WORKING GROUP ON NORM

Working Group Report
DATE OF MEETING: 11-12 DECEMBER 2017

ATTENDEES:

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1.0 OPENING AND WELCOME

The chairperson welcomed the attendees to the Meeting of the NORM Working Group and explained the Terms of Reference of the Working group. The Chair explained that what was important was for those present to engage in robust discussions and ultimately to reach agreement/disagreement on how SSR-6 applies to NORM transports.

2.0 SCOPE

At the outset it is important to note that the discussions currently relate solely to NORM in the context of the mining/milling of minerals containing uranium/thorium. There was a proposal to extend this to oil and gas NORM and that will be included at a later date.

It is not the intention of this work to review/revise anything contained in the current IAEA TECDOC 1728 (Regulatory Control for the Safe Transport of Naturally Occurring Radioactive Material (NORM)). Rather it is hoped that the work performed here would serve to compliment TECDOC 1728.

The feeling is that TECDOC 1728 did not address all aspects of the use of SSR-6 for NORM transport. It is the intention of this discussion to address this shortfall. We may at a later stage use information from TECDOC 1728, or decide to suggest a revision of
TECDOC 1728, if we feel there is good justification. The discussions of the Group will always use the Graded Approach.

3.0 PURPOSE

The Purpose of the Working Group was to have an open dialogue amongst competent authorities, and industry, who have an interest in the transport of NORM containing uranium/thorium.

The purpose of this dialogue was to identify where there is both agreement and disagreement with respect to the application of relevant paragraphs of SSR-6 to such transports.

CONSOLIDATION OF DISCUSSIONS TOO DATE

Definitions

247 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).

NORM 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 (NORM). Naturally occurring radioactive material or NORM should be used in the singular unless reference is explicitly being made to various materials.

PURPOSE

The Purpose of the text is to reflect on discussions among both competent authorities, and industry, who have an interest in the transport of NORM containing uranium/thorium. This text to identify issues related to the application of relevant paragraphs of SSR-6 to such transports.

PRELIMINARY CONSIDERATIONS

Bi-Lateral Agreements

It is noted that, in some cases, the shipment of NORM between two countries could be facilitated through the implementation of relevant bi-lateral agreements between these countries.
For example, within countries implementing the ADR (…….) Article 4 of the ADR provides for bi-lateral and multi-lateral agreements.

**THE DEFINITION OF RADIOACTIVE MATERIAL**

It is important to note that, in accordance with para 236 of the SSR-6 –

*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 cases of the transport of tens of tonnes of minerals however, this may not be the case when relatively small packages are transported to and from radiometric laboratories.

For example, if a rare earth or heavy mineral concentrate containing 20 Bq/g of natural thorium (and almost no uranium) is transported, two limits will apply to the shipment (taking into account that the material is “natural”):

(a) Activity concentration limit for exempt material, 10 Bq/g for natural thorium, and  
(b) Activity limit for an exempt consignment, 10,000 Bq for natural thorium.

The first limit will be exceeded (20 Bq/g > 10 Bq/g), however if the total mass of the package is less than 500 grams – the shipment will not fall under the provisions of the Regulations and will not need to be placarded or labelled.

**THE METHOD OF DETERMINING EXEMPTION FOR NORM.**

Different Calculational Methodology Based Upon the Equilibrium Status of The Material.

We refer to paragraph 107 (f) of the Regulations [1];

**107 (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.*

Para 404 of SSR-6 further states –
404. In the calculations of A1 and A2 for a radionuclide not listed in Table 2, 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; and the activity to be taken into account and the A1 or A2 value to be applied shall be that corresponding to the parent nuclide of that chain.

If NORM is in secular equilibrium, both $^{232}$Th and $^{238}$U will have much longer half-lives than any other nuclide in their respective decay chains – therefore, as per the above paragraph, only the values for Th(natural) and U(natural), need to be used in accordance with the footnote (b) under the Table 2 of SSR-6 containing Basic Radionuclide Values.

Additionally, para 404.1 of the IAEA SSG-26 (advisory material to SSR-6) confirms this: “...only the chain parent should be considered because the contribution of the daughters was considered in developing the A1/A2 values...”

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.

The equation from para 405 will apply to the materials where the chains are not in equilibrium. Para I.88 in the SSG-26 (advisory material) repeats the equation from para 405 of SSR-6.

For NORM, in the context of this discussion, we first need to determine if the NORM is in secular equilibrium or not in secular equilibrium.

**Determining Exemption Status for NORM in Secular Equilibrium**

Using the first sentence in 107 (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.

This tells us that, in cases where the NORM is in secular equilibrium, the determination of exemption status is a matter of comparing the value of the parent nuclides ($U$-238 or Th-232) against the U(natural) or Th(natural) values from Table 2, given as 1 Bq/g in both cases and raising these values to 10 Bq/g by virtue of paragraph 107 (f).

The calculation, in the case of secular equilibrium, is performed as follows (based upon the provision of activity in ppm, as is common within the industry):

$$
(Th(\mu g/g) \times 4.09 \times 10^{-3}) + (U(\mu g/g) \times 1.236 \times 10^{-2})
$$
[Where the ppm to Bq/g conversion factors are in good agreement with those derived in Spreadsheet 1]

If the result is less than 10 the material is not classified as radioactive for transport. That is to say, for purposes of transport, the material does not need to comply with the requirements of the Regulations.

In accordance with para 404 of SSR-6;

**Determining Exemption Status for NORM not in Secular Equilibrium**

The second half of paragraph 107 (f) tells us;

*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.*

Paragraph 405 carrying the Mixtures Equation;

This was supported by reference to paragraph 107.4 of SSG-26;

“The scope of the Transport Regulations does not include ores and natural or processed materials containing naturally occurring radionuclides, provided that the activity concentration of the materials does not exceed 10 times the exempt activity concentration values (Table 2 or calculated in accordance with paras 403–407). Following the conclusion of the IAEA Coordinated Research Project (CRP) on Regulatory Control for the Safe Transport of Naturally Occurring Radioactive Material (NORM) [5], it was agreed that this exclusion does not depend on the prior or intended use of the material, i.e. whether it is to be used for its radioactive, fissile or fertile nuclides or not. The CRP modelling and analysis of realistic transport scenarios found that in cases when the provision of 10 times the exempt activity concentration values for this material is applied, the maximum annual dose from unregulated transport of the material would generally be substantially less than 1 mSv (referring to para. 71 of ICRP 104 [6], an annual dose criterion of 10 μSv does not apply to exposure situations involving natural sources, as this value is at least one or two orders of magnitude below the variability of the background radiation). The BSS [1] set an annual dose criterion of 1 mSv for exemption for NORM. The CRP concluded that the exclusion is appropriate from a radiological protection consideration and from a risk based regulatory consideration since the potential radiological dose from the material during transport is dependent on the activity concentration of the material. Guidance for determining activity levels and basic nuclide values is provided in paras 403–407 for reference in the use of Table 2.

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(natural) and Th(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.”

It is noted that the use of the U(natural) and Th(natural) values for the determination of exemption values would identify an exemption level which would be lower than that determined through the use of the Mixtures Equation.

It was not 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.

It is further noted that, for NORM with an activity in the realm of exemption, there was no safety concern related to an incorrect determination of the exemption status. However there could be trade advantages related to the NORM being classified as exempt. Having said that a regulators first priority should be safety.

Any exemption relates to transport only and beyond this the NORM would be authorized as a practice.

**THE METHODOLOGY FOR CALCULATING THE EXEMPTION OF NORM USING THE MIXTURES EQUATION.**

Given that a mixtures calculation needs to be performed how should this be done?

When considering which radionuclides to use in the mixtures equation;

**Thorium Decay Chain:**

isotopes other than $^{232}$Th, $^{228}$Ra and $^{228}$Th are very short-lived, so these three are sufficient.

**Uranium Decay Chain,**

Taking into account all industrial processes:

a. $^{238}$U. In the footnote (b) to the Table 2 of SSR-6 $^{238}$U is only linked to $^{234}$Th and $^{234m}$Pa, but not to $^{234}$U. However, as none of NORM industries separate isotopes of uranium in any way it can be assumed that $^{234}$U will be equal to $^{238}$U. Also, whilst the half-life of $^{234}$Th is 24 days (more than 10), we can assume that $^{238}$U still "covers" it.

b. $^{230}$Th of course, as chemically it behaves quite differently...

c. $^{226}$Ra, as it will also behave differently. The footnote (b) to the Table 2 of the SSR-6 states that $^{226}$Ra "covers" the remainder of the decay chain – which is not
entirely correct: in the processing of NORM radium and lead/polonium will behave in a different way...

d. $^{210}\text{Pb}$, and
e. $^{210}\text{Po}$, if possible.

Without the data for all of the above eight radionuclides (with a possible exception of $^{210}\text{Po}$) it is impossible to determine if material is classified as ‘radioactive’ for transport or not.

The reason that analysis for the nuclides of the $^{235}\text{U}$ decay chain is typically not required for the following reasons:

- As natural abundance of $^{235}\text{U}$ of only 0.72%, the values are usually not important in the determination of the applicability of the regulations. In many cases the concentration of $^{235}\text{U}$ could be simply estimated by multiplying concentration of $^{238}\text{U}$ by 0.01;
- Smaller laboratories (at mining and processing sites) would provide the data as ‘total uranium’ in parts per million for $\text{U}_3\text{O}_8$ (without any isotopic analysis), and the 1% that $^{235}\text{U}$ represents is almost always within the margin of typical laboratory errors/variance;

In some cases, however, measurements of concentrations of $^{235}\text{U}$ decay chain nuclides are carried out. Then, the analysis will be required for the following radionuclides: $^{235}\text{U}$ (that, as per footnote (b) of the Table 2 of SSR-6, “covers” $^{231}\text{Th}$, $^{231}\text{Pa}$, and $^{227}\text{Ac}$ that “covers” the remainder of the $^{235}\text{U}$ chain (as per footnote (a) of the Table 2 of SSR-6)).

A specific example below serves as an illustration:

See Appendix X

Include an example of the use of the Mixtures Equation.

**DETERMINING THE TRANSPORT INDEX FOR A SHIPMENT OF PACKAGED NORM ON A SINGLE CONVEYANCE.**

Paragraphs 523 and 524 state that;

523. The $\text{TI}$ 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 $\text{TI}$. 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) shall be multiplied by the appropriate factor from Table 7.

(c) The value obtained in steps (a) and (b) shall be rounded up to the first decimal place (e.g. 1.13 becomes 1.2), except that a value of 0.05 or less may be considered as zero.

The typical practice in uranium mining and processing is to transport uranium concentrate as LSA-I 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 never be as high as the default values.

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 when considering a shipment of NORM, either transported unpackaged in the back of a vehicle, or packaged in IP-1 or IP-2 containers, we would use paragraph 524. The use of paragraph 524 would provide us with two options for determining the total TI of the shipment;

**Option 1:**

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…………

In this case, for a collection of IP-1 or IP-2 packages, determine the TI of each individual Package and sum the TI’s to obtain the TI for the shipment.

**Option 2:**

524 ……………… 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*.

The TI for a freight container, tank, unpackaged LSA-I or unpackaged SCO-I is the maximum dose rate at 1 m from the external surface of the load, expressed in mSv/h and multiplied by 100 and then further multiplied by an additional factor which depends
on the largest cross-sectional area of the load. This additional multiplication factor, as specified in Table 7 of the Transport Regulations, ranges from 1 up to 10. It is equal to 1 if the largest cross-sectional area of the load is 1 m\(^2\) or less. It is 10 if the largest cross-sectional area is more than 20 m\(^2\). The TI for a freight container may be established alternatively as the sum of the TIs of all the packages in the freight container. For an open-sided or open-top freight container, surfaces of a rectangular prism encompassing the container structure and the load can be considered as the surfaces of the load, and the largest cross-sectional area of that prism is used to determine the additional multiplication factor in Table 7.

CLASSIFICATION OF NORM AS LSA-1 MATERIAL

Referring to paragraph 409 of the Regulations;

CLASSIFICATION OF MATERIAL

Low specific activity (LSA) material

409. LSA material shall be in one of three groups:

(a) LSA-I:

(i) Uranium and thorium ores and concentrates of such ores, and other ores containing naturally occurring radionuclides;

(ii) Natural uranium, depleted uranium, natural thorium or their compounds or mixtures, that are uneradicated 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 402–407. Fissile material may be included only if excepted under para. 417.
Paragraphs 409 (a) (i), (ii) and (iii) are used as a basis for the classification of NORM as LSA-I material.

The reference to “other radioactive material” in paragraph 409 (a) (iv) excludes all uranium and thorium ores from this paragraph and thereby excludes the classification of uranium/thorium ores as either LSA-I or LSA-II by virtue of paragraph 409 (a) (iv).

MARKING, LABELLING AND PLACARDING.

Once it has been determined that the material to be transported is classified as 'radioactive' in accordance with the IAEA SSR-6, several steps need to be taken to ensure that both transport documentation and associated labels/placards are fully compliant with the requirements of the Regulations. The details are provided below.

- The LABELS are on Figures 2, 3 and 4 (pages 69-71 of SSR-6). Those are small, 10x10 cm.
- The PLACARD is on Figure 6 (page 74 of SSR-6), this one is large, 25x25 cm.

Paragraph 543 says:

543. Large freight containers carrying 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 Figs 2–4, except having the minimum size shown in Fig. 6.

Therefore for large freight containers:

- If there are several packages with radioactive material in the vehicle each of the packages is LABELLED, and the vehicle itself is PLACARDED.
- Full compliance with SSR-6 will require placing both labels and placards on the vehicles – but there is a provision in para 543 that instead of putting those side-by-side, the LABEL is enlarged to 25x25cm size and is used instead of a PLACARD – on all four sides of the vehicle.

The note to the figure 6 illustrating the PLACARD says –

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.

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.

Therefore by way of paragraph 544;

If the vehicle is used to transport bulk mineral:
Option 1:
• The enlarged LABEL is placed on it as required;
• The word “RADIOACTIVE” may be replaced with “UN2912” or “UN2913” as appropriate;
• On the LABEL the contents may be simply “LSA-I”, as per para 540(a)(ii) – if the material is classified as such;
• If material is classified as LSA-II, the data on the radioisotope(s) is required;
• Transport Index will need to be measured with the gamma monitor, as per paragraph 523(a). Then, in accordance with 523(b) a multiplication factor from Table 7 of SSR-6 will have to be used.

Option 2:
• Both LABELS and PLACARDS are placed on the vehicle as required;
• The word “RADIOACTIVE” on the PLACARD may be replaced by “UN2912”;
• The word “RADIOACTIVE” may not be replaced by “UN2912” on smaller LABELS, they will also need to contain the information on the contents and Transport Index.

**Determination of the Transport Index (TI)**

This is fully described under section 8.0 above.

**Determination of the transport label**

In accordance with para 529 and Table 8 of SSR-6, the measurement of gamma radiation level is undertaken at the surface.

• If TI is not more than 0.05, and the surface radiation level is below 5 microSv/hour, the category of the label will be I-WHITE.
• If TI is more than 0 but less than 1, and the surface radiation level is above 5 microSv/h, but below 500 microSv/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 microSv/h, the category of the label will be III-YELLOW.

This is clearly illustrated in the Flowchart Below;
Determining the Label Category to be applied.

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.

EXCLUSIVE USE

Exclusive use

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.

Exclusive use means that a single consignor has the sole use of a:

- conveyance; or
- large freight container,
And all initial, intermediate and final loading and unloading is carried out in accordance with the directions of the consignor or consignee.

The bulk of “unpackaged” materials in the minerals industry may only be transported under the exclusive use arrangement, as per para 520(b) of SSR-6:

LSA material and SCO in groups LSA-I and SCO-I 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.

Note: This paragraph states that when transporting SCO-I material, and the contamination on both the accessible and inaccessible surfaces does not exceed 10 times the values shown in paragraph 214, the SCO-I material need not be transported under exclusive use.

The definition of exclusive use is given in para 221 of SSR-6:

The main advantage of the exclusive use provision is that, in accordance with para 514 of SSR-6, there is no need to decontaminate the internal surfaces of the conveyance after each shipment.

It is also important to note that –

- In accordance with para 546(m), the transport documentation must contain the statement “EXCLUSIVE USE SHIPMENT”, and
- In accordance with paras 526 and 567 of SSR-6 if the value of Transport Index exceeds 10, it can only be transported under the exclusive use arrangement.

SURFACE CONTAMINATION

The Transport Regulations [IAEA SSR-6] provide the definition for ‘surface contamination’ and ‘low toxicity alpha emitters’:

214. 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.

227. 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 physical and chemical concentrates; or alpha emitters with a half-life of less than 10 days.
Additional information is provided in the IAEA Safety Guide (SSG-26) issued in the support of transport safety regulations:

214.3. Any surface with levels of contamination lower than 0.4 Bq/cm² for beta and gamma emitters and for 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.

Therefore, when the level of contamination exceeds 0.4 Bq/cm² the Transport Safety 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 is likely to be applicable for the classification of surface contaminated objects.

214.3. Any surface with levels of contamination lower than 0.4 Bq/cm² for beta and gamma emitters and for 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.

There always will be alpha emitting isotopes present in surface contamination in uranium industry. 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 $^{210}$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 0.04 Bq/cm² is the one where the vehicles may need to be placarded as carrying SCO-I. Unless it is known that the material on the surface does not contain a significant proportion of $^{226}$Ra, in which cases the placarding is needed at levels above 0.4 Bq/cm².

For the simplicity of the argument, we assume that most of contamination on surfaces of objects from uranium and other NORM mines and plants contains $^{226}$Ra in an ‘overall mix’ and that only “low toxicity alpha emitters” are present.
In accordance with para 413 of SSR-6 there are different values for non-fixed and fixed surface contamination. Then – 413 (a)(i) says that SCO-I is anything up to 4 Bq/cm², and 413(b)(i) says that SCO-II is anything up to 400 Bq/cm².

The conclusion – 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 placarding of any kind required;
- > 0.4 Bq/cm², but < 4 Bq/cm² – SCO-I placarding required;
- > 4 Bq/cm², but < 400 Bq/cm² – SCO-II placarding required;
- > 400 Bq/cm² – one would not be allowed to transport these items, but values of this kind are 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/cm².

However, it is important to also note that the definition for non-fixed contamination in the IAEA 2007 Safety Glossary is: “Contamination that can be removed from a surface during routine conditions of transport”.

(para 413 a(iii)  Safety Glossary 2017/2018)

It is, therefore, recommended to ensure that all potentially contaminated objects are cleaned up prior to their transport, to ensure that no residual contamination can be accidentally removed ‘during the routine conditions of transport’. Failing this the operator may Add plastic or other bags or caps to the ends of an open pipe (for example) in order to capture any fall-off during transport.

In these cases, different limits will apply (para 413(a)(ii)): 40,000 Bq/cm² for beta and gamma emitters and low toxicity alpha emitters, or 4,000 Bq/cm² for all other alpha emitters – the levels of this magnitude are not usually expected in the mining and mineral processing industry.

Other practical notes in regards to controls required:

There are three more paragraphs in the IAEA SSR-6 regulations that need to be considered (one is referenced in paragraph 413, another two – are not):

Paragraph 508 (not referenced ???):

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/cm² for beta and gamma emitters and low toxicity alpha emitters;
   (b) 0.4 Bq/cm² 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 a sealed truck, for example), but the limits from para 508 for the levels on the outside surfaces of these 'packages' shall not be exceeded.

Paragraph 520 (referenced ???):

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.

Clarifying paragraph 520 (b) as written, If the conveyance is transporting only SCO 1 material, for which the levels of surface contamination on both the accessible and the inaccessible surfaces is not greater than 10 times the applicable level specified in paragraph 214 then it need not be transported under exclusive use.

In accordance with para 520(a), the surface contamination is an “ore containing NORM”, except where any processing has taken place.

Effectively, the rules for SCO-I should be less stringent than for SCO-II:
- SCO-II may be only be transported appropriately packaged.
- SCO-I may be transported unpackaged, unless (as per paragraph 520(b) ) the surface contamination levels exceed ten times the values in para 214. In which case they are classified as SCO-II – in accordance with 413(b)(i).
- If it is suspected (not proven, just 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 potentially SCO-II: one needs to take measures that whatever is on the inside does not get out. An example is the transport of pipes from oil and gas industry: the pipe may be 8-10 meters long and there is typically no equipment and no possibility to measure what surface contamination may be on the 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 nothing falls out of 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.

Paragraph 505 (not referenced):
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/cm² for beta and gamma emitters and low toxicity alpha emitters and 0.04 Bq/cm² for all other alpha emitters.

The following conclusion is based on alpha surface contamination levels, as:
(a) Unprocessed ore and concentrates: in the uranium chain, there are 8 alpha emitters and 6 beta emitters, so measuring and ensuring that alpha emitters meet the surface contamination limits also makes sure that the short-lived beta emitters do not exceed the surface contamination levels either.
(b) Freshly extracted uranium, there are obviously more alpha emitters – as it will contain alpha-emitting isotopes, \(^{238}\text{U}\), \(^{234}\text{U}\) and \(^{235}\text{U}\).
(c) Tailings with \(^{238}\text{U}\) and \(^{234}\text{U}\) removed – leaving 6 alpha emitters and 6 beta emitters, so, as in the case (a) above, measuring only alpha surface contamination levels should be sufficient.

Taking all of the above into consideration, the general suggestion is to have five types of surface contaminated objects, based on alpha surface contamination – which are easy to differentiate from each other:

1. Less than 0.04 Bq/cm² – clean, material is considered Exempt;
2. More than 0.04 Bq/cm², but less than 0.4 Bq/cm² –, can be transported unpackaged and not placarded, More than 0.4 Bq/cm², but less than 4 Bq/cm² – surface contaminated object class SCO-I, placarding and transport declaration required;
3. More than 4 Bq/cm², but less than 400 Bq/cm² – surface contaminated object class SCO-II, control measures, placarding and transport document. required; (Check SSR-6 statement).
4. More than 400 Bq/cm² – typically not allowed to be transported, try to clean the surface and contact the regulatory authority for the advice.