NORM WORKING GROUP MEMBERS

<table>
<thead>
<tr>
<th>Name</th>
<th>Country/Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>J Duffy</td>
<td>Ireland</td>
</tr>
<tr>
<td>M Morshuizen</td>
<td>Netherlands</td>
</tr>
<tr>
<td>D Daigle</td>
<td>Canada</td>
</tr>
<tr>
<td>S Fallle</td>
<td>Canada</td>
</tr>
<tr>
<td>A Eshraghi</td>
<td>Iran</td>
</tr>
<tr>
<td>M Charette</td>
<td>Canada</td>
</tr>
<tr>
<td>R Chavasse</td>
<td>TIC</td>
</tr>
<tr>
<td>B H Lee</td>
<td>Korea</td>
</tr>
<tr>
<td>Y Hirao</td>
<td>Japan</td>
</tr>
<tr>
<td>I Hasanuddin</td>
<td>Indonesia</td>
</tr>
<tr>
<td>S Sarkar</td>
<td>Australia</td>
</tr>
<tr>
<td>N Bruno</td>
<td>Brazil</td>
</tr>
<tr>
<td>B Mohamed</td>
<td>Egypt</td>
</tr>
<tr>
<td>F Koch</td>
<td>Switzerland</td>
</tr>
<tr>
<td>J Templeton</td>
<td>Australia</td>
</tr>
<tr>
<td>R Boyle</td>
<td>USA</td>
</tr>
</tbody>
</table>

Application of the Regulations for the Safe Transport of Radioactive Material to the Transport of Mining and Mineral Processing
1.0 PURPOSE

The following discussion is based on the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6, 2012)[1] and Advisory Material for these Regulations (SSG-26, 2014)[2].

The purpose of this document is to provide guidance to Mining and Minerals Processing users with regards to the correct packaging and transport of materials in compliance with the requirements of the International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Material. Hereafter called the IAEA Regulations.

2.0 SCOPE

In order to define the Scope of industries included within this Guide it is first necessary to define what is meant by NORM.

Referring to the IAEA Safety Glossary 2007 Edition definition of mining and mineral processing;

Naturally Occurring Radioactive Material (NORM)

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
- Naturally Occurring Radioactive Material or MINING AND MINERALS PROCESSING should be used in the singular unless reference is explicitly being made to various materials

In contrast to the above the same IAEA Glossary defines “naturally occurring radionuclides” as;

Naturally Occurring Radionuclides

Radionuclides that occur naturally on earth in significant quantities

The term is usually used to refer to the primordial radionuclides Potassium 40, uranium 235, uranium 238 and thorium 232 and their radioactive decay products

Contrasted with radionuclides of artificial origin, and also with artificial radionuclides, anthropogenic radionuclides and human-made radionuclides.

Although the term mining and mineral processing covers many industries this text is aimed at those industries where the radioactivity levels are low enough to warrant discussions on exemption and serves to clarify the process of determining exemption.
The requirements for the transport of mining and minerals processing materials are not industry specific. However, the material which is required to be transported is industry specific and in this regard the exact transport requirements per industry would be defined by the material to be transported. These exact industry-specific requirements would be composed of the requirements given below.

3.0 LEGAL INFRASTRUCTURE

Persons transporting mining and minerals processing materials, either domestically or internationally, must do so in compliance with all applicable transport requirements required by their recognised competent authority as well as by the requirements of the IAEA Regulations.

4.0 DETERMINING IF THE MATERIAL TRANSPORTED IS EXEMPT FROM THE REGULATIONS?

4.1 Exemption from Regulation Vs Exemption for Transport

At the outset it is essential that the user understands that should a shipment of materials satisfy the criteria for Exemption from the need to comply with the IAEA Regulations, this does not imply that the material is Exempt from the need to be authorised under the requirements for the authorisation of radioactive material, as determined within the users country by the regulatory authority.

Exemption for transport purposes, and Exemption from authorisation, are two separate processes, each with their own specific criteria, and should not be confused.

4.2 Transport within the Boundaries of an authorised Site is Exempt.

If the transport is within the boundaries of an authorised mining/processing site, the IAEA Regulations are not applicable. The authorisation of the site being in accordance with the local regulations pertaining to the use of radioactive material. This is in accordance with para 107(b) of the IAEA Regulations:

107. The Regulations do not apply to:

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

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

4.3 Exemption on the Basis of the Definition of Radioactive Material

The following discussion applies only in instances where the material is relatively low in activity and where there may be a need to prove exemption from the IAEA Regulations. In instances where the radioactivity of the material is
relatively high it may be obvious that exemption is not an option. This region is not within the scope of this text.

If the material is not exempt from the perspective of being transported on an authorised facility we next need to ask the question;

Does the material meet the definition of Radioactive Material?

The definition of “radioactive material”, for transport purposes, is given in paragraph 236 of the IAEA Regulations as follows;

Paragraph 236

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 paragraphs 402 – 407

The key phrase in paragraph 236 is;

**BOTH** the activity concentration **AND** the total activity in the consignment

Hence, to be exempt from the IAEA Regulations it is not necessary that **BOTH** the activity concentration limit **AND** the total activity limit be satisfied. As long as one of these limits is not exceeded the material is exempt from the IAEA Regulations.

4.3.1 Exempt by way of the Activity Limit for an Exempt Consignment.

**NOTE:**

It is common practice, in the minerals industry, to quote material activity concentration in parts per million (ppm). This is not very helpful when comparing with the IAEA Regulations which require values in Bq/g.

The following equation is used to estimate the activity of the material, based on ‘parts per million’ (microgram per gram) figures typically obtained by laboratory analysis, and assuming that thorium and uranium are 100% of $^{232}$Th and $^{238}$U respectively:

$$
\text{Th (μg/g) } \times 4.055 \times 10^{-3} \text{ Bq/μg } ^{232}\text{Th } + \text{ U (μg/g) } \times 1.2384 \times 10^{-4} \text{ Bq/μg } ^{238}\text{U } = \\
\text{activity of the material (Bq/g).}
$$

Looking at an extract from Table 2 of the IAEA Regulations;
If we are trying to make a decision on a consignment containing only Ra-228 (not a very realistic example but it serves to illustrate the point). We first need to decide if the consignment is even classified as “radioactive material” in accordance with the IAEA Regulations.

For this we need to consider both the “Activity Concentration limit for exempt material” (column 3 of Table 2) as well as the “Activity limit for an exempt consignment” (column 4 of Table 2) as indicated above.

If the **Total radioactivity** in the shipment is less than, the **Activity limit for an exempt consignment** (in this example 1 x 10^5 Bq,) then the shipment is not defined as radioactive material and is Exempt from the need to be shipped in accordance with the IAEA Regulations.

This is irrespective of the value of the activity concentration as compared against the “Activity concentration for exempt material” in column 3 since the material is already below one of these Limits.

In this example this is a very small quantity of radioactive material and typically might only be satisfied for a small shipment, perhaps a sample being sent to a laboratory for analysis.

Should the total quantity of activity in the shipment exceed the “Activity limit for an exempt consignment” and we still wish to seek exemption, then we must consider the activity concentration of the material and compare it against the “Activity concentration limit for exempt material”.

### 4.3.2 Exemption by way of Activity Concentration

**Determination of Activity Concentration and Exemption**

Once again, using our example of a shipment comprising only Ra-228, if we wish to test exemption based upon Activity concentration then, in this example, we need only compare the activity concentration of Ra-228 against the Limit shown for Ra-228 in column 3 of Table 2.

This Limit is given as 1 x 10^1 Bq/g (10 Bq/g).
Hence we might think that if our material to be transported has an activity concentration of 10 Bq/g then we are exactly on the Limit. However we must take account of paragraph 107 (f) which reads:

These 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;

This paragraph deals with instances where the IAEA Regulations do not apply and tells us that, in comparing our Ra-228 activity concentration with the Limit from column 3, we must multiply the Limit by a factor of 10. Hence we must compare the activity concentration of our shipment against a Limit of 100 Bq/g.

If our shipment activity concentration is below this Limit of 100 Bq/g then the material is exempt.

An important thing to notice is that the factor of 10 is applied only to the Activity concentration limit and not to the Activity for an exempt consignment limit.

Hence, up to this point, for our unrealistic shipment consisting of only Ra-228, the exemption options are as follows:

<table>
<thead>
<tr>
<th>Material to be Transported</th>
<th>Activity concentration limit for exempt material</th>
<th>Activity limit for exempt consignment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 Bq/g</td>
<td>10 000 Bq</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case</th>
<th>Activity concentration</th>
<th>Total activity</th>
<th>Exemption status of material to be transported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110 Bq/g</td>
<td>90 000 Bq</td>
<td>Exempt</td>
</tr>
<tr>
<td>2</td>
<td>90 Bq/g</td>
<td>200 000 Bq</td>
<td>Exempt</td>
</tr>
<tr>
<td>3</td>
<td>100 Bq/g</td>
<td>100 000 Bq</td>
<td>Exempt</td>
</tr>
<tr>
<td>4</td>
<td>110 Bq/g</td>
<td>120 000 Bq</td>
<td>Not Exempt</td>
</tr>
</tbody>
</table>

5.0 Determining Exemption for a Mixture of Radionuclides

5.1 The Mixtures Equation
In reality mining and minerals processing materials are in fact a mixture of radionuclides. Hence we will never have the situation where we have a material having only a single radionuclide.

If we consider the material to be a mixture of radionuclides then, in accordance with paragraph 107 (f) we determine the Activity concentration limit for exempt material by using the Mixtures Equation given in paragraph 405.

**Paragraph 405**

405. For mixtures of radionuclides, the basic radionuclide values referred to in para. 402 may be determined as follows:

\[
X_m = \frac{\sum_i f(i) X(i)}{\sum_i f(i)}
\]

Where

- \(f(i)\) is the fraction of activity or activity concentration of radionuclide \(i\) in the mixture.
- \(X(i)\) is the appropriate value of \(A_1\) or \(A_2\) or the activity concentration limit for exempt material or the activity limit for an exempt consignment as appropriate for the radionuclide \(i\).
- \(X_m\) is the derived value of \(A_1\) or \(A_2\), or the activity concentration limit for exempt material or the activity limit for an exempt consignment in the case of a mixture.

This paragraph makes reference to paragraph 402 which reads;

**Paragraph 402**

402. The following basic values for individual radionuclides are given in Table 2:

(a) \(A_1\) and \(A_2\) in TBq;

(b) Activity concentration limits for exempt material in Bq/g;

(c) Activity limits for exempt consignments in Bq.

The underlining on items (b) and (c) is the authors and points out that, for a mixture, we determine the “Activity limit for an exempt consignment” as well as the “Activity concentration for an exempt material” by application of the Mixtures Equation to all the nuclides in the mixture.

Meaning that in calculating the activity concentration limit for exempt material for a mixture we let \(f(i)\) be the fractional activity in the mixture for nuclide \(i\) while when calculating the Activity limit for exempt consignment, for the mixture, we let \(f(i)\) be the fraction of activity for nuclide \(i\) in the total mixture.

Telling us that when calculating the Activity concentration for exempt material for a mixture we let the \(X(i)\) be the Activity concentration limit for exempt material for nuclide \(i\), while

When calculating the Activity limit for an exempt consignment, for a mixture, we let \(X(I)\) be the Activity limit for exempt consignment for nuclide \(i\).
This is well and good but there is a practical problem.

When calculating the $f(i)$ when determining the Activity concentration limit for exempt material, we have measured the activity concentrations of the individual nuclides. Then we simply need to take, for each measured radionuclide, the ratio;

If

$$AC^i = (\text{Measured activity concentration of nuclide } I \text{ in the mixture})$$

And

$$Ga = (\text{Gross activity concentration of the mixture})$$

$$f(i)^c = \text{The fraction of activity concentration of radionuclide } i \text{ in the mixture.}$$

Then;

$$f(i)^c = \left(\frac{AC^i}{Ga}\right)$$

This would suggest that the way to do this calculation when determining the Activity limit for exempt consignment is as follows;

If;

$$Ta^i = (\text{Total activity of nuclide } I \text{ in the mixture})$$

And

$$Ta^M = (\text{Total activity of the mixture})$$

$$f(i)^T = \text{The fraction of activity of radionuclide } i \text{ in the mixture.}$$

Then

$$f(i) = \left(\frac{Ta^i}{Ta^M}\right)$$

The problem here is that we do not know the value of $Ta^i$ for any nuclide in the mixture.

Paragraph 505.3 of SSG 26 helps us here;

405.3. Calculation of the activity concentration for exempt material is only permitted in the case of a homogeneous mixture, since the models for determining these activity concentrations are based on the assumption that the isotopes are distributed homogeneously throughout the material. Issues relating to homogeneity are discussed in paras 409.5 and 409.10–409.14.
This tells us that we may only use the Mixtures Equation if the mixture is homogenous.

This being the case

\[ f(i)^T = f(i)^C \]

Hence, more realistically, for a mixture of radionuclides, we determine the Activity concentration limit for exempt material and the Activity limit for an exempt consignment from use of the Mixtures Equation.

The use of the Mixtures Equation is summarised in Appendix 2

### 5.2 Natural Uranium Or U_{natural}

You will notice that Table 2 contains values for both U_{natural} and Th_{natural} as well as values for the individual radionuclides which would be contained in a MINING AND MINERALS PROCESSING sample (in varying concentrations). You will also notice that paragraph 247 defines “natural uranium”. How do these materials feature in our considerations?

(See Appendix 1 Response from the TRANSSC Working Group on A1 and A2 values on proposals WNTI/6 and USA/2015/10 for a discussion on this point)

In determining exemption, in some cases we should compare the material gross activity concentration against the U_{natural} or Th_{natural} values, while in other cases we should take the Table 2 entries for all of the Uranium/thorium isotopes given in Table A below

<table>
<thead>
<tr>
<th>Table A.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uranium-238</strong></td>
</tr>
<tr>
<td><strong>Uranium-235</strong></td>
</tr>
<tr>
<td><strong>Thorium-232</strong></td>
</tr>
</tbody>
</table>

And enter these values into the Mixtures Equation in order to determine, for that specific shipment, the Activity concentration for exempt material and the Activity limit for exempt consignment.

Except that, since the percentage abundance of U-235 in nature is only 0.72%, and since the processing of MINING AND MINERALS PROCESSING in no way enriches this percentage, you may be forgiven for not including the isotopes in the U-235 chain.

### 5.2.1 Natural Uranium

Para 247 of the Regulations 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 nuclide mixture of the uranium chain may be disrupted but that the uranium nuclide mixture ($^{238}\text{U}$ to $^{235}\text{U}$ ratio) is undisturbed (the uranium is not enriched in the $^{235}\text{U}$ isotope).

5.2.2 $U_{\text{natural}}$

“$U_{\text{natural}}$” is not the same as “natural uranium”. Whilst “natural uranium” refers to the non-enriched but possibly chemically separated uranium, “$U_{\text{natural}}$” refers to chemically undisturbed uranium in secular equilibrium.

Therefore, mining and minerals processing material which has not been subjected to any chemical or thermal processing of any kind may be considered as “$U_{\text{natural}}$”.

This same argument applies to Thorium ores which have not been processed and may be classified as $Th_{\text{natural}}$.

5.2.3 When to Use Natural Uranium and when to Use $U_{\text{natural}}$

5.2.3.1 Material that has not been the Subject of Chemical or Thermal Processing

It is very unlikely that secular equilibrium for both thorium and uranium chains will be disrupted during the simple physical concentration/separation of mineral concentrates, such as, for example, gravimetric separation of heavy mineral sands.

Considering paragraph 107 (f) we may split the paragraph into two parts;

107 (f) [Part 1]

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.

107 (f) [Part 2]

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;

Hence, in cases where the material is in secular equilibrium we use Part 1 of paragraph 107 (f).

In this case the determination of exemption status is a matter of comparing the value of the parent nuclides ($U$-238 or $Th$-232) against the $U_{\text{natural}}$ or $Th_{\text{natural}}$ values from Table 2.
5.2.3.2 Material that has been Subjected to Chemical or Thermal Processing

In cases where the material is not in secular equilibrium we use Part 2 of paragraph 107 (f);

It is not always clear which form of processing would lead to the material no longer being in secular equilibrium and further clarification on this point should be sought from your competent authority.

However the following paragraph 107.4 of SSG-26 provides some guidance;

“For ores and other natural or processed materials containing natural occurring radionuclides of the uranium–radium and/or thorium decay chain, the basic nuclide values for exempt activity concentration as given in Table 2 for U_{\text{natural}} and Th_{\text{natural}} can only be used if the radionuclides are in secular equilibrium. If this is not the case, this means that owing to processing activities such as chemical leaching or thermal treatment, the natural radioactive equilibrium state does not exist and the formula for mixtures of radionuclides according to para. 405 has to be applied to calculate the exempt activity concentration.”

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

a) Any chemical processing of the material, such as leaching or adding flotation agents to the process;
b) Any thermal processing of the material. Due to the variety of different materials in the industry 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 250-300°C is suggested as a general guide at which additional analysis of the material may be required.

If the complete analysis of the material has been carried out

Typically, the analysis of the material for some isotopes in both thorium and uranium chains is carried out. In some cases the results for each and every radionuclide in each chain are also obtained.

As to which radionuclides should be measured and which may be assumed it may be said that, unless a good motivation can be provided for any exclusions, all radionuclides listed in Table A of this document, should be used in the mixtures calculation. An exception here are the radionuclides in the U-235 chain which, although listed in Table 2, are considered (In the absence of any U-235 enrichment) to be too low for inclusion.

Of course this should be confirmed with your competent authority. It should also be confirmed with your competent authority, whether you will need to prove exemption
for each and every shipment or whether they will be prepared to accept only one proof of exemption or periodic proof of exemption.

**If the complete analysis of the material has not been carried out**

This method can be used when the detailed information about radionuclide concentrations in the material is not available.

Table 3 in para 407 of the IAEA Regulations suggests the values that should be used in these circumstances.

<table>
<thead>
<tr>
<th>Radioactive content</th>
<th>$A_1$ (TBq)</th>
<th>$A_2$ (TBq)</th>
<th>Activity concentration limit for exempt material (Bq/g)</th>
<th>Activity limit for an exempt consignment (Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only beta or gamma emitting nuclides are known to be present</td>
<td>0.1</td>
<td>0.02</td>
<td>$1 \times 10^1$</td>
<td>$1 \times 10^4$</td>
</tr>
<tr>
<td>Alpha emitting nuclides, but no neutron emitters are known to be present</td>
<td>0.2</td>
<td>$9 \times 10^{-5}$</td>
<td>$1 \times 10^{-1}$</td>
<td>$1 \times 10^3$</td>
</tr>
<tr>
<td>Neutron emitting nuclides are known to be present or no relevant data are available</td>
<td>0.001</td>
<td>$9 \times 10^{-5}$</td>
<td>$1 \times 10^{-1}$</td>
<td>$1 \times 10^3$</td>
</tr>
</tbody>
</table>

407. For individual radionuclides or for mixtures of radionuclides for which relevant data are not available, the values shown in Table 3 shall be used.

Hence, if Table 3 values are used;

(associated activity concentration limits multiplied by the factor of 10 for ‘natural material’ [paragraph 107 (f)] are presented in the brackets):

- **Only beta or gamma emitting nuclides are known to be present** (100 Bq/g)
- **Alpha emitting nuclides, but no neutron emitters, are known to be present** (1 Bq/g)
- **Neutron emitting nuclides are known to be present or no relevant data are available** (1 Bq/g)

As it would be very rare that a mineral to be transported has only beta and gamma emitting nuclides the value of 100 Bq/g should only be used when the absence of alpha emitting nuclides has been conclusively proven.
Again the use of Table 3 should be confirmed with your competent authority.

6.0 Determination of the Classification of MINING AND MINERALS PROCESSING

This Section discusses the steps used to classify the material for transport labelling purposes.

Correct material Classification will ensure that the proper placards are displayed during the transport.

**Determination of Transport Index**

Firstly, there is a need to determine the Transport Index (TI) and the Category of the consignment.

Para 523:

523. The TI for a package, overpack or freight container, or for unpackaged LSA-I or SCO-I, shall be the number derived in accordance with the following procedure:

(a) Determine the maximum radiation level 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 and SCO-I. The value determined shall be multiplied by 100 and the resulting number is the TI. For uranium and thorium ores and their concentrates, the maximum radiation level at any point 1 m from the external surface of the load may be taken as:

(i) \(0.4\ mSv/h\) for ores and physical concentrates of uranium and thorium;

(ii) \(0.3\ mSv/h\) for chemical concentrates of thorium;

(iii) \(0.02\ mSv/h\) for chemical concentrates of uranium, other than uranium hexafluoride.

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

Typically there are two transport situations where we need to determine the TI of the shipment.

**Case 1: Non-Packaged MINING AND MINERALS PROCESSING in a Transport Vehicle;**

If we are presented with a transport containing loose MINING AND MINERALS PROCESSING, as in the picture below;
Determining the TI is a matter of conducting the measurements described above and then multiplying the value from step (a) by a value from Table 7 of the IAEA Regulations;

**TABLE 7 - MULTIPLICATION FACTORS FOR TANKS, FREIGHT CONTAINERS, AND UNPACKAGED LSA-1 AND SCO-P**

<table>
<thead>
<tr>
<th>Size of load $\leq 1 \text{ m}^3$</th>
<th>Multiplication factor $\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1 \text{ m}^3 &lt; \text{ size of load} \leq 5 \text{ m}^3$</td>
<td>2$\beta$</td>
</tr>
<tr>
<td>$5 \text{ m}^3 &lt; \text{ size of load} \leq 20 \text{ m}^3$</td>
<td>3$\beta$</td>
</tr>
<tr>
<td>$20 \text{ m}^3 &lt; \text{ size of load}$</td>
<td>10$\beta$</td>
</tr>
</tbody>
</table>

$L\beta$ - Largest cross-sectional area of the load being measured.

**Case 2:** MINING AND MINERALS PROCESSING packaged in individual packagings and then loaded onto a transport vehicle.

If our MINING AND MINERALS PROCESSING has been packaged into individual Type IP-1 containers (for example) as below;
How do we determine the TI in this case?

Paragraph 524 provides the method.

524. The TI for each overpack, freight container or conveyance shall be determined as either the sum of the TIs of all the packages contained, or by direct measurement of radiation level, except in the case of non-rigid overpacks, for which the TI shall be determined only as the sum of the TIs of all the packages.

Hence we could determine the TI per IP-1 container (as per the methodology above) and then simply sum the TI values for all the IP-1 packages on the transport.

Once the Transport Index (TI) has been determined we then proceed to Paragraph 529 and Table 8 to determine the Category of the shipment.

Para 529:

529. Packages, overpacks and freight containers shall be assigned to either category I-WHITE, II-YELLOW or III-YELLOW in accordance with the conditions specified in Table 8 and with the following requirements:

(a) For a package, overpack or freight container, the TI and the surface radiation level conditions shall be taken into account in determining which category is appropriate. Where the TI satisfies the condition for one category but the surface radiation level satisfies the condition for a different category, the package, overpack or freight container shall be assigned to the higher category. For this purpose, category I-WHITE shall be regarded as the lowest category.

(b) The TI shall be determined following the procedures specified in paras 523 and 524.
(c) If the surface radiation level is greater than 2 mSv/h, the package or overpack shall be transported under exclusive use and under the provisions of paras 573(a), 575 or 579, as appropriate.

(d) A package transported under a special arrangement shall be assigned to category III-YELLOW except under the provisions of para. 530.

(e) An overpack or freight container that contains packages transported under special arrangement shall be assigned to category III-YELLOW except under the provisions of para. 530.

The category of the load is determined based on the transport index and the radiation level on external surface.

It is important to note the difference – transport index is determined by measuring radiation levels at a distance of 1 metre from the shipment, for categorisation of the load an additional measurement on the surface is required.

<table>
<thead>
<tr>
<th>Conditions:</th>
<th>Maximum radiation level at any point on external surface:</th>
<th>Category:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>Not more than 0.005 mSv/h</td>
<td>I-WHITE:</td>
</tr>
<tr>
<td>More than 0° but not more than 1°</td>
<td>More than 0.005 mSv/h but not more than 0.5 mSv/h</td>
<td>II-YELLOW:</td>
</tr>
<tr>
<td>More than 1° but not more than 10°</td>
<td>More than 0.5 mSv/h but not more than 2 mSv/h</td>
<td>III-YELLOW:</td>
</tr>
<tr>
<td>More than 10°</td>
<td>More than 2 mSv/h but not more than 10 mSv/h</td>
<td>III-YELLOW:</td>
</tr>
</tbody>
</table>

† If the measured TI is not greater than 0.05, the value quoted may be zero in accordance with para. 523(c)***

† † Also be transported under exclusive use except for freight containers, see Table 10. |
7.0 Labelling

In accordance with paragraph 548 of the IAEA Regulations;

538. Each package, overpack and freight container shall bear the labels conforming to the applicable models in Figs 3-5, except as allowed under the alternative provisions of para. 543 for large freight containers and tanks, according to the appropriate category. In addition, each package, overpack and freight container containing fissile material, other than fissile material excepted under the provisions of para. 417, shall bear labels conforming to the model in Fig. 5. Any labels that do not relate to the contents shall be removed or covered. For radioactive material having other dangerous properties see para. 507.

Figure 3
Figure 4
8.0 Placarding

Large freight containers carrying packages other than excepted packages, and tanks shall bear three placards, which conform with the model given below. The placards shall be affixed in a vertical orientation to each sidewall and to the back tailgate of the large freight container or transport. Any placards, which do not relate to the contents shall be removed.

Figure 3 Placard

Except as permitted by para. 570 minimum dimensions shall be as shown; when different dimensions are used the relative proportions must be maintained. The number ‘7’ shall not be less than 25 mm high. The background colour of the upper half of the placard shall be yellow and of the lower half white, the colour of the trefoil and the printing shall be black. The use of the word “RADIOACTIVE” in the bottom half is optional to allow the alternative use of this placard to display the appropriate United Nations number for the consignment.
Figure 4 Placard for separate displays of United Nations number. The background colour of the placard shall be orange and the border and United Nations number shall be black. The symbol “****” denotes the space in which the appropriate United Nations number for radioactive material, as specified in Table VIII of the IAEA Regulations, shall be displayed.

Instead of using both labels and placards, it is permitted as an alternative to use enlarged labels only. (Differences between ADR and IMO in accordance with regards to the number of labels – CHECK !) (4 by sea and 3 by road)

Where the consignment in the freight container or transport is unpackaged LSA-I or SCO-I or where an exclusive use consignment in a freight container is packaged radioactive material with a single United Nations number, the appropriate United Nations number for the consignment shall also be displayed, in black digits not less than 65 mm high, either:

(a) in the lower half of the placard shown below, preceded by the letters “UN” and against the white background, or

(b) on the placard shown (Replace the “ * ” s by the appropriate UN number – e.g. 2912)

Typically MINING AND MINERALS PROCESSING shipments will comprise either surface contaminated objects (SCO-1 items) or mineral sands (LSA-1 material). This being the case only two UN Numbers will be applicable as follows;
<table>
<thead>
<tr>
<th>Material</th>
<th>UN Number</th>
<th>UN Proper Shipping Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UN-2912</td>
<td>RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-I), Non-Fissile or Fissile Excepted</td>
</tr>
<tr>
<td></td>
<td>UN-2913</td>
<td>RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-I OR SCO-II), Non-Fissile or Fissile Excepted</td>
</tr>
<tr>
<td></td>
<td>UN-2910</td>
<td>RADIOACTIVE MATERIAL, EXCEPTED PACKAGE LIMITED QUANTITY OF MATERIAL</td>
</tr>
</tbody>
</table>

Labelling the individual Drums

As appropriate following the Categorisation exercise.
8.0 Low Specific Activity Material:

Paragraph 226 defines;

Low specific activity material

226. 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.

There are 3 Classes of LSA material defined in the IAEA Regulations;

- LSA-1
- LSA-II
- LSA-III

The LSA Classification of your material will determine the permitted packaging options by way of Table 5 as well as the conveyance activity limits by way of Table 6 of the IAEA Regulations.

Looking at paragraph 409

Para 409 LSA material shall be in one of three groups (we are here only interested in the first group);
(a) LSA-I

(i) Uranium and thorium ores and concentrates of such ores, and other ores containing naturally occurring radionuclides which are intended to be processed for the use of these radionuclides;
(ii) Natural uranium, depleted uranium, natural thorium or their compounds or mixtures, that are unirradiated and in solid or liquid form.
(iii) Radioactive material for which the $A_2$ value is unlimited. Fissile material may be included only if excepted under para. 417.
(iv) Other radioactive material in which the activity is distributed throughout and the estimated average specific activity does not exceed 30 times the values for activity concentration specified in paras 401–405, excluding fissile material in quantities not excepted under para 672.

It must be noted that in using paragraph iv) to define the upper limit for LSA-I material and the transition to LSA-II, the factor of x10 (from paragraph 107 (f)) is not to be used in conjunction with the x 30 factor.

The above are the four criteria for a material to be classified as LSA-I material.

Generally, mining and minerals processing materials will be Classified as LSA-I by virtue of paragraph 409 (iii);

This is because if you look at Table 2, of the IAEA Regulations, at all the entries for nuclides related to either the U-238 chain or the Th-232 chain you will notice that they all have “unlimited” as their $A_2$ value.

However, since both Ra-226 and Ra-228 do not have unlimited $A_2$ values, in Table 2, any materials having significant (as defined by the regulatory authority) quantities of either radionuclide could be classified as either LSA-I or LSA-II.

**Paragraph iv) LSA-II**

(iii) Radioactive material for which the $A_2$ value is unlimited. Fissile material may be included only if excepted under para. 417.

Hence, by Table 5 (Page 62):
LSA I MINING AND MINERALS PROCESSING may be packaged in Type IP-1 containers.

LSA I MINING AND MINERALS PROCESSING may also be transported unpackaged but care should be taken to cover the load so as to prevent blow-off or spillage.

Additionally, by Table 6 on page 63 of the IAEA Regulations:

**Table 6: Conveyance activity limits for LSA I material and SCO in industrial packages or unpackaged**

<table>
<thead>
<tr>
<th>Nature of material</th>
<th>Activity limit for conveyances other than inland waterway craft</th>
<th>Activity limit for a hold or compartment of an inland waterway craft</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSA I</td>
<td>No limit</td>
<td>No limit</td>
</tr>
</tbody>
</table>

Conveyance activity limits for LSA II

There is no limit to the total activity within the conveyance during transport.

*All material containing only naturally occurring radionuclides which are above the exemption quantities for transport, are 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.*
ADDITIONAL TEXT ON EXCEPTED PACKAGES

1. Determination if the shipment can be transported as ‘excepted package’

There is a possibility that the load can be classified as excepted package (please note the difference with exempted package [activity less than 10 Bq/g], when Regulations do not apply at all).

The main criterion for the determination of the excepted package is in the para 516: The radiation level at any point on the external surface of an excepted package shall not exceed 5 microSv/h.

The other criteria for classification as an excepted package is that the activity is a fraction of the A2 value. However, for material where the A2 value is unlimited the restriction for classification as an excepted package remains that the gamma doserate does not exceed the 5μSv/hr.

Para 515 gives 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. Para 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.

Using the data provided in Table 1 of the Regulations, the conclusion can be made that in the case of minerals’ transport as an excepted package the load/container will be marked only with ‘UN2910’ instead of the “radioactive” sign. This sign, however, will be required to be visible when, for example, the tarp is taken from the top of the truck or when a container is opened (the word “RADIOACTIVE” must be visible upon opening the package) – there are different technical ways to address this.
Appendix 1

Response from the TRANSSC Working Group on $A_1$ and $A_2$ values on proposals WNTI/6 and USA/2015/10

Proposals made by TRANSSC delegations as part of step 11 of the revision of the regulations for the safe transport of radioactive material (2018 edition) (document DS495) were presented at the TRANSSC 34th meeting (12-13 July 2017). Proposal WNTI/6 submitted by WNTI was to assign footnote “(a)” to U(natural) and Th(natural) in the first column of Table 2. Footnote “a” should read as follows: “$A_1$ and $A_2$ values for Th (natural) and for U (natural) include contribution from their progeny at secular equilibrium”. The reason for this proposal was given as “to reflect TRANSSC decision regarding comment USA/2015/10”. The proposal was rejected with the motivation that “more detailed discussion and a conclusion in $A_1/A_2$ Working Group of experts is needed before changing current status of Table 2”. During the discussion, the IAEA stated that TRANSSC is still awaiting for a definite answer from Working Group of experts on proposal USA/2015/10.

Proposal USA/2015/10 was presented at TRANSSC 30th meeting (16-18 June 2015) and is slightly more elaborate than proposal WNTI/6. It asks to “Clarify the proper use of Table 2 when determining the $A_2$ value for uranium and thorium decay chains in secular equilibrium with their progeny when the $A_2$ values are listed as unlimited”. The reason for the proposal is given as: “The entries for $U(nat)$ and $Th(nat)$ in Table 2 do not reference footnote (a), while footnote (b) does identify which progeny are included for the $Th(nat)$ and $U(nat)$ decay series (in secular equilibrium). It is unclear what progeny, if any are included for $U(nat)$ or $Th(nat)$ when determining the $A_1$ or $A_2$ limits. The definition in paragraph 247 for $U(nat)$ does not mention the progeny from the decay of $U(nat)$. The ‘unlimited $A_2$’ for $U(nat)$ does not seem to account for the potential radiation dose hazard that could be encountered from some of the long-lived decay daughters (e.g. Ra-226).” The proposal therefore not only asks to clarify what progeny were included in the calculation of the A values, but also raises some doubt on the actual ‘Unlimited’ value assigned to $U(nat)$.

Proposal USA/2015/10 was discussed at the meeting of the WG held in Cologne in September 2015 together with other proposals related to basic radionuclide values for which input from the WG was requested; a note, dated 9 September 2015, with the response from the WG on these proposals was circulated at the TRANSSC extraordinary meeting held from 21 to 25 September 2015. In relation to proposal USA/2015/10 the note says that “the WG assumes that the progeny have been taken into account properly” and that “the WG will calculate $A_2$ values for $U(nat)$ and $Th(nat)$ using the current Q system for the proposed nuclides in order to investigate the possible impact of the progeny (e.g. Ra-226)”.

---

1 The proposal and the record of the discussion can be found on page 4 of the document http://www-ns.iaea.org/committees/files/TRANSSC/1771/INF-08aAgendaitem2.5.2FinalDS495TRANSSC34resolution_table_SSC_comments.pdf.
The WG noted that very limited information is available that provides clear evidence to determine whether secular equilibrium was assumed in the calculation of \( A_1 \) or \( A_2 \) values for U(nat) and Th(nat) or an explanation the reason why a value of ‘Unlimited’ was assigned to U(nat).

The WG also agreed that there is a confusion in the current regulations between U(nat), U-natural and natural uranium. “Natural uranium” is clearly defined in Section II of the IAEA transport regulations[^4]. “U-natural” is quoted in footnote (b) of Table 2 only for the exemption values of U(nat) and is defined in the EC report RP 65 as being unprocessed natural uranium (secular equilibrium). In 2015, the WG expected U(nat) to be the same material as “U-natural”.

Calculations on whether progeny was included in the calculations of Q values for U(nat) and Th(nat) were carried out by 3 different organisations using models and software code specifically designed to calculate Q values using the current system. It should be noted that a direct comparison between some of the Q values calculated by these codes and those used to determine the \( A_1 \) and \( A_2 \) values (namely \( Q_C \) and \( Q_D \)) is not possible as the latter are not known and Table I.2 of SSG-26 only reports them as ‘Unlimited’. The ‘Unlimited’ value is assigned to radionuclides which satisfy the criterion that the specific activity of the radionuclide or material has to be less than \( 10^{-4} \times Q_C \) or \( 10^{-5} \times Q_D \). This criterion is based on the the activity contained in 10 mg of material, which is considered to be the maximum mass of material that a person could inhale in a dusty atmosphere following an accident or the activity in 10 mg cm\(^{-2}\) on the skin, which is the maximum mass of material considered to be realistically retained on the skin.

As far as whether the value of ‘Unlimited’ applies to the \( A_2 \) value of U(nat) and Th(nat) therefore the question that needs to be answered is whether their specific activities fulfil the criteria for \( Q_C \) or \( Q_D \) described above. The term ‘specific activity’ is defined in the transport regulations as “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”. The terms U(nat) and Th(nat) do not refer to a single radionuclide and, although there is no indication in SSG-26 of what material these 2 terms apply to, a specific activity can be calculated by assuming that all radionuclides in the decay chain of U(nat) and Th(nat) as given in Footnote (b) of Table 2 of SSR-6 are in secular equilibrium, i.e. have the same activity, with the heads of the decay chain (\(^{238}\)U and \(^{232}\)Th). The specific activities for U(nat) and Th(nat) calculated in this way are about 14 times and 10 times higher than those for \(^{238}\)U and \(^{232}\)Th and are still less than the values of \( 10^{-4} \times Q_C \) or \( 10^{-5} \times Q_D \) which the WG calculated for U(nat) and Th(nat) (as mentioned above, the WG does not know the actual \( Q_C \) and \( Q_D \) values for U(nat) and Th(nat) used for the current version of the IAEA transport regulations).

As far as the \( A_1 \) value is concerned, the WG noted that Table I.2 of SSG-26 gives \( Q_A \) and \( Q_B \) values for U(nat) (0.64 TBq and 0.13 TBq respectively) but not for \(^{238}\)U, that these values are very similar to the values for \(^{226}\)Ra and are also consistent with the \( Q_A \) and \( Q_B \) values calculated by the WG assuming secular equilibrium of all radionuclides as given in current footnote B of Table 2. The WG therefore concluded that secular equilibrium was considered for U(nat). Evidence of this assumption, which also applies to Th(nat), could be found in working papers presented during

[^4]: Current definition contained in IAEA report SSR-6 is: “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).
SAGSTRAM TCM-800 (1992-1995) on the previous review of the radionuclide basic values, the result of which was included in the 1996 edition of the IAEA transport regulations (ST-1) and the 2002 edition of the advisory material, TS-G-1.1 (ST-2). Additionally the WG concluded that the A1 value for U(nat) was given as ‘Unlimited’ because a source containing the QA and QB activities reported in Table I.2 of SSG-26 could not be considered to be a point source and therefore the assumptions made and the approach used in the current Q system for the calculation of QA and QB values would not apply. For example a source 0.13 TBq of U(nat) would have a mass of about 800 kg and a diameter of more than 40 cm. The method included in the Q system for calculation of the QA value does not take account of the effect of auto-shielding for gamma and beta radiation which would be a significant factor for a source of this size. Although the WG did not calculate QA and QB values for a non-point source with the size of 40 cm, it concluded that the effect of auto-shielding would result in much higher Q values and that it would be reasonable to assign an ‘Unlimited’ A1 value to both U(nat) and Th(nat).

Conclusions and recommendations

The conclusions and recommendations from the TRANSSC Working Group on A1 and A2 values on proposals WNTI/6 and USA/2015/10 are as follows:

1. In relation to proposal USA/2015/10 the Working Group on A1 and A2 values has concluded that all the progeny as given in footnote (b) of Table 2 for Th(nat) and U(nat) were taken into account when Q values were calculated. The Working Group on A1 and A2 values is happy for proposal WNTI/6 to be accepted by TRANSSC and that a footnote as indicated in the proposal is added to Table 2 of the IAEA Transport regulations.

2. The Working Group on A1 and A2 values agrees with the Q values derived for U(nat) and Th(nat) reported in Table I.2 of SSG-26 and with the ‘Unlimited’ A1 and A2 values reported in the same table and in Table 2 of the IAEA Transport Regulations (SSR-6) for the following reasons:

   (i) The limiting factors when determining the A2 values for U(nat) and Th(nat) are the activity contained in 10 mg of material, which is considered to be the maximum mass of material that could be inhaled following an accident or the activity in 10 mg cm⁻² on the skin, which is the maximum mass of material considered to be realistically retained on the skin. The calculations from the group showed that the activities of all the radionuclides in the U(nat) and Th(nat) decay chain assumed to be in secular equilibrium with the head of the chain in such quantities of material, including those of long-lived progeny with a higher potential radiation hazard than ²³⁸U and ²³²Th (e.g. ²²⁶Ra), are not high enough to cause doses above the dose criteria adopted in the Q system.

   (ii) In relation to the determination of the A1 values for U(nat), the ‘Unlimited’ value attributed to U(nat) can be assumed correct because a source of U(nat) containing an activity that meets the dose criteria for type A packages could not be considered a point source and therefore the method adopted in the current Q system is not applicable to the calculation of QA and QB values which are used to determine the A1 value. The Working Group concluded that the effect of auto-shielding for a source of U(nat) containing an activity that meets the dose criteria for type A packages would be significant and would result in much higher Q values than those calculated using the Q system and therefore it would be reasonable to assign an ‘Unlimited’ A1 value to U(nat). The same considerations apply to Th(nat).
This note was agreed by the TRANSSC Working Group on A₁ and A₂ at its 9th meeting, held at the IAEA Headquarters in Vienna on 10 and 11 December 2017. Further contribution was provided by Mr Baptiste Louis from the Institut de Radioprotection et de Sûreté Nucléaire (France).

Mr Tiberio Cabianca, Public Health England, United Kingdom
20 March 2018
APPENDIX 2

FULL CALCULATION OF EXEMPTION STATUS USING THE MIXTURES EQUATION

We assume that we have complete information on the parent and daughter concentrations within the ore.

i.e on the activity concentrations of the nuclides shown in the Table A below;

<table>
<thead>
<tr>
<th>Table A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium-238</td>
</tr>
<tr>
<td>Uranium-235</td>
</tr>
<tr>
<td>Thorium-232</td>
</tr>
</tbody>
</table>

Hence we proceed by using Eq.1c religiously, and entering the data concerning the parent and daughter nuclides.
For the mixture:

Calculating the Activity Concentration for Exempt Material

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Sum the activity concentrations in the mixture for ALL nuclides to yield the TOTAL activity concentration in the mixture</th>
<th>$\sum C(i)$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 2</strong></td>
<td>For each nuclide &quot;i&quot; divide the activity concentration, measured for that nuclide, by the sum in Step 1 above, to yield the FRACTION of nuclide $i$ in the mixture</td>
<td>$f(i)$</td>
</tr>
<tr>
<td><strong>Step 3</strong></td>
<td>Divide the $f(i)$, derived above, by the $X(i)$, being the appropriate limit from paragraphs 401 – 406. (multiplied by the Factor of 10 as allowed by paragraph 107 (f))</td>
<td>$\frac{X(i)}{f(i)} = X_M$</td>
</tr>
<tr>
<td><strong>Step 4</strong></td>
<td>Compare the $X_M$ as calculated with the measured gross activity concentration of the ore.</td>
<td></td>
</tr>
</tbody>
</table>

**IF**

Gross activity concentration $\leq X_M$

MINING AND MINERALS PROCESSING is Exempt;
For the mixture:

Calculating the Activity Limit for an Exempt Consignment

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Sum the activity limits for an exempt consignment for the nuclides in the mixture for ALL nuclides to yield a TOTAL $\sum c(i)$</th>
</tr>
</thead>
</table>

For each nuclide present – do the following

<table>
<thead>
<tr>
<th>Step 2</th>
<th>Since the material is homogenous this is simply equal to the $f(i)$ from Step 2 above. $f(i)$</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Step 3</th>
<th>Divide the $f(i)$, above, by the $X(i)$, being the activity limit for an exempt consignment for nuclide (i) from paragraphs 401 – 406. $X(i)/f(i) = X_M$</th>
</tr>
</thead>
</table>

| Step 4 | Compare the $X_M$ as calculated with the measured gross activity concentration of the ore. |

**IF**

Gross activity in the shipment $\leq X_M$

**MINING AND MINERALS PROCESSING** is Exempt;