**Proceedings of the 17th International Symposium on the Packaging and Transportation of Radioactive Materials**
**PATRAM 2013**
**August 18-23, 2013, San Francisco, CA, USA**

# COORDINATED RESEARCH PROJECT ON THE "APPROPRIATE LEVEL OF REGULATORY CONTROL FOR THE SAFE TRANSPORT OF NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM)"

**K. Kasturi Varley**
International Atomic Energy Agency

**Christopher Bajwa**
International Atomic Energy Agency

## ABSTRACT

In 2006, the International Atomic Energy Agency (IAEA) established a Coordinated Research Programme (CRP) on Safety of Transport of Radioactive Material in response to the recommendation made by the IAEA Transport Safety Standards Committee (TRANSSC) "to examine the adequacy of the current safety standards pertaining to the transport of naturally occurring radioactive material (NORM)". The CRP considered research studies from nine countries related to the transport of a variety of NORM. The research areas provide full coverage of the subject, including exposures to both the public and workers. One important consideration to the work of the CRP is consideration of the basis of the current exemption levels for transport of NORM; namely, the basis for the 10× larger exemption level of 10 Bq/g for NORM not intended for the extraction of radionuclides, is unclear. Details of the research, outcome, conclusions, and potential applications to transport regulations will be presented in this paper.

## BACKGROUND

Rational for the CRP

In July 2003 an International Conference on the Safety of Transport of Radioactive Material[i] took place in Vienna to address a range of important issues associated with the safe transport of radioactive material [1]. Among the issues identified for further work was reconsideration of the applicability of transport regulations to naturally occurring radioactive material (NORM).

The Conference identified a need for additional research to relieve unnecessary regulatory burdens related to the transport of very low activity NORM. Since the 1996 edition of the IAEA Transport Regulations [2] introduced radionuclide-specific exemption levels in lieu of the single 70 Bq/g value, ores, tailings, and backfill from large mining operations (e.g. phosphate, coal, gold and monazite) have been brought within the scope of the Regulations. To address this situation, the 1996 Regulations included an allowance for a factor of 10 higher than the exemption quantities for naturally occurring materials, provided they are not intended to be processed to extract the naturally occurring radionuclides. The Conference suggested that the full impact of and technical basis for the 'factor of 10' exemption be thoroughly researched.

Subsequent to the Conference, the Board of Governors approved the Action Plan for Safety of Transport of Radioactive Material in which an action required the Secretariat to initiate a CRP on the appropriate regulatory control for the safe transport of NORM. In 2005 TRANSSC made a recommendation to examine the adequacy of the safety standards pertaining to the transport of NORM. This led to the creation of the CRP on the "Appropriate Level of Regulatory Control for the Safe Transport of Naturally Occurring Radioactive Material (NORM)".

With the change to the exemption levels in the IAEA's Transport Regulations, materials, which previously were not considered radioactive material for transport purposes, are now subject to the packaging, communication, training and emergency response requirements. This situation has significantly increased the cost of shipping certain materials. During the transport of NORM the radiological safety of the worker, the public and the environment must be ensured. Therefore the radiation hazards need to be evaluated and decisions made regarding the degree of control, within the current transport safety regulations, which should be exercised to ensure their safe transport. Additional research to relieve unnecessary regulatory burdens related to the transport of very low activity naturally occurring radioactive material was warranted.

A CRP is usually organized to investigate a particular area of concern with regard to the regulations. Results of the CRP may be used to revise the Regulations or to develop guidance in Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (TS-G-1.1 Rev1)[3] to address transport and packaging of NORM. Recommendations from a CRP do not feed directly into the process for revision of the IAEA Transport Regulations. One or more Member States interested in pursuing recommendations from a CRP should submit proposals for change to the IAEA. The current procedures for review and revision of the Transport Regulations are started every 2 years. Completion of the CRP usually involves the preparation of a TECDOC which summarizes the work performed under the CRP and includes any recommendations made by the CRP.

The CRP schedule usually involves three Research Co-ordination Meetings (RCM's) about 18 months apart. A preparatory meeting was held in November 2006. RCM's were held in April 2007, February 2008 and November 2009. A TECDOC is currently being finalized.

Regulatory Context

The IAEA is the United Nations (UN) agency which has a mandate "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world."[4] Included in this mandate is the authorisation "To establish or adopt, ... standards of safety for protection of health and minimization of danger to life and property (including such standards for labour conditions),"[5]. The first set of transport regulations was completed in 1961. Over the following decades comprehensive reviews by Member States and international organizations were undertaken. The research project addresses the "Regulations for the Safe Transport of Radioactive Material" 2009 Edition (TS-R-1)[6]. TS-R-1 acts as a recommendation and forms the basis for other modal and national regulations, for example: "Recommendations on the Transport of Dangerous Goods, Model Regulations" (UN Model Regulations); "International Maritime Dangerous Goods Code" (IMDG Code) for transport by sea and "Technical Instructions for the Safe Transport of Dangerous Goods by Air" (ICAO Technical Instructions) for transport by air. A companion document, the Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Guide No. TS-G-1.1 (Rev 1) was published in 2008.

Regulations for the Safe Transport of Radioactive Material 2012 Edition No. SSR-6 Specific Safety Requirements [7] now published and addresses the recommendation of the CRP. Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Guide No. SSG26 [8] is presently in publishing.

TS-R-1 provides radionuclide-specific activity concentration (Bq/g) and radionuclide-specific total activity (Bq) exemption values below which the regulations do not apply. Both the concentration and total activity limits have to be exceeded in the consignment before the transport regulations apply. The current IAEA exemption value for the transport of NORM is defined by TS-R-1 para. 107(e) as: "Natural material and ores containing naturally occurring radionuclides which are either in their natural state, or have only been processed for purposes other than for extraction of the radionuclides, and which are not intended to be processed for use of these radionuclides, provided the activity concentration of the material does not exceed 10 times the values specified in Table 2, or calculated in accordance with paras 403–407".

This is further explained in TS-G-1.1 (2008), para 107.4: "factor of 10 times the exemption values for activity concentration was chosen as providing an appropriate balance between the radiological protection concerns and the practical inconvenience of regulating large quantities of material with low activity concentrations of naturally occurring radionuclides."

The exemption limits are raised by a factor of 10 for natural materials and ores "whose usefulness does not lie in the fissile, fertile or radioactive properties of those nuclides", including materials processed by physical and/or chemical means provided the purpose was not to extract radionuclides. For the transport of NORM, the radionuclides of concern are often only Th(nat) and U(nat) provided that these two elements are in natural equilibrium with their decay products. The exemption limits listed in TS-R-1 are 1 Bq/g for both Th(nat) and U(nat), therefore for NORM not intended for use of the radioactive properties the exemption limit is 10 Bq/g. These exemption values were initially derived for inclusion in the overall IAEA Basic Safety Standards (BSS)[9] for radiation protection by establishing a set of representative exposure scenarios and determining the activity concentrations and total activities that would give rise to doses to appropriate critical groups that correspond to the dose criteria for the exemption of practices without further consideration set out in Schedule I of the BSS, on the basis that the dose is of the order of 10 μSv/y or less. IAEA TS-G-1.1 (2008) para 401.4 also notes that the scenarios used to derive the exemption values in the BSS (1996) were not specifically related to transport situations. Subsequent calculations for transport scenarios were performed and it was found that the derived limits were similar to the BSS values and hence, to avoid potential complications, the exemption values derived for the BSS were adopted for the transport regulations.

## CRP APPROACH

Experts from 9 countries participated in the CRP: Brazil, Canada, France, Germany, Iran, Israel, Romania, UK and USA. A wide range of materials from NORM industries were reviewed in the studies including: tantalum, phosphate, potash, zirconium (zircon sands) and other materials for the ceramics industries, scales from oil and gas extraction industries, coal and coal ash, residues from waterworks, wastes from rare earths extraction, ore and waste material from uranium mines. Australia produced a report which was made available to the participants of the CRP, but did not take part.

Participating countries conducted surveys of national industries involving transport of NORM and an assessment of doses to workers and members of the public associated with the transport of NORM. These doses were evaluated using a combination of models and measurements and were based on work practices in place in these countries. Information such as time spent driving or loading, distances from the material etc., was used to characterise transport operations and develop exposure scenarios. Canada, France, Germany and Israel also carried out assessments of doses associated with the transport of NORM based on a normalised modelled approach for a unit activity concentrations in the material transported for a number of radionuclides (K-40, U-238, U-235, Ra-226, Ra-228 U-nat, Th-nat).

Doses were generally calculated for drivers (either employees or members of the public) transporting material in a conveyance (road, rail and sea) and for individuals (either employees or members of the public) loading materials into a conveyance. For each of these materials experts characterised the radionuclides, their activity concentrations, the volumes transported as well as the typical loading of packages containing NORM and the types of packages used to transport NORM, etc.). On the basis of the result of the assessment of doses participants carried out an analysis of regulatory provisions for the transport of NORM. The emphasis of this analysis varied from country to country and included consideration of the validity of exemption levels. Some countries proposed new values to the IAEA for exemption of NORM materials and consideration of the general exemption for specific types of NORM and suggestions to modify regulations applying to transport of NORM (e.g. Para 107(e)).

Brazil

The main objectives of the Brazilian study were to establish the quantities of Naturally Occurring Radioactive Material (NORM) that can be excepted from IAEA Transport Regulations and to specify the quantities of NORM that can be transported in excepted packages. The study also aimed to provide sound basis for the classification of NORM as LSA–I, regardless its activity concentration above values adopted for exclusion from Transport Regulations. To achieve these goals, a mathematical model and a computer program was developed taking into account different sizes of the consignment, (small to infinite size) and the U and Th decay chains in secular equilibrium, and considered both accident scenarios of the Q system combined with the trivial dose of 10 µSv (20 µSv/h during ½ hour) and a normal transport condition scenario with a dose limitation of 0.3 mSv/a to the driver. Summary of the results obtained, showed that the most conservative scenario for the transport of NORM was considered to be the external dose to the driver under normal transport conditions, and not the accident scenarios based on the Q system hypotheses. Thus for this most conservative scenario an average factor of 15 could be used for the exclusion of NORM materials from the transport regulations, when no shielding between the radioactive load and the driver is considered. This factor is conservative and of the same order of magnitude of the 10 factor already adopted in the Regulations. Results also pointed out that the limiting factor of 30 adopted in the Transport Regulations for the classification of NORM as LSA–I should not exist, since it is impossible when transporting NORM to reach the limiting condition of 10 mSv/h at a distance of 3 metres. Finally, calculations suggested that a factor of 20 times the exemption value of natural U or Th in secular equilibrium given in

Table 1 of TS-R-1 could be adopted to limit the activity concentration of NORM transported in excepted packages.

Canada

The main objectives of this study were to determine the radiological characteristics of the transport of tantalum raw materials, specifically tantalite and tin slag and to evaluate the potential radiological exposures associated with normal transport and in the event of an accidental spill. The radiation doses to transport workers and the public were evaluated. Chemical and physical analysis and radiation survey was carried out on 71 shipments of material Analysis of 67 of the shipments of tantalite and slag showed a range of about a factor of 10 in radioactivity concentrations, with an average activity concentration (U-238 + Th-232 combined) of about 20 Bq/g for tantalite and about 25 Bq/g for slag. The majority (78%) of tantalite shipments and 45% of the slag shipments had concentrations exceeding 10 Bq/g.

A model showing the relationship between tantalum raw materials and expected dose rate was developed. Based on Microshield, it was found to provide a consistent but somewhat conservative estimate (overestimate) of measured gamma dose rates. Exposure scenarios that considered both duration and location of exposure were established for several types of transport workers and for members of the public. Based on an evaluation of potential exposure pathways, exposure to gamma radiation was determined to be the only significant exposure pathway. Doses from exposure to spilled materials due to potential accidents were calculated and determined not to be a regulatory concern, as the resulting doses were less than 10 μSv/y.

An assessment of potential dose rates around the transport containers was conducted using the range of measured radioactivity concentrations and modelling of the associated gamma radiation doses using the Micro Shield model. The modelling approach overestimated the measured dose rates, primarily due to the assumption that the transport containers always carried full loads whereas in practice the loading pattern varied. On the basis of the analyses of doses arising from the transport of tantalum raw materials described in the report there is no apparent reason with regards to radiological dose for an exemption value as restrictive as the current value of 10 Bq/g for these materials. No one would be expected to receive a dose above 1 mSv/y arising from the transport of tantalum raw materials. Irrespective of the exemption value selected, the radiological dose assessments described in the report provide assurance to the tantalum industry and to its shippers that the doses arising from the transport of tantalum raw materials are low and well within international norms for both transport workers and members of the public. Using conservative assumptions and on the basis of a 0.3 mSv/y reference dose, an exemption value of at least 30 Bq/g is considered appropriate for the transport of tantalum raw materials.

France

France aimed at calculating $A_2$ values for the ‘unlimited’ materials, and exemption values for larger quantities of material (~20 Tonnes). The study also examined the validity of the 10 mg limiting intake, addressed the $A_2$ values derived for accident conditions. The study took account of different transport conditions e.g. whether the material is in drums or bags. Results covered dose assessment based on the normalised scenarios, evaluation of $A_1$ and $A_2$ values for NORM according to the Q-system and one industrial field; coal combustion in power plants handling NORM was assessed. A study of the workplaces of the drivers was performed. Dose assessments were based on realistic scenarios, and the results of calculations are in good agreement with measurements. For normalised Ra-226 concentration of 1 Bq/g results showed that the annual dose to the driver is 330 µSv/year and the annual dose to the forklift driver is 500 µSv/year. Deposits in pipes (very high concentration in Ra-226 is reached, especially in phosphate industry: up to 1 600 Bq/g) was also investigated. The dose to a scrap specialized in dismantling industrial facilities was calculated and found to be in good agreement with measurements. The doses for a normalised concentration of the deposit of 1 Bq/g of Ra-226 was 0.13 µSv/year to the driver, 0.39 µSv to the driver for one transport of 3 hours and 100 µSv/year for a full-time activity of 800 hours/year. Industrial workplaces studies from different types of industrial facilities such as coal combustion in thermal power plants, treatment of tin, aluminium, copper, titanium, niobium, bismuth and thorium ores, production of refractory ceramics were done. In those evaluations the doses received by operators was assessed. 3800 measurements performed on 475 samples of materials. The transport of uranium ore from mines to concentrating plants was studied. Material transported was viewed in terms of activity concentration, density and dust inhalation. Workplaces such as truck driver, fork-lift truck driver, truck loader, worker on a stack of material were considered. Study concluded that density has a low impact on the dose rates and external dose rates to the four workers are in the same order of magnitude. Realistic scenarios of occupational exposure (truck driver and fork-lift truck driver), were evaluated and showed that transporting 1 Bq/g of uranium ore would induce an annual dose of about 100 to 150 µSv and transporting 10 Bq/g of radium wastes induce an annual dose of about 1 to 1.5 mSv

NORM not intended to be processed for the use of their radionuclides, a factor of around ten could be assumed to take into account the variability of the activities in the loadings transported all over the year. Taking into account that factor of 10, transporting of an ore not intended to be processed for the use of their radionuclides, containing uranium up to 10 Bq/g induced an annual dose of about 100 µSv.

Some materials at equilibrium or not can lead to an annual dose higher than 1 mSv. For example, an employee dealing with loading and transport of baddeleyite (raw material with a uranium activity concentration of 7 Bq/g) can reach an annual dose greater than 1 mSv/y in around 725 h/y only by external exposure. Moreover, an employee handling a big-bag containing sands used for underground water filtration ($^{226}$Ra: 3.7 Bq/g; $^{228}$Ra: 3.3 Bq/g) can receive an annual dose of 1 mSv in less than 1000 h/y only by external exposure. It is emphasised that this activity concentration in radium (7 Bq/g) is much lower that the exemption limit for a material not intended to be used for the use of its radionuclides (100 Bq/g). Compared with the exemption value of 10 µSv/y, the values of the assessed doses seem to be high.

Germany

The overall objective of the German contribution was to review and categorise the most important materials containing natural radionuclides; review, analyse and evaluate the radiation exposure imposed by the shipment of NORM and expected exposure of the shipment staff and the population; develop evaluation criteria and safety requirements to provide adequate safety standards for the transportation of NORM; develop procedures to determine the limits for exempt materials/consignments for transportation according to Transport Regulations for all NORM.

Finally, on the basis of the results on dose calculation for the transport of NORM; the following recommendations are given as far as the proposed dose limit of 0.3 mSv $yr^{-1}$ for transport personnel is accepted.

1. For bulky transport of NORM with radioactive equilibrium the five-fold activity concentration for exempt material meet these requirement independent on the kind and use of such materials.

2. Accordingly, para 106 (e) could be amended as follows:

– Delete the indented use (i.e. „… other than for the extraction of the radionuclides, and that are not intended to be processed for use of these radionuclides,…”).

– Furthermore, the last part of the sentence in para 106 (e) with the hint to paras 401 (b) to 406 should be replaced by a new paragraph which contains the limits for natural radionuclides only, i.e.:

  – 5 Bq $g^{-1}$ for $U_{nat}$ and $Th_{nat}$ in case of radioactive equilibrium;

  – in case of radioactive non-equilibrium the activity concentration for exempt material should be calculated by means of the formula in para 404 of TS-R-1 with the following limitations

    - 15 Bq $g^{-1}$ for Ra 226 and 10 Bq $g^{-1}$ for Ra 228, and

    - the 10 fold exempt limit of 100 Bq $g^{-1}$ for Pb 210 and Po 210, each in non-equilibrium is thoroughly applicable regardless there limitation to 50 Bq $g^{-1}$ of each by application of the formula in para 404 of TS-R-1.

Islamic Republic of Iran

The study examined bulk shipments of phosphate rock from Morocco and Jordan. Assessments were carried out on the radiological impact of NORM in the phosphate industry, commercial zircon and uranium ore materials industries. Dose rates from material and exposures to a variety of workers involved during vessel discharge, loading and unloading, cleaning and transport operations were measured. Uranium ore bulk shipments were assessed from mine site through processing plant to transport routes, including various dose measurements. There are various ores which are blended to achieve 10 Bq/g of U-238 with low levels of Th-232 and K-40. The truck driver received 0.062mSv/y whereas the loader operator received 2.07mSv/y.

It was noted that the external dose inside the cabin was also four times higher for the loader as opposed to the truck driver, due to the loader being closer to the phosphate rock stockpile and for a longer period of time. Data was collected on types and volumes of shipment, radionuclide content of these materials, types of packaging and vehicles used, dose and dose rates around the packages used to transport these materials and the details of the transport operations for each type of material. Data was presented for bulk transport of phosphate rock. For each shipment, the range of radionuclide concentrations in various samples of phosphate rock was measured.

The occupational exposure scenarios for an exposed person in bulk transport of phosphate rock are mentioned and in each scenario annual exposure time was estimated. Measurements of external gamma, short lived alpha emitting particles and long lived radionuclides exposure pathways were taken. The results of dose assessments for occupational scenarios for bulk unpackaged phosphate rock were presented. In this study marine transport and loading of ships weren't included, only offloading of ships and storage at the end of the transport route were considered. The results of dose assessments for occupational scenarios were presented. The dose during offloading (discharge) in all bulk transport scenarios was less than 20 μSv per shipment. Activity concentrations in uranium ore from Iran were measured and the dose to workers from transport of uranium ore was estimated and presented in the final report.

Israel

The study estimated occupational exposure during activities related to transport of potash, phosphate rock and phosphatic fertilisers. Those materials are transported on a bulk scale (a few million tonnes per year) in an unpackaged form. Measurements were conducted in the loading stage of the phosphate and potash products and measurements' of radionuclide content in phosphate and potash products, airborne radionuclide concentrations at the loading facilities, and airborne dust size distribution external. Based on these measurements the total dose rate for a loading worker was estimated. Based on an assumption of the total annual working hours the annual dose of the loading worker was estimated and compared to the relevant dose limits.The annual dose to the loading workers at the phosphate and potash facilities is estimated to be less than 0.3 mSv. It is assumed that the dose to members of the public due to this work is less than 10 μSv per year. The concentrations of phosphate and potash products are below Safety Guide, Application of the Concepts of Exclusion, Exemption and Clearance, RS-G-1.7[ii] exemption levels when including the additional factor of 10 in the graded approach (par. 5.12). The annual dose assessment to phosphate and potash loading workers indicates that TS-R-1 exemption values are better adopted for loading activities of these materials, including the additional factor of 10 for phosphate and potash.

Romania

This study looked at the safe disposal and transports of tailings from the Crucea uranium mine. Identification and the evaluation of the potential risks and radiological consequences due to the transport and disposal of the very low level radioactive materials (NORM) were undertaken.

Tailing sites in order to determine values of radon population doses that would be more representative of present day and likely future conditions were examined. The assessment of the collective dose factors, air concentration modelling (e.g. modelling of long range transport which requires sophisticated models, comprehensive meteorological data and extensive set-up effort), and radon source terms population densities, population doses (exposure) estimation, estimation of the background dose, estimation of the normalized tailings surface area were done. The results showed that the effective dose for workers was no more than 20 mSv/y and collective dose determined using a mathematical coded showed 0.2 mSv/y. Dispersion factors: external irradiation: (0.5 ÷ 5 μSv/h); Total effective dose of Radon: in the witness zone: 5.88 mSv, in the impact zone: 15.50 mSv; Estimated annual effective dose: lower than 0.2 mSv/y.

Annual effective dose for all radionuclides transferred to the environment it was estimated not to exceed 1.4 × 10 × E-6 Sv/y.

United Kingdom

This study reviewed the transport of materials containing naturally-occurring radionuclides in the United Kingdom and where appropriate the radiological impact of these transport operations was assessed. It firstly collected data on activity concentrations of naturally occurring radionuclides in material typically transported in the UK and secondly estimated the radiation exposures that may result from the transport of NORM in the UK. Coal, coal ash, iron and steel production, building materials, potash, phosphate rock and fertilisers, ores and mineral sands, wastes from the oil, gas and China Clay industries were all surveyed.

United States of America

The research undertaken by the United States included evaluation of the inconsistencies in the application of the exempt activity concentrations, particularly as they are applied on the basis of the intended use of the material being transported (e.g. paragraph 107(e) of the Transport Regulations, TS-R-1). It was concluded that the 10x provision of paragraph 107(e) is consistent with the IAEA's common practice of relaxing radionuclide exemption concentrations within cautious bounds to achieve a balance between practical issues and radiological concerns. Analyses based on realistic transport scenarios indicated that, in cases where the 10x provision is applicable, the maximal annual dose from unregulated transport of natural uranium or thorium would generally be substantially less than the IAEA's "practical dose constraint" of 1 mSv. Realistic transport scenarios were identified in which the provisions of paragraph 107(e), together with the rounding methods used to establish the exemption values, led to exemption values differing by two orders of magnitude for two materials that emit the same types and energies of radiation and deliver the same dose per unit activity concentration to the person presumed to receive the highest dose. This is inconsistent with the principle that the exemption values should be risk-based.

With respect to the special provisions in paragraph 107(e), regarding the Prior or Intended Use (PIU) restriction. It was concluded that the prior or intended use provision of paragraph 107(e) is not justified and should be removed. If exemption values are to be risk-informed, they should be based on dose implications, not on the prior or intended uses of the material being transported. Consequently, allowance of a 10-fold increase in the exemption values for natural material and ores containing naturally occurring radionuclides should be applied to all such material regardless of their past or intended use. If paragraph 107(e) is modified to eliminate the "intended use" clause, it will also be necessary to remove a corollary clause from the definition of LSA-I. This definition includes *"uranium and thorium ores and concentrates of such ores, and other ores containing naturally occurring radionuclides which are intended to be processed for the use of these radionuclides"*.

The project also measured and estimated doses associated with the transport of uranium ore and other NORM and the treatment of progeny (daughter products) in TS-R-1, Table 2 - footnotes (a) and (b).

Based on evaluations, it was recommended that the footnotes should be revised as follows: If a radionuclide is listed with a footnote (b) for its exemption values then it need not also be listed with a footnote (a); consequently, radionuclides with a footnote (b) should have the footnote for their A values changed from (a) to (b). This would indicate the same physical information was used in deriving the limits. Future efforts to rationalize the treatment of daughter products in the two calculation systems (A values and exemption values) should be based on ICRP Publication

## CONCLUSIONS

The following conclusions were agreed upon at the final (third) RCM meeting, 16-20 November 2009.

(1) The doses to personnel involved in transport operations (drivers and loaders) calculated by participants to the CRP were found to be within the range described in the regulatory context.

(2) The doses to the general public calculated by participants in the CRP were at least an order of magnitude lower than the doses to personnel involved in transport operations. Derived activity concentrations of NORM that result in an annual dose of 10 μSv (based on a normalized 400 h driver exposure time) ranged between 0.2 and 14 Bq/g regardless of prior or intended use. Therefore, a factor of 10 applied to the activity concentration for exempt material in Table 1 of the IAEA TS-R-1 Safety Requirements, 2009 Edition [6], although conservative, may be considered adequate to exempt NORM in secular equilibrium from the transport regulations;

(3) An activity concentration of 1 Bq/g is appropriate as the basic exemption value for U-nat and Th-nat, and the provision for the activity concentrations of NORM not to exceed 10 times the values specified in Table 2 of TS-R-1 (2009)[6] as specified in paragraph 107(e) of TS-R-1 (2009) [6] was both appropriate and necessary.

(4) An exemption value for $^{40}K$ of 10 Bq/g may be too restrictive, given the ratio of this isotope to stable potassium in the natural environment.

(5) There was agreement with all represented countries, except France, that the language "intended to be processed for the use of these radionuclides" of NORM restriction in paragraphs 107(e) and para 409 be removed and replaced with the following suggested text.

These Regulations do not apply to:

> Paragraph 107. (e) Natural material and ores containing naturally occurring radionuclides which are either in their natural state or 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 paragraphs 403–407;

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 which exceed the values specified in paragraph 107(e);

(ii): Natural uranium, depleted uranium, natural thorium or their compounds or mixtures, that are unirradiated and in solid or liquid form;

(6) The provision that the activity concentrations of NORM not exceed 10 times the values specified in Table 2 of TS-R-1 (2009) [13], as specified in paragraph 107(e) of TS-R-1 (2009) [1], should be made clearer to ensure its effective application. Options suggested by participants to the CRP include the addition of a footnote to the entries for $^{40}K$, Th-nat and U-nat referring to paragraph 107(e).

(7) The need to apply paragraph 405 of TS-R-1 (2009) [13] to radionuclides that are not in secular equilibrium should also be clearer. This requirement is best illustrated by radium isotopes that have been separated from the decay chain of their parent. The exemption value of 10 Bq/g for $^{226}$Ra and $^{228}$Ra may be too high when the rule for mixtures is not applied.

Recommendations from this Coordinated Research Project are reflected in the 2012 Edition of the Transport Regulations [7]. These requirements, approved by the Board of Governors in March 2012 are now published. Excerpts from the regulations and companion guidance material are outlined below.

Transport Regulations, TS-R-1, 2012 Edition

Paragraph 107. "These Regulations do not apply to any of the following:

(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";

Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material

(2012 Edition) TS-G-1.1 [8]

"Para 107.4. 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 to paras 403–407).

Following the conclusion of the IAEA Coordinated Research Program (CRP) on transport of NORM 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 radionuclides 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, an annual dose criterion of 10 μSv does not apply to exposure situations involving natural sources, as this value is one or two orders of magnitude at least below the variability of the natural radiation background). The new BSS (IAEA Draft Safety Requirements DS 379) [10] sets an annual dose criterion of 1 mSv for exemption for NORMs. 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 use of Table 2.

For ores and other natural or processed materials containing natural occurring radionuclide of uranium-radium and / or thorium decay chain, the basic nuclide values for exempt activity concentration as given in Table 2 for Unat and Thnat can only be used if the radionuclides are in secular equilibrium. If this is not the case, that means that due 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.

As the value of activity concentration for exempt material of TS-R-1, Table 2 e. g. for Th-228 activity concentration is by a factor 10 lower than this for the isotopes Ra-226 and Ra-228 as well as Pb-210 and Po-210, the limit of activity concentration decisively depends on the fraction of Th-228 (fTh228) in nuclides mixture, when applying the formula in para. 405.

This issue is depicted at the following example:

In the process of extraction of crude oil and natural gas, scaling takes place at the inner walls of the production pipes. The scales consist in most cases of barium sulphate in which radium isotopes co-precipitate, while the parent nuclides (U-228, Th-232) do not occur in the deposit. Accordingly the secular equilibrium of the U-Ra decay chain and / or Th decay chain is disturbed. While Pb-210 and Po-210 are slowly re-growing from Ra-226 (the equilibrium is reached after about 100 years) Th-228 re-grows from Ra-228 with a so called "flowing equilibrium" within few years. Therefore the fraction of Th-228 of the total activity is increasing with time (reaching equilibrium of 1.46 times Ra-228 activity concentration). The insertion of measured activity concentrations as provided in German report [3] into the formula of para. 405 leads to the following exempt activity concentration (sum activity):

(fRa226 + fPb210 + fPo210 + fRa228) = 0.84 while fTh228 = 0.16

From this it follows that (0.84)/10 + 0.16/1 = 0.244, and next 1/0.244 = 4.1 Bq/g as exempt activity concentration, i.e. the sum activity of all relevant nuclides. This value can now be multiplied by 10 according to para. 107 f), while the specific activity of each radionuclide is given by its fraction.

However, there are ores in nature where the activity concentration is much higher than the exemption values. The regular transport of these ores may require consideration of radiation protection measures. Hence, a factor of 10 times the exemption values for activity concentration was chosen as providing an appropriate balance between the radiological protection concerns and the practical inconvenience of regulating large quantities of material with low activity concentrations of naturally occurring radionuclides."

**TABLES 1 AND 2 SUMMARIZE THE TECHNICAL OBJECTIVES AND ACTIVITIES CONDUCTED BY THE PARTICIPANT COUNTRIES (E.G. WHICH COUNTRY CONDUCTED MEASUREMENTS AND/OR MODELLED DOSES).**

**TABLE 1. PROJECT OBJECTIVES**

| TECHNICAL TOPIC | BRAZIL | CANADA | FRANCE | GERMANY | ISLAMIC REPUBLIC OF IRAN | ISRAEL | ROMANIA | UNITED KINGDOM | UNITED STATES OF AMERICA |
|---|---|---|---|---|---|---|---|---|---|
| CALCULATE THE LIMITING UPPER VALUES FOR CLASSIFICATION OF NORM AS LSA-I | X | | | | | | | | |
| CALCULATE THE QUANTITIES OF NORM IN EXCEPTED PACKAGES, BASED ON $A_1$ AND $A_2$ | X | | | X | X | | | | |
| CALCULATE THE $A_2$ OF NORM BY Q SYSTEM | X | | X | | | | | | |
| PROVIDE SOUND THEORETICAL BASIS FOR LIMITS ADOPTED BY IAEA REGARDING LSA-I | X | | | | | | | | |
| PROPOSE NEW VALUES TO THE IAEA FOR EXCLUSION OF NORM MATERIALS | X | X | | X | | X | | | |

| TECHNICAL TOPIC | BRAZIL | CANADA | FRANCE | GERMANY | ISLAMIC REPUBLIC OF IRAN | ISRAEL | ROMANIA | UNITED KINGDOM | UNITED STATES OF AMERICA |
|---|---|---|---|---|---|---|---|---|---|
| DEVELOP MODEL FOR RELATIONSHIP BETWEEN ACTIVITY AND DOSE RATE | X | X | | X | | | | X (IF POSSIBLE) | |
| EVALUATE DOSES TO TRANSPORT WORKERS AND THE PUBLIC | X | X | X | X | X | X | X | X | X |
| EVALUATE EXPOSURE FROM ACCIDENT SCENARIO | X | X | | | | | X | | |
| CONSIDER VALIDITY OF EXEMPTION AND EXCLUSION LEVELS | X | X | X | X | X | X | | | X |
| EVALUATE DOSES TO WORKERS DURING LOADING/UNLOADING AND STORAGE DURING TRANSPORT | | X | X | X | X | X | | X | |
| CONSIDER GENERAL EXEMPTION FOR SPECIFIC TYPES OF NORM | X | X | | | | X | | | |

| TECHNICAL TOPIC | BRAZIL | CANADA | FRANCE | GERMANY | ISLAMIC REPUBLIC OF IRAN | ISRAEL | ROMANIA | UNITED KINGDOM | UNITED STATES OF AMERICA |
|---|---|---|---|---|---|---|---|---|---|
| EXAMINE AREAS FOR RADON DOSES | | | | X | X | X | X | | |
| DETERMINE COLLECTIVE POPULATION DOSES | | | | | X | | X | | |
| DETERMINE AIR DISPERSION FACTORS | | | | X | | | X | | |
| EVALUATION OF BACKGROUND DOSES NEAR SITES | | | | | X | | X | | |
| APPLY 107(E) TO ALL NORM EQUALLY | X | | | X | | | | | X |
| EVALUATE TRANSPORT DIFFERENCES BETWEEN NON-FUEL AND FUEL CYCLE NORM | X | | | | | | | | X |

**TABLE 2. PROJECT TECHNICAL TOPICS[a]**

| TECHNICAL TOPIC[B] | BRAZIL | CANADA | FRANCE | GERMANY | ISLAMIC REPUBLIC OF IRAN | ISRAEL | ROMANIA | UNITED KINGDOM | UNITED STATES OF AMERICA |
|---|---|---|---|---|---|---|---|---|---|
| CHARACTERIZATION OF NORM (E.G. RADIONUCLIDES, ACTIVITY CONCENTRATIONS, SHIPMENT VOLUMES) | | X | X | X | X | X | | X | X |
| TYPICAL LOADING OF PACKAGES CONTAINING NORM | | X | X | X | X | | | X | X |
| TYPES OF PACKAGES USED TO TRANSPORT NORM | | X | X | X | BULK ONLY | BULK ONLY | X | X | X |

**TABLE 2. PROJECT TECHNICAL TOPICS [a]**

| TECHNICAL TOPIC | BRAZIL | CANADA | FRANCE | GERMANY | ISLAMIC REPUBLIC OF IRAN | ISRAEL | ROMANIA | UNITED KINGDOM | UNITED STATES OF AMERICA |
|---|---|---|---|---|---|---|---|---|---|
| DOSE RATE MEASUREMENT OR CALCULATIONS FROM PACKAGES AND CONVEYANCES | X | X | X | X | X | X | | X | |
| TRANSPORT OPERATIONS CHARACTERISATION (E.G. EXPOSURE SCENARIOS, TIMES, DISTANCES, INTAKES) | | X | X | X | X | X | | X | X |
| MEASUREMENT AND MODELLING OF WORKER DOSES | | X | X | X | X | X | X | X | X |

| TECHNICAL TOPIC | BRAZIL | CANADA | FRANCE | GERMANY | ISLAMIC REPUBLIC OF IRAN | ISRAEL | ROMANIA | UNITED KINGDOM | UNITED STATES OF AMERICA |
|---|---|---|---|---|---|---|---|---|---|
| MODELLING OF PUBLIC DOSES, INCLUDING IMPLICATIONS FOR NON-OCCUPATIONALLY EXPOSED WORKERS | X | X | X | X | | | X | X | |
| *PACKAGE PERFORMANCE UNDER NORMAL AND ACCIDENT CONDITIONS (EXTENT OF DISPERSAL OF CONTENTS)*[b] | | X | | | | | | | |
| *CONSEQUENCES OF TRANSPORTING CERTAIN SPECIFIC NORM UNPACKAGED* | | | X | | | X | X | X | X |
| *RISK IMPACTS DUE TO BREACH OF CONFINEMENT OF THE RADIOACTIVE MATERIALS (MODELLING ACCIDENT RISKS)* | X | X | | | | | | | |

| TECHNICAL TOPIC | BRAZIL | CANADA | FRANCE | GERMANY | ISLAMIC REPUBLIC OF IRAN | ISRAEL | ROMANIA | UNITED KINGDOM | UNITED STATES OF AMERICA |
|---|---|---|---|---|---|---|---|---|---|
| ANALYSIS OF REGULATORY PROVISIONS (E.G. 107(E), LSA-I DEFINITION, UNIRRADIATED URANIUM DEFINITION) | X | X | X | X | X | X | X | X | X |

[a] THE FULL DESCRIPTIONS OF THE STUDIES ARE GIVEN IN THE PROJECT PROPOSALS.

[b] TOPICS IN ITALICS ARE DRAWN FROM THE LOGICAL FRAMEWORK OUTPUTS DEFINED IN THE TRANSSC 10 IP14 DOCUMENT, SECTION 9

## ACKNOWLEDGMENTS

### CONTRIBUTORS TO DRAFTING AND REVIEW OF CRP REPORT

| | |
|---|---|
| Cabianca, T. | Health Protection Agency, United Kingdom |
| Chambers, D. | SENES Consultants Ltd., Canada |
| Cook, J. | U.S. Nuclear Regulatory Commission, United States of America |
| Deevband, M.R. | Iranian Nuclear Regulatory Authority, Islamic Rep. of Iran |
| Fathabadi, N. | Iranian Nuclear Regulatory Authority, Islamic Rep. of Iran |
| Garg, R. | Canadian Nuclear Safety Commission, Canada |
| Hughes, S. | Health Protection Agency, United Kingdom |
| Koch, J. | Soreq Nuclear Research Center, Israel |
| Kravchik, T. | Nuclear Research Center Negev, Israel |
| Lati, J. | ICL Fertilizers, Israel |
| Loriot, G. | Institut de Radioprotection et de Sûreté Nucléaire, France |
| Louis, B. | Institut de Radioprotection et de Sûreté Nucléaire, France |
| Moutarde, M. | Institut de Radioprotection et de Sûreté Nucléaire, France |
| Perrin, M.L. | Autorité de Sûreté Nucléaire, France |
| Pires, N. | Institut de Radioprotection et de Sûreté Nucléaire, France |
| Rawl, R.R. | Transportation Technologies Group, United States of America |
| Schwela,U. | Tantalum-Niobium International Study Center, Belgium |
| Vieru, G. | Institute for Nuclear Research, Romania |
| Weiss, D. | Gesellschaft für Anlagen- und Reaktorsicherheit, Germany |
| Xavier, A.M. | Comissão Nacional de Energia Nuclear, Brazil |

## REFERENCES


[1] INTERNATIONAL ATOMIC ENERGY AGENCY, International Conference on the Safe Transport of Radioactive Materials, 2003

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standards Series No. ST-1, Regulations for the Safe Transport of Radioactive Material 1996 edition

[3] INTERNATIONAL ATOMIC ENERGY AGENCY , Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material 2008 Edition (TS-G-1.1)[4]Statute of the IAEA, 23 October 1956, as amended 28 December 1998, Article II

[5] Statute of the IAEA, 23 October 1956, as amended 28 December 1998, Article III, para. 6.

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material" 2009 Edition (TS-R-1)

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material 2012 Edition, Specific Safety Requirements No. SSR-6.

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material, Specific Safety Guide No. SSG-26 (presently in publishing)

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series 115, IAEA, Vienna (1996).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, Interim Edition No. GSR Part 3 (Interim) General Safety Requirements Part 3