# Regulation of Natural Radioactivity in International Transport and Trade

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## 1. Introduction

During the TENR symposium in Rio de Janeiro in 1999 participants from the Southern Hemisphere recognised that a certain division was being formed between *consumer* countries (China, Japan, EU, USA) and *mineral producer* countries (Australia, Africa, South America, Middle East). The need for a joint approach in dealing with issues emerging from the IAEA Basic Safety Standards (BSS) [1] world-wide implementation has become evident.

An analysis of the suitability of IAEA Basic Safety Standards for the Naturally Occurring Radioactive Materials (NORM) was made in 1999 [2, 3] and followed up in 2000 [4].

Strengthening of radiation protection regulations (including border controls) in *consumer* countries may potentially lead to the partial or complete loss of market for some mineral producers, and the resulting economic and logistical constraints have become a serious consideration for individual industries in countries such as Brazil, South Africa and Australia.

'Natural Materials Radiation Control Initiative' group was formed [4] and, after two workshops in South Africa the work is now continuing at the IAEA, where several safety reports addressing radiation protection issues in different industries are currently being prepared [5, 6]. It is expected that documents will be more comprehensive that the one produced by the IAEA for the Oil and Gas Industry [7].

## 2. Guideline for the transport of mineral concentrates containing NORM

Whilst the control of NORM in processing/storage environment and the disposal of the waste generated in mining and minerals processing industry are well covered in international guidelines, the transport of potentially radioactive ores and concentrates does not receive sufficient attention. IAEA Regulations for the Safe Transport of Radioactive Material [8, 9] and Advisory Material for these Regulations [10] provided instructions on the transport of material with elevated concentrations of natural radionuclides, but these documents are somewhat complex for a common user and are easily misunderstood. Therefore, a simplified step-by-step guideline has been developed for both minerals industry and appropriate regulatory authorities [11].

The guideline is taking into account the fact that in different jurisdictions different regulations may apply to the transport of minerals containing NORM. In some states/countries IAEA 2005 Regulations [9] are (or shortly will be) in force; in other ones – 1996 Regulations [8] apply; in rare cases a special amendment was made to the exemption clause for NORM prior to the adoption of international regulations, like, for example, in Australia [12]. In case of any doubt a user of the guideline is directed to an appropriate regulatory authority for additional consultation.

The guideline contains, firstly, a description of the criteria for the application of transport regulations, depending on where the materials are being transported.

The second part deals in detail with determination of activity concentration in the transported material and the applicability of exemption. Different scenarios are considered and practical calculation examples are presented for cases of (a) material that has not been a subject of chemical or thermal processing, and (b) when such processing took place. Also, in the case when secular equilibrium in the material is disrupted, two different examples of calculations are given and discussed in detail – depending on the availability of the ‘full chain’ analysis. If it is determined that a specific material is subject to regulation, four requirements that must be followed are summarised.

Part three deals with the classification of materials. Transport index, category and specific activity categorisation are discussed.

Parts four, five, six and seven describe in depth the conditions under which a material can be transported as an excepted package, placarding requirements, advantages and disadvantages of having material transported in the vehicle under exclusive use, and the need for the covering of the material that is being transported.

Part eight describes the possibilities of blending materials with different specific activities prior to transport. The implications of this practice for the crossing of international borders are addressed in part 4 of this paper.

Part nine provides detailed explanation of the requirements for the assessment of surface contamination in regards to NORM. There is no specific exemption provision for ‘natural material’ in the international regulations in regards to surface contamination, which may present significant problems – particularly during the decommissioning of plant equipment and the transport of scrap metal resulting from this decommissioning.

This guideline [11] is available for download from http://eneabba.net/radlinks/tenorm.

3. International trade in commodities containing NORM

The first mentioning of commodities containing NORM was in 1999, in the ICRP Publication 82 [13]:
*…due to the globalisation of markets, intervention exemption levels of radionuclides in commodities cannot be established on a case-by-case basis; rather, they need to be standardised. …in order to avoid unnecessary restrictions on international trade, it may be necessary to establish intervention exemption levels that would indicate a line of demarcation between freely permitted exports or imports and those that should be the subject of special decisions.*
The suggestion was also made that, –
*…concerned national and, as appropriate, relevant international organisations should derive generic, and radionuclide-specific, intervention exemption levels for individual commodities.*

Potentially contaminated commodities under consideration were, in the first place, some foodstuffs and other consumer goods that contained certain amounts of artificial radionuclides after the Chernobyl incident in Ukraine in 1996; and scrap metal from nuclear power plants decommissioning. The issue of commodities containing naturally occurring radionuclides, particularly mineral concentrates shipped internationally, is relatively new.

In recent years there have been numerous calls for the standardisation of international exemption levels applicable to materials containing naturally occurring radionuclides. It has been pointed out, for example [14], that, –

- *Guidance is lacking on how to deal with inconsistencies in classification and transport of NORM residues that have been released from regulatory control;*
- *To avoid problems in competition and cross-border transport of materials within the European Union, it should be highly desirable to decide on an internationally agreed approach for disposal options and setting clearance levels.*

Another document [15] specifies that *the guidance should be prepared on how to assess the levels of natural radionuclides in an effective and economic way for the purpose of clearance,* and that *the harmonisation of exemption and clearance levels between Member States is important to reduce complications for cross border movement of materials. Thus the use of common value (as recommended by the European Commission) by all Member States is strongly recommended.*

Further confusion may arise due to the fact that in some countries different methods of activity calculations and different limits apply to the release of a material from regulations and its transport. It has been pointed out in [14] that, –
*Even though a Member State may have exempted a residue containing NORM from regulation, its natural radioactivity may still be controlled by national or international transport regulations.*

One example of this possibility is presented in [16], where Table 2 specifies that the general clearance level for a wet sludge from the oil and gas industry is 100 Bq/g for 'U-nat' and for $^{232}$Th. These materials, whist exempted from a national regulation, would still be a subject to the international transport one. This case, however, is mainly theoretical as normally only $^{226}$Ra and $^{228}$Ra (and not $^{238}$U and $^{232}$Th) are considered in the assessment of radioactivity in oil and gas sludge and scales. Radium concentrations are usually quite significant due to its solubility, uranium and thorium are less soluble in the formation water (in reservoir rocks) and their concentrations in the sludge and scales are typically negligible. Administratively, the value of total activity concentration (TAC) for oil and gas sludge and scale in Malaysia is calculated as TAC = (6 x $^{226}$Ra activity) + (8 x $^{228}$Ra activity), with thorium and uranium not considered. Some other countries use the same assessment method.

An example from Germany is presented in [17]:
*…the maximum permissible concentration of natural radionuclides for release from radiological supervision may be higher than the minimum specific activity according to the regulation of transport of radioactive materials. Whereas according to StrlSchV* [German Radiation Protection Ordinance] *the release is based on the maximum specific activity of the nuclide with the highest activity, for transport issues the sum of all long living radionuclides must be considered… this results in a "flowing minimum permissible activity" for shipment.* As it is correctly stated, "a variable limit is a challenge for the licensing body" – and even more so when this licensing body will have to explain this principle to an authority in another country…

It appears that an obstacle like this 'variable limit' may be easily eliminated by adopting Title VII of the European Council Directive 96/29/Euratom [18], as suggested in [19].

It must be noted, however, that the Directive [18] gave a principle that the work activities *of concern* are those that cause *a significant increase in the exposure of workers or members of the public*, without a reference to any numerical value. A follow-up document from European Commission [20] also did not provide any guidance on what 'a significant increase' actually is. It was left to appropriate regulatory authorities in separate countries to determine what to regulate and what – not, resulting in an additional confusion. Numerous supplementary technical documents to the EU Directive have been provided in recent years, but it is still unclear how the situation of the transfer of a material containing naturally occurring radionuclides from one country to another should be handled – particularly in a case when these two countries have different regulatory approaches.

The situation is even more complex when different regulations apply within the same country due to the federal system of government. For example, it has been agreed in Australia that, –
*There was a need for uniform cross-jurisdictional transport regulations and licensing. Although the 2001 Transport Code (ARPANSA RPS 2) has been adopted by all jurisdictions except Victoria, licensing requirements are different between jurisdictions* [21].
Whilst transport regulation in Australia is relatively uniform, different activity exemption levels apply to NORM in different States [22], which leads to more uncertainties – particularly for a company that operates is several jurisdictions.
National Directory for Radiation Protection [23] is intended to provide an agreed legislative framework in Australia, but the first edition does not apply to mining and mineral processing industry. It is expected that, after the second edition of the National Directory is published and, together with the relevant Code of Practice [24], adopted by all Australian States and Territories (within next several years), the same exemption limits and licensing requirements will apply across the country.

A similarly complicated situation exists in the USA [25]:
*…through the Conference of Radiation Control Program Directors, Inc. (CRCPD), the states establish consensus and develop uniform radiation protection standards in the form of the Suggested State Regulations for the Control of Radiation (SSRCRs). In April 2004, the CRCPD has approved its regulation and implementation guidance (Part N) for NORM and TENORM. Despite such effort at the state level, there remain a number of issues to be resolved. First, implementation of the SSRCRs is voluntary rather than mandatory; thus the regulations cannot be enforced uniformly. In fact, a few states do not even regulate NORM or TENORM, leaving the trans-border control of such materials difficult.*
It is sometimes hard to understand the rationale of different state regulatory authorities in the same country that, for some or other reason, do not wish to adopt the common approach to a particular issue, such as for example, an adoption the same guidelines for NORM [26, 27].

US Environmental Protection Agency and other federal government bodies also regulate NORM to some extent (particularly when the radionuclides' concentrations have been technologically enhanced), which complicates the issue even further. Detailed information on the regulation of naturally occurring radioactivity in the USA is provided in the publication of the US National Research Council [28].

A big step forward was the publication of the IAEA Safety Guide RG-S-1.7 [29] in 2004, which was followed by the publication of the associated Safety Report in 2005 [30]. Any considerations in regards to the transport of materials are, however, omitted and it is noted that activity concentrations as limits for material in transport are established in the Transport Regulations [8, 9].

Safety Guide [29] establishes the exclusion value of activity concentration for all radionuclides of natural origin at 1 Bq/g (except $^{40}K$, for which the value is 10 Bq/g), which is consistent with Basic Safety Standards [1]. It must be noted that this value was set on the basis of consideration of worldwide distribution of activity concentrations of these radionuclides [29, 30], instead of a very complicated (and probably unnecessary) modelling of exposure to NORM.
The Safety Guide [29] contains a specific part on 'Trade', which is of a particular interest, as it proposes that, –

- *"…the regulatory bodies concerned should co-ordinate their activities and share their concerns… to facilitate the movement of materials"*; and
- *"…to avoid unnecessary hindrances to trade at boundary transfer points, States should co-ordinate their regulatory strategies and their implementation…"*

Currently, it is not entirely clear how IAEA Safety Guide RS-G-1.7 [29] will apply to international trade in minerals that contain natural radionuclides in concentrations that are exempted under the international transport regulations [8, 9] but are above those specified in the Guide (NORMs in "the bracket" between 1 and 10 Bq/g).
Basically, it is suggested that *"…authorities in exporting States should ensure that systems are in place to prevent unrestricted trade in material with higher activity concentrations. In general, it should not be necessary for each importing State to set up its own routine measurement programme solely for the purpose of monitoring commodities, particularly if there is confidence in the controls exercised by the exporting State".*

It is important to ensure that controls over commodities containing NORM are established in the exporting country and communicated to the appropriate authority in the importing country – prior to an exporter company encountering problems at a port or a border crossing, due to the lack of proper documentation or because of a simple misunderstanding [31].

The Safety Guide [29] also establishes the concept of 'graded approach' that contains a suggestion for a regulatory body for a case when activity concentrations in NORM exceed the value specified (1 Bq/g) "*by several times (e.g. up to ten times)"*. It may be possible not to apply regulatory requirements to a material, providing an exemption on the case-by-case basis.

It would be, however, hard to come across the case when a particular material containing naturally occurring radionuclides with activity concentrations just under 10 Bq/g may be exempted form regulations in regards to the storage and processing. For example, gamma dose rate in air from a mineral concentrate containing 9 Bq/g of $^{232}Th$ will be in order of 5.5 microGy/hour [32], which is above the typical level of background radiation by about two orders of magnitude [32]. The suggestions on the practical application of 'graded approach' are provided in the end of the paper (**suggestion 2.1**).

The main reason for the '10-times' exemption for natural materials in transport regulations is that possible radiation exposure of workers and general public during transport is likely to be too low to require regulation. Essentially, a shipment of NORM can be transported between countries without having to comply with transport regulations, but will need to be considered by the appropriate regulatory authority for possible control (or exemption) because it is above typical background. This is likely to occur not when a mineral reaches its destination, but at a border crossing point, typically – in an international port.

It is quite impractical to place a radiation protection specialist at every border crossing, so the authority to conduct measurements and make assessments of materials crossing the border must stay with personnel that is in charge of the situation in the first place – customs officers. The complexities of regulations dealing with transport of potentially radioactive materials and minuscule differences that may qualify a mineral concentrate for exemption are typically hard to understand – even for a 'regulator', without a prior (and quite extensive) study of the issue.

A full understanding of the regulations can hardly be expected from a customs official, who normally deals with many other (and very different) matters on a day-to-day basis, and a situation at a border crossing may become rather difficult. A customs officer will definitely require a detailed guideline from his/her country appropriate authority on how to use a particular radiation monitoring equipment and how to handle a material that looks a bit 'hot'.

It is, therefore, suggested that a company in any country planning to export material containing naturally occurring radionuclides to a specific country contacts an appropriate authority in this 'importing' country and inquire about possible requirements for a particular material. The suggestions on how this contact can be made are provided in the end of the paper (**suggestion 1.1**).

Co-ordinated Research Project (CRP) on the issue of transport of potentially radioactive material will commence at the International Atomic Energy Agency in the very near future. It is expected that risks associated with different transport scenarios for NORM will be quantified, but the project will take some time and its outcomes cannot be predicted with certainty. It is still unclear at the current time how to deal with transport of NORMs with activity concentrations in order of 5 Bq/g across international borders.

Several quite comprehensive documents describing NORM in detail may be of help for appropriate regulatory authorities [33, 34, 35], but it is unlikely that an average customs officer will be familiar with all aspects of a particular NORM – therefore, a comprehensive guideline is essential. The only known standard of this type (specifically addressing the inspection of the radioactivity content in the process of minerals' import) has been developed in the People's Republic of China in 2005. It appears that the procedure suggested in this document is based on the comparison of background radiation level and the radiation emitted from a particular material.

## 4. <u>Control of NORMs at international borders</u>

As a rule, the transport of materials containing naturally occurring radionuclides is not even mentioned in national [36] and international studies [37, 38]; therefore it is unlikely that any guidance on NORM may be found in the 'general type' reports.

Three guidelines of a special importance were published in September 2002 by the International Atomic Energy Agency. To prevent incidents and to harmonise policies and procedures IAEA issued technical documents, co-sponsored by the World Customs Organization, Europol and Interpol, on the inadvertent movement and illicit trafficking of radioactive material. The first is 'Prevention of the Inadvertent Movement and Illicit Trafficking of Radioactive Material' [39], the second – 'Detection of Radioactive Materials at Borders' [40], and the third is 'Response to Events Involving the Inadvertent Movement or

Illicit Trafficking of Radioactive Material' [41]. These documents are supported by the reference manual on equipment specifications and test procedures, issued in 2006 [42].

The first document [39] deals with the definition of 'illicit trafficking', administrative framework, and the role of customs and other law enforcement agencies. Several important points are contained in this document:

- It is suggested that a regulatory authority in the country into which radioactive material is being imported *enters into agreements with suppliers to ensure that the authority is notified of intended shipments of radioactive materials*. This is confirmed by the suggestion that a regulatory authorities in exporting countries should require that suppliers from their country *notify regulatory authorities in importing countries of radioactive materials sent to their respective countries*.
- The needs to raise public awareness on the issue, as well as the requirement for the training of relevant personnel are clearly stated.

The third document [41] deals with the response to an actual event of illicit trafficking, mitigation of health hazards, investigation of an incident and media awareness.

The second document [40] is of a particular importance and needs to be discussed in detail, together with the reference manual [42].

Firstly, a definition of 'illicit trafficking' must be considered by all stakeholders. It is important to note that one of the criminal activities under consideration is "violation of transport regulations". The carrier and the company sending a mineral concentrate to another country must be absolutely certain that all proper analyses were carried out and relevant forms completed, to ensure that a shipment of an ordinary NORM does not create an international border incident.

Further, the TECDOC [40] provides detailed information on the process of detection, selection of instruments, investigation levels, alarm settings and their verification, localisation and verification of the presence of radioactive material. The reference manual [42] contains technical data for border monitoring equipment, test procedures and many practical examples.

It is obvious that the use of radionuclide identification devices (RIDs) is much more preferable then the use of hand held gamma survey instruments, since RIDs can be used both for identification of radioactive material and for radiation safety measurements. A detailed explanation of what features a gamma spectrometer must have to qualify as RID is provided, and it is noted that it is important that non-experts should be able to operate this equipment. As the technical note from the SAVER program of the US Department of Homeland Security [43] and an information sheet for a typical portable gamma spectrometer from the Gammasonics Institute for Medical Research [44] specify, the instruments are very easy to operate and natural radionuclides ($^{40}$K, $^{232}$Th, $^{238}$U and their decay products) are easily separated from special nuclear materials (containing $^{233}$U, $^{235}$U, $^{237}$Np, $^{239}$Np, $^{239}$Pu, etc), 'medical' radionuclides ($^{67}$Ga, $^{51}$Cr, $^{75}$Se, $^{99m}$Tc, $^{103}$Pd, $^{123}$I, $^{125}$I, $^{131}$I, $^{201}$Tl, $^{133}$Xe, etc), and 'industrial' radionuclides ($^{57}$Co, $^{60}$Co, $^{133}$Ba, $^{137}$Cs, $^{192}$Ir, $^{204}$Tl, $^{241}$Am, etc). A special case is the transport of NORM containing relatively significant amounts of $^{238}$U, where additional documentation may be required to confirm that this radionuclide originated in the material 'naturally'.

Majority of actual alarms at borders will be *innocent* ones, – resulting from the presence of medical radionuclides administered to patients, NORM (such as $^{232}Th$, $^{226}Ra$, $^{40}K$, natural U in minerals and also in industrial material such as ceramic tiles, fertilizer, cat litter, porcelain toilets, etc.)[45], and legal shipments of radioactive materials. Such alarms cause significant operational issues as all portal alarms should be fully investigated.

After a shipment of NORM caused an alarm and relevant radionuclides have been identified; interviews with the personnel involved, and an examination of all relevant documentation are the complementary activities that will be part of the investigation. A suggestion for a NORM exporter on what documentation must be provided and what information it must contain is provided in the end of the paper (**suggestion 1.2**).

Technical Document [40] also contains a very important point that is directly relevant to blending of materials with different specific activities prior to transport, as mentioned earlier in part 2 of this paper and described in the detailed NORM transport guideline [11].

The considerations for blending of different materials are caused by certain difficulties in regards to the transport of NORM, namely – the possibility of a 'denial of shipping' for a particular material.
The issue of 'denial of shipment' has an increasing impact in international trade, *manifested in such actions as the denial of service by airline pilots and truck drivers, or refusals by various carriers, ports and handling facilities to deal with radioactive material* [46].
It has been noted that the difficulties in shipping of certain minerals have been encountered, particularly denial of service by shippers for materials labelled as 'radioactive' [22].

Basically, a shipping company is not willing to transport radioactive material due to the over-complicated and time-consuming procedures resulting from the requirements of individual countries. It would be, therefore, desirable for a mineral concentrate to be transported as 'excepted package' (part 4 of the guideline [11]), when a shipment does not have to be signposted as 'radioactive'. There are several ways to achieve this – radioactive material can be blended with the 'radioactively-inert' one, or drums/bags containing material emitting gamma-radiation could be placed in the middle of a sea-container that is later filled with ballast material.

Both of these methods, however, are bound to generate an additional interest (and, possibly, a lengthy delay) at a border crossing point, due to the following description in the TECDOC [40]:
*…for truck traffic and cargo containers the most frequent alarms will be innocent alarms caused by large quantities of naturally occurring radioactive material. For example, large shipments of fertilizer, agricultural produce, tobacco products, some ores, porcelain, and timber have been known to cause alarms. However, it should be noted that these radiation signatures are uniformly distributed through the load and therefore, are different from the usually more localized signature of individual sources or trafficked radioactive material.*
A suggestion for a NORM exporter on what documentation must be provided in this case is provided in the end of the paper (**suggestion 1.3**).

From the practical point of view, the monitoring of shipments of different materials in the USA indicates a significant difference between data obtained for commercially available products and for low specific activity radioactive material [47].

The data was obtained with the help of a portal monitor that was used for the inspection of trucks on a highway, and the comparison is presented in counts per second:
Tobacco: 1500-2000 cps
Cat Litter: 2000-3000 cps
Bauxite ore: 2000-4000 cps
Roofing tiles: 4000-4500 cps
Fibreboard ceiling tiles: 1000-9000 cps
Ceramic tiles: 1000-19000cps
Radioactive material LSA: 70000-260000 cps
Typical values obtained for Technologically Enhanced NORM (TENORM) were around 10000 cps (ceramics), and between 14000 and 20000 cps (earthen materials).

It is, therefore, evident that materials containing naturally occurring radionuclides in concentrations above 1 Bq/g (but below 10 Bq/g, which makes them exempt from transport regulations) would attract specific attention as the expected 'count' on the monitor used in the study would be between 10000 and 40000 cps, depending on radionuclides' concentrations.

The Technical Document [40] is notably deficient in one way: the information on radionuclides typically present in NORMs is provided and the reference is made to Annex I, but the Table II of this Annex gives information in regards to radionuclides in NORM that is (a) incomplete, and (b) in some cases, incorrect.

Whilst the completeness of the list of substances can be debated, an example of information provided for 'monazite sand' calls for the table to be revised. The data in the TECDOC [40] specifies that this material contains approximately 0.03-1.0 Bq/g of $^{226}$Ra and 0.05-3.0 Bq/g of $^{232}$Th; when another IAEA document states that monazite sand contains 6-20 Bq/g of $^{238}$U ($^{226}$Ra) and 160-170 Bq/g of $^{232}$Th [33]. In practice, the material may contain 30 Bq/g of $^{238}$U ($^{226}$Ra) and 250-270 Bq/g of $^{232}$Th.

An updated table containing approximate activity concentrations for materials that are likely to be encountered at international borders is provided in the **Appendix I** of this paper. The information in this table will be expanded and regularly updated in the online version of the paper on the website mentioned in [11].

## 5. Practical suggestions

Several practical suggestions are presented below. Some of them are relevant for companies dealing with NORM (1.1-1.3), others (2.1-2.3) – for appropriate regulatory authorities, and one (3) – for all stakeholders.

### Suggestion 1.1

A company in any country planning to export NORM to a specific country needs to contact an appropriate authority in this 'importing' country and inquire about possible requirements for a particular material [39].

This contact can be made:

(a) Via the company that imports the material. On the first sight, this seems to be the preferred way, but this is not necessarily so. Relationships between exporters and importers could be quite complex, and the company selling the material will probably not want to put an additional burden on the buyer. Different aspects of the concept of ‘product stewardship’ that is becoming prevalent in the international trade in minerals are not addressed in this paper, but it would be prudent to assume that the burden of obtaining all necessary approvals lies with the seller of the material.

(b) Directly – using a radiation protection adviser with the detailed knowledge of all relevant regulations. Radiation safety officers that may be employed by some mineral processing companies typically deal with day-to-day radiation protection and monitoring issues and are unlikely to be able to help in the interpretation of a specific regulation, particularly to a ‘foreign’ regulatory body. Also, it seems more appropriate to employ an ‘independent expert’ – to demonstrate to all stakeholders that a possibility of biased conclusions is minimised to the maximum extent practicable.

(c) Via the appropriate regulatory authority in the exporting country. This method is, naturally, more appropriate, but due to some constrains on regulatory authorities it may take significant time before any contact with a ‘foreign’ regulatory body is made.

Typically, there are four stakeholders in international trade in NORMs: exporter, importer, and appropriate authorities in both countries. It appears that approach specified in (b) above is the one that is likely to achieve relatively quick and satisfactory outcome for all stakeholders.

The approach in (c) must also be followed, to ensure that in time appropriate direct contacts are established between regulatory authorities in relevant countries.

Suggestion 1.2

It is suggested that transport documentation for a particular material contains detailed information about the concentrations of naturally occurring radionuclides in this material. One of the suggestions was provided in Canadian NORM Guidelines issued in 2000 [52]: *Ensure that the transport manifest contains the descriptor “Naturally Occurring Radioactive Material – NORM”.* It may, however, no longer be sufficient at a particular border crossing.

As it is clear that requirements for documentation will differ from country to country, it is suggested to provide all necessary information in the document that is already accompanying every mineral shipment – Material Safety Data Sheet (MSDS).

It appears that at the moment only the mineral sands industry (titanium and zirconium minerals) provides ‘radiation-related’ information in its MSDS for materials with low activity concentrations (under 10 Bq/g). The typical information provided in an MSDS for NORM is:
*…contains traces amount of the naturally occurring radioactive substances such as uranium and thorium…*
Several MSDS that are publicly available (out of many) were analysed at random [53-58] and it appears that only the ones supplied by Iluka Resources from Western Australia [56, 57] do contain the data on thorium and uranium concentrations (in Bq/g) for a particular mineral.

Most MSDS provide some information on a possibility of radiation exposure from a particular mineral (in the form of dust concentrations specified in $mg/m^3$, exposure time in close vicinity of the material, etc)

In regards to the issue considered in this paper the information in an MSDS simply refers a buyer of a material to a regulation ‘in general’:

- *…The regulation pertaining to radiological protection varies from country to country. It is the responsibility of the buyer to ensure that those are met in accordance with his/her country law…*
- *…It is recommended that you consult with current regulations…*
- *…Consult and comply with current regulations…*

As the statements quoted above appear to be inconsistent with the principle of 'product stewardship', it is suggested that all relevant companies review their MSDS to ensure that all of them contain not only detailed information on concentrations of naturally occurring radionuclides but also an example of gamma-spectra for a particular mineral (in the form of either table or a chart). Whilst not absolutely necessary, this information would help in the process of clearing a particular NORM through the radiation detection equipment at international border crossings.

Suggestion 1.3

It may be that NORM is transported as an 'excepted package' due to either blending of radioactive material with an 'inert' one or due to the fact that bags/drums with the material are placed in the middle of a sea container with ballast/shielding material around them.

In this case, in addition to the information provided as per suggestion 1.2 above, supplementary documentation that may be required is as follows:

- In the case of blending: information on radioactivity content of blended materials and a certificate from an appropriate regulatory authority to confirm that the blending has been approved by this authority. The IAEA Safety Guide [29] clearly states that *deliberate dilution of material… to meet the values of activity concentration… should not be permitted without the prior approval of the regulatory body*.
- In the case of several bags/drums in the middle of a sea container: detailed data on the material and its packaging, and a drawing specifying the location of the package inside and provisions for its stability in the centre of this container in case of an accident.

Suggestion 2.1

IAEA Safety Guide [29] suggests that a 'graded approach' can be used when activity concentration exceeds the relevant values by several times; and it is also suggested that it should be consistent with the magnitude and likelihood of radiation exposure.

When NORM is imported to a country for processing, two aspects should be considered:

a) Possible radiation exposures of workers and general public, and
b) Potential contamination of the environment by residues from this processing.

In the first place the level of possible radiation exposure should be established. Naturally, under no circumstances the limit of 1 mSv/year for a member of general public (or a fraction of this limit, if specified in the legislation) can be exceeded.

A factory processing NORM will need to submit a radiation management plan to a regulatory authority. Upon receiving this plan, an appropriate authority may apply 'graded approach' to possible occupational exposures in NORM processing as follows:

1. Possible dose is "in order of several tens of microsieverts per year", say, less than 0.1 mSv per year – no regulation will be necessary;

2. Possible dose is below 1 mSv per year – a brief justification statement is to be prepared for the review by an appropriate regulatory authority. A licence/authorisation may then be issued.
3. Possible dose is below 6-10 mSv per year, but higher than 1 mSv/year (depending on the radiation protection legislation in a particular jurisdiction) – a comprehensive management plan is prepared for the appropriate regulatory authority. This document is a subject for review by this authority, which must ensure that the best practicable technology is used in the processing of NORM and doses are as low as reasonably achievable. Then a licence/authorisation could be issued, and appropriate monitoring and reporting requirements would be established.
4. An all-inclusive periodic review of working practices will be required and strict controls placed on a processing company if occupational exposure can potentially exceed 20 mSv/year.

A separate (but a similar) process must be followed to ensure that any possibility of the contamination of the environment and radiation exposure of the biota is minimised. As the processing of NORMs typically involves chemical and thermal treatment of the material and many hazardous substances may be used in the process, all approvals are typically obtained via an environmental protection authority, with radiation protection being only a part of an overall environmental impact assessment.

It is suggested that the decision to allow the importation of a particular NORM into the country should be based on information described above, and not on a simple comparison of numerical data, such as concentrations of radionuclides. For example, milling of a mineral containing 4 Bq/g of $^{232}$Th in a facility with appropriate dust control system will result in the radiation exposure of a plant operator that may be significantly less than in the case of milling similar material containing 2 Bq/g of $^{232}$Th in a factory with no provisions for dust suppression.

It is, therefore, important to ensure that an appropriate regulatory authority has all necessary information before the decision about a particular shipment of a particular mineral is made. The 'graded approach' can then be applied to relevant work practices and to the re-use or disposal of waste products generated by these practices, and specific exemptions could then be issued for the information of customs officers in regards to particular material shipments.

Suggestion 2.2

IAEA Safety Guide [29] suggests that –

- *"…the regulatory bodies concerned should co-ordinate their activities and share their concerns… to facilitate the movement of materials"*; and
- *"…to avoid unnecessary hindrances to trade at boundary transfer points, States should co-ordinate their regulatory strategies and their implementation…"*

As suggested in 1.3 above, it is likely that appropriate regulatory authorities in exporting countries will be approached by companies exporting NORM and asked for the assistance in contacting authorities in importing countries.
It is expected that, in accordance with IAEA Safety Guide [29], controls over the export of NORMs will need to be established [31] and communicated to appropriate authorities in importing countries.

Suggestion 2.3

Appropriate regulatory authorities in importing countries must provide comprehensive guidelines on the detection of radioactive material at international borders to the law enforcement personnel such as customs officers and police. It is expected that appropriate monitoring equipment in accordance with technical reference manual [42] is provided, and the suggestions from three international guidelines [39-41] are included in relevant procedure manuals.

One of the tests of the border monitoring equipment described in the manual [42] calls for the exposure to “natural thorium and $^{40}K$ (fertilizer)”. It is, however, not specified what may be the source of natural thorium. Therefore, it is suggested that small parcels of mineral monazite (containing up to 270 Bq/g $^{232}Th$ and 30 Bq/g of $^{238}U$) are used in these tests. Monazite can be obtained from companies involved in heavy mineral sands mining and processing in South Africa, India, Malaysia and Australia.

Suggestion 3 – Training and education

- Government:

Appropriate regulatory authorities must be fully familiar with NORM processes in their state/country to ensure that correct advice is given to other government departments, to the users of NORMs, and to the general public. As it is correctly stated in the report of the European Committee on Radiation Risk, –
*In areas of complex scientific issues where there may be low probability, high impact risks, proper scientific advice is crucial* [59].
It is also important that a comprehensive border monitoring guideline described in 2.3 above is supplemented by appropriate training of all relevant personnel.

- Industries producing/using NORMs:

Training programs for all workers dealing with NORM are essential; all employees must clearly understand the risks of radiation exposure and the need for radiation monitoring. It is also important to ensure that results of any monitoring and/or assessments are communicated and explained to every worker involved in the monitoring program.

It is also necessary that the management of a company dealing with NORM has access to qualified radiation protection advice and is aware of any current and future legislation that is potentially applicable to company’s products or imported materials in all states/countries where this company operates.

- Shipping/transport industry

The importance of training for relevant personnel cannot be understated. The fear of radiation has been described in detail in the full text of the paper [2] and, unfortunately, it still prevails when a shipping company does not wish to transport any substance that is labelled ‘radioactive’.

Whilst the transport of the material as an ‘excepted package’ [11] may provide some answers, the fact that the sign ‘radioactive’ must be visible when the package/container is opened may create an unwarranted panic in case of an accident.

One recent court case in the USA [60] indicates that a person could sustain ‘compensable injury’ simply from fear of radiation. This particular case was a result of a truck driver’s contact with a leaking container that was mistakenly labelled as radioactive waste. Although the driver suffered no physical injuries and was not actually exposed to radiation, the court determined that the driver’s post traumatic stress disorder, depression, fatigue and anxiety were rationally connected to his contact with the hazardous material; and are, therefore, compensable under Tennessee’s Workers Compensation Act.

A complete training program for all workers involved in loading, transporting, and unloading NORMs must be designed and carried out by a qualified radiation protection adviser; with the approval of an appropriate regulatory authority. Monitoring of radiation exposure of certain transport occupations and communication of data obtained to relevant personnel is also essential. This exposure is very low and, in most cases, can only be modelled theoretically – due to the fact that measured levels are often less than minimum detection limit of the equipment in use.
Two studies carried out in the Republic of South Africa indicate that, –

- The maximum dose that can be received by personnel transporting igneous phosphate rock (concentrations of $^{238}$U=0.14 Bq/g and $^{232}$Th=0.47 Bq/g) is 0.08 mSv/year [61];
- The maximum dose that can be received by personnel transporting zircon sand (concentrations of $^{238}$U=3.1-4.4 Bq/g and $^{232}$Th= 0.4-0.8 Bq/g) is 0.144 mSv/year. An actual incident during the bulk transport of zircon sand and the following clean up has resulted in radiation exposures in the range between 0.4 and 5.1 *micro*Sieverts [62].

A shipping company may consider an additional study, which will address a particular NORM in particular situations. Other organisations, such as port authorities, could also commission similar studies.

## Appendix I
## Activity concentrations for materials that could be encountered at international borders

Information was collected from several publications [16, 32, 33, 48, 49, 50, 51], proceedings of conferences mentioned in [2, 4, 5, 6, 14, 46] and from other papers referenced on the Internet site mentioned in [11]. A particular attention was paid to the materials that may trigger an alarm at an international border crossing.

| Substance | Approximate activity concentration in Bq/g | | |
|---|---|---|---|
| | $^{40}K$ | $^{226}Ra$ ($^{238}U$) | $^{232}Th$ |
| Mining and minerals processing | | | |
| Bauxite (aluminium production) | 0.01-0.60 | 0.1-9.0 | 0.03-2.3 |
| Spodumen (beryllium ore) | n/a | 0.59 | 0.022 |
| Coal (Brazil) | n/a | 0.359 | 0.033 |
| Coal (China) | 0.104 | 0.036 | 0.030 |
| Coal (EU) | 0.001-0.3 | 0.007-0.185 | 0.003-0.022 |
| Coal (Hungary) | n/a | 0.3-0.9 | n/a |
| Coal (Japan/Australia) | 0.010-0.500 | 0.005-0.050 | 0.005-0.070 |
| Coal (Poland) | 0.785 | n/a | 0.159 |
| Columbite (columbium production) | n/a | n/a | up to 50.0 |
| Copper ore | 0.466 | 0.03-100.0 | 0.02-0.11 |
| Gold ore concentrate (Brazil) | n/a | 0.114 | 0.049 |
| Gold ore concentrate (Finland) | n/a | up to 54.0 | n/a |
| Iron ore | n/a | 0.005-0.245 | 0.005 |
| Iron slag | 0.035 | 0.12-0.15 | 0.15-0.23 |
| Pyrochlore (niobium production) | n/a | 6.0-10.0 | 7.0-80.0 |
| Niobium ore (Brazil) | n/a | 0.93-4.55 | 0.904-6.390 |
| Nb/Ta concentrate (niobium production) | n/a | up to 70.0 | up to 8.0 |
| Phosphate ore (Brazil) | n/a | 0.11-0.88 | 0.204-0.753 |
| Phosphate ore (China) | n/a | 0.15 | 0.025 |
| Phosphate ore (Christmas Island) | n/a | 0.30 | 0.007 |
| Phosphate ore (Cuba) | 0.027-0.238 | 0.09-2.70 | 0.003-0.039 |
| Phosphate ore (Israel/Jordan) | n/a | 1.30-1.85 | n/a |
| Phosphate ore (Morocco/Tunisia) | n/a | 0.59-1.70 | 0.010-0.200 |
| Phosphate ore (Nauru) | n/a | 0.85 | n/a |
| Phosphate ore (Senegal/Togo) | n/a | 1.3-2.3 | 0.07-1.00 |
| Phosphate ore (South Africa) | n/a | 0.14 | 0.47 |
| Phosphate ore (Tanzania) | 0.28 | 5.76 | 0.35 |
| Phosphate ore (former USSR) | 0.037 | 0.04-0.39 | 0.04-0.23 |
| Phosphate ore (USA) | n/a | 0.15-4.80 | 0.01-0.08 |
| Rare earth concentrate | n/a | 1.0 | 6.0-1.0 |
| Rare earth concentrate (monazite) | n/a | 1.0-30.0 | 3.0-270.0 |
| Ta/Nb concentrate (tantalum production) | n/a | up to 70.0 | up to 8.0 |
| Tantalum ore | n/a | 0.06 | 0.005 |
| Tin ore | n/a | 1.0-2.0 | 0.3 |
| Tin slag for tantalum production | n/a | 4.0 | 11.0 |
| Tin by-product (amang) | n/a | 2.0-17.8 | 3.0-326.7 |
| Titanium heavy sands concentrate | n/a | 0.2-1.7 | 0.6-6.6 |
| Rutile – natural and synthetic (titanium production) | n/a | 0.2-0.5 | 0.2-2.9 |
| Ilmenite (titanium production) | 0.005 | 0-1.0 | 0-4.1 |
| Cassiterite (zinc production) | 0.065 | 0.001 | 0.021-0.300 |
| Baddeleyite (zirconium production) | n/a | 7.0 | 0.3 |
| Zircon sand (zirconium production) | 0 | 3.7-16.0 | 0.3-13.0 |

| Substance | Approximate activity concentration in Bq/g | | |
|---|---|---|---|
| | $^{40}K$ | $^{226}Ra$ ($^{238}U$) | $^{232}Th$ |
| Building materials | | | |
| Bricks | 0-0.981 | 0.014-2.893 | 0-0.648 |
| Cement | n/a | 0.04-0.20 | 0.03-0.20 |
| Cement with 20% fly ash | 0.18 | 0.055 | 0.040 |
| Cement with 20% blast furnace slag | 0.219 | 0.02 | 0.038 |
| Clay | 0.5 | 0.04 | 0.02 |
| Concrete | 0.15-1.60 | 0.04-2.2 | 0.04-0.20 |
| Concrete with 20% copper slag | n/a | 0.14 | 0.035 |
| Coal ash (brick and concrete production) | 0.44 | 0.1-0.3 | 0.10-0.12 |
| Gypsum (natural) | 0.008-0.4 | 0.007-0.02 | 0.001-0.01 |
| Granite | 0.6-4.0 | 0.03-0.5 | 0.04-0.36 |
| Phosphogypsum (for plasterboard) | up to 0.12 | up to 1.0 | up to 0.3 |
| Sand and gravel | n/a | 0.015 | 0.02 |
| Sandstone | 0.04-1.00 | 0.02-0.07 | 0.02-0.07 |
| Slate | 0.5-1.0 | 0.03-0.07 | 0.04-0.07 |
| Tiles (floor and wall) | 0.19-0.27 | 0.028-0.096 | 0.014-0.083 |
| Tuff | 0.9-2.0 | 0.11-0.26 | 0.19-0.35 |
| Wall board (from natural gypsum) | 0-0.19 | 0.02 | 0.01 |
| Wall board (from phosphogypsum) | n/a | 0-0.452 | 0-0.02 |
| Other materials | | | |
| Phosphoric acid | n/a | 1.2-1.5 | n/a |
| Mono-ammonium phosphate (MAP), Morocco | 0.028 | 2.741 | 0.009 |
| Mono-ammonium phosphate (MAP), Russia | 0.037 | 0.041 | 0.014 |
| Di-ammonium phosphate | n/a | 2.3 | 0.015 |
| Di-calcium phosphate | n/a | 0.74 | 0.037 |
| Triple superphosphate | 0.092 | 0.080-2.160 | 0.007-0.048 |
| Bony superphosphate | 0.045 | 0.057 | 0.004 |
| Normal superphosphate | n/a | 0.52-1.1 | 0.015-0.044 |
| PK (phosphate/potassium) | n/a | 0.41 | 0.015 |
| NPK (nitrogen/phosphate/potassium) | n/a | 0.44-0.47 | 0.015 |
| Alumina | n/a | 0.3-0.6 | 0.5-1.2 |
| Glazes (zirconium) | n/a | 1.0 | 0.4 |
| Scrap metal from oil & gas (scale & sludge) | n/a | 1-100 (up to 4000) | 0-0.5 |
| Refractory brick | n/a | 4.0-10.0 | 0.2-10.0 |
| Slag wool (old insulation doors & bakery ovens) | n/a | 3.0-5.0 | 10.0-15.0 |
| Zirconia | n/a | 7.0 | 0.3-1.0 |

NOTES:

- Material containing more than 10 Bq/g of $^{232}Th$ will be a subject to international transport regulations [8, 9]. If it is known that $^{226}Ra$ is in equilibrium with its parent $^{238}U$, the same 10 Bq/g activity concentration limit appears to be applicable. If, however, $^{238}U$ has been removed (or not present – as in oil and gas sludge), the limit for $^{226}Ra$ will be 100 Bq/g (assuming that an exemption from para 107(e) of the regulations [8, 9] is applicable to a particular material).
- The data on the materials containing naturally occurring radionuclides in very low concentrations has also been provided, for the reference. For example, it is very unlikely that a container with natural gypsum would trigger an alarm. If, however, an alarm is triggered, – the data in the table above would indicate that either material in question is not what is stated in transport documents, or some other substance/object is present in this particular container.
- The information in this table will be expanded and regularly updated in the online version of the paper on the website mentioned in [11].

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