Practical cases of NORM transport – problems and solutions

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Abstract. A serious and complex issue in the transport of NORM is associated with international NORM shipments. This process requires involvement of several logistics companies and government departments in different countries, which typically do not have a full understanding of the legislative requirements and associated hazards, or sometimes are not aware of them at all.
Several practical examples are discussed:

- Transport of mixed dangerous goods where the presence of other hazardous substances contained in the material must also be considered,
- Application of regulations to NORM containing radionuclides that are not in secular equilibrium, and to material at transit locations,
- Detection of NORM at border crossings,
- Build-up of radon in containers and hulls of ships,
- Selection of correct surface contamination limits, and
- The lack of communications in international trade in NORM.

1. INTRODUCTION

There are many situations where in the handling, storage and transport of Class 7 (radioactive) dangerous goods other hazardous substances contained in the same material also have to be considered. An additional issue associated with the transport of Class 7 dangerous goods (especially where other hazardous substances are present in the material) is the general ignorance of both the legislative requirements and of potential exposures of the transport workers to hazardous substances.

The situation becomes much more complex when the material is transported internationally – involving several companies and government departments in different countries, which typically do not have a full understanding of the legislative requirements and associated hazards, or not aware of them at all.
This issue has already caused:

- Several mineral shipments being returned to the countries of origin or being held for a long time at customs, resulting in financial difficulties for the producers and logistics companies;
- Workers compensation and other successful legal claims for the injury caused by an unknown level of exposure to a hazardous substance, and for the diminution of the values of the properties located in the vicinity of the transport routes.

2. TRANSPORT OF MIXED DANGEROUS GOODS

The International Maritime Dangerous Goods Code [1] and Australian Dangerous Goods Code [2] contain the following requirement:
5.1.4 Mixed packing
When two or more dangerous goods are packed within the same outer packaging, the package shall be labelled and marked as required for each substance.

In many cases this requirement remains unknown to the personnel of both logistics companies and relevant government departments, and is not being followed as required.
The following five cases describe the situation where mixed dangerous goods were transported in accordance with the legislative requirements. Neither specific companies, nor individual countries are named due to the confidentiality reasons.

2.1. Radioactive and environtally hazardous material – Africa

A specific addition was made to DG Class 9: "Environmentally Hazardous Substances NOS". In many cases in accordance with the requirement 5.1.4 on mixed packing in addition to any other DG label another one may need to be placed on the package. The transport of uranium concentrate from one of the African countries to an overseas customer is an example of full compliance with the IMDG Code [1], where each drum with the concentrate and the container in which these drums are placed are labelled as both "radioactive" and "environmentally hazardous" substance.

2.2. Radioactive and corrosive material – Australia

In the process of remediation of one of the sites in Australia several corroded drums with sludge from mineral processing were discovered. The material needed to to be transported for re-processing on a public road, it was known that it is radioactive and needs to be labelled as such for transport. However, taking into account:

(a) The poor conditions of the drums, and
(b) The information that the sludge was originally highly acidic (pH in order of 1) –

The drums were placed into the lined container and signposted as both "radioactive" and "corrosive".

2.3. Radioactive and biologically hazardous material – Asia

At one of water treatment plants in Asia the sludge is transported for disposal in small trucks. The material was considered to be biologically hazardous substance until relatively high concentrations of ^{226}Ra were found in the sludge. The truck now bears two labels – both "biologically hazardous" and "radioactive". In this case it was considered that the signs in a local language are more preferable.

2.4. Radioactive and flammable material – Middle East

In one of the countries in the Middle East radioactive sludge from oil and gas production is being placed into drums for the eventual disposal in approved facilities. When the drums are transported to the disposal sites they are signposted as both "radioactive" and "flammable". Similarly to the case 3 above, it was considered that signs in a local language are more practical.

2.5. Radioactive and toxic material – Middle East

The pipes from oil and gas production facilities are transported to a NORM processing facility where the scale from inside the pipes is removed and pipes are subsequently returned to service. Due to the radium-bearing scales being on the inside surfaces, the pipes were plugged at both ends and vehicles were labelled as transporting SCO (Surface Contaminated Material). When safety personnel at the processing facility has discovered that pipes coming from one oil field also contain relatively high concentrations of mercury – additional safety procedures were introduced at the plant and vehicles transporting the pipes are now also labelled with a "toxic" sign. As in the case above, the signs in the local language, from the locally applicable Dangerous Goods Code, were placed on the vehicles.

3. APPLICATION OF REGULATIONS TO MATERIALS WHERE NORM RADIONUCLIDES ARE NOT IN SECULAR EQUILIBRIUM

In order to ensure that material is transported correctly two IAEA documents need to be consulted – the Regulations [3] and the Advisory Material [4]. The 'factor of 10' used to assess the applicability of the Regulations is well-known, but the case where radionuclides are not in the state of secular equilibrium is not fully understood by many companies and government departments.

The paragraph 107 (f) of the Regulations [3] states –
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 [4] provides additional information for these cases–
…the basic nuclide values for exempt activity concentration as given in Table 2 for U(nat) and Th(nat) can only be used if the radionuclides are in secular equilibrium. If this is not the case, owing to processing activities such as chemical leaching or thermal treatment, the natural radioactive equilibrium state does not exist and the formula for mixtures of radionuclides according to para. 405 has to be applied to calculate the exempt activity concentration.

The complete data on the possible disruption of the secular equilibrium in ^{238}U and ^{232}Th decay chains during processing of mineral concentrates is often not available, and it is prudent to assume that this may occur in cases of:

- Any chemical processing of the material, such as leaching or adding flotation agents,
- Any thermal processing of the material. Due to the variety of materials it is impossible to establish a universal cut-off point for the temperature at which some radionuclides (such as ^{210}Pb and ^{210}Po) could volatilise and disrupt the equilibrium; however, the value of 250-300^{o}C is suggested as a general guide at which an additional analysis of the material may be required,
- Any combination of chemical and thermal treatment of ores and minerals.

The data would typically be required for ^{238}U, ^{230}Th, ^{226}Ra, ^{210}Pb, ^{232}Th, ^{228}Ra and ^{228}Th.

For example, in the heavy mineral sands industry (titanium and zirconium minerals):

- The mineral concentrates (separated using gravimetric methods) and individual minerals (separated using electrostatic and electromagnetic methods) are analysed for thorium and uranium only, as the separation process does not disrupt the secular equilibrium in ^{238}U and ^{232}Th decay chains.
- The minerals that have undergone (a) chemical treatment (such as washing zircon sand grains with acid solution), (b) thermal treatment (such as heating titanium mineral ilmenite to remove excessive iron in the production of synthetic rutile), and (c) the combination of chemical and thermal processing (further treatment of synthetic rutile to remove other impurities) – should be analysed for other radionuclides in ^{238}U and ^{232}Th decay chains, prior to the decision on the applicability of Transport Regulations [3] to these materials.
- All materials in the downstream processing of heavy mineral sands (e.g. in the production of titanium dioxide pigment and fused zirconia) should also be analysed for other radionuclides in ^{238}U and ^{232}Th decay chains.

4. APPLICATION OF REGULATIONS TO MATERIALS IN TRANSIT

In some jurisdictions specific provisions have been made for the material that is located in a transit storage area. The main reason for such provision is that typically mining and mineral processing companies transport their products not directly to the port, but to a transit location, where a sufficient number of containers or bulk material would be accumulated prior to the their transport to the nearby port.

Thus, a certain volume of material is almost always present at a transit location. This results in the situation where –

- From one side, the material could be considered to be “in transport”, but
- From the other side, an almost permanent storage of material may need to be regulated.

In order to address this situation different arrangements could be made, the solution adopted in Western Australia is as follows:

If NORM containing U(nat) and Th(nat) in concentrations between 1 Bq/g (Table 2 of SSR-6 [3]) and 10 Bq/g (‘10-times’ exemption for NORM, paragraph 107(f) of SSR-6 [3]) is stored at any transit location for more than 24 hours, the regulation 28 of the Radiation Safety Regulations [5] (conditions on registration of premises) would apply and the transit location must be registered for storage of radioactive substances with the appropriate authority (The Radiological Council of Western Australia).

5. DETECTION OF RADIOACTIVITY FROM NORM AT BORDER CROSSINGS

This note is relevant to the transport of all NORM, whether it is exempted from the Transport Regulations or not.

Even if a material is exempt from the Regulations and the associated signposting, the concentrations of radionuclides may cause gamma radiation levels outside the packages (e.g. sea containers) that are easily detectable by the equipment that is commonly used at border crossings and in ports worldwide. The alarms at border crossings cause significant operational issues, as all portal alarms should be fully investigated. After a shipment of NORM has caused an alarm, the identification of relevant radionuclides, interviews with the personnel involved, and an examination of all relevant documentation are the complementary activities of the investigation.

Therefore, the transport documentation for many materials needs to contain detailed information about the concentrations of naturally occurring radionuclides in this material, irrespective of its classification. As the requirements for this documentation differ from country to country, all necessary information may be provided in the document that is accompanying every material shipment – Material Safety Data Sheet (MSDS).
The inclusion of the gamma-spectrum for a particular material, in the form of either table or a chart into an MSDS is highly advisable. Whilst not absolutely necessary, this information would assist in the process of clearing a particular NORM through the radiation detection equipment at international border crossings.

6. BUILD-UP OF RADON IN CONTAINERS AND HULLS OF SHIPS

This note is relevant to the transport of all NORM, whether it is exempted from the Transport Regulations or not.

Even if a material is exempt from the requirements and the associated signposting, the concentrations of radionuclides may cause significant concentrations of radon (^{222}Rn) inside the sealed shipping containers and hulls of ships used to transport minerals in bulk. Where such occurrence is discovered, the typical approach is to instruct workers opening containers and ship hulls at the destination to stay away from the material for a certain time (typically one hour) to allow for radon concentrations to decrease through natural ventilation.

For example, when a material containing only 1.5 Bq/g of ^{238}U was stored in a sealed container in Australia, in approximately 36 hours concentration of ^{222}Rn has reached 8000 Bq/m^3. It is important to note that a worker dealing with this “exempt” material would exceed the public exposure limit (1 mSv/year) in just over 22 hours and a worker limit (20 mSv/year) in ~450 hours, just from the inhalation of ^{222}Rn and its decay products.

7. SELECTION OF CORRECT SURFACE CONTAMINATION LIMITS

The Regulations [3] provide the definition for ‘surface contamination’ and ‘low toxicity alpha emitters:
214. Contamination shall mean the presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters, or 0.04 Bq/cm^2 for all other alpha emitters.
227. Low toxicity alpha emitters are: natural uranium, depleted uranium, natural thorium, uranium-235, uranium-238, thorium-232, thorium-228 and thorium-230 when contained in ores or physical and chemical concentrates; or alpha emitters with a half-life of less than 10 days.

Typically, objects with surfaces contaminated by NORM will only have ‘low toxicity’ alpha-emitters on these surfaces – with a notable exception of ^{226}Ra.

The fact that ^{226}Ra is not classified as a 'low toxicity' alpha emitter is typically not known or is ignored. However, whilst the limit of 0.4 Bq/cm^2 generally applies to all NORM, in a specific situation (e.g. when transporting contaminated items from oil and gas industry, from some plants for the production of titanium dioxide pigment, etc.) – the limit of 0.04 Bq/cm^2 is applicable for the classification of surface contaminated objects.

8. THE LACK OF COMMUNICATIONS IN THE INTERNATIONAL TRADE IN NORM

In many cases there is an insufficient level of communication in regards to the legal requirements between the exporter and importer of a mineral concentrate containing NORM. The lack of communications between logistics companies and government departments in different countries on this issue and misinterpretations of different legislative acts, regulations and guidelines often results in serious problems, particularly for the customers of the mining and mineral processing industry.

The issue becomes much more complex if we consider the fact that International Transport Safety Regulations [3] are not adopted simultaneously across the world and different requirements may apply in different jurisdictions. Each of the examples below presents a situation that has been encountered in different countries in the process of the import of NORM and it is hoped that these issues will no longer arise for the mining and mineral processing industry.

8.1. Containers held in a port due to lack of documentation

There are three cases where the problems have occurred in the process of import of the containers with NORM – in all three cases material was not considered to be radioactive in accordance with International Regulations [3].

In one case the containers have triggered a border alarm and only basic information on the concentrations of radionuclides in the material was available.
Due to:

- The fact that border portal monitors were installed only several days prior to this event, and this was the first actual case or the alarm being triggered, and
- A heated argument at customs where a shipping agent was demonstrating documents in English, which local border control personnel did not understand –

The shipping agent spent several days in prison for "trying to import radioactive material into the country illegally" and the containers were held in a quarantined area of the port for several months.

In another case the containers with mineral concentrate sent from the country where earlier version of Transport Regulations was in force (not requiring the analysis for any radionuclides except thorium and uranium) were refused entry into another country where the latest version of Transport Regulations [3] explicitly requiring this analysis was in force. The containers were held in a port for several weeks and were only released after additional analyses of the material were carried out and the relevant data has become available.

In yet another case, the opposite has occurred. The containers with mineral concentrate from the country that adopted the latest version of regulations (at the time 2005 edition) were transported to the country where the local regulations were last updated in 1987. This has resulted in a situation where the NORM concentrate exempt from regulations in the country of origin and internationally had to be signposted as 'radioactive' in an importing country.

8.2. Country- and port-specific guidelines and standards

There may be a guideline applicable in a country (or even in one particular port) that is not known to the exporting company. An example of such guideline is the standard (specifically addressing the inspection of the radioactivity content in the process of minerals' import) in the People's Republic of China in 2005 [6]. The procedure suggested in this document is based on the comparison of the background gamma radiation level and the radiation emitted from a material that is being unloaded. If gamma radiation levels measured from the surface of the imported material exceed a pre-determined value (or are ten times higher than background gamma radiation), unloading of this material has to be stopped immediately; additional investigations and sampling need to take place. In some cases the entry of the mineral concentrate into the country is refused and mineral has to be shipped back to the country of origin or to other potential customer.

Several cases are known where mineral concentrates were not allowed to enter the country, resulting is significant financial and production difficulties – for the exporter, importer and logistics companies involved in the transport of NORM.

8.3. Transit of NORM shipments through international ports

Many NORM concentrates that are transported in containers are trans-shipped through different international ports, where these containers are transferred to other marine vessels.

It is important to note the following:

(a) In some ports the 'radiological screening' of containers (as discussed in part 5 above) would still take place,

(b) In other ports both import and export license may be required, even if a container with a mineral concentrate only stays in a port for a day or two.

In case (a) it is advisable for the logistics companies and relevant shipping agents to personally visit the port, explain the character of the material and present the samples of the material to the Port Chemist. This process has been carried out several times by different Australian companies and has eliminated any issues with certain types of NORM being trans-shipped through one of Asian ports.

In case (b) it would be essential to involve a locally registered shipping agent to obtain all necessary import and export permits. In one of the cases the material has received only an import licence, therefore, further trans-shipment to the destination was not possible for some time – before the export license was obtained.

9. THREE COMMON MISTAKES

There are three other common mistakes that are made in the NORM transport:

(a) In the transport of mineral exploration samples an exploration company does not have the data on the concentrations of radionuclides and the shipments are usually not signposted at all, as the application of the Regulations to the transport of exploration samples is not well understood. In many of these cases the samples may be transported as an "excepted package", in accordance with paragraph 516 of the Regulations [3]: *The radiation level at any point on the external surface of an excepted package shall not exceed 5 microSv/h*.

(b) At many mining and mineral processing sites the personnel responsible for the transport of NORM receives the data on the concentrations of thorium and uranium from an on-site laboratory. A very common mistake in calculations of activity concentrations of thorium and uranium is that a typical laboratory would provide the data in parts per million (ppm – microg/kg) for ThO_2 and U_3O_8, not for Th and U. In these cases it is important to note that 1 ppm of ThO_2 is equal to 0.879 ppm of Th, and 1 ppm of U_3O_8 is equal to 0.848 ppm of U.

(c) When mineral concentrates are transported in bulk relatively often the vehicles (especially trucks with trailers) are not signposted appropriately and the Transport Index is not adjusted accordingly. In is essential to ensure that –
    - The definition of the vehicle (paragraph 248 of the Regulations [3]) is used when considering the signposting of the vehicles, and
    - The multiplication factors for unpackaged LSA-I and SCO-I associated with the "largest cross sectional area of the load being measured" (Table 7 of the Regulations [3]) are taken into account when calculating the Transport Index for the shipment.

10. ASSOCIATED LEGAL ISSUES

In some situations the companies and government departments may become involved in legal challenges without actually transporting radioactive material or exposing workers and/or general public to any levels of radiation.

The fear of radiation has been discussed in detail in 1999 [7] and in 2013 [8], it was also described in many other papers and documents. Unfortunately, it still prevails when a shipping company does not wish to transport any substance that is labelled ‘radioactive’. Even if material is transported as an “excepted package” [3] when the warning labels need to be present only inside the shipping container, 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.

The following cases describe two situations where a legal challenge was successful, despite the fact that no radiation exposures have actually taken place.

10.1. Diminution of property values

The perceived risk of radiation exposure was determined to be a reason for litigation and subsequent compensation in one case.
New Mexico Supreme Court in Santa Fe v. Komis, 845 P.2d 753 (1992) addressed a claim of diminution of property values based on perceived risks of nuclear waste transportation. The case involved partial condemnation of land taken by the City of Santa Fe to construct a highway for primarily normal public use but also for occasional transportation of nuclear waste from Los Alamos to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico.
The jury in the District Court awarded $489,582 for the land actually taken, $60,784 for severance damages to the buffer zone and $337,915 for perceived loss due to public perception. The New Mexico Supreme Court affirmed judgement of the District Court and stated:
“If people will not purchase property because they fear living or working on or near a WIPP route, or if a buyer can be found, but only at a reduced price, a loss of value exists. If this loss can be proven to the jury, the landowner should be compensated.” [9]

10.2. Compensable injury from fear of radiation

Another court case from the USA [10], reported at NORM-V Congress [11] indicates that a person could sustain a “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.

11. CONCLUSIONS

a. The transport of mixed dangerous goods is, almost always, a very complex issue. It is hoped that the examples in this paper will be useful both for the companies involved in this process, and for the relevant government departments administering relevant transport safety regulations.
b. It is expected that the specialist advice will be required in many cases to ensure compliance with all relevant regulations and guidelines.
c. Mining and mineral processing and logistics/shipping companies, as well as relevant government departments, may need such advice, in the absence of qualified personnel familiar with all requirements. There is an IAEA Safety Guide for this process for the government departments [12], but relevant companies and organisations may also adopt the general principles contained in this document.

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