$ values are unlimited, therefore the use of values in Table 4 is not required.

This, however, is not the case where the transport of materials containing individual radionuclides is undertaken. The values of $A_1$ and $A_2$ are not unlimited for natural radionuclides such as $^{210}$Pb, $^{210}$Po, $^{226}$Ra, $^{228}$Ra, $^{228}$Th and $^{230}$Th and the values given in Table 4 of the Regulations need to be considered.

**Practical example 8**

The dose rate on the surface of a large package (container) is 2.5 microSv/h (below 5 microSv/h), but the package contains $^{226}$Ra and, therefore, $A_1$

and $A_2$ values need to be considered.

For $^{226}Ra$ $A_1$=2 x $10^{-1}$ TBq and $A_2$=3 x $10^{-3}$ TBq, we also need to consider in which "form" the transported material is. The definition is provided in §239 of the Regulations, –
*Special form radioactive material shall mean either an indispersible solid radioactive material or a sealed capsule containing radioactive material.*

The material in the package is the solid scale from oil and gas industry, therefore we can consider that the form is "special", to which the limit of $10^{-3}$ of $A_1$ value applies, as per Table 4.

The $A_1$ value is 0.2 TBq (200 GBq) and, after applying the factor from Table 4, the limiting value for this specific package is 0.2 GBq of $^{226}Ra$.

The amount of $^{226}Ra$ in the package needs to be estimated and compared with the limit of 0.2 GBq. One gram of $^{226}Ra$ equals 3.7 x $10^{10}$ Bq (37 GBq) and in some cases there would be more than one gram of $^{226}Ra$ in a large package containing scale from oil and gas industry; and, most definitely more than 5.5 mg of it (which equals to 0.2 GBq).

Therefore, despite the fact that the surface dose rate from the package is significantly below 5 microSv/hour, that package cannot be classified as *excepted* and must be labelled/placarded in accordance with the Regulations.

**Practical example 9**

If the material contains about 15 Bq/g of Th(nat) a radiation level from its surface will be approximately 7 µSv/hour.

If, however, (a) the thickness of the wall of the trailer used for the transport of this material is increased, or (b) bags or drums used for the transport of the material are placed inside a container relatively far from all external surfaces (including top and bottom), the surface radiation level from the package would be lowered to approximately 3-4 µSv/hour, and the material can be classified as *excepted* package. As the material is Th(nat), the limiting values from Table 4 of the Regulations do not apply.

§515 of the Regulations [6] provides details of markings required for an excepted package: *Packages shall bear the marking "RADIOACTIVE" on an internal surface in such a manner that a warning of the presence of radioactive material is visible on opening the package.*

§531 further describes required markings: *In the case of excepted packages, other than those accepted for international movement by post, only the United Nations number, preceded by the letters "UN", shall be required.*

The illustration of such signposting is Figure 7 of the Regulations [6].

Based on the data provided in Table 1 of the Regulations [6], in the case of the transport of NORM as an *excepted* package the load/container will be marked only with 'UN2910' instead of any "radioactive" labels or placards.

The sign, similar to the one given in Figure 6 of the Regulations [6] will, however, be required to be visible when, for example, a container is opened (the word "RADIOACTIVE" must be clearly visible upon opening the package).

This method is commonly used to transport NORM mineral exploration samples to the laboratory, where the concentrations of radionuclides are not known, but gamma radiation level from the surface of the package can be measured.

## 3 PRACTICAL CONSIDERATION IN THE TRANSPORT OF NORM

### 3.1. Procedure to follow

After it has been determined that the material to be transported is classified as 'radioactive' in accordance with the Regulations [6], several steps need to be taken to ensure that both transport documentation and associated labels/placards are fully compliant with the requirements.

The following usually takes place:

- The carrier must possess an appropriate licence to transport radioactive material.

- Three copies of the appropriate transport declaration are prepared by a responsible person (typically a radiation safety officer). Two copies are provided to the driver (one stays with the transporting company, another is for the receiver of the material), the third copy is kept by the responsible person. In the case of multiple transport of the same material a 'standing declaration' could be acceptable, provided that prior agreement has been reached with the Regulatory Authority.
- Appropriate training must be provided to all workers involved in the transport, loading and unloading the material, in accordance with §§311-315 of the Regulations [6].
- The material must be accurately classified and the appropriate placards should be placed on the vehicle, in accordance with §§530-532, 537-540 and 543-544 of the Regulations [6].

### 3.2. Determination of the Transport Index

The first step is the determination of the Transport Index (TI), in accordance with §523 of the Regulations [6]:

*(a) Determine the maximum dose rate in units of millisieverts per hour (mSv/h) at a distance of 1 m from the external surfaces of the package, overpack, freight container or unpackaged LSA-I, SCO-I and SCO-III. The value determined shall be multiplied by 100.*

…

*(b) For tanks, freight containers and unpackaged LSA-I, SCO-I and SCO-III, the value determined in step (a) shall be multiplied by the appropriate factor from Table 7.*

The SCO-III category does not apply to NORM, it applies to very large objects (typically steam generators from nuclear power plants) which are too large to be placed inside any transport package.

Please note that the measurement of gamma radiation level is to be carried out at a distance of 1 metre from the package, not on its surface.

**Practical example 10**

Measured radiation level at 1 metre from the truck containing radioactive mineral concentrate is 3 microSv/hour (0.003 millisieverts per hour) gives the transport index as 0.3. The values in Table 7 are given in m$^2$ for the largest cross-sectional area of the load being measured. For large road trains it is prudent to assume that the value associated with the size of the load >20m$^2$ will be applicable and the multiplication factor will be 10. For a single truck a different value will apply (associated with the size of the load >5m$^2$, but < 20m$^2$), and the multiplication factor will be 3.

Therefore, if material is transported in a truck with a single trailer, the transport index will be 0.9, if a large road train is used, the transport index will be 3.

It should be noted that §523(a) of the Regulations provides default *maximum dose rate at any point 1m from the external surface for uranium and thorium ores and their concentrates*. These values are very high and should only be used when a gamma radiation monitor is not available for direct measurement. For example, the value of 400 µSv/hour is assumed for ores and physical concentrates of uranium and thorium, when in practice is highly unlikely that levels above 150 µSv/hour would be measured.

When the material is transported in multiple drums inside one container (for example, in the process of shipment of tantalum concentrates), the gamma radiation dose rate needs to be measured from the container. Measuring radiation levels from each individual drum is likely to result in an incorrect determination of the Transport Index, as this process will not take into account the shielding offered by the walls of the container and, sometimes, also by the drums with ballast material that may also be placed inside a transport container.

### 3.3. Selection of the correct transport label/ placard

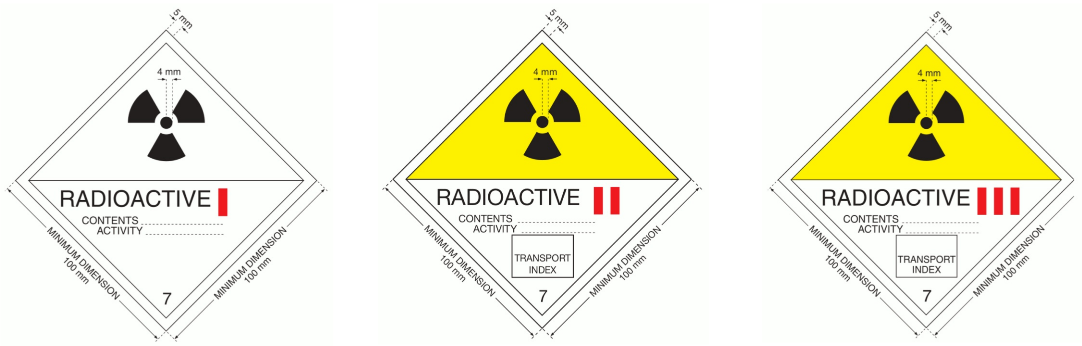
The category of the shipment is determined based on the Transport Index (TI) and the radiation level on external surface, in accordance with §529 and Table 8 of the Regulations [6].

Please note the difference: Transport Index is determined by measuring radiation levels at a distance of 1 metre from the package, for categorisation of the load the measurement on the surface is also required.

The illustrations for the labels are provided in Figure 1 and the process of the selection of the correct one is provided below.

overpack or freight container shall be assigned to the higher category.

**Figure 1. Transport labels (reproduced from Figures 2, 3 and 4 of the Regulations [6])**




The process of selection:

- If TI is not more than 0.05, and the surface radiation level is below 5 µSv/hour, the category of the label will be I-WHITE (unless the package is *excepted*, when label is not required);
- If TI is more than 0 but less than 1, and the surface radiation level is above 5 µSv/h, but below 500 µSv/h, the category of the label will be II-YELLOW;
- If TI if more than 1 but less than 10, and the surface radiation level is more that 500 µSv/h, the category of the label will be III-YELLOW;
- III-YELLOW category is also used if material is transported under special arrangement, please refer to §238 of the Regulations [6].

In minerals industry, the typical categories will be I-WHITE, II-YELLOW and, occasionally, III-YELLOW.

It is highly unlikely that surface gamma radiation levels measured from naturally occurring radioactive materials will exceed 300-350 µSv/h. Due to the use of the multiplication factor for large loads, it is expected that the primary criterion for the selection of the correct label for minerals industry will be the Transport Index (TI) and not the surface radiation level, as detailed in §529(a) of the Regulations [6]:

Where the TI satisfies the condition for one category but the surface dose rate satisfies the condition for a different category, the package, overpack or freight container shall be assigned to the higher category.

§529 of the Regulations needs to be considered together with §523 (described in part 3.2 above), which provides two options:

- Measuring the actual value of Transport Index, or
- Using the values for uranium and thorium ores and concentrates, provided in §§523(a)(i)-(iii).

The typical practice in uranium mining and processing is to transport uranium concentrate as LSA-I (please see part 3.5) with YELLOW-III label, and TI of 6, using the 0.02 mSv/h value provided in §523(a)(iii), multiplied by the factor of 3 for a typical 20-foot container. For ores and low-grade concentrates containing naturally occurring radionuclides it is advisable to always use measured values, as gamma dose rates will not be as high as the default values.

### 3.4. Notes on the exclusive use arrangement

The bulk (unpackaged) materials in the minerals industry may only be transported under the exclusive use arrangement, as per §520(b) of the Regulations [6]:

*LSA material and SCO in groups LSA-I, SCO-I and SCO-III may be transported, unpackaged, under the following conditions:*

*(b) Each conveyance shall be under exclusive use, except when only transporting SCO-I on which the contamination on the accessible and the inaccessible surfaces is not greater than 10 times the applicable level specified in para. 214.*

The definition of exclusive use is given in §221:

*Exclusive use shall mean the sole use, by a single consignor, of a conveyance or of a large freight container, in respect of which all initial, intermediate and final loading and unloading and shipment are carried out in accordance with the directions of the consignor or consignee, where so required by these Regulations*.

Further information is provided in para 221.1 of the Advisory Material [9]:
*The special features of an 'exclusive use' shipment are: that a single consignor makes the shipment and has, through arrangements with the carrier, sole use of the conveyance or large freight container; and that all initial, intermediate and final loading and unloading and shipment of the consignment are carried out only in strict accordance with directions from the consignor or consignee.*

It is very uncommon for a truck transporting radioactive mineral from 'A' to 'B' to deviate for a delivery of another material (such as fertiliser) for a different company from 'B' to 'A'. Therefore, if a truck transports mineral concentrate from a mine site to a processing plant and then is used by the same company to transport processing tailings back to a mine site it does so under the exclusive use arrangement.

The main advantage of that arrangement is that, in accordance with §§513 and 514 of the Regulations [6], there is no need to decontaminate the internal surfaces of the conveyance after each shipment.

It is also important to note that –

a In accordance with §546(m), the transport declaration must contain the statement "EXCLUSIVE USE SHIPMENT", and

b In accordance with §526 if the value of Transport Index (TI) exceeds 10, it can only be transported under the exclusive use arrangement.

**3.5. Determination of the class of low specific activity (LSA) material**

The definition of LSA (low specific activity) material is provided in §226 of the Regulations [6]:
*Low specific activity (LSA) material shall mean radioactive material that by its nature has a limited specific activity, or radioactive material for which limits of estimated average specific activity apply. External shielding materials surrounding the LSA material shall not be considered in determining the estimated average specific activity.*

In accordance with §409 of the Regulations [6] most materials transported in the minerals industry will be classified as LSA-I.

§409(a)(i) and (ii) clarifies that NORM is classified as LSA-I:
*Uranium and thorium ores and concentrates of such ores, and other ores containing naturally occurring radionuclides.*
*Natural uranium, depleted uranium, natural thorium or their compounds or mixtures, that are unirradiated and in solid or liquid form.*
*409 (iii) Radioactive material for which the $A_2$ value in unlimited, fissile material may be included only if excepted under paragraph 417.*

As noted above, for many natural radionuclides the A2 value is not unlimited and the following needs to be considered:
$^{226}$Ra and $^{228}$Ra would not be present in ores and concentrates in "significant" amounts, even in the case of transport of contaminated items from oil and gas industry. One of the cases where the package would be classified as LSA-II is a full container of drums with scale that contains predominantly $^{226}$Ra and $^{228}$Ra. In this case the amount of this radium isotope may be "significant" and the local Regulatory Authority must be contacted for advice.

The definition from §409(a)(iv) may be used for all NORM that is not an "ore" or a "concentrate", such as waste/residues/sludge/etc:
*Other radioactive material in which the activity is distributed throughout and the estimated average specific activity does not exceed 30 times the values for the activity concentration specified in paras 402–407.*

**Correction Note 4:** The previous version of this paper [1] contained an incorrect assumption that '10-times' exemption factor for NORM can be used in the interpretation of the limit in §409(a)(iv) and the limiting value for U(nat) and Th(nat) is 300 Bq/g.

This is not correct and the limiting value for the classification of shipments of materials containing U(nat) and/or Th(nat) as LSA-I is 30 Bq/g, not 300 Bq/g.

**Practical example 11**

If the activity of the material (U(nat) and Th(nat) combined) to be transported is less than 30 Bq/g, the marking "LSA-I" should be used on the transport label/placard. If, however, the value exceeds 30 Bq/g, the marking should be "LSA-II".

**Practical example 12**

Taking into account that the limiting value for $^{226}$Ra in the Table 2 of the Regulations is 10 Bq/g and without the application of the '10-times' exemption factor for NORM:

- The scale containing 290 Bq/g of $^{226}$Ra will be classified as LSA-I, but
- The scale containing $^{226}$Ra in concentration of 310 Bq/g will be classified as LSA-II; therefore, additional safety measures may need to be taken in the process of its transport.

### 3.6. Determination of the information that needs to be on the transport label/placard

There appear to be many misinterpretations of signposting requirements, especially in the transport of NORM materials in bulk using road transport, particularly in regards to the use of UN numbers and selection of correct information for the transport labels and placards:

- The LABEL is small in size, 10x10 cm.
- The PLACARD is larger in size, 25x25 cm.

The §543 of the Regulations [6] states, with added highlight:

*Large freight containers carrying unpackaged LSA-I material or SCO-I or packages other than excepted packages, and tanks shall bear four placards that conform to the model given in Fig.6. The placards shall be affixed in a vertical orientation to each side wall and to each end wall of the large freight container or tank.*

*Any placards that do not relate to the contents shall be removed. Instead of using both labels and placards, it is permitted, as an alternative, to use enlarged labels only, where appropriate, as shown in Fig.2–4, except having the minimum size shown in Fig.6.*

As a result:

- If there are several packages with radioactive material in the vehicle (for example, in the one that is transporting radioactive samples to or from a laboratory), each of the packages is LABELLED, and the vehicle itself is PLACARDED.
- Full compliance with the Regulations [6] requires placing both labels and placards on the vehicles; but there is a provision in §543 (cited above) that instead of putting those side-by-side, the LABEL can be enlarged to 25x25cm size and is used instead of a PLACARD, on all four sides of a container.

The note to the Figure 2 (Figure 6 in the Regulations) illustrating the PLACARD states,

*The use of the word "RADIOACTIVE" in the bottom half is optional, to allow the alternative use of this placard to display the appropriate UN number for the consignment.*

An illustration is provided in Figure 3 below.

**Figure 2. Transport placards (reproduced from Figures 6 and 7 of the Regulations [6])**

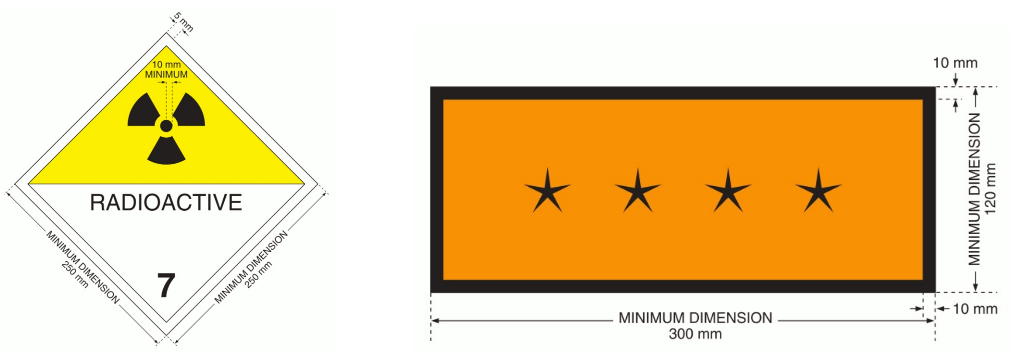


**Figure 3. Transport placards**


It is important to note that:

- The replacement of the word "RADIOACTIVE" can be done for PLACARDS only,
- This option is not available for LABELS, even if they are enlarged ones and are used instead of PLACARDS.

**Practical example 13**

If the vehicle is used to transport radioactive mineral samples in steel drums (type A containers):

- Each drum is LABELLED as per Figure 1, as required;
- The vehicle itself is PLACARDED as per Figure 2, the word "RADIOACTIVE" may be replaced with UN2912, or UN3332, as needed (please refer to Table 1 of the Regulations [6] to select the correct UN number).

**Practical example 14**

If the vehicle is used to transport small surface contaminated objects in several packages:

- Each package is LABELLED as per Figure 1, as required;
- The vehicle itself is PLACARDED as per Figure 2; the word "RADIOACTIVE" may be replaced with UN2913.

**Practical example 15**

There are two options in cases where the vehicle is used to transport bulk NORM:

Option 1:

- The enlarged LABEL is placed on it as required;
- The word "RADIOACTIVE" may not be replaced with UN2912, UN3321 or UN3322, as required;
- On the LABEL the contents may be simply "LSA-I", as per §540(a)(ii), but only if the material is classified as such;
- If material is classified as LSA-II or LSA-III, the data on the radioisotope is required;
- Transport Index will need to be measured with the gamma monitor, as per §523(a). Then, in accordance §523(b) a multiplication factor for loads of different sizes from Table 7 of the Regulations will need to be used. The details are provided in part 3.2

Option 2:

- Both LABELS and PLACARDS are placed on the vehicle as required;
- The word "RADIOACTIVE" on the PLACARD may be replaced by UN2912, UN3321 or UN3322;
- The word "RADIOACTIVE" may not be replaced by the UN number from Table 1 of the Regulations [6] on smaller LABELS; they will also need to contain the information on the contents of the material and the

Transport Index.

An alternative method is provided in §544 of the Regulations, as follows:

*Where the consignment in the freight container or tank is unpackaged LSA-I or SCO-I or where a consignment in a freight container is required to be shipped under exclusive use and is packaged radioactive material with a single UN number, the appropriate UN number for the consignment (see Table 1) shall also be displayed, in black digits not less than 65 mm high, either:*

*(a) In the lower half of the placard shown in Fig. 6 and against the white background; or*
*(b) On the placard shown in Fig. 7.*

*When the alternative given in (b) is used, the subsidiary placard shall be affixed immediately adjacent to the main placard shown in Fig. 6, on all four sides of the freight container or tank.*

The alternative placard is illustrated in Figure 4 and an advice from the Regulatory Authority is required in regards to the correct signposting/ placarding of the shipment.

In many practical cases at least one placard on the vehicle/package contains the word 'RADIOACTIVE' (as in Fig.6 of the Regulations) and subsidiary placards are either the ones as in Fig.7 of the Regulations) or the alternative ones, i.e., similar to Figure 4 below.

**Figure 4. Alternative placard**


### 3.7. Practical considerations for signposting and placards

Detailed data on marking, labelling and placarding of loads are provided in §§531–540 and 543–545 of the Regulations [6]. There are two important points on the placement of placards:

Location

§571 of the Regulations [6] specify that:
*Vehicles carrying packages, overpacks or freight containers labelled with any of the labels shown in Figs 2–5, or carrying unpackaged LSA-I material, SCO-I or SCO-III, shall display the placard shown in Fig. 6 on each of:*
*(a) The two external lateral walls in the case of a rail vehicle;*
*(b) The two external lateral walls and the external rear wall in the case of a road vehicle.*

§543.1 of the Advisory Material [9] provides an additional comment:
*Placards, which are used on large freight containers and tanks (and on road and rail vehicles (see para. 571 of the Transport Regulations)), are designed in a similar way to the package labels… in order to identify clearly the hazards of the dangerous goods. Displaying the placards on all four sides of the freight containers and tanks ensures ready recognition from all directions. The size of the placard is intended to make it easy to read, even at a distance. To prevent the need for an excessive number of placards and labels, an enlarged label may only be used on large freight containers and tanks where it also serves the function of a placard.*

Definition of the vehicle

The definition of the vehicle, provided in §248 of the Regulations [6] should be taken into account prior to arranging the transport of minerals by road and rail:
*Vehicle shall mean a road vehicle (including an articulated vehicle, i.e., a tractor and semi-trailer combination), railroad car or railway wagon. Each trailer shall be considered as a separate vehicle.*

**Practical example 16**

A road train (two trailers or semi-trailers hauled by a prime mover) will need to have six placards: one each at the front and at the back, and two on each side. A longer road train, however, (for example, a truck with three trailers) will require eight placards (two more on the extra trailer). Please note that placard at the front is optional, in accordance with §571(b) of the Regulations [6].

In the case of transporting radioactive material by rail in several carriages each carriage will need two signs on each side and, in case of the carriage with radioactive material is the last one, it is recommended to have a sign at the rear of this carriage as well.

### 3.8. Practical considerations for blending of different NORM in one conveyance

There are two possibilities of blending/mixing the material:

a) Several different materials are simultaneously collected in one storage bin prior to transport and then loaded into a vehicle; and
b) Several different materials are loaded separately into a vehicle, one after another.

The method (b) above cannot be used in practice, as described below.

There are no specific notes in Regulations [6] explicitly prohibiting the practice. There are, however, three main reasons for it not to be used, unless activity concentrations of blended materials do not differ more than by a factor of ten, which is introduced in §409.11 of the Advisory Material [9],
*For material in which the activity is required to be distributed throughout…, a simple method for assessing the average specific activity is to divide the volume occupied by the LSA material into defined portions and then to assess and compare the specific activity of each of these portions. A difference in specific activity between portions of a factor of less than ten should cause no concern.*

Please note that in case of the transport of LSA-III material the activity concentrations should not differ more than by a factor of three, in accordance with §409.15 of the Advisory Material [9].

1) Impossibility of determining the specific activity of the material in accordance with §240 of the Regulations:
*Specific activity of a radionuclide shall mean the activity per unit mass of that nuclide. The specific activity of a material shall mean the activity per unit mass of the material in which the radionuclides are essentially uniformly distributed.*

2) Impossibility of the correct classification of the material, in accordance with the definition of LSA-I in §226 of the Regulations [6].
*Low specific activity (LSA) material shall mean radioactive material that by its nature has a limited specific activity, or radioactive material for which limits of estimated average specific activity apply.*

§236.2 of the Advisory Material [9] provides an additional clarification:
*If the activity concentration varies across packages within the consignment or across inner containment systems or receptacles within the packages, the highest activity concentration should be considered as the activity concentration of the consignment.*
The uniform distribution cannot possibly be achieved when different NORM is loaded into a vehicle separately. One NORM may be exempt from the Regulations [6], but if another NORM may not be, then the highest activity concentration will need to be used in the classification and signposting of the transport of blended material.
It is *theoretically* possible to dilute the ‘radioactive’ material with ‘less radioactive’ one, provided that their specific activities do not differ more than by a factor of 10 a factor of 3 for LSA-III).

3) The Transport Index of the package is determined by measuring of the maximum radiation level at a distance of 1 metre and categorisation is carried out by measuring of the maximum surface radiation level, as detailed in part 3.2. A practical example describes the potential challenges.

**Practical example 17**

If 2 tonnes of monazite concentrate (specific activity of 90 Bq/g) are placed on the bottom of the trailer and then covered with 22-23 tonnes of the material with much lesser activity, for example, sand processing tailings with specific activity of 2 Bq/g:

- The specific activity and class of the material cannot be determined by simple averaging, as the activity concentrations differ by a factor that is more than 10, therefore, the radionuclides are not uniformly distributed.
- The measured maximum radiation levels at both 1 metre and on the surface will still be high enough at some locations to require appropriate placarding of the truck.

If, however, a material with a specific activity of 15 Bq/g is mixed with the same sand tailings containing 2 Bq/g, the radionuclides in this NORM may be considered uniformly distributed and the overall specific activity of the load can be calculated. It is also likely that the surface radiation level from a vehicle/ container will be less than 5 µSv/hour. In this case, transporting of the mixed material as an 'excepted package' is possible, at least in theory.

However, given the gamma radiation levels at the distance of 1 metre from the truck will be very different and the determination of the correct Transport Index will be, therefore, problematic.

There is also an uncertainty on how the surface radiation levels, that are required for the categorisation of the material for transport (part 3.3 above) should be measured. In theory, the measurements should be done not only on the side surfaces, but also on the bottom and top of the load. In this case any options to transport a material with activity concentrations above 10 Bq/ g as 'excepted package' after blending of materials in the truck appear to be impractical.

**Practical example 18**

Discussion about the possibility of blending of different materials directly inside the truck/trailer in regards to heavy minerals sands (considering that by prior arrangement with an appropriate Regulatory Authority the measurement of the surface gamma radiation levels from the bottom of the trailer would not be required):

If, as in practical example 17, we consider blending of monazite concentrate (90 Bq/g) with sand tailings (2 Bq/g), the outcome will depend on the amount of monazite concentrate that was placed in the truck prior to covering it with 'other' tailings.

If it is only an about 2 $m^3$ pile in the centre of the trailer and the material does not touch the walls from the inside, there is a possibility that this load could be an 'excepted package' (measurements will have to be carried out in any case). Basically, unless these 2-3 $m^3$ are positioned directly in the middle of the trailer and are separated from the walls from all sides, the Regulations [6] will apply.

Even if this method is considered in theory, it will be quite impossible to implement in practice, as a slight inaccuracy in positioning of the 'radioactive material' in the middle of the trailer or minor overloading will require for the trailer to be emptied and the operation repeated. Additionally, irrelevant of how accurate the positioning and amount of the material in the middle of the trailer may be, the sandy material will undoubtedly move to at least one side of the trailer during the travel to another storage bin for the loading of 'less radioactive' material.

### 3.9. Surface contamination, definitions

A different issue is associated with the fact that there are no special provisions for NORM in the Regulations [6] in regards to surface contamination. In case of heavy mineral sands, rare earths, tin and tantalum, if even a 1-mm thick layer of NORM is present on the surface of an item to be transported, it is likely that this item will be classified as a Surface Contaminated Object (SCO).

§214 of the Regulations [6] and §214.3 the Advisory Material [9] define 'surface contamination':

*Contamination shall mean the presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm² for beta and gamma emitters*

*and low toxicity alpha emitters, or 0.04 Bq/cm² for all other alpha emitters. [6]*
*Any surface with levels of contamination not exceeding 0.4 Bq/cm² for beta and gamma emitters and low toxicity alpha emitters or 0.04 Bq/cm² for all other alpha emitters is considered a non-contaminated surface in applying the Transport Regulations. For instance, a non-radioactive solid object with levels of surface contamination lower than the above levels is beyond the scope of the Transport Regulations and no requirement is applicable to its transport. [9]*

The definition of 'Low toxicity alpha emitters' is given in §227 of the Regulations [6]:
*Low toxicity alpha emitters are: natural uranium, depleted uranium, natural thorium, uranium-235, uranium-238, thorium-232, thorium-228 and thorium-230 when contained in ores, or in physical and chemical concentrates; or alpha emitters with a half-life of less than 10 days.*

Therefore, when the level of surface contamination exceeds 0.4 Bq/cm² the Regulations apply to the transport of such items on public roads.

Typically, objects that may have surface contamination due to NORM will have only 'low toxicity' alpha-emitters – with a notable exception of $^{226}$Ra.

$^{226}$Ra is not classified as a 'low toxicity' alpha emitter and, whilst the limit of 0.4 Bq/cm² generally applies to all NORM, in a specific situation (e.g., when transporting some contaminated items from oil/gas industry, from the plants for the production of uranium concentrate, tantalum, some rare earth minerals, etc), the limit of 0.04 Bq/cm² may be applicable for the classification of surface contaminated objects.

There always will be alpha emitting isotopes present in surface contamination in minerals industry dealing with NORM. There are some special cases in gas industry and titanium pigment production when beta-emitting $^{210}$Pb and $^{228}$Ra are present and there are almost no alpha-emitters (examples are fresh $^{210}$Pb films formed inside gas processing and storage vessels, and $^{228}$Ra scale in titanium pigment plants). But normally it is assumed that alpha-emitting radionuclides are always present, taking into account the fact that there will be an ingrowth of alpha-emitting $^{210}$Po from $^{210}$Pb, and alpha-emitting $^{228}$Th from $^{228}$Ra, within a few months.

The level of 0.4 Bq/cm² is the one where the vehicles may need to be signposted as carrying surface contaminated objects, SCO-I. This level applies unless it is confirmed that the material on the surface contains a significant proportion of $^{226}$Ra, in which cases the signposting is needed at levels above 0.04 Bq/cm².

In the following discussion it is assumed that most of contamination on surfaces of objects from NORM mines and plants contains $^{226}$Ra in an 'overall mix' and that only "low toxicity alpha emitters" are present.

In accordance with §413 of the Regulations [6] there are different values for non-fixed and fixed surface contamination. In mining and mineral processing all surface contamination is usually considered to be "non-fixed", since it can be removed in almost all cases, if there is a real need for it.

The §413(a)(i) states that SCO-I is any object with the levels up to 4 Bq/cm², and §413(b)(i) – that SCO-II is any object with the levels up to 400 Bq/cm². SCO-III classification is not considered to be relevant for NORM.

Thus, it may be concluded that there are four types of surface contaminated objects that can be classified in accordance with alpha surface contamination levels (226Ra excluded):

- < 0.4 Bq/cm² – not contaminated, no signposting required, item is not an SCO;
- > 0.4 Bq/cm², but < 4 Bq/cm² – SCO-I signposting required;
- > 4 Bq/cm², but < 400 Bq/cm² – SCO-II signposting required;
- > 400 Bq/cm² – SCO-III signposting required, but values of this kind are very unlikely to be measured in mining and mineral processing. Even if any are found, it should be relatively easy to remove at least some of the contamination to lower the value

to be below 400 Bq/cm$^2$.

Therefore, if any object is found to have surface contamination in excess of 0.4 Bq/cm$^2$ it will need to be transported in accordance with the requirements of the Regulations [6].

### 3.10. Surface contamination, practical considerations

Potentially all equipment and buildings used in the processing of NORM may become 'surface contaminated objects' and it is important to ensure that no contaminated equipment and/or scrap metal is re-used in other industries and/or melted.

In mining and minerals processing industry it would be impractical to carry out wipe tests and send them to be analysed in a laboratory; therefore, simple surface contamination tests are carried out. In case of a single object only one or two measurements will be required; but in case of a truck already filled with numerous potentially contaminated items many separate tests will need to be done. Therefore, it is advisable to survey the items prior to the loading of the vehicle.

A simple check of gamma radiation levels in the vicinity of a potentially contaminated item may reveal the presence of radioactive material on internal and/or external surfaces. When gamma radiation levels at a distance of 1 metre of an item are measurably higher than the background level in the area, it is highly likely that an item will be classified as 'surface contaminated object'.

Surface contamination measurements that typically follow the measurement of gamma radiation levels:

- A monitor capable of measuring surface contamination should be available;
- A monitor should be appropriately calibrated, i.e., the certificate should state a conversion factor between obtained cpm (counts per minute) and the value in Bq/cm$^2$;
- A monitor should have a window that can be opened and closed, shielding the probe from damage;
- Measurements are typically carried out over a one-minute interval in a close proximity to the surface (less than 5 mm);
- It is necessary to ensure that material is dry before surface contamination readings are carried out. Two measurements are taken, first with the window closed (that will be a 'background' reading), second, with the window open, and two values in 'counts per minute' obtained;
- The 'background' value should then be subtracted from the second reading and the result compared with the limits specified in the Regulations [6] (using the conversion factor for a particular monitor).

There are three more paragraphs in the Regulations [6] that need to be considered:

*§508. The non-fixed contamination on the external surfaces of any package shall be kept as low as practicable and, under routine conditions of transport, shall not exceed the following limits:*

a) 4 Bq/cm$^2$ for beta and gamma emitters and low toxicity alpha emitters;

b) 0.4 Bq/cm$^2$ for all other alpha emitters.

This paragraph addresses the packages, not the items themselves. It is irrelevant what is being transported and how it is packaged (it may be SCO-I or SCO-II, items inside a container or in a sealed truck, for example), but the limits from §508 for the levels on the outside surfaces of these 'packages' should not be exceeded.

*§520. LSA material and SCO in groups LSA-I and SCO-I may be transported, unpackaged, under the following conditions:*

a) All unpackaged material other than ores containing only naturally occurring radionuclides shall be transported in such a manner that under routine conditions of transport there will be no escape of the radioactive contents from the conveyance nor will there be any loss of shielding.

b) Each conveyance shall be under exclusive use, except when only transporting SCO-I on which the contamination on the accessible and the inaccessible surfaces is not greater than 10 times the applicable level specified in para. 214.

c) For SCO-I where it is suspected that non-fixed contamination exists on inaccessible surfaces in excess of the values specified in para. 413(a)(i), measures shall be taken to ensure that the radioactive material is not released into the conveyance.

The radiation safety provisions for SCO-I are less stringent than for SCO-II:

- SCO-II could only be transported appropriately packaged.
- SCO-I could be transported unpackaged, unless, as §520(b) states, the surface contamination levels reach ten times of the ones in §214. Which then make this item an SCO-II, in accordance §413(b)(i).
- If it is suspected (not proven, only suspected) that there may be some non-fixed contamination on inaccessible surfaces of SCO-I objects being transported in excess of values in §413(a)(i), making this item potentially SCO-II: one needs to take measures that the material from the inside of the objects cannot 'escape from the conveyance'.

An example is the transport of contaminated pipes from oil production: the pipe may be 8-10 meters long and there is typically no equipment and no possibility to measure what surface contamination may be inside of the pipe, some 4-5 meters "in". Then the plastic or metal caps are placed on each end of the pipe to make sure that no material may fall out from these pipes when they are transported.

Lastly, following from §520 above: after the transport, a vehicle used for this purpose will need to be decontaminated to much lower levels.

*§505. Freight containers, IBCs, tanks, as well as other packagings and overpacks, used for the transport of radioactive material shall not be used for the storage or transport of other goods unless decontaminated below the level of 0.4 Bq/cm$^2$ for beta and gamma emitters and low toxicity alpha emitters and 0.04 Bq/cm$^2$ for all other alpha emitters.*

§505 of the Regulations [6] provides guidance on what items may be suitable for the release of items to other industries and to the general public. It should be noted that in this case, especially in regards to the possible radiation exposure of the members of the general public, the lower value (0.04 Bq/cm$^2$) is much more appropriate.

Further information on issues associated with surface contamination and a detailed technical advice can be found in IAEA TECDOC-1449 [18.

## REFERENCES

1 Application of the Regulations for the Safe Transport of Radioactive Material to Bulk Shipments of Materials in Minerals Industry (N. Tsurikov, P.J. Hinrichsen, M. Omar, H.M. Fernandes), 'Radiation Protection in Australasia', vol.24, No.2, September 2007, pp.9-19

2 Regulations for the Safe Transport of Radioactive Material, Safety Requirements No. TS-R-1, International Atomic Energy Agency (IAEA), Vienna, 2005 Edition

3 Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Guide No. TS-G-1.1, International Atomic Energy Agency (IAEA), Vienna, 2002

4 Regulations for the Safe Transport of Radioactive Material 2009 Edition, Safety Requirements No. TS-R-1, International Atomic Energy Agency (IAEA), Vienna, 2009

5 Regulations for the Safe Transport of Radioactive Material 2012 Edition, Specific Safety Requirements No. SSR-6, International Atomic Energy Agency (IAEA), Vienna, 2012

6 Regulations for the Safe Transport of Radioactive Material 2018 Edition, Specific Safety Requirements No. SSR-6 (Rev.1), International Atomic Energy Agency (IAEA), Vienna, 2018

7 Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Guide No. TS-G-1.1 (Rev.1), International Atomic Energy Agency (IAEA), Vienna, 2008

8 Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2012 Edition), Specific Safety Guide No. SSG-26, International Atomic Energy Agency (IAEA), Vienna, 2014

9 Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition), Specific Safety Guide No. SSG-26 (Rev.1), International Atomic Energy Agency (IAEA), Vienna, 2022

10 Code of Practice – Safe Transport of Radioactive Material, Radiation Protection Series No.2, Australian Radiation Protection

and Nuclear Safety Agency (ARPANSA), 2001

11 Code of Practice – Safe Transport of Radioactive Material, 2008 Edition, Radiation Protection Series No.2, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2008

12 Code – Safe Transport of Radioactive Material, Radiation Protection Series No.C-2, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2014

13 Code – Safe Transport of Radioactive Material, Radiation Protection Series No.C-2 (Rev.1), Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2019

14 Technical reference note and MS Excel calculator, both files are available for download at http://calytrix.biz/papers/index.htm

15 IAEA Safety Glossary, Terminology Used in Nuclear Safety and Radiation Protection, 2018 Edition, International Atomic Energy Agency (IAEA), Vienna, 2019

16 P. Burns, P. Crouch. Exemption Levels for Transport of Ores and Concentrates Containing Uranium and Thorium, Radiation Protection in Australasia, Vol.23, No.1, May 2006, pp.12-14

17 Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements Part 3, No. GSR Part 3, International Atomic Energy Agency (IAEA), Vienna, 2014

18 IAEA TECDOC-1449, Radiological Aspects of Non-fixed Contamination of Packages and Conveyances, International Atomic Energy Agency (IAEA), Vienna, 2005

# HONORARY FELLOWS

## Presidents Announcement of the 2023 Honorary Fellowship Award to

# ANDREW JOHNSTON

## 2023 AGM Gold Coast

It is with great pleasure that I can announce that the ARPS Executive has awarded "Honorary Fellowship" status to Andrew Johnston (generally known as AJ).

AJ cannot be present at this conference because he has gone back to university and is currently in lectures on history and archaeology. The South Australian branch of ARPS will be conducting a ceremony for AJ later in the year, pending his exam timetable.

When AJs name was first brought up at an ARPS executive meeting as a possible candidate for honorary fellowship, there was instant unanimous agreement. This shows the high level of esteem in which he is held by fellow radiation protection practitioners.

I have had the pleasure of knowing AJ for almost 40 years and feel honoured to be providing this short overview. In compiling this short presentation, we sought comments from many of AJs colleagues and friends and received many stories, most of which should remain hidden away. However, there was a clear common theme from all contributors and that was the deep level of respect that everyone has for AJ and for his patience.

Before briefly presenting his career, it is important to note that AJ is also the long standing Public Officer for ARPS. He patiently and skilfully guides us through the complexities and formalities of any constitutional change for which ARPS is eternally grateful.

Career Highlights (with thanks to Graeme Palmer):

AJ was employed as a radiation protection officer by the South Australian Government's Radiation Protection Branch for over 30 years from 1979 to mid 2011.

Andrew's career in radiation protection focused on regulation of uranium mines and mineral sands mining operations (including past, present and proposed operations), and environmental radiation issues, including surveillance or remediation of legacy sites such as Maralinga, Radium Hill uranium mine and the Port Pirie uranium treatment plant.

For approximately 10 years before leaving the EPA Andrew was the Team Leader of the Mining and Environment Group with responsibility for mentoring a small team of scientific staff and the overall management of administration of the radiation licences granted to the Olympic Dam, Beverley and Honeymoon uranium mines projects and mineral sands mining operations, under the Radiation Protection and Control (RPC) Act.

Andrew's work in regulation of mining operations included, but was not limited to:

- Assessments and evaluations of Environment Impact Assessments for proposed uranium and mineral


sands mines, and providing high level advice to Government and proponents on requirements to meet relevant regulatory requirements for approvals

- Assessments and approvals of radiation management plans and radioactive waste management plans for mining operations, and proposals for characterisation and remediation of sites where uranium mining and processing were conducted in the past
- Assessments and approvals of processes for construction and operation of conventional and in-situ recovery uranium mines and processing plants, and
- Planning and overseeing the EPA's surveillance and auditing of mining operations' compliance with conditions on their licences under the RPC Act.

When AJ left the EPA, he continued his work in radiation protection including in contracting roles and also as a technical expert on the Alligator Rivers Region Technical Committee. He has also found time between boat building to build a radon chamber with Peter Haigh.

AJ has contributed to ARPANSA and IAEA documents on many topics including NORM, regulation of waste, and uranium mining.

With AJ's many years as a radiation protection regulator and subsequently as a consultant to uranium and mineral sands mining operations, and to the International Atomic Energy Agency on radiation safety in mining operations, he can be regarded as one of Australia's most qualified and experienced experts in this field.

On a personal level, there are many stories of AJ's love of cricket and the ABC's landline on long country drives to and from Roxby Downs. AJ also loved old books and his ability to identify a good book by its smell is legendary.

AJ was and remains very community oriented and was a volunteer fire spotter for the CFS. For hours on end, he would sit in a watch tower in the Adelaide foothills looking for smoke.

It is therefore fitting that AJ is a recipient of the ARPS Honorary Fellowship award.

I would like to finish with two quotes, one from Dr Phil Crouch and one from Peter Haigh.

"AJ was always very supportive of all he dealt with.  He was always there to help with word or deed whenever problems, personal or professional arose."

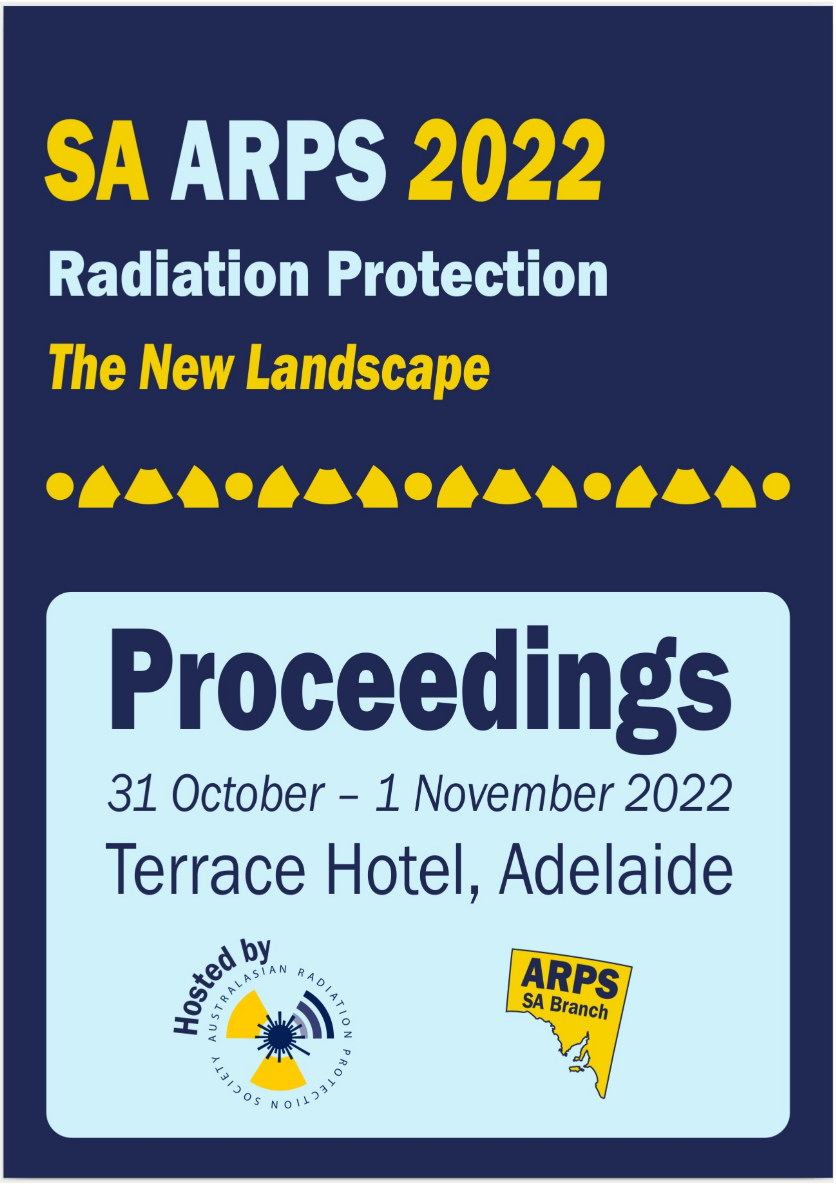
"AJ was always my reliable go to on questions I didn't know the answer to - a font of knowledge if not wisdom."

# Report of ARPS SA Symposium - 2022

**31 October – 1 November 2022, The Terrace Hotel, Adelaide, South Australia**

by
**C. Jeffries and A. Jagger**

Submitted: 10/10/2023 Accepted: ?/?/2023



The Symposium had the following presentations, which most are included as abstracts in the following pages:

- **Modelling the effect of daughter migration on dosimetry estimates for Actinium-225 in Targeted Alpha Therapy** - by Stephen Tronchin
- **Optimising contact pattern models to improve the precautions given following radionuclide therapy** - by Erin Lukas
- **Simulation study of over-the-barrier tertiary scatter of diagnostic x-rays -** by Mitchell Herrick
- **Investigating immunological and respiratory effects in a healthy, in vivo, radon inhalation exposure model** - by Dylan De Bellis
- **Hold my theranostic and watch this!** - by Daniel Badger
- **SCOs – more questions than answers** – by K. Gregory
- **Harnessing the Unique Energy Value of Radioactive Emitters** – by J. Kelly
- **Introduction to Micro-X and Nano Electronic X-Ray (NEX) Technology** – by S. Bennett
- **Radon as a Radioactive Material: How do I comply? –** by C. Jeffries
- **How do you solve a problem like conservatism?** - by Cameron Jeffries
- **A Case Study in Pb-210 Dominant Contamination** - by Simon Booth
- **Recent trends in radiation protection monitoring of U-mining and milling** - by Peter Haigh
- **NORM and Communicating the Risks** - by Jim Hondros
- **Past, present, future the Health Physic Surveyor Accreditation process** - by Jason Coltan
- **Developing Regulations – The Human Story** - by EPA [not included]
- **Radiation Safety Considerations in the Design of Australia's first Proton Beam Therapy Centre** - by Scott Penfold
- **Dose assessments from atmospheric plume modelling** - by Chris Kalnins
- **The Centre for Radiation Research, Education, and Innovation: 3 years on!** - by Tony Hooker
- **Food Irradiation Testing – Regional Capability Development at the University of Adelaide** - by Nigel Spooner

# Modelling the effect of daughter migration on dosimetry estimates for Actinium-225 in Targeted Alpha Therapy

by
**Stephen Tronchin**[a,b]

## Introduction

Targeted Alpha Therapy (TAT) is a form of targeted systemic cancer therapy. Why alpha particles? Alpha particles have a short path-length in tissue, only a few cell diameters, and a high linear energy transfer (LET). This means alpha particles produce dense ionisations within a cell, causing irreparable double-stranded DNA breaks, resulting in cell death. The short path-length and high-LET of alpha particles allows TAT to deliver a highly localized dose to tumour cells while reducing radiation exposure to the surrounding healthy tissue.

## Problems with TAT?

In TAT, an alpha-emitting radionuclide is bound to a targeting vehicle which carries the radionuclide to the desired location (this can be a primary cancer site, individual circulating cells, or even micrometastases). However, the decay energy of the alpha-emissions is sufficient to break the bond to the targeting vehicle, resulting in free daughter radionuclides released in the body. This is especially concerning for parents that produce multiple unstable daughters, such as actinium-225. In nuclear medicine dosimetry, daughter migration is generally ignored and this can produce inaccurate dose estimates.

## Method

A compartment model for actinium-225 and its daughters was developed in Python, where we account for unique biokinetics by assigning each daughter unique transfer rates between compartments. The transfer rates for the elements in the actinium-225 decay chain were taken from the ICRP Occupational Intake of Radionuclides reports. Using this model, we obtained the activity of each isotope in the different compartments as a function of time. We determined organ doses for two scenarios: 1) assuming the daughters decay at the site of actinium, and 2) assigning the daughters unique biokinetics. Organ doses were determined for 1MBq of free actinium-225 placed in the plasma.

## Results

Using the kidneys as an example organ, when the daughters of actinium-225 have their own unique biokinetics, there is a 10.6% increase in dose to the kidneys compared to assuming the daughters decay at the site of actinium-225.

## Conclusion

These results highlight that accurate absorbed dose estimates require accurate modelling of daughter biokinetics. Next, we plan to study include tumour uptake/retention.

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# Optimising contact pattern models to improve the precautions given following radionuclide therapy.

by
**Erin Lukas[b]**

## Introduction

Radionuclide therapy is a nuclear medicine procedure used to treat a wide range of conditions. The treatment of diseased cells by a radioactive substance that is preferentially taken up by these cells allows for a highly localised and targeted deposition of dose. However, the radionuclide will remain in the patient's body until it decays away or is excreted, so the patient can be radioactive for days or weeks following their treatment depending on the type of treatment and the radionuclide used.

Exposure of other people to radiation from the patient following radionuclide therapy can result in close contacts receiving a radiation dose exceeding the 1 mSv annual effective dose limit for members of the public [1]. Those most at risk of exceeding this dose limit are household members and family members, who typically have the most prolonged contact at close distances with patients. Precautions for limiting the radiation exposure received by contacts during this period are therefore required to prevent contacts from exceeding the 1 mSv limit.

Many centres provide general precautions following treatment that are based only on past practice and are not adjusted for individual patient characteristics, resulting in overly conservative restriction periods. The use of contact patterns and patient activity measurements to create individualised precautions improves these precautions somewhat, but even these are overly conservative in most cases. Further optimisation of these contact patterns and the precautions they produce may therefore reduce discomfort and emotional distress in patients, as well as reducing the burden on the hospital system.

A comprehensive review of contact pattern data, dose estimation algorithms, caregiver dose studies and interpersonal distance studies was conducted to guide the development of a better method for creating optimised precautions that is simple to implement and use. Though the general contact patterns currently used by our dose estimation software were supported by the available literature, this review highlighted the need to develop individualised contact patterns based on patients' unique circumstances. A patient questionnaire with the results used by the dose estimation software is recommended as a time efficient and standardised method of optimising the precautions given to each patient, without significantly increasing staff workload.

## References

[1] Radiation Protection and Control (Ionising Radiation) Regulations 2015.

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# Simulation study of over-the-barrier tertiary scatter of diagnostic X-rays

by

**M. Herrick[1,2], D. Badger[1], J. Forster[1,2] and K. Hickson[1,3]**

**Keywords**

radiation safety, tertiary scatter, shielding design

## Introduction

In the shielding design for x-ray/CT rooms, workloads can be high enough that tertiary scatter of radiation over the primary barrier must be considered.

The de facto height for barriers is 2.1 m, despite a room height typically between 3-5 m, it is possible then, that the annual dose in adjacent rooms due to tertiary scatter could exceed dose limits or design constraints.

The model obtained using semi-empirical simulation from Martin and Sutton (2012) is the current standard when assessing tertiary scatter over the barrier. Here we present results from an independent Monte Carlo simulation for assessing tertiary scatter over a barrier.

## Methods

Using the GEANT4 toolkit, we constructed a simulation to assess tertiary scatter over the barrier. The simulation involved a room (6x4x14 m) with a concrete ceiling and floor with the side walls removed. Two sensitive volumes (air, 10 cm diameter) were placed on either side of a barrier matching the setup of Martin and Sutton (2012). An isotropic 85 kVp X-ray scatter source was placed 3 m from the barrier and was directionally biased in a frontal hemisphere towards the barrier. The energy, location and direction of photons entering the volumes were recorded, and air kerma calculated. The ratio of tertiary air kerma to the scatter source air kerma was plotted against barrier height and compared to predicted values.

## Results

Initial results showed reasonable agreement between predicted and simulated air kerma ratios at barrier heights greater than 3 m (Figure 1). However, at barrier heights below 3 m, we observe a difference in air kerma ratios. Further investigation identified that the work done by Martin and Sutton (2012) excluded a portion of the ceiling for scatter, likely due to computation limitations, in their simulation work leading to a smaller kerma estimate. After accounting for the smaller ceiling area in our air kerma calculation, we observe excellent agreement across all barrier heights.

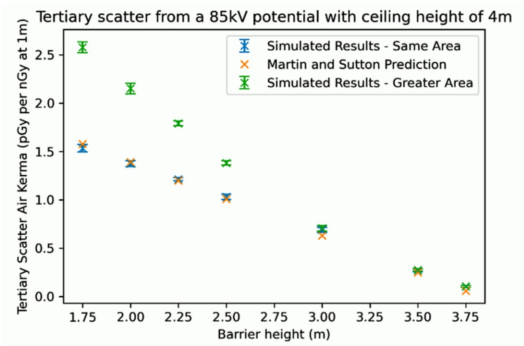


**Fig 1**. *Tertiary scatter air kerma calculations for various barrier heights using Martin and Suttons model (Orange), our simulated results using a larger ceiling area (green) and our corrected simulation results using the same ceiling area (blue).*

## Conclusion

Our Monte Carlo simulation has independently verified the model under the assumptions used by Martin and Sutton (2012). The results obtained in this work also highlight the need for further investigation outside their assumptions

## References

Martin CJ, Sutton DG, Magee J, McVey S, Williams JR, Peet D. (2012), Journal of Radiological Protection 32: 373

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# Investigating immunological and respiratory effects in a healthy, in vivo, radon inhalation exposure model.

by
**D. De Bellis[1], J. McEvoy-May[1,2], S. Puukila[1,3], A.M. Hooker[1,2], D. Boreham[3], D-L. Dixon[1,3]**

**Keywords**

Radon, radiation, immunology, lung, radiation biology

**Introduction**

Radon gas is believed to be the second leading cause of lung cancer after smoking (National Research Council, 1999). Although this statement has been accepted worldwide, recent evidence has generated debate over its validity.

In Australia, to prevent radon induced lung cancer, regulatory authorities recommend that radon exposure does not exceed 200 Bq/m$^3$ at home and 1000 Bq/m$^3$ in the workplace (APRANSA, 2022). Although numerous studies investigating exposure to high doses of radon exist, there are limited studies investigating the effects of low dose exposure and its effects on pulmonary inflammatory responses. Thus, the aim of this study was to investigate the effects of low single and chronic exposures to inhaled radon (200 Bq/m$^3$ and 1000 Bq/m$^3$) on the inflammatory response in the respiratory system.

**Method**

For this experiment, our purpose built, small animal Flinders University Radon Facility was used (Puukila et at, 2020). Male Sprague-Dawley (SD) rats were housed with or without radon for 1x 18-hour, 1x 90-hour, 2x 90-hour, or 4x 90-hour exposure. After exposure, rats were anaesthetised, euthanised, and outcomes measured including respiratory function (lung mechanics), physiology (pulmonary oedema and epithelial layer damage), and immunology (cellular infiltrate into the lung and cytokine profile).

**Fig 1**. *The purpose-build radon chamber*

**Results**

Our outcomes found that exposure to either 200 Bq/m$^3$ or 1000 Bq/m$^3$ radon gas did not elicit an immune response, as there was no significant increase in pro-inflammatory cytokines in rats exposed to radiation. Additionally, radon exposure did not result in increased immune cell infiltration into the lungs. However, when a total exposure time comparison was performed, a significant increase of lavage proteins and lung compliance was observed in rats placed in the chamber from 1x 90-hour onwards.

**Conclusion**

Our results suggest that radon at 200 Bq/m$^3$ and 1000 Bq/m$^3$ exposure does not elicit an immune response in Sprague Dawley rats. However, there was an observable change in lung physiology and function, the mechanism of which requires further investigation.

**References**

National Research Council, 1999, 'Health Effects of Exposure to Radon: BEIR VI', The National Academy Press, Washington, D.C

Australian Radiation Protection and Nuclear Safety Agency (APRANSA), 2022, 'Radon exposure and health', https://www.arpansa.gov.au

S. Puukila et al, 2020, Journal of Environmental Radioactivity, 220-221.

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# Hold my theranostic and watch this!

by
**D Badger[1]**

Radionuclide therapy is a well-established and effective part of Nuclear Medicine, used in treatment for a number of diseases, including a number of cancers. Saul Hertz had the idea in 1936 that thyroid cells could be targeted and killed if iodine could be made radioactive. He subsequently performed the first radioiodine therapy to treat a patient with Graves disease in 1941, using a mix of I-130 and I-131 produced in the MIT cyclotron.

The primary requirements of successful radionuclide therapy are being able to cause significantly higher uptake in the target tissues and using radionuclides with short-ranged radiation emissions (particles like electrons or alphas) to limit dose outside the immediate area of the target.

Targeting can be via simple chemistry, as with iodine uptake in the thyroid, or radioactive materials can be attached to other molecules that bind to specific receptors; or even encapsulated in larger physical materials such as resins, glass or silicones.

Recently a number of new targeting vectors have been introduced, and in combination with the abilities of diagnostic Nuclear Medicine to image the uptake sites via gamma emissions of the therapeutic agent or agents with substituted radioactive atoms, this has led to the coining of the term “Theranostics”, a portmanteau of “therapy” and “diagnostics”. With the promise of large profits available in treating common cancers this field has suddenly expanded.

While all practitioners hope for uncomplicated procedures with no issues, this is not always the case, and in the use of radioactive materials one should have in place contingency plans and access to qualified experts to deal with those rare but possible complications. This paper mentions a few things to consider from the author’s years of experience in providing radionuclide therapies at a public hospital.

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# SCOs – more questions than answers

by
**K. J. Gregory[1]**

**Keywords:**
surface contamination, SCO

Surface contaminated objects (SCOs) are defined as radioactive material in the South Australian Radiation Protection and Control Regulations 2022. SCOs are objects that are not themselves radioactive, but have radionuclides on their surfaces in concentrations that exceed either 0.04 Bq per cm$^2$ (for high toxicity alpha particles such as Po210) or 0.4 Bq per cm$^2$ (for radionuclides that emit all other radiation types).

The regulation of SCOs in South Australian legislation raises a number of questions. This presentation seeks to answer some of those questions, being;

1. Is there a requirement for the contamination to sum up to at least the exempt quantity of that radionuclide?
2. If the answer to the above question is NO, what is the risk posed by an SCO?
3. How easy is it to measure 0.4 Bq/cm$^2$ and 0.04 Bq/cm$^2$?
4. Are there any unintended consequences to regulating SCOs at this level?

The risk posed by ingesting or inhaling radioactive material on an SCO that is contaminated at the minimum levels is, in many cases, zero. The risk is between 2 to 5 orders of magnitude lower than the risk posed by an exempt quantity of radioactive material for a range of common radionuclides.

Measurement of surface contamination can quickly become a complex task, requiring the use of expensive instrumentation together with a statistically derived number of measurements taken over a statistically derived sampling period. For some surfaces, measurements become very complex. Examples of complex surfaces include filters (see figure 1, very large surface area), pipes (curved surfaces that may have alpha particles attached but the entire sensor cannot be close enough to detect alphas), and other objects where the contaminated surfaces are difficult to access. For some radionuclides (such as H3), it is not possible to measure surface contamination at 0.4 Bq/cm$^2$.

Regulation of SCOs may reduce recycling of material that has been in contact with radioactive materials, and impose additional expense on businesses, as they have to purchase expensive meters and take additional time to assess contamination levels.

Recommendations regarding the maximum contamination on surfaces related to laboratory settings were published in 19951. While the document was limited in scope, the recommendations were based on a scientifically derived level of risk. An update to these recommendations, together with further publications covering other areas where SCOs may be detected, is recommended.

**Figure 1**. *This fibrous dust filter containing Po210 is an example of a surface with a large but unknown surface area. The curved surface makes measuring alpha contamination difficult when using a large area alpha sensor.*

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1. Recommended limits on contamination on surfaces in laboratories (1995), NHMRC

# Harnessing the Unique Energy Value of Radioactive Emitters

by
**J.F. Kelly, M. de los Reyes**

entX develops industrially-relevant energy technologies that harness the unique energy delivery mechanisms associated with radioactive particles. These are categorised into four main areas:

**Uranium from Phosphate Deposits**

entX co-owns the 'PhosEnergy' process for extracting uranium as a by product from phosphate deposits (in which it often occurs as an unwanted contaminant). A demonstration plant was designed and built in Australia and demonstrated in the field (US).

A number of market drivers are now supporting the business viability of the PhosEnergy process:

- A strong rebound in the uranium price, from post-Fukushima lows.
- Strong demand for phosphate due to geopolitical supply pressures, thereby rendering P-sources containing NORM more attractive.

**Radiocatalysis**

entX has demonstrated that the energy of radioactive beta-emitters can be harnessed to drive desirable chemical reactions, including the conversion of $CO_2$ into valuable industrial compounds such as formaldehyde. Emitters such as **$^{210}$Pb, $^{90}$Sr, $^{137}$Cs, $^{226/8}$Ra, $^{11}$C**, can be formed into robust catalytic ceramic materials that serve for extended periods as energised surfaces on which 'redox' reactions can proceed.

entX also aims for its radiocatalysts to drive the water-splitting reaction, ie, be able to produce hydrogen & oxygen.

**Radioisotope Power Systems**

entX is protoyping proprietary solid-state 'betavoltaic' devices for providing ultra-reliable, perpetual DC power. Long-lived radioisotopes including: **$^{14}$C, $^{3}$H, $^{210}$Pb, $^{90}$Sr, $^{63}$Ni, $^{137}$Cs**, can energise semiconductors within smart betavoltaic structures that draw upon development in the electronics industry (eg, OLEDs).

Separately, entX is testing what will be a low-cost production route for a thallium radioisotope that provides a significant thermal output. Spacecraft often require an on-board power source to provide heat to parts of the vehicle (such as electronics). Radioisotopes can be the only credible solution, however, access to classic heat-generating isotopes such as $^{238}$Pu is essentially impossible for non-state players.

**Nuclear Medicine**

entx is facilitating the supply of parent radioisotope for new cancer drugs. Radioimmunotherapies are a rapidly emerging cancer treatment modality in which α or β particle emitters serve as cytotoxic payloads on molecules that selectively target cancer cells. The short-range nature of this radiation means that little dose is delivered to surrounding healthy tissue. The preferred emitter for these drugs is the **$^{212}$Pb** isotope, for which the best parent is **$^{228}$Th**. entX is facilitating new supply options for **$^{228}$Th** by tapping NORM and mineral industry sources of thorium-232.

The supply of several medical isotopes is threatened by the availability of their parent stable isotope. entX is trialling an innovative chemical system for enriching a naturally occurring isotope that is used for producing a cancer-therapeutic radioisotope.

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# Introduction to Micro-X and Nano Electronic X-Ray (NEX) Technology

by
**S Bennett**

Micro-X is an ASX-listed, hi-tech company working to continually push the boundaries of science and technology across every industry. As first movers in the development of cold cathode carbon nanotube emitter technology, we are developing and commercialising a brand of innovative products for global health and security markets. Our electronically controlled NEX Technology enables us to create x-ray products that are significantly smaller, lighter and more efficient than traditional x-rays. These benefits enable greater mobility and ease of use across new security and defence applications, as well as in existing x-ray markets.

Micro-X employs 102 people across two sites - Tonsley Innovation Precinct in Adelaide, South Australia, and Seattle, United States – where teams of engineers, scientists and manufacturing experts are working together to bring new and life changing products to customers. Some of our staff members and contractors also work remotely from Queensland, Victoria and Europe.

Micro-X's first product to market, the Mobile DR x-ray system addresses the medical, veterinary and OEM customer segments. The Argus, to be launched in FY2023, is an x-ray camera providing rapid assessment of improvised explosive devices, transforming how bomb disposal technicians work and providing greater safety by reducing the need to go down range to place a detector behind a suspected bomb.

Micro-X is developing next generation miniaturised CT baggage scanners that will be able to scan a passenger’s carry-on luggage, with no need to remove items such as liquids and electronics. The company is also leading a consortium of global experts to design a passenger self-screening airport checkpoint, funded by the US Department of Homeland Security.

Micro-X has been chosen as the technology partner for the Australian Stroke Alliance to develop the world’s first miniature brain CT scanner which will deliver diagnostic quality images in a unit that is small and light enough to be mounted in any road or air ambulance.

We are on a mission to build an inclusive future that benefits our employees, communities, and the planet. We’re not focusing on how we can change the world overnight, but what we can do today that will take us one step closer to our goal.

# Radon as a Radioactive Material: How do I comply?

by
**C. Jeffries[1]**

**Keywords:**
radon, healthcare, occupational exposure, exposure controls, nuclear medicine.

Radon is a naturally occurring radioactive gas that occurs everywhere. Elevated concentrations of radon gas are associated with increased health risks and generally occur in workplaces or areas with elevated concentrations of uranium or thorium, such as in mines. Recently, there has been an increased recognition that radon is potentially a wider health risk and the International Atomic Energy Agency (IAEA) has established exposure standards through its Basic Safety Standards. (IAEA, 2014) These require consideration of exposure to $^{222}$Rn in all workplaces, including those that would not normally be considered.

In Australia, the reference levels for radon concentration are 200 Bq.m-3 for dwellings and 1,000 Bq.m-3 for workplaces. Note that the workplace reference level equates to approximately 20 mSv/y for full time (2,000 h/y) exposure. The reference levels have been adopted at a national level by ARPANSA. Each State and Territory is responsible for implement of radiation safety controls.

The work described in this paper was undertaken at a metropolitan teaching hospital that is a major trauma centre and offers a full range of healthcare services. The nuclear medicine department undertakes radioiodine (131I) therapy treatments for patients. Iodine contaminated waste resulting from therapy is held in storage to allow for radioactive decay (t1/2 = 8 days) before disposal. The radioactive waste is stored either in the nuclear medicine department or in a dedicated radioactive waste store.

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The waste store is located on the lower level of the hospital and is partially open to bare earth within a fully enclosed area. In 2020, the radioactive waste store was inspected by the Radiation Safety Officer (RSO), with a focus on the potential for elevated airborne radon concentrations due to poor air quality and limited ventilation.

Continuous radon monitoring was implemented in June 2020 using an FT Lab Radon Eye (Model RD200, Serial No. RE21703060023) which logs radon concentrations hourly. The mean, geometric mean, minimum and maximum radon concentration were 145.7, 137.6, 44.0 and 381 Bq.m$^{-3}$ respectively. Radon monitoring was continued in the waste store using the Radon Eye due to the elevated radon concentrations.

Monitoring data was retrieved from the Radon Eye in early August and analysed. A summary of radon concentrations by calendar month is shown in Figure 1. The maximum radon concentration was 519 Bq.m$^{-3}$.

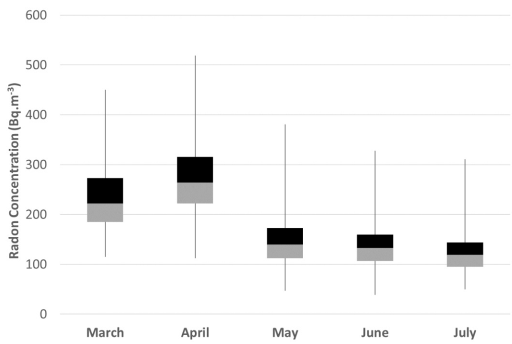


**Figure 1**. Summary by month showing minimum, first quartile, median, third quartile and maximum radon concentration in radioactive waste store

Exposure to radon in the waste store can be effectively controlled by restricting. Nuclear Medicine staff require access to place new contaminated material, or to remove decayed waste. The maximum exposure time is twenty hours per year. An interim control allows access to the waste store when the radon concentration is less than 400 Bq.m[-3]. Approximately 1% of results exceeded this level.

The radiation dose is approximately 0.07 mSv per year in the maximum exposure case (20h, 400 Bq.m-3) based on a dose conversion factor of 9 nSv/Bq.h.m-3 (UNSCEAR, 2019). Radiation dose will be lower due to the use of PPE (i.e. masks) for Covid-19.

The monitoring results indicate a potential for the radon concentration to exceed 1000 Bq.m-3. The new South Australian Radiation Protection and Control Regulations (due to commence February 2023) define this concentration of radon as a radioactive material. The presentation will compare the approach in the Regulations with the recommendations of IAEA 2014, and explore some of the questions that arise in how this radioactive material will be regulated in practice.

**References**

IAEA (2014) Radiation protection and safety of radiation sources: international basic safety standards, International Atomic Energy Agency, Vienna.

UNSCEAR (2019) Sources, Effects and Risks of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, New York.

# How do you solve a problem like conservatism?

by
**Cameron Jeffries[1], Jim Hondros[2]**

**Keywords:**

ICRP, radiological protection, radiation protection, LNT, reasonableness, threshold, IRPA, future radiation protection

This presentation is an update version of a presentation low dose radiation protection at the ARPS 2021+1 conference in Canberra, March 2022. The following abstract was prepared for the ARPS Conference and has been updated for presentation at the ICRP 2021+1 Symposium in Vancouver, Canada November 2022.

The International Commission for Radiological Protection (ICRP) has commenced a review of the system of Radiological Protection. This review commenced with a discussion paper, Keeping the ICRP Recommendations Fit for Purpose (C Clement et al 2021 J. Radiol. Prot. 41 1390), and workshop in October 2021. The review, planned to take ten years, is an opportune time to rethink the way we do radiation protection. ARPS members are at the cutting edge of implementation of ICRP recommendations. As practitioners we know there can be undue effort applied at low doses (< 5 to 10 mSv/y). This effort may, at times, divert resources from more significant radiation protection matters. This paper proposes practical approaches to the application of LNT for radiation protection at doses in the range of natural background levels. The proposals adopted the IRPA position of reasonableness and aim to be consistent with the IAEA graded approach to regulation of radiation.

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2 JRHC Enterprises

# A Case Study in Pb-210 Dominant Contamination

by
**S.A. Booth[1], A. M. Field[1], L. J. Steen[1]**

**Keywords**
NORM, contamination, disequilibrium, Pb-210, Ra-226.

Radiation Services WA (RSWA) provide contract Radiation Safety Officer (RSO) services for clients in the Energy, Resources, Education and Research sectors.

RSWA were recently asked to assist with the decommissioning of a facility that had been used to process material known to contain elevated levels of NORM. This plant was to be sold to another mining company, for future use in a copper and nickel operation.

This plant had been used to concentrate and extract various minerals from ore that was known to contain elevated levels of uranium, thorium and their various decay products.

The process plant involved a beneficiation circuit, a hydro metallurgical circuit and various stages adjusting pH and other aspects of the process stream. The hydrometallurgical component of the plant involved a kiln(operating below 3000C), leaching circuit and many inputs to adjust acidity.

RSWA's focus was:

- Ensuring plant equipment leaving site was free from contamination;
- Oversee radiation protection to ensure exposure of workers was ALARP; and
- Ensuring that generated waste was managed correctly.

A study had been performed by ANSTO in 2014 – the project based on the theoretical physical and chemical process flows and analysis had been performed on the mining process. The outcomes of this study were focused on the production outputs of the plant, rather than analysis of where various radionuclides might be found in process component parts, or within the waste streams.

Since this study had been undertaken, a number of changes to the plant chemistry had occurred and required consideration.

In Western Australia, there are two NORM regulatory bodies - the Radiological Council are typically the principal radiation regulator for radiation. However, in the mining sector, the principal radiation regulator is the Department of Mines, Industry Regulation and Safety (DMIRS).

RSWA's involvement in this project included:

- Discovery and investigation of the client process with a heavy focus on radionuclide migration through the process plant;
- Develop risk management procedures and protocols specific to this operation; and
- Provide oversight for the project for the 12-week decommissioning campaign.

Project outcomes were:

- There was no Australian guidance on surface contamination limits where there is a mixture of radionuclides present (always the case with NORM);

**Table 1**. *Contamination limit based on dominant radionuclide.*

| Dominant Radionuclide (HOC) | Contamination Limit ($Bq/cm^2$) |
|---|---|
| U-238 / Th-232 | 0.4 |
| Ra-226 / 228 | 0.4 |
| Pb-210 | 0.28 |

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- RSWA developed a methodology for calculation of the various radionuclide balances (dominance) that could be applied to this and future projects, and had this endorsed by the radiation regulators;
- The waste (and contamination) present for this project was Pb-210 (and progeny) dominant;
- It was determined that a contamination limit of 0.28 Bq/cm$^2$ would be applied;
- Theoretical values showing the relationship between uranium, thorium, radium, lead and polonium were confirmed using laboratory analysis and in-field monitoring techniques; and
- Practical methodology was developed to allow the client to make use of their existing radiation monitoring equipment to determine values in Bq/cm$^2$.

**References**

Booth, S.A., Field, A. M. (2020), NORM_RCWA2012_TM, Radiation Services WA.

Griffith, C. S., Brown, S. A. (2014), Project X – Radionuclide Deportment – Beneficiation Pilot Plant and Increased Impurity Rejection Flowsheet, ANSTO.

Hartog, F.A., Knaepen, W.A.I., Jonkers, G. (2022) Radioactive Lead: An Underestimated NORM Issue?, Shell Research B.V.Koninklijke/Shell-Laboratorium.

# Recent trends in radiation protection monitoring of U-mining and milling

by
**Jiri Kvasnicka[1], Sankaran Kutty[2], Allan Seini[3], Kathryn Liedig-Levingstone[4]**

The Radiation Protection Monitoring Programs (RPMPs) of U-mining and milling have been based on the same principles for decades. The monitoring of personal external gamma dose is carried out by means of TLDs and gamma dose rate meters are used for area surveys. Long-lived alpha activity (LLAA) dust monitoring is based on the use of various air sampling pumps and dust filters which are then counted for alpha activity. Both personal and area dust monitoring follow similar methodologies. Radon progeny monitoring includes continuous area monitoring and/or grab sampling of the PAEC and personal monitoring for the PAEE. To estimate the personal effective dose equivalents attributed to personnel working at uranium mines from these results is generally speaking a “cumbersome process”.

It is inevitable that some uncontrolled leakage of dry uranium product dust will occur in the calciner and the product packaging areas. To date there have not been any specialised long-lived alpha activity concentration air monitoring systems that would alert a Radiation Safety Officer (RSO) and the production crews that such a leak has occurred.

The on-line radiation monitors developed by RDS address some of the shortcomings of the RPMPs of U-mining and milling. The on-line Environmental Radon Daughter Monitor (ERDM) sends monitoring data to the RDS Monitoring Platform (RDSMP) every 10 minutes. The software of the RDSMP allows the user to observe graphs of average PAEC values in 10 min, 1 hour, 6 hours, 1 day and 1 month monitoring intervals. Monitoring data can then be downloaded into a Microsoft excel compatible format. This enables the RSO to attribute monitoring values to specific exposure tasks that have a recorded time-stamp. The environmental monitoring figures of the PAEC of radon progeny are coupled with wind direction and speed data to estimate the impact of radon released from the project area on the critical member of the public group.

Remote access to site monitoring data is important from a time management point of view. The RSO does not have to spend time placing and collecting the radiation monitors in order to download the data or have to input the data into a computer system and carry out the processing as this can all be done from the comfort of their office, or from any computer with an internet connection.

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# NORM and Communicating the Risks

by
**J. Hondros[a]**

Naturally Occurring Radioactive Materials (NORM) is a complex area, covering a range of industries and practices that do not normally associate with radioactivity. In these industries and practices, risks need to be managed in perspective in order to ensure that appropriate resources are allocated to the right risks. However, due to the perceptions associated with the presence of radioactivity and the uncertainty in the international approach to NORM, there are many practical difficulties. In recognition of the widespread difficulties with management of NORM, in 2019, the IRPA Executive established a task group (TG), with the aim of providing advice, guidance and assistance for the everyday practitioner on NORM in industry. The TG has brought together some of the world's leading experts in the area of NORM and one of the key objectives of the TG is to produce a clear and simple handbook for practitioners. While this work is progressing, the TG has also been considering its role in providing international guidance on NORM and in providing input to the upcoming review of the ICRP system of protection. This is an ideal opportunity to hear the voice of practitioners and this paper will provide an overview of the IRPA NORM TG and importantly provide practical thoughts to improve the ICRP system of protection.

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# Past, present, future the Health Physic Surveyor Accreditation process

by

**Jason Coltan[1], Josh Smith[1], Liam Brophy[1], Lindsay Downe[1], Nicholas Karantonis[2]**

An ANSTO Health Physics Surveyor provides hands-on radiation protection and safety advice and monitoring services to a range of operational areas to ensure the safety of staff, contractors and visitors; and compliance with ANSTO's WHS Standards and Practices, and with regulatory requirements. The purpose of the ANSTO Health Physics Surveyor Accreditation is to document the training required to be recognised and certified as a Health Physics Surveyor at ANSTO.

ANSTO recognises that locally developed measures are more relevant and sustainable than those imported substantially from outside. It is therefore important to support and facilitate indigenous methods and to factor in Australia's and ANSTO's culture – 'the way we do things here' – whilst still achieving radiation protection objectives that reflect international norms. For this reason, ANSTO's Health Physics Surveyor Accreditation process was developed entirely in-house.

The scope of the training documents outlines accreditation tasks required and knowledge to be attained by all Health Physics Surveyors, and this training has been proven to suit a variety of people that are of different skill sets and educational backgrounds.

Training documents are based as a self-paced read through format, with a written exam to be completed with each module. This training and accreditation process results in a valuable functional capability to work as a Health Physics Surveyor at ANSTO.

This presentation begins with the journey of four people, from different backgrounds, undergoing the Accreditation process, and concludes with my personal journey with using the CORIS360® for site characterisation at ANSTO.

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2. Detection and Imaging, Australian Nuclear Science and Technology Organisation

# Radiation Safety Considerations in the Design of Australia's first Proton Beam Therapy Centre

by
**S.N. Penfold[1]**

**Keywords**
proton therapy, radiation shielding, radioactivation.

The Australian Bragg Centre for Proton Therapy and Research (Bragg Centre) is currently under construction in the Adelaide BioMed City Precinct. The Bragg Centre will be Australia's first proton beam therapy (PBT) centre and home to Australia's highest energy proton accelerator. PBT is a form of external beam radiation therapy making use of energetic proton beams to deliver a lethal radiation dose to tumour cells while minimizing radiation exposure to normal healthy tissues.

The Bragg Centre accelerator will be capable of accelerating protons to 70 – 250 MeV for treatment and up to 330 MeV for proton imaging applications. While the proton beam itself only has a range of up to 60 cm in water (at 330 MeV), the secondary radiation produced in nuclear reactions of the proton beam produces high energy photons and neutrons that are not easily stopped. Furthermore, nuclear interactions can also result in radioactive isotopes that can contribute to radiation exposures of staff, members of the public and the environment.

Assessment of the design in terms of radiation shielding of secondary photons and neutrons was performed with the Monte Carlo toolkit Geant4 (Agostinelli et al. 2003). Assessment included instantaneous dose rates at maximum energy and annual doses considering workload, gantry and energy use factors, and occupancy factors.

Assessment of the design in terms of radioactivation of building materials and soil was also performed with Geant4 making use of measured chemical compositions of these materials. Saturation radioactivity levels were compared to IAEA recommended bulk disposal exemption limits (IAEA 2014).

Assessment of the design in terms of radioactivation of air was performed using an analytical method that incorporated activation cross-sections and air clearance rates from the various radiation areas.

Being the first facility of its type in Australia has required a close working relationship with the radiation safety regulator. A staged approval approach has been adopted with each stage requiring a separate submission to demonstrate that an understanding and mitigation of the radiation related hazards and risks has been satisfactorily undertaken.

**References**

Agostinelli, S, J Allison, K Amako, J Apostolakis, H Araujo, P Arce, M Asai, et al. 2003. "Geant4—a Simulation Toolkit." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 506 (3): 250–303.

IAEA. 2014. "Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. General Safety Requirements Part 3 No. GSR Part 3."

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# Dose assessments from atmospheric plume modelling

by
**C. Kalnins[1], S. Edwards[2], A. Hooker[1], N. Spooner[1,3]**

**Keywords**
Dose assessment, atmospheric modelling

Radioisotopes may be incorporated into satellites, serving as radiation heating units or beta-voltaic devices. These devices are generally small, but high-activity.

Any satellite launch carries the risk of failure. In extreme cases, an explosion of the rocket part-way into the atmosphere can create a scenario where debris is spread over a wide area, including radioisotopes from a satellite in the payload. A Flight Safety Analysis is required as part of the approval process for inclusion onto a payload launch, analysis of such an extreme-case scenario would form a part of this safety analysis.

The scenario considered here is the launch of a satellite, containing a certain mass of a radioisotope, which explodes at a height of 70m above the NASA Kennedy Space Centre launch site. Modelling of the atmospheric concentration of a radioisotope in the explosion plume was performed by EMM Consulting using CALPUFF, an atmospheric pollution and dispersion simulation suite. Figure 1 shows the plume data overlaid on a map of Cape Canaveral. From this data, the highest concentration to which a person may be exposed was identified: 1.96 $\mu g/m^3$.

Using this dispersion data, dose effects were studied for several isotopes of interest assuming submersion in a uniformly contaminated atmospheric cloud. Since this scenario would occur in the United States, guidance was taken

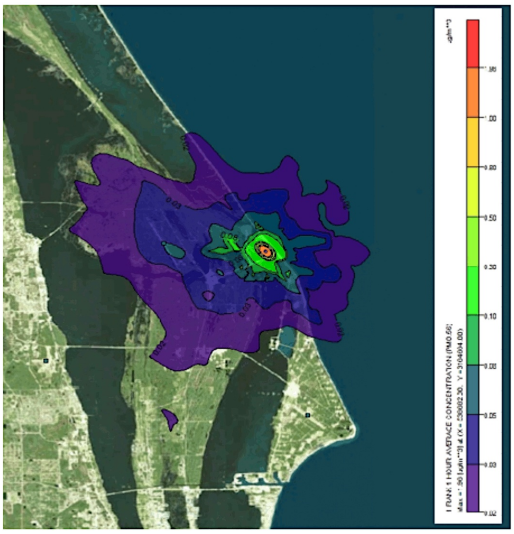

**Fig 1**. *Atmospheric dispersion model of worst-case launch explosion scenario at Cape Canaveral.*

from US Environmental Protection Agency (EPA) documents (Eckerman, 1993). Air submersion dose coefficients to a variety of organs plus effective dose are readily available for a wide variety of isotopes, these were used in conjunction with the atmospheric modelling data to compare with exposure limits in the United States to a member of the public: 1 mSv/year and 0.02 mSv/hour (US NRC (1991)).

Table 1 summarises an example of the simulated dose received by a person standing in the highest-concentration location of the plume for 1 hour, and at a distance of 2.5 km. If the radioisotope of interest is $^{65}$Ni, a person at the centre of the plume would receive an effective dose far in excess of the public limit; however this exposure scenario is physically infeasible. At 2.5 km, the exposure from $^{65}$Ni is 0.01 mSv, half that of the regulated hourly dose maximum.

Other radioisotopes of interest were all calculated to produce an effective dose well below regulatory limits, even in the event of a person

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**Table 1**. *Effective dose for submersion in air for 1 hour within the highest-concentration location, and at 2.5 km from the plume.*

| Isotope | Effective Dose (Max. Conc.) (µSv) | Effective Dose (2.5 km) (µSv) |
|---|---|---|
| $^{65}$Ni | 1.40e+02 | 9.27e+00 |
| $^{177}$Lu | 4.69e-02 | 3.12e-03 |
| $^{210}$Pb | 1.13e-06 | 7.49e-08 |

standing at the centre of the plume for 1 hour.

This dose estimate model is a quick method of assessing the worst-case scenario of exposure to a dose plume containing radioisotopes. Values were calculated for several radioisotopes of interest and all were found to fall below regulatory limits for any physically feasible exposure scenario. This model may be used for a wide variety of different radioisotopes and payload concentrations, providing useful information for Flight Safety Analyses.

## References


K. F. Eckerman and J. C. Ryman (1993) Federal Guidance Report No. 12: External Exposure to Radionuclides in Air, Water and Soil, EPA 402-r-93-081

United States Nuclear Regulatory Commission (1991) NRC Regulations Title 10, Code of Federal Regulations Subpart D - 20.1301


# The Centre for Radiation Research, Education, and Innovation: 3 years on!

by
**A.M Hooker[1] and N.A. Spooner[1]**

**Keywords**

Radiation, Services, Education, Research

## Introduction

The Centre for Radiation Research, Education, and Innovation (CRREI) was established by the University of Adelaide to address several strategic opportunities in Australia. CRREI is an internationally recognised centre for advancement of radiation research, education, training, and innovation. CRREI works closely with the International Atomic Energy Agency (IAEA), the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), the Australian Nuclear Science and Technology Organisation (ANSTO), the Defence Science and Technology Group (DSTG) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The CRREI is the only centre of its type within Australia and has recently been endorsed as an IAEA Capacity Building Centre for the Asia Pacific region.

CRREI's mission is to deliver innovative, timely solutions, radioanalytical services and tertiary education to industry and the community, and to support engagement with an understanding of radiation related activities. In addition, CRREI is providing and growing a network throughout Australia to develop collaborative research grant opportunities.

## Radioanalytical services

CRREI provides a modern, commercial, high throughput radioanalytical facility using the latest technologies for routine analytical services. Our staff are highly trained across several research areas including mining and mineral processing, geochemistry, medical physics and radiation biology.

- Gamma-ray Spectrometry (HPGe, SAGe)
- Alpha-particle Spectroscopy
- Alpha-particle counting
- Alpha particle autoradiography
- Alpha/Beta counting
- Food Irradiation Testing
- Environmental Radiation Dosimetry
    - o Retrospective dosimetry
    - o Nuclear forensics – Luminescence (concrete, soils, etc)
    - o Geochronology
    - o Optical Dating and Thermoluminescence Dating
    - o Quartz & Feldspar OSL; Zircon Auto-regen
- Radiation Monitoring and Imaging
    - o Radiation-sensitive optical fibres – distributed sensing
    - o Drone-borne radiation field intensity measurement
    - o Medical – beam monitoring; 3D gamma-beam imaging

## Education

Whilst other universities may offer limited courses such as medical radiation physics, CRREI is working to establish a suite of tertiary radiation education courses, including Masters, Graduate Certificates, short courses and micro-credentialing (e.g. professional development), to satisfy industry, government and research demand.

The Graduate Certificate in Radiation Management commenced in 2023 and fills the demand for qualified radiation management professionals in workplaces and industrial sites with emphasis on mining, industrial, scientific, regulatory and security sectors. The program is offered part-time over one year with lectures and tutorials delivered online and with compulsory on-campus, week-long, practical component for each

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course. This delivery method enables individuals to access the course content from remote locations and outside their working hours.

In collaboration with the IAEA, CRREI is working with national and international partner organisations to advance the CRREI as a regional hub for education on nuclear technologies and their applications. In 2023, CRREI will host for the first time in Australia, the IAEA Nuclear Engineering Management School for participants from the Asia Pacific region.

**Research**

CRREI continues to build on its previous research success and now has several research projects across a range of areas including environmental assessment, geological adsorption of radionuclides, biological effects of radiation, development of new alpha radionuclides for targeted cancer therapy, the development of beta voltaic batteries for the space and defence sectors and drone borne radiation sensors to name a few.

# Food Irradiation Testing – Regional Capability Development at the University of Adelaide

by
**N.A. Spooner[1,2,5], D. Christy[1,4], K. McDonnell[1,2], M. Saarela[3], J. Carragher[4]**

**Keywords**
Food Irradiation, OSL, ESR, dosimetry

The University of Adelaide and SARDI commenced a pilot study in 2019 aiming to investigate the feasibility of establishing a regional capability for Food Irradiation Testing (FIT).

Food Irradiation facilities administer doses ranging from 0.05 - 50 kGy of gamma-rays, X-rays or electron beams to food materials, tailored for the target material and desired outcomes - non-sterilising or sterilizing (Department of Agriculture, 2014). However, on occasion there is need to ascertain if food has been irradiated and to quantify dose if feasible - these main drivers for FIT are:

1. Verify compliance with irradiation orders
2. Certify non-irradiation of some exports
3. Detect spoilage-masking clandestine radiation

Techniques suitable for FIT include Optically Stimulated Luminescence (OSL), Infrared Stimulated Luminescence (IRSL) & Thermoluminescence (TL), with target materials including mineral grains/dusts, biogenic crystals and phytoliths. In addition, ESR (Electron spin resonance spectroscopy) can quantify dose by measuring the population of radiation damage-induced unpaired electrons, and is applicable to suitable materials such as teeth, shell, and bone (EN1786), cellulose (EN1787) and sugar (EN13708); chemical and biological methods have been studied with varying success (Chauhan et al., 2008).

Our pilot project focused solely on OSL emissions in the UV, observed during blue-light (470 nm) excitation, given OSL's very low false positive rate, availability of apparatus, applicability to samples without any prior preparation, and measurement a room temperature enabling analysis of temperature-sensitive materials.

The pilot study first tested the viability of then-existing apparatus of the Prescott Environmental Luminescence Laboratory (PELL) and Centre for Radiation Research, Education and Innovation (CRREI) for FIT, using a range of 60 foodstuffs dosed at Steritech Ltd. (Dandenong, Victoria). We reported the preliminary results at ARPS 2020; our subsequent measurement program confirmed the viability of FIT testing within PELL/CRREI.

Here we will briefly review the new results from 2021-2022, including those collected in an Honours project by DC, outlining the expansion of the testing to more food types, the discovery of new OSL signals, investigation and trialing of various sample preparation techniques, including exploring the effects of crushing or grinding, grinding under liquid nitrogen, analysis to create dose-response curves and pilot luminescence imaging utilizing the Photon-Counting Imaging System (PCIS).

The successful concept demonstration in this pilot program revealed both weaknesses in the existing Ris TL/OSL readers capability for optimum FIT analysis, and also invited further expansion of the FIT technique suite. The key

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weakness was found to be the small sample aliquot size (maximum 9.7 mm diameter) required by Ris  TL/OSL readers; the expansion opportunity is to utilize the ESR (EPR) technique to non-OSL emitting food.

The University of Adelaide Division of Research & Innovation consequently provided funding to acquire a custom-built FIT OSL reader, along with an X-ray source for high dose-rate (approx. 0.5 Gy/second), with both designed to utilize 50 mm diameter samples, which will greatly reduce the sampling issues encountered in the use of the Ris  TL/OSL readers.

In addition, a Bruker ESR spectrometer has been procured to enable the extension of the range of materials that can be analysed in SA to now include bone, cellulose, sugars etc, and also to utilize alanine dosimetry over the range 0.5 to 200 kGy.

These apparatus will also be described, as will the evolving PELL/CRREI FIT capability.

## References


Department of Agriculture (2014), Gamma irradiation as a treatment to address pathogens of animal biosecurity concern, Dept. Agriculture, Canberra.

Chauhan, S.K., Kumar, R., Nadanasabapathy, S., and Bawa, A.S. (2008) Detection Methods for Irradiated Foods. Vol.8, 2009- COMPREHENSIVE REVIEWS IN FOOD SCIENCE AND FOOD SAFETY.


## Acknowledgements


The authors thank Danielle Questiaux, Chris Kalnins and Tony Hooker for useful discussion.

Opening address, 46th ARPS Conference, 29 October – 2 November 2023

# Radiation protectionists – role and responsibilities

by
**Riaz Akber**

Submitted: 02/10/2023 Accepted: 04/10/2023

Upon the list of all that is omnipresent, the word ‘radiation’ glows near the top. Radiation is ubiquitous; its presence permeates our environment, as both a hazard and a resource. Sometimes we create or harness radiation for benefits to society; on other occasions we deal with it as a surplus – a byproduct of little use. In this duality, radiation protectionists find the essence of their work.

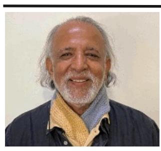
Radiation protectionists not only protect people and the environment from radiation; they also protect radiation from being subject to apprehension, rejection, and hate. This latter role of radiation protectionists must not be underestimated or ignored. They research to create knowledge and use the existing knowledge to form regulations, techniques, and equipment. They develop models and collect empirical data for validating those models.

Radiation stays as an integral part of human endeavours in the skies and on earth. We cannot view radiation protection in isolation from other processes which play a role in sustaining today’s life. Humanity has learnt a hard way that sustainability is an intergenerational responsibility. In 1987, the United Nations (UN) defined sustainability as ‘meeting the needs of the present without compromising the ability of future generations to meet their own needs.’ The UN views that ‘sustainable development requires an integrated approach that takes into consideration environmental concerns along with economic development.’ The International Atomic Energy Agency (IAEA) is committed to support the UN Sustainable Development Goals.

Radiation protection intersects with diverse sectors including energy, health, mineral extraction, security, and environmental conservation. For this reason, the radiation protectionists are stakeholders on matters affecting humanity. I, therefore, think that the time is right for blurring the boundaries between radiation protection and matters of sustainability. Modern day radiation protection cannot sit aloof on a desk outside the boardrooms where the decisions are made, they got to be in there supplying scientific insights that mitigate both perceived and actual risks. Radiation protectionists are a part of the solution and not a part of the problem.

In our corner of the globe, where ARPS lives, the South Pacific presents unique demographic and environmental contexts that make our work even more challenging. Our total land area is about 9 million km2; and 53 million people live here. This makes an average population density of only six people per km2. By comparison, neighbouring Asia has five times more land and 25 times higher population density. In the South Pacific, we have vast open lands. At the same time, large country to country variations in the traditional rural to urban human population ratios. This ratio ranges from 20% rural occupancy in some areas of the South Pacific to 80% in the others. A South Pacific radiation protectionist would, therefore, need to consider large differences in the demography and lifestyle of the representative persons. These considerations should be made proactively, at the time of initiating a project involving radiation and radioactivity, and not as an after-thought

Our coastline length per square kilometre of the land is about double than that of Asia. Our sea to land area ratio is also higher – the northern hemisphere has 39% of the total area as land, the southern half has only 19%. The marine environment is a resource for us, as well as a



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traditional and ecological responsibility. We are feeling the impact of climate change as heightened urban temperatures, ice melting, changing rainfall patterns, and rise in sea levels. It is true that the world has always been changing, but the rate of environmental change is accelerating along with the anthropogenic demands of energy, communication, health, transport, minerals, and waste management. Radiation and radiation protection cannot be a silent observer on the sidelines of this exciting and critical juncture of the proposed Anthropocene Epoch. So let the fun begin, I present to you ARPS 2023.

# Editor's Note
## Submission of Graphics (Tables and Images)

In the past, graphics (figures, tables, diagrams) were to be provided as separate files, preferably in **TIF, GIF or JPEG** format. In cooperation with Focus Printing, size is not quite the limiting factor that it was previously – that is in sending the formatted RPiA document to the printing company.

As such the editor prefers that **JPG** not be used for any of the graphics for submission. This is due to the lossy compression that JPG uses to store the image.

The preference in order of quality is **".SVG", ".TIF", ".PNG", or "GIF". SVG** is a vector graphic and is produced and edited by Inkscape, Adobe and CorelDraw. If SVG is too difficult then one of the other three formats should be used – **PNG** and **GIF** not requiring as much disc space as does **TIFF** but giving almost equivalent quality. **GIF** being the preferred option.

Following is a comparison of space requirements for the same image of the suggested formats:


As can be seen from the above the saved size can vary greatly and the quality is quite different in each format. **GIF** and **PNG** are the easiest to use (raster format), have an acceptable saved size and are generally quite good quality for editing and printing (as seen in the image below comparing GIF to JPG).


**Figure 1**. *Two images for comparison, both are of the same subject, same physical size but the top is GIF format and the bottom one is in JPG format. Note the difference in the quality of the text between the two and that the colour is "deeper" in the GIF.*

# PRESIDENT'S COMMUNIQUÉ

This is our last Journal for the year and my first message as President. I really appreciate the messages of support since Jim Hondros handed the Cup over.

Jim was the perfect person to be ARPS President during the last two years. I think we can all acknowledge the challenge he faced in leading the Society out of the “pandemic mentality”. He re-engaged interest, made connections and fostered activity. Thank you, Jim, for your energy, leadership and friendship.

As you know, the ARPS year culminated in the ARPS Conference, which was held at the Gold Coast (Queensland) from 29 October. It was so good to see old friends, meet new ones, and see what is happening outside of our immediate circle. Thank you to the local conference organising committee, led by Drew Watson, for hosting an event that was both professionally stimulating and sociable. It would be remiss of me not to mention our sponsors and exhibitors – without you, a conference is simply not viable. Several corporate members also supported the conference by each allowing several delegates to attend the conference – I know that this can have an impact on business and your continued active support is both acknowledged and appreciated.

All the organising in the world does not make a successful conference – it is you, the members of ARPS, that do this. Your active contribution, support and willingness to share information, offer sanguine advice and be inclusive is really what the conference is all about. Please continue this enthusiasm with your Branch activities as we go into the new year as there are always specific areas of interest at the local level, whether it be policy, operational or technical, that can be shared. Your contributions to the Journal, Newsletter and on-line magazine are most welcome.

Our ARPS Chatterboxes are Bridget McCarron and Amy Lubrano. I thank both of you for volunteering to develop and manage ARPS’ social media and online communications. It is a great way to maintain connections and stay informed, so please watch this space.

I would also like to take this opportunity to address concerns that were raised in a survey that was circulated prior to the conference to inform the panel session titled Setting the Scene for Nuclear. The word ‘nuclear’ did result in some emotive language. Please remember - ARPS is apolitical. ARPS is not a lobby group advocating for nuclear energy or a nuclear industry. Rather, ARPS is a Society that brings operational radiation protection practitioners together across all industry types.

Nevertheless, ARPS should be aware of and be available to assist in the technical aspects of political decision making. Should Australia move towards a more nuclear future, our remit is to support the radiation protection industry at the operational level and provide professional ‘real world’ advice to policy makers to assist them in forming policy decisions that are workable on the ground. During the panel session the panel members stimulated a lot of interest and discussion on the practicalities of a nuclear industry, and I felt that attendees were engaged. A paper on the panel session is currently being prepared which is intended to collect the thoughts of ARPS and capture our practical questions.

I am looking forward to working with Brent Le Vert, our Vice President from ‘across the ditch’, as we further strengthen the ‘Australasian’ part of ARPS. The ARPS Executive is already working towards assisting in the development of a Young Generation Network under the guidance of Ismael Khan, reaching out to our pacific neighbours to offer operational radiation protection assistance, reviewing our Strategic Plan and finalising our Executive Handbook to ensure our business practices are sound and transparent. The ARPS Executive will keep you informed on progress in these areas.

To end with a quote attributed to Albert Einstein which I think we can all relate to: “*You don’t really understand something unless you can explain it to your grandmother.*”.

Until next time,
Paula Veevers

# To the Editor – ARPS Journal,

Submitted: 13/11/2023 Accepted: 22/11/2023

To the ARPS Editor and ARPS Members,

During the 2023 ARPS Conference at SeaWorld, an impromptu panel session was held when a gap appeared in the conference program.

The panel session was facilitated by Paula Veevers and involved the undersigned as panel members. Simply, the aim of the session was to explore the question "what is dose?"

This might seem a technically easy question, however the answer depends upon your knowledge, experiences and background. The three of us have quite different and varied background and we were surprised during an informal discussion how much our answers varied and hence the idea of an opportunistic panel emerged.

Jim is from a mining background and says that "dose is a standardised measure of impact that can take into account different exposure pathways in order to compare to constraints or limits".

Pete is from a nuclear background and says "dose can either be a measure of risk or an indication of harm, depending on the type of dose"

Cameron has a mixed background, including mining, regulation and medical and says that "dose is a measure of potential impact and can also be used to measure X-ray machine performance. Dose is not KERMA."

We therefore thought that through the Journal, we would formally ask this question of ARPS members and look forward to commencing a discussion and hearing your views.

From
Jim Hondros, Peter Bryant, Cameron Jeffries

# ARPS Newsletter

Issue 69

December 2023

## Inside This Issue



## Welcome to the Australasian Radiation Protection Society Newsletter.

## Editor's Musings

Welcome to the second newsletter for 2023.

Welcome to the second newsletter for 2023.

In this issue, there are links to articles of interest for radiation protection professionals in Australia. A few more articles and links to the lost source in WA, and a few more articles on NIR safety. Some interesting general RP news along with snippets around 'lost' sources and potential radioactive sources 'discovered' in various public settings now that the national waste repository has been put on hold.

Also, an update on the 2024 conference where we will have our third 'face to face' conference post Covid.

I would love to hear from members on RP issues they would like to discuss; review, etc. so please feel free to contact me at ron.rubendra@gmail.com

## ARPS NEWS

### 2024 ARPS Conference

At the ARPS conference dinner on the Gold Coast, it was announced that the next ARPS conference (2024) will be held on 20-24 Oct 2024 at the be Pacific Bay Resort in Coffs Harbour, NSW. More details to come. Check out the venue here

<Pacific Bay Resort>.

https://arpsconference.com.au/

## RADIATION SAFETY NEWS

### International

#### Research Unveils Neutron-Shielding Film for Radiation Safety

A groundbreaking advancement in neutron shielding, a critical aspect of radiation protection, has been achieved. This breakthrough is poised to revolutionize the neutron shielding industry by offering a cost-effective solution applicable to a wide range of materials surfaces.

A research team, led by Professor Soon-Yong Kwon in the Graduate School of Semiconductors Materials and Devices Engineering and the Department of Materials Science and Engineering at UNIST has successfully developed a neutron shielding film capable of blocking neutrons present in radiation. This innovative shield is not only available in large areas but also lightweight and flexible.

"The developed Maxine-Boron carbide composite shielding film is several tens of micrometres' thick, over 1,000 times thinner than conventional commercial materials," noted Professor Kwon. "It can be effortlessly applied to various surfaces, resembling the act of painting."

Neutrons, which are integral to nuclear power generation, medical devices, and aerospace industries, possess inherent dangers when leaked. They can trigger unexpected phenomena in electronic devices or living organisms through interactions with other atoms.

More here: https://www.miragenews.com/research-unveils-neutron-shielding-film-for-1124023/

**IAEA Unveils Synergies Between Nuclear Security, Safety**

The relationship between nuclear safety and nuclear security is an aspect that underpins the IAEA's work and assistance offered to countries around the world. Now international experts, members of the Advisory Group on Nuclear Security (AdSec) and the International Nuclear Safety Advisory Group (INSAG) have issued their first joint report addressing the question of interfaces and synergies between nuclear safety and nuclear security, taking into account the developments of the last decade.

Safety focuses on ensuring proper operating conditions, preventing - or mitigating the consequences of - accidents and, hence, protecting workers, patients, the public and the environment from undue radiation hazards. In the case of nuclear security, the focus is on the prevention and detection of, and response to, criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities or associated activities.

However, the IAEA Deputy Director General and Head of the Department of Nuclear Safety and Security explains that they share the same objective. "The IAEA Fundamental Safety Principles and the Nuclear Security Fundamentals identify the overarching objective to protect people, society and the environment from harmful effects of ionizing radiation."

More here: https://www.miragenews.com/iaea-unveils-synergies-between-nuclear-security-1057890/

**DFAT Comments on Fukushima's ALPS Treated Water Release**

Australia has confidence in the process that has led to the decision by Japan to release the treated water. Australia supports the critical role of the International Atomic Energy Agency (IAEA) in Japan's plans for managing the release. In early July, the IAEA found the release of the treated water would be consistent with internationally accepted safety standards which ensure the protection of people and the environment. Australia has full confidence in the IAEA's independent, impartial, and science-based technical advice. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) issued advice on 11 July 2023 supporting the IAEA's assessment that the proposed discharge will not adversely impact people or the environment.

https://www.dfat.gov.au/news/media-release/statement-release-alps-treated-water-fukushima-daiichi-nuclear-power-plant?utm_source=miragenews&utm_medium=miragenews&utm_campaign=news

## National

### Australia to consider change to food irradiation rules

An application has been made to amend food irradiation rules in Australia.

The proposal seeks to increase the maximum permitted energy level of machines generating X-rays for irradiating food from 5 to 7.5 megaelectronvolts (MeV) as long as the X-ray target is made of tantalum or gold.

The assessment will not start until October 2023 with a comment period planned for early 2024, according to Food Standards Australia New Zealand (FSANZ).

No change is sought to currently approved foods that may be irradiated or the conditions, including the dose range. The modification involves delivery of the radiation dose. Fresh produce except dried pulses, legumes, nuts and seeds can be treated with irradiation to kill pathogens that cause foodborne illnesses. Irradiation does not make food radioactive.

The application was made by Steritech. In 2021 to 2022, the company irradiated 7,777 tons of fresh produce for export.

Reasons given by the firm for wanting the change include to increase efficiency of food irradiation and to reduce dependence on the radioactive isotope cobalt-60. X-rays are only produced when required and the radiation source can be switched off when not in use.

If operated at 7.5 MeV instead of 5 MeV, there would be a decrease in processing time and increased throughput; faster turnaround times and greater dose uniformity in food, according to the proposal.

Steritech said the change will translate to increasing the radiation processing rate from 12 pallets per hour to 17 or 18 pallets per hour. The United States, Canada, Indonesia, India and Korea have already raised the maximum permitted energy for X-ray production to 7.5 MeV, said Steritech. More here:
https://www.foodsafetynews.com/2023/01/australia-to-consider-change-to-food-irradiation-rules/

### ASNO and Geoscience Australia sign 5-year MOU for the provision of nuclear explosion monitoring services

The Australian Safeguards and Non-Proliferation Office (ASNO) and Geoscience Australia have entered a 5-year arrangement to extend their partnership on monitoring for nuclear explosions globally under the Comprehensive Nuclear-Test-Ban Treaty (CTBT).

A new Memorandum of Understanding (MOU) reaffirms their 30-year partnership since the signing of the first nuclear monitoring MOU in 1993. The MOU will see ASNO provide $3.6 million to Geoscience Australia over four years to expand the global monitoring of nuclear explosions.

Australia has a total of 21 facilities used to monitor for nuclear explosions as part of the International Monitoring System under the CTBT, the third largest of any country. These facilities are strategically positioned over a large part of the Southern Hemisphere, from Cocos Islands in the Indian Ocean to Macquarie Island in the Southern Ocean and from Darwin to Antarctica. More here:
https://www.dfat.gov.au/news/asno-and-geoscience-australia-sign-5-year-mou-provision-nuclear-explosion-monitoring-services

## Radiation Waste Storage

### Australia's nuclear waste is scattered in 'cupboards and filing cabinets' – and the pile is growing

More than 20 tonnes of reprocessed nuclear fuel will stay at Australia's only reactor in southern Sydney, while nuclear waste will remain scattered in "cupboards and filing cabinets" around the country, after the federal court blocked plans for a long-term storage site in outback South Australia.

The site in Kimba was selected more than 40 years after Australia started planning for a centralised repository. But this month, that decision was quashed by the courts.

Successive governments and agencies have said there are more than 100 sites that are storing nuclear waste littered across the land, in hospital basements and universities, on defence and mining sites and in research laboratories.

There's no definitive list, because of a licensing split between the federal and state governments, but the vast majority is produced and stored at the Australian Nuclear Science and Technology Organisation (Ansto) facility in Lucas Heights.

A national inventory published last year found Australia's 2,061 cubic metres of intermediate-level waste (ILW) will more than double to 4,377 cubic metres in the next 50 years.

More here:
https://www.theguardian.com/environment/2023/jul/29/nuclear-waste-australia-how-much-why-kimba-lucas-heights

### Arncliffe apartment Radioactive material, testing finds no evidence of exposure

Residents of a suburban Sydney street have been allowed to return home after emergency services raided an apartment block and found radioactive material.

At around 8.00am Australian Border Force (ABF) officials and Fire and Rescue HAZMAT operators began an operation at an apartment building on Kelsey Street, Arncliffe in Sydney's south.

The specialist Fire and Rescue NSW (FRNSW) crews found low level radioactive isotopes, commonly used in several industries, inside an apartment. FRNSW says the material was found in suitable and effective containers with no release of radiation and specialists were able to further seal the material without incident.

The Australian Nuclear Science and Technology Organisation (ANSTO) sent radiation and scientific support teams to assist and a 10-metre exclusion zone was established around the property.
More here:
https://www.abc.net.au/news/2023-08-17/sydney-apartment-raided-by-australian-border-force/102742424
and here,
https://www.cbsnews.com/news/australia-home-radioactive-material-discovered-uranium-nuclear/
https://www.bbc.com/news/world-australia-66530479

### Potentially hazardous': Box labelled 'yellowcake' discovered at asbestos-plagued high school

"Potentially hazardous" material has been discovered in a storeroom at NSW's largest high school, forcing the area into lockdown until specialist contractors can remove the box — which was only noticed after white powder suspected to be asbestos fell onto it.

Castle Hill High School has been embroiled in an asbestos scandal since last year, when news.com.au first revealed that thousands of students and teachers may have been exposed to the deadly building material for years even after a sample of the dust had come back positive.

More here:
https://www.news.com.au/lifestyle/parenting/school-life/potentially-hazardous-radioactive-yellowcake-discovered-at-asbestosplagued-high-school/news-story/9ede01bb678a273848e632e88496a968
and here:
https://www.theguardian.com/australia-news/2023/sep/06/castle-hill-hazardous-material-school-sydney-found

## Lost Source

### How a tiny capsule sparked debate around transport of radioactive materials

In what unfolded as a series of cinematic events in January, mining giant Rio Tinto lost a radioactive capsule in the vast expanse of the Western Australian desert. The device was smaller than the smallest Australian coin, but the search area stretched along a 1400km (870 mile) stretch of highway.

The object of the search: a small silver cylinder measuring 0.3 inches by 0.2 inches, containing a small amount of cesium-137 that makes it dangerously radioactive. What followed was a large-scale search with assistance from defence forces, emergency services and radiation experts.

While emergency teams declared it could take weeks or even months to search for the capsule, the social media sphere rose to the challenge of scriptwriting a mockumentary for the company.

More here: https://www.mining-technology.com/features/rio-tinto-radioactive-capsule-loss/?cf-view

### No charges or fines for WA's wayward radioactive pill

An investigation into the disappearance of a potentially deadly radioactive mining capsule in outback Western Australia has concluded with no charges or fines laid.

The item, measuring 8mm by 6mm, fell out of a density gauge while being trucked from a Rio Tinto mine in the Pilbara region to Perth in January.

Search crews spent six days scouring a 1400km route amid warnings the caesium-137 in the capsule could cause radiation burns or sickness if handled, and potentially dangerous levels of radiation from prolonged exposure.
The missing capsule sparked international headlines and national media coverage in addition to widespread interest in WA.

An investigation by WA's Radiological Council found no charges or fines should be laid. Dr Robertson said the next steps would be a review of the "specific, technical aspects" of the incident.

More here: https://www.illawarramercury.com.au/story/8384502/no-charges-or-fines-for-was-wayward-radioactive-pill/
And here:
https://www.australianmining.com.au/no-charges-laid-for-small-radioactive-capsule-loss/

### Australian Authorities Investigating Missing Radioactive Material

Authorities in Australia have initiated a comprehensive investigation following the reported disappearance of radioactive material from a steelworks in Whyalla, South Australia. The SA Environment Protection Authority (EPA) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) confirmed the ongoing search for a specific piece of equipment, a bin-level gauge containing a Cobalt-60 radioactive source, which is utilized for measuring stored materials in industrial silos and bins.

Despite deploying emergency response teams equipped with specialized tools for extensive radiological and physical searches, the efforts have thus far been unsuccessful in locating the missing equipment. Keith Baldry, the director of science and systems at the EPA, assured the public that the decay of the Cobalt-60 source over the past 35 years has significantly reduced its original activity, minimizing potential risks to both workers and the general public. As of now, authorities maintain the belief that the gauge remains within the premises of the steelworks.

More here: https://ibcworldnews.com/?p=116586 and here:
https://www.sbs.com.au/news/article/a-quite-small-radioactive-device-has-gone-missing-in-sa-heres-what-we-know/rf5pqruz3

## Non-Ionising Radiation

### Transmission towers – are they safe?

The Australian Energy Market Operator has said more than 10,000km of new transmission lines are needed to meet our renewable energy targets. This means new transmission towers across regional Australia.

Glenn Morrison and Marie Low talk with Associate Professor Ken Karipidis from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) about any health risks posed by transmission lines. They are also joined by Jacqui Gidley-Baird, a farmer from Dungowan in New South Wales, who has been told her family's property will be the location for two new 500 kilovolt transmission towers.

https://cosmosmagazine.com/technology/transmission-towers-are-they-safe/

### Apple says iPhone 12 meets radiation rules

Apple defended its iPhone 12 model on Wednesday after a French watchdog ordered a halt to its sales citing breaches of European Union radiation exposure limits.

The French move raised the prospect of further bans in Europe. Germany's network regulator BNetzA said it might launch similar proceedings and was in close contact with French authorities, while Spain's OCU consumers' group urged authorities there to halt the sales of the iPhone 12.

Apple said in a statement the iPhone 12, launched in 2020, was certified by multiple international bodies as compliant with global radiation standards, that it had provided several Apple and third-party lab results proving the phone's compliance to the French agency, and that it was contesting its findings.

Researchers have conducted a vast number of studies over the last two decades to assess health risks resulting from mobile phones.

More here:
https://www.reuters.com/technology/apple-disputes-french-findings-says-iphone-12-complies-with-radiation-standards-2023-09-13/

### Alarming rates of sunburn in children and young people

Parents and carers are being urged to protect their children from the sun, with an alarming number of children and young people being treated in emergency departments for sunburn.

Health Minister Ryan Park acknowledged more needs to be done to reduce the incidence of skin cancer joining NSW Chief Cancer Officer Professor Tracey O'Brien and Member for Coogee Dr Marjorie O'Neill to launch the NSW Skin Cancer Prevention Strategy 2023 to 2030 at the Prince of Wales Hospital.

"It is pretty shocking to hear more than 800 people presented last financial year to our state's emergency departments with sunburn, with the majority children and young people," Mr Park said.

"Melanoma is the deadliest form of skin cancer, and by the end of the year, we anticipate close to 6000 people in NSW will be diagnosed with this devastating cancer.

"Sun damage and skin cancers are highly preventable, and we're encouraging the community to do really simple things like seeking shade when outdoors, wearing sunscreen, putting on a hat, sunglasses and protective clothing to safeguard themselves.

More here: https://www.miragenews.com/alarming-rates-of-sunburn-in-children-and-young-1133835/

## AUKUS/Nuclear Submarines

### Green light for nuclear ships, submarines in Tas port

A Tasmanian port has been given the green light to host nuclear-powered vessels after being verified by the national safety agency.

A quarterly report by the Australian Radiation Protection and Nuclear Safety Agency said staff completed work at the Hobart port to ensure it could host such vessels and respond in an emergency.

Staff also travelled to Western Australia for a visit by two US nuclear submarines.

ARPANSA said it is helping oversee arrangements "to ensure the Australian public and the environment is safe during visits from nuclear-powered vessels".

American and British nuclear submarines will begin more frequent rotations and visits through Australian ports as part of the alliance known as AUKUS.

More here: https://www.theleader.com.au/story/8323560/green-light-for-nuclear-ships-submarines-in-tas-port/?src=rss

### Albanese government introduces naval nuclear power safety legislation

Deputy Prime Minister and Defence Minister, the Honourable Richard Marles has announced the Albanese government has introduced the Australian Naval Nuclear Power Safety Bill 2023 to support the delivery of Australia's fleet of nuclear-powered submarines.

This new legislation will establish a new, independent regulator to ensure Australia applies the highest standards of nuclear safety across its nuclear-powered submarine enterprise and can continue to implement AUKUS without delay.

The Deputy Prime Minister said: "This robust and comprehensive approach to regulating Australia's nuclear-powered submarine program recognises the Albanese government's commitment to nuclear stewardship and upholding the highest standards for nuclear safety and security."

The new legislation represents the second legislative package introduced to support the implementation of the AUKUS pathway. This new Australian Naval Nuclear Power Safety Regulator will draw on the experience of the US and the UK to deliver international best practice in nuclear safety, as the government delivers Australia's conventionally armed, nuclear-powered submarine capability.

The ANNPS Bill, when enacted, will enable the establishment of a new fit-for-purpose regulatory framework to ensure nuclear safety within Australia's nuclear-powered submarine enterprise and capability lifecycle. More here:

https://www.defenceconnect.com.au/naval/13142-albanese-government-introduces-naval-nuclear-power-safety-legislation

# ARPS Corporate Members List

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| ANSTO | Locked Bag 2001, Kirrawee DC NSW 2232<br>www.ansto.gov.au<br>www.ansto.gov.au/contact-us |
| Australian Government<br>Australian Radiation Protection and Nuclear Safety Agency | Australasian Radiation Protection and Nuclear Safety Agency (ARPANSA)<br>619 Lower Plenty Road, Yallambi VIC 3085<br>www.arpansa.gov.au<br>https://www.arpansa.gov.au/contact-us |
| CamRad radiation services | Camrad Radiation Services Pty Ltd<br>0418 154 029<br>cameron@camrad.net.au<br>https://www.camrad.net.au/ |
| Centre for Radiation Research Education and Innovation | Centre for Radiation Research Education and Innovation<br>The University of Adelaide, The Braggs Building, North Terrace, Adelaide SA 5000<br>https://www.adelaide.edu.au/crrei/<br>https://www.adelaide.edu.au/crrei/contact-us |
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## Training

If anybody would like to promote their training events and activities please contact me at: ron.rubendra@gmail.com

## Upcoming events

ARPS Conference 2024

Pacific Bay Resort

More information https://arpsconference.com.au/

ARPAB maintains a certification process to distinguish professionals who have demonstrated proficiency and knowledge in radiation safety. ARPAB also maintains a register of people who have achieved certification. The register can be referenced to determine whether a person has been awarded such certification.

Persons on the register have been assessed in both a general knowledge of radiation protection principles, and an in-depth knowledge in their areas of radiation safety expertise. As part of the certification process, ARPAB provides both examiners for the theoretical component, and assessors for the practical evaluation of applicants. Once certification has been awarded and a person is placed on the register, they need to demonstrate to ARPAB that they have maintained their professional skills for their certification to be renewed.

ARPAB holds regular meetings to review applications for certification, approve applicants who have passed the requirements for certification, and to provide advice to those who need to broaden their knowledge or skills to attain the standards required.

The work of ARPAB is funded by the charges levied for the initial certification process, renewal fees for remaining on the register, and support from the sponsoring societies. Secretarial services are kindly provided by ARPS, and members of ARPAB as nominees of the sponsoring societies provide their services on a voluntary basis.

Businesses, regulatory bodies and the public can be assured that by engaging a person with ARPAB certification for radiation safety advice, the advice is being provided by a person who has had their competency assessed, and is bound by ARPAB's Code of Ethics.

**GAINING CERTIFICATION**
If you would like to see what's involved in obtaining ARPAB certification, or you wish to do some study ahead of submitting your application, download and read the Candidate's kit…

ARPAB-Candidates-Kit-2021 (https://www.arpab.org.au/how-to-get-accredited/)

Ready for assessment? Just download this application form…
20200110-ARPAB-application-form

…and send it to the ARPAB Secretariat at: office@arpab.org.au.

## Notes for Journal Contributors

The Australasian Radiation Protection Society invites contributors of original scientific articles, technical notes, discussion papers and comments on topics concerned with radiation safety including:

* ionizing and non-ionizing radiation hazards
* occupational, public and environmental radiation protection standards
* radiation protection practice
* radiation protection in relation to medical applications of radiation
* physiological, histological and epidemiological studies related to radiation protection
* radioactive waste disposal
* radiation dosimetry and standardisation
* techniques of measurement of radiation parameters
* education in radiation matters, and the provision of information to the public

Manuscripts submitted for publication as journal articles may be refereed; if accepted, they are annotated: 'Article', 'Technical Note', 'tutorial paper' etc. on the title page. Other contributions may be accepted for publication without refereeing, subject to editorial discretion; they are marked: 'Contribution'. In accordance with the Society's policy, any paper presented at an annual conference of the Australasian Radiation Protection Society may be published, without refereeing, for public record; such papers are marked: 'Conference Paper'.

Please provide hard copy of article plus text and graphics electronically with the following properties:

### TEXT

- In MS Word or LibraOffice writer
- Using Times New Roman 10 point type or equivalent
- Single spacing
- No formatting of paragraphs (e.g. no 2.44mm before and 1.23mm after each paragraph - often used to set heads or subheads away from text) or text (no columns)
- One line space between paragraphs
- One space between sentences
- Headings in plain or bold type, but not italic; and subheads in upper and lower (NOT all in UPPER) case
- Include contact details and a very short note about your speciality for the author title and description plus the possibility of a head photo

References in the text should be indexed by a number (eg.,7) and listed at the end thus:

7. Rosen, R., and Bartolo, W., "An Alternative Method of Quantifying the Safety of Radioisotope Laboratories", Radiation Protection in Australasia (2014), Vol 31 No.1, pp. 2-15

### PICTURES, FIGURES, GRAPHICS AND TABLES

Graphics (figures, tables, diagrams) should be provided as separate files, preferably in **SVG, TIF, GIF** or **PNG** format, but Word compatible graphics and figures are acceptable. Colour for graphics is acceptable. **SVG** or **GIF** being the preferred options.

The Quality of the graphics is to be vector (or raster if vector is not possible) graphics of a minimum of 600 DPI.

Indicate position in text by (Figure 1 here) followed by text for caption, e.g:

(Figure I here)
Figure I, Age distribution for diagnostic examinations

Letters to the Editor should include the full name and address of the author.

Please address Journal correspondence to: Mr W Bartolo, Editor, Radiation Protection in Australasia, PO Box 264, Jannali, NSW, 2226. Tel: 0479 070 151. Email: bartolo-safety@hotkey.net.au OR the ARPS Secretariat address below.

**Scheduled publication dates and deadlines:**

| Deadline for Articles | Publication Date |
|---|---|
| 1 April | May |
| 1 October | November/December |

Off-Prints of contributed articles are available as electronic versions provided that they are requested well before publication. Individual issues and back issues (if available): $10 (Members), $25 (Non-members). Library subscription rate: $50 p.a. Contact the ARPS Secretariat for back issues and subscription information.

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# RADIATION PROTECTION IN AUSTRALASIA

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