The trade in radioactive materials – potential problems and possible solutions

Nick Tsurikov

Calytrix Consulting Pty Ltd
P.O. Box 8223, Perth B.C. WA, 6849, Australia

Abstract. 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. IAEA Regulations for the Safe Transport of Radioactive Material (TS-R-1) and Advisory Material (TS-G-1.1) provide detailed instructions on the transport of material with elevated concentrations of natural radionuclides. However, these documents are somewhat complex for a common user and this paper presents an overview of a simplified step-by-step guideline developed for both minerals industry and appropriate regulatory authorities. Also presented are considerations for regulatory control of natural radioactivity in international transport and trade, potential radiation protection and regulatory problems that may arise during transport and at international border crossings; solutions for these problems are offered in the conclusion.

1. Introduction

An analysis of the suitability of IAEA Basic Safety Standards [1] 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].

2. Guideline for the transport of mineral concentrates containing NORM

Whilst the control of NORM in processing/storage environment and the disposal of the generated waste 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 [7, 8] and Advisory Material for these Regulations [9] 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 guideline has been developed for both minerals industry and appropriate regulatory authorities [10]. 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 [8] are (or shortly will be) in force; in other ones – 1996 Regulations [7] apply; in rare cases a special amendment was made to the exemption clause for NORM prior to the adoption of international regulations [11]. 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 and 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 [10] is available for download from http://calytrix.biz/radlinks/tenorm/.

3. International trade in commodities containing NORM

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 [12], that, – *guidance is lacking on how to deal with inconsistencies in classification and transport of NORM residues that have been released from regulatory control.* Another document [13] 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.* 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 [12].

It appears that potential problems may be easily eliminated by adopting Title VII of the European Council Directive 96/29/Euratom [14]. It must be noted, however, that this Directive 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 [15] 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 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 becomes even more complex when different regulations apply within the same country due to the federal system of government, like, for example in Australia and in the USA.

A big step forward was the publication of the IAEA Safety Guide RG-S-1.7 [16] in 2004, which was followed by the publication of the associated Safety Report in 2005 [17]. 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 [7, 8]. Safety Guide [16] 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, instead of a very complicated (and probably unnecessary) modelling of exposure to NORM.

The Safety Guide [16] 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 [16] will apply to international trade in minerals that contain natural radionuclides in concentrations that are exempted under the international transport regulations [7, 8] 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 [18].

The Safety Guide [16] 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 below 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 [19], which is above the typical level of background radiation by about two orders of magnitude [19]. 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 are 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 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 (**suggestion 1.1**).

Several quite comprehensive documents describing NORM in detail may be of help for appropriate regulatory authorities [20-22], 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 [23]. The procedure suggested in this document is based on the comparison of background radiation level and the radiation emitted from a particular material.

4. Control of NORMs at international borders

Three guidelines of a special importance were published in September 2002 by the International Atomic Energy Agency. To prevent incidents and to harmonize 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 [24-26]. These documents are supported by the reference manual on equipment specifications and test procedures [27].

The second document [25] is of a particular interest and needs to be discussed in detail, together with the reference manual [27]. The TECDOC [24] 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 [27] contains technical data for border monitoring equipment, test procedures and many practical examples.

Majority of actual alarms at borders will be *innocent* ones, – resulting from the presence of medical radionuclides administered to patients, NORM, 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. Suggestions for a NORM exporter on what documentation must be provided and what information it must contain is provided in the end of the paper (**suggestions 1.2** and **1.3**).

The Technical Document [25] 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 [25] specifies that this material contains 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 [20]. 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 could 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 [10].

5. Conclusion – practical suggestions

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 [24]. This contact can be made via the company that imports the material, directly – using a radiation protection adviser with the detailed knowledge of all relevant regulations, or via the appropriate regulatory authority in the exporting country.

Suggestion 1.2
The transport documentation for a particular material needs to contain detailed information about the concentrations of naturally occurring radionuclides in this material. As the requirements for documentation will differ from country to country, all necessary information may be provided in the document that is typically accompanying every material shipment – Material Safety Data Sheet (MSDS). 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 material (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:

- In the case of blending: information on radioactivity content of blended materials and a certificate from an appropriate regulatory authority to confirm that this authority has approved the blending. The IAEA Safety Guide [16] 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 [16] suggests that a 'graded approach' can be used when activity concentration exceeds the relevant values by several times; and it is also suggested that this should be consistent with the magnitude and likelihood of radiation exposure.

A factory processing NORM would 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:

- 0.0 – 0.1 mSv/year: no regulation will be necessary.
- 0.1 – 1.0 mSv/year: a brief justification statement is to be prepared for the review by an appropriate regulatory authority. A licence/authorisation may then be issued.
- 1.0 – 6.0 mSv per year: a comprehensive management plan is prepared for the review by the appropriate regulatory authority. After it has been established that the best practicable technology is used in the processing of NORM and doses are as low as reasonably achievable a licence/authorisation could be issued and appropriate monitoring and reporting requirements would be established.
- An all-inclusive periodic review of working practices will be required and strict controls placed on a processing company if occupational exposure may exceed 6 mSv/year.

A separate (but a similar) process must be followed to ensure that any possibility of the exposure of members of the public, contamination of the environment and radiation exposure of the biota is minimized. 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 material 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 [16] 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 [16], controls over the export of NORMs will need to be established [18] 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 [27] is provided, and the suggestions from three international guidelines [24-26] are included in relevant procedure manuals.

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* [28]. It is also important that a 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' [10] 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 [29] 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 Law.

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 typically 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.

Acknowledgements. The paper is based on an extensive study [30] performed with the help of P.J. Hinrichsen (Republic of South Africa). M. Omar (Malaysia) and H.R.S.M. Fernandes (Brazil).

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

Information was collected from several publications [19, 20, 31-35], proceedings of conferences mentioned in [2, 4, 5, 6, 12, 36] and from other papers referenced on the Internet site [10]. The information in this table will be expanded and regularly updated in the online version of the paper at http://calytrix.biz/radlinks/tenorm/.

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 [7, 8]. 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 [7, 8] 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.

REFERENCES:

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No.115, IAEA, Vienna (1996)

[2] TSURIKOV N., KOPERSKI J., TENORM Legislation – Theory and Practice, IAEA TECDOC-1271, Technologically enhanced natural radiation (TENR-II), Proceedings of an International Symposium, Rio de Janeiro, Brazil, September 1999, pp.3-9 (full text of the report is available at http://calytrix.biz/radlinks/tenorm)

[3] KOPERSKI J., TSURIKOV N., Impact of ARPANS-like Legislation on Minerals Industry in Australia – the TENORM Issue, presented at the 24th Annual Conference of the Australasian Radiation Protection Society, Margaret River, Western Australia, 1999

[4] FERNANDES, H.M., KRUGER I.D., OMAR M., TSURIKOV N., VAN DER WESTHUIZEN R., Cooperation – the Way Out, Proceedings of the International Congress on the Safety of Natural and Artificial Radionuclides, Cape Town, Republic of South Africa, October 2000

[5] GUSTAFSSON M., MRABIT K., NA S.H., Natural Radiation at Work: Current and Future IAEA Activities, presented at NORM-III Symposium, Brussels, Belgium, September 2001

[6] WYMER D., Application of International Safety Standards to Work Involving Exposure to Natural Radiation, IAEA-TECDOC-1472, Proceedings of the NORM-IV Symposium, Szczyrk, Poland, May 2004, pp.419-430

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Requirements No.TS-R-1, IAEA, Vienna (1996 Edition, revised in 2000)

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Safety Requirements No.TS-R-1, IAEA, Vienna (2005 Edition)

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Guide No.TS-G-1.1, IAEA, Vienna (2002)

[10] TSURIKOV N., HINRICHSEN P.J., OMAR M., FERNANDES H.R.S.M., Application of the Regulations for the Safe Transport of Radioactive Material to Bulk Shipments of Materials in Minerals Industry, submitted for publication in Radiation Protection in Australasia, (also at http://calytrix.biz/radlinks/tenorm)

[11] AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY, Code of Practice – Safe Transport of Radioactive Material, Radiation Protection Series No.2, ARPANSA (2001)

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulatory and management approaches for the control of environmental residues containing naturally occurring radioactive material (NORM), Proceedings of a technical meeting held in Vienna, 6–10 December 2004, IAEA-TECDOC-1484, Vienna (2006)

[13] EUROPEAN COMMISSION, Evaluation of the application of the concepts of exemption and clearance for practices according to title III of Council Directive 96/29/Euratom of 13 May 1996 in EU Member States, Radiation Protection 134, Volume 1: Main Report, EC, Brussels (2003)

[14] EUROPEAN COMMISSION, Council Directive 96/29/Euratom of 13 May 1996 Laying Down Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionizing Radiation, Official Journal of EC, 29 June 1996, No.L159/1-28

[15] EUROPEAN COMMISSION, Communication from the Commission concerning the implementation of the Council Directive 96/29/Euratom, 98C/133/03, EC, Brussels (1998)

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, Safety Guide No.RS-G-1.7, IAEA, Vienna (2004)

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance, Safety Report No.44, Vienna (2005)

[18] TSURIKOV N., NORM and National Directory, Radiation Protection in Australasia, Vol.22, No.2, July 2005, pp.64-67
[19] UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, Report to the General Assembly, 2000, Sources and Effects of Ionizing Radiation, Volume I – Sources, Annex B – Exposures from natural radiation sources, Tables 6 and 7, pp.116-118
[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Extent of Environmental Contamination by Naturally Occurring Radioactive Material (NORM) and Technological Options for Mitigation, Technical Report Series No.419, IAEA, Vienna (2003)
[21] EUROPEAN COMMISSION, Effluent and dose control from European Union NORM industries: Assessment of current situation and proposal for a harmonised Community approach, Radiation Protection 135, EC, Brussels (2003)
[22] U.S. NUCLEAR REGULATORY COMMISSION, Systematic Radiological Assessment of Exemptions for Source and By-product Materials, NUREG-1717, NRC (1999)
[23] STATE QUALITY SUPERVISION AND QUARANTINE INSPECTION BUREAU, PEOPLE'S REPUBLIC OF CHINA, Professional Standard for Quarantine Inspection at Entry and Exit of People's Republic of China – Rules of Radioactivity Inspection for Import Minerals, SN/T 1537-2005, China Standard Publisher, May 2005 (in Chinese)
[24] INTERNATIONAL ATOMIC ENERGY AGENCY, Prevention of the inadvertent movement and illicit trafficking of radioactive materials, IAEA-TECDOC-1311, Vienna (2002)
[25] INTERNATIONAL ATOMIC ENERGY AGENCY, Detection of radioactive materials at borders, IAEA-TECDOC-1312, Vienna (2002)
[26] INTERNATIONAL ATOMIC ENERGY AGENCY, Response to events involving the inadvertent movement of illicit trafficking of radioactive materials, IAEA-TECDOC-1313, Vienna (2002)
[27] INTERNATIONAL ATOMIC ENERGY AGENCY, Technical and Functional Specifications for Border Monitoring Equipment, Technical Guidance Reference Manual, Nuclear Security Series No.1, Vienna (2006)
[28] EUROPEAN COMMITTEE ON RADIATION RISK, Criteria for "Clearance": Controlling the Release of Solid Materials of Very Low Average Activity for Reuse, Recycling and Disposal. Guidance Note No.2003/1, ECRR, Brussels (June 2003)
[29] Saylor v. Lakeway Trucking S.W.3d 2005 WL 3163521 (Tenn., November 29, 2005)
[30] TSURIKOV N., HINRICHSEN P.J., OMAR M., FERNANDES H.R.S.M., Regulation of natural radioactivity in international transport and trade, presented at the Second Asian and Oceanic Congress on Radiation Protection, Beijing, China, October 2006
[31] EUROPEAN COMMISSION, Practical use of the concepts of clearance and exemption, Radiation Protection 122, Part II – Application of the concepts of exemption and clearance to natural radiation sources, EC, Brussels, 2002
[32] US NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Radiation Protection in The Mineral Extraction Industry, Report No.118, NCRP (1993)
[33] HARVEY M.P., HIPKIN J., SIMMONDS J.R., MAYALL A., CABIANCA T., FAYERS C., HASLAM I., Radiological consequences of waste arising with enhanced natural radioactivity content from special metal and ceramic processes. National Radiological Protection Board (NRPB), UK. Issued by European Commission, EUR15613EN, EC, Brussels (1994)
[34] MARTIN A., MEAD S., WADE B.O., Materials containing natural radionuclides in enhanced concentrations. Alan Martin Associates, UK. Issued by European Commission, EUR17625EN, EC, Brussels (1997)
[35] COOPER M., Naturally Occurring Radioactive Materials in Australian Industries – Review of Current Inventories and Future Generation, Report for the Radiation Health and Safety Advisory Council, ERS-006 (December 2003)
[36] INERNATIONAL ATOMIC ENERGY AGENCY, Safety of Transport of Radioactive Material, Proceedings of an international conference, Vienna, July 2003, Vienna (2004)