RADIOACTIVE WASTE INVENTORY FORECASTING AND CHARACTERISATION IMPLICATIONS FOR PACKAGING AND TRANSPORT

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ABSTRACT

A large variety of process wastes arise in the nuclear fuel cycle industry, from mining, conversion, enrichment and fuel fabrication, reactor operations, reprocessing and more recently from decommissioning of a wide variety of nuclear facilities. These wastes vary greatly in their chemical, physical and radioactive properties and the degree of homogeneity is sometimes difficult to assess.

Traditionally, waste management has been mainly focused on the need to ensure safe storage of waste, either interim or long term, in the raw or conditioned state. The assessment of waste against the best practical environmental options for disposal; namely, saving valuable space in national repositories, is also important. However, it is important to note that all these waste streams will have to be transported eventually in some form or another and the IAEA Regulations for the Safe Transport of Radioactive Material, TS-R-1 [1], must be able to cater for these materials without imposing unjustified constraints which could result in significant operational difficulties and economic penalties. The World Nuclear Transport Institute (WNTI) has, therefore, formed an industry working group to share experiences amongst its members in the interest of focusing on the various issues affecting the future packaging and transport of radioactive wastes. This paper is concerned with one important issue - the forecasting of the inventory and the characterisation of low and intermediate level radioactive wastes which are essential precursors for packaging and transport operations for these materials.

The current transport regulatory position is discussed for characterising and classifying low and intermediate activity radioactive wastes for transport and the potential challenges the current regulations imply. Radioactive assay methods are also covered for characterising low activity and some intermediate activity radioactive wastes for transport and disposal. In addition, the implications of waste inventory forecasting and its importance on transport are considered.

INTRODUCTION

Managing radioactive waste is topic that most countries are faced with, whether it is waste originating from the fuel cycle or waste originating from nuclear research or the medical sector. Many steps must be taken into consideration such as

- forecasting
- characterisation
- segregation of the wastes generated
- treatment steps to reduce waste volume and stabilise its form
- conditioning (liquid/sludge) and higher activity wastes

- packaging development
- treatment from the supply chain
- direct disposal site location
- long term interim storage site location

Many of the above steps are seen as critical drivers to the management of radioactive waste for example, location of national disposal sites, waste volume reduction technology, but in fact the first steps that require significant attention are accurate waste inventory forecasting and waste characterisation. These fundamental steps are used to determine the general path of the waste and are vital to the efficient management of the radioactive waste.

Forecasts of radioactive waste arisings are based on assumptions as to the nature and scale of future operations and activities. The importance of forecasting can not be overstated. Inventory data is used as a consistent reference source of information on radioactive wastes by Government Departments (primarily to ensure the appropriate funding is allocated to safely manage the wastes) and Agencies responsible for national strategies for radioactive waste management and for regulation of waste management operations and disposal.

Generally Intermediate and High Level wastes (ILW and HLW) will require transport in Competent Authority Approved Package Types (eg Types B(U) and B(M)) and less hazardous wastes in IAEA Self Assessment Packages. However, wastes belonging to the other categories listed in below (LLW, etc.) will not naturally match the IAEA package types. This means that a wide range of package designs are required to be developed and approved and multiple bulk packaging manufacturing contracts will need to be placed. All of these processes are dependent on the accuracy of the waste inventory data and the waste characterization practices.

RADIOACTIVE WASTE

Radioactive wastes from civil applications of nuclear energy are produced, for instance, as a result of the generation of electricity in nuclear power stations and from the associated production and processing of the nuclear fuel, and from the use of radioactive materials in industry, medicine and research.

Radioactive wastes may contain naturally occurring radioactive materials, generally uranium, thorium and the products into which they decay, and radioactive materials arising from the activities of man. Most of the man-made radioactive materials result from the fission of uranium in nuclear reactors. They include fission products together with their radioactive decay products and activation products produced in reactor internal and structural materials by the absorption of neutrons. Some of the radioactive materials used in medicine, industry and research, which can give rise to radioactive wastes, are produced in particle accelerators rather than nuclear reactors.

Material that has no further use, and is contaminated by, or incorporates, radioactivity above certain levels defined in the legislation, is known as radioactive waste. Radioactive wastes cover a wide range, from those that contain high concentrations of radioactivity to general industrial and medical wastes that are only lightly contaminated with radioactivity. For instance, in the UK radioactive wastes are classified in terms of the nature and quantity of radioactivity they contain and their heat-generating capacity, as High Level Wastes, Intermediate Level Wastes or Low Level Wastes. By volume the ratio of waste belonging to these categories in the UK is approximately: 93.1% LLW, 6.9% ILW and less than 0.1% HLW.

High Level Wastes (HLW) Wastes in which the temperature may rise significantly as a result of their radioactivity, so this factor has to be taken into account in the design of storage, transport or disposal facilities. These wastes are normally well characterised; for example, high level vitrified waste from reprocessing operations, and are not considered further in this paper.

Intermediate Level Wastes (ILW) Wastes exceeding the upper boundaries for LLW, but which do not require heating to be taken into account in the design of storage, transport or disposal facilities.

Low Level Wastes (LLW) Wastes having a radioactive content not exceeding 4GBq per tonne of alpha, or 12GBq per tonne of beta/gamma activity. The lower activity limit for LLW, below which waste is not required to be subject to specific regulatory control, is also specified for various types of waste.

Very Low Level Waste (VLLW) This is a sub-category of LLW that comprises:

- wastes that can be safely disposed of to an unspecified destination with municipal, commercial or industrial waste, each 0.1 cubic metre of material containing less than 400kBq of total activity, or single items containing less than 40kBq of total activity. There are additional limits for carbon-14 and tritium in wastes containing these radionuclides.

- High Volume VLLW (bulk disposals) – wastes with maximum concentrations of 4MBq per tonne of total activity that can be disposed of to specified and authorised landfill sites. There is an additional limit for tritium in wastes containing this radionuclide.

REGULATIONS RELATING TO RADIOACTIVE WASTE

Usually, radioactive waste is subject to a fourth regulatory control, this being concerned with environmental protection; Figure 1 demonstrates the interaction of the regulatory bodies generally concerned with radioactive waste management.

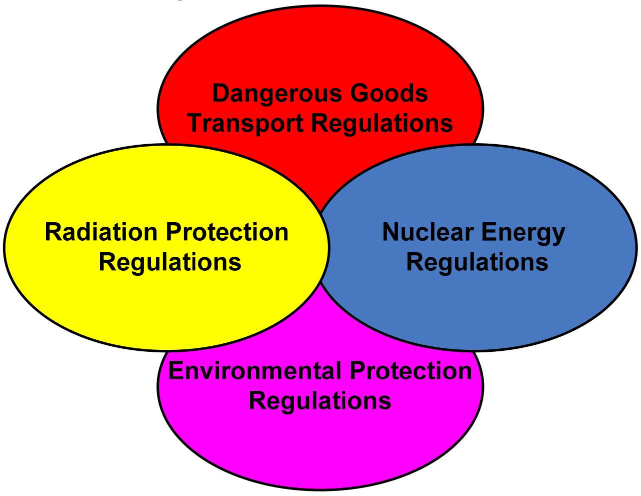

Figure 1- Regulatory interfaces for waste management

WASTE INVENTORY FORECASTING

The preparation of an inventory of radioactive waste is driven by two international obligations: the Euratom Community Plan of Action in the Field of Radioactive Waste and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.

The Euratom Plan of Action requires the Commission to provide the Council periodically with an analysis of the situation and prospects in the field of radioactive waste management in Member States. This is based on data provided by the Member States, including the amounts of the various categories of waste disposed or in interim storage, and an estimate of future arisings. The Joint Convention requires each Contracting Party to submit a report on the measures taken to implement the obligations of the Convention.

These national reports contain an inventory of radioactive waste that is held in storage, that has been disposed, or that has resulted from past practices. The UK Low Level Waste Repository (LLWR) site is used as a case study.

The LLWR is located in West Cumbria and is the only dedicated disposal route for solid Low Level Radioactive Waste (LLW) available in the United Kingdom (UK). Waste Inventory is the term used by LLW Repository Ltd to cover the range of radioactive waste that falls into the LLW category of waste not exceeding 4 GBq per tonne of Alpha or 12 GBq per tonne of Beta/Gamma activity and is either in-situ, in-process, conditioned or ready for final disposal.

In terms of the time period, this will include all waste consigned for treatment or disposal between the present and 2130 when the final stage decommissioning of all existing nuclear reactors, reprocessing plants and associated clean-up activities in the UK are expected to be completed.

LLWR requires accurate Waste Inventory data to inform three key elements of its business:

1. Operations Planning (includes transport packaging and logistics operations)
2. Future Strategy (includes transport packaging and logistics operations)
3. Environmental Safety Case (includes degradation of transport packaging designs)

At present, waste inventory data is gathered primarily via two main sources; UK Radioactive Waste Inventory and Waste Accountancy Templates:

- UK Radioactive Waste Inventory. The UK Radioactive Waste Inventory is compiled by the Nuclear Decommissioning Authority (NDA) on behalf of the UK Department of Energy and Climate Change (DECC) on a triennial basis and includes an inventory of all radioactive wastes held both within and outside the nuclear industry

- Waste Accountancy Template. The Waste Accountancy Template process was developed by the Nuclear Decommissioning Authority (NDA) for each of its 20 nuclear licensed sites and is formulated on an annual basis. The template provides comprehensive information about wastes held on NDA sites and can provide additional details not currently reported in the UK Radioactive Waste Inventory i.e. annual volumes for waste ‘in-situ’, ‘in process’, ‘conditioned’ and ‘disposed’ and potential treatment opportunities. However, the template does not capture radioactivity data.

LLW Repository Ltd also operates a Waste Forecasting process which defines the overall quantity of waste to be consigned to the LLW Repository over the forthcoming 12 month period for each Waste Service Option; such as metallic, combustible or super-compactable waste treatment. This process is undertaken every 6 months to achieve a rolling 12 month forecast.

According to the latest UK Radioactive Waste Inventory [2], there is ~3,200,000m3 of LLW throughout the UK. Upon further analysis of the individual Waste Management Organisations inventory data submissions, the data suggests that LLW Repository Ltd should be receiving ~3100 half height IP-2 ISO containers per year until 2020. However, when comparing this data against actual site receipts at the LLW Repository Ltd, there can be a difference of up to ~80% (see Figure 2):

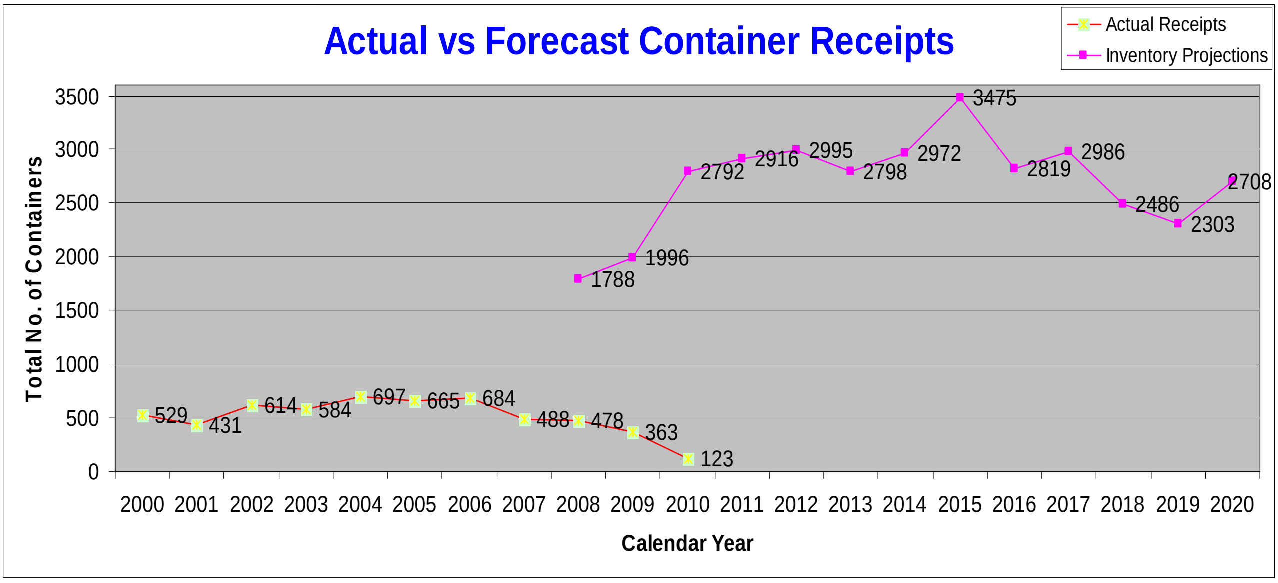

Figure 2 – Actual Receipts versus Inventory Projections

In order to resolve these inaccuracies and improve the underpinning data that supports Waste Management Organisations data submissions, a portfolio of work termed the 'Waste Inventory and Forecasting Initiative' (WIFI) is being deployed across the UK which primarily focuses on

- Waste Inventory Management Systems
- Modification of existing Waste Inventory tools; ensuring they are 'fit for purpose'
- Application of Waste Inventory Site Review Methodology

The WIFI portfolio will bring great benefit to those responsible for managing the treatment and final disposal of radioactive waste and inform key elements of the business, such as transport and logisitics. The benefits of having underpinned and accurate inventory data will also allow early engagement with Waste Management Organisations in facilitating the transportation of radioactive waste to its appropriate location.

WASTE CHARACTERISATION

The radionuclides in the wastes can be divided into three broad groups, according to the ways in which they are produced: *Fission products, Activation products* and *Actinides* (including their decay products).

- Fission products The main source of fission products in both natural uranium and enriched uranium fuels is thermal-neutron fission of U235. Reprocessing of spent nuclear fuel separates the fission products from reusable uranium and plutonium, and results in a number of process waste streams that contain fission product contamination.

- Activation products Waste in the form of activation products arise from the neutron activation of stable isotopes of all masses. Reactions involving the absorption of a neutron followed by the emission of a gamma ray tend to produce the largest amounts of activation products.

- Actinides and their decay products The actinides in the wastes are principally of two types: uranium and its decay products, and actinides of higher atomic number, such as plutonium.

Characterisation techniques for LLW and VLLW are generally improving through advanced technology. However to comply with the current transport regulations there remain many wastes, such as large surface contaminated items, which are difficult to characterise using conventional methods.

For example, many ILW wastes, especially historic or legacy ones, are physically non-uniform and this can create difficulties for sampling and radiometric assay. Some examples are:

- metallic fuel element wastes from reprocessing of spent fuel (chopped pins, end fittings, etc.,)
- resins and sludges from effluent treatment operations
- wastes from fuel cycle intermediates which cannot be easily recovered, such as UO2 residues
- plutonium contaminated wastes from various research and fuel manufacturing operations

Waste characterisation is one of the topics which are being studied by the WNTI Waste Transport Working Group.

IMPLICATIONS FOR PACKAGING AND TRANSPORT

Radioactive waste materials identified through accurate waste inventory forecasting practice, destined for disposal will arise with a very wide variety of properties. All will need to be packaged and high percentage conditioned prior to transport to disposal facilities and will have to satisfy the appropriate regulations for transport. In order to facilitate this it is important to consider to what extent these wastes could be classified into broad groups, such as the various low level waste streams and those waste streams listed above which have similar characteristics, with the objective of rationalising the choice and design of packaging, prior development and bulk manufacture.

There are many situations where this might be possible. A notable example, which is considered elsewhere in this conference [3], are some of the waste streams from fuel processing and decommissioning operations, including both LLW and ILW materials, which may contain only a small quantity of fissile material in a large quantity of non-fissile material. Many also contain very large quantities of neutron absorbers and some contain both absorbers and moderators. These wastes are normally destined for conditioning and disposal and need to be transported. The current 2009 transport regulations may require them to be transported in fissile packages when there is no realistic criticality hazard even under accident conditions. However it must be noted that the development of the new draft fissile excepted criterion intended for implementation into the 2013 edition of the transport regulations should if ratified by IAEA give more flexibility with certain fissile waste shipments

Another important example [4] is the transport of large components arising from the decommissioning of fuel plants and reactors which are usually surface contaminated. In some cases the level of contamination is not easily assessed and the current regulations do not facilitate for large surface contaminated items. The groups listed in the waste characterisation section above, provide other likely examples,

CONCLUSIONS

A large variety of process wastes arise in the nuclear fuel cycle industry, from mining, conversion, enrichment and fuel fabrication, reactor operations, reprocessing and more recently from decommissioning of a wide variety of nuclear facilities. These wastes vary greatly in their chemical, physical and radioactive properties and the degree of homogeneity is sometimes difficult to determine.

Most will need to be packaged prior to transport for disposal facilities and the Regulations for the Safe Transport of Radioactive Material, TS-R-1 [2], must be able to cater for these materials without imposing unnecessary constraints. The involvement of WNTI has been essential in sharing experiences amongst its members to consider the various issues affecting the future waste inventory forecasting practices, characterization techniques, packaging and transport of radioactive wastes.

The key topics of waste inventory forecasting and waste characterisation are being addressed and good progress is being made. This information will then be used to consider:

- the classification of wastes into broad groups, having similar characteristics, with the objective of rationalising the choice and design of packaging

- how the principles for package design and safety case could be developed for these broad categories

- how best to accommodate these principles in future editions of TS-R-1, the benefits which this approach would bring (particularly with regard to package design, licensing and procurement) and to identify problem areas which need to be addressed

REFERENCES

[1] International Atomic Energy Agency, Regulations for the Safe Transport of Radioactive Material TS-R-1 2009

[2] The 2007 UK Radioactive Waste Inventory, Nuclear Decommissioning Authority (2007)

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[4] PARTRAM Conference, The transport of large components from decommissioning operations - Jürgen Werle (*World Nuclear Transport)*