Addressing the Legacy Waste Challenge - IAEA Activities in Support of Member States – 16304

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ABSTRACT

The International Atomic Energy Agency (IAEA) promotes the safe and peaceful uses of nuclear energy including the safe management of radioactive waste. Although safe and effective radioactive waste processing technologies and practices are well established and widespread, the issue of legacy waste remains a challenge for many IAEA member states.

The primary source of the world-wide legacy waste inventory has its origins in past nuclear weapons programs and associated research and development activities. Other sources include historical waste in old storage and disposal facilities that were either never intended to be a permanent end-state or are no longer considered adequate from a safety perspective. Additionally, many IAEA member states with less advanced nuclear energy programs, often have small inventories of legacy radioactive waste arising from medical, research and industrial activities but lack the processing capabilities to put these wastes into a safe form for storage and disposal. These wastes have the potential to create a safety and environmental hazard and pose a radioactive waste management challenge for many reasons including lack of characterization data and process knowledge, waste package degradation, or the presence of hazardous or mixed waste components.

The Waste Technology Section (WTS) within the Department of Nuclear Energy at the IAEA has an extensive program of activities to support the safe retrieval, processing, storage and disposal of radioactive waste including legacy waste. These include publications, co-ordinated research projects, technical co-operation activities, and information exchange forums including workshops, technical meetings and virtual networks.

This paper will present an overview of recent IAEA activities and accomplishments aimed as assisting member states with addressing their legacy waste inventories.

INTRODUCTION

The International Atomic Energy Agency (IAEA) promotes the safe and peaceful uses of nuclear energy including the safe management of radioactive waste. The Waste Technology Section (WTS), within the Department of Nuclear Energy has the prime responsibility for supporting Member States (MS) with their radioactive waste management activities in the areas of predisposal, decommissioning, environmental remediation, management of disused sealed radioactive sources and disposal.

Within the WTS, the predisposal scope covers all activities associated with the management of radioactive waste prior to disposal, including characterization, processing (treatment and conditioning), and storage. In addition to the technological aspects of predisposal management, areas also covered include waste management policy, strategy and planning, economics, inventory assessment, technology selection and waste minimization.

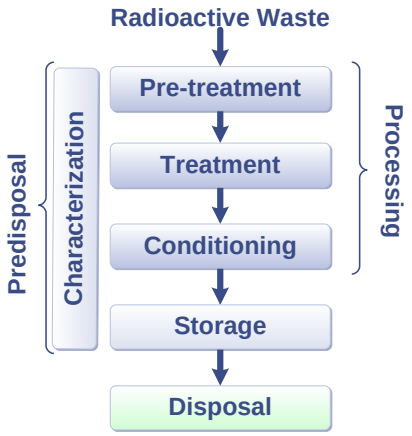

Fig. 1. Stages of Predisposal Radioactive Waste Management

The primary activities of the Predisposal Group include:

1. Publications to facilitate the dissemination of technical information relating to specific predisposal topics.
2. Co-ordinated Research Projects, which bring together research projects carried out as part of member state programs and whose purpose is to foster information exchange on areas of common interest
3. Technical Co-operation Projects. These are targeted assistance to member states with a particular problem. WTS provides the technical support to the Technical Co-operation team in the IAEA. TC projects tend to focus on individual member states or groups of member states and also focus on those member states without a well-developed nuclear industry.
4. Training courses and workshops. These again focus on particular topics of interest to MS such as the retrieval of previously disposed waste or the clearance of radioactive waste from regulatory control. These workshops and training courses are usually arranges on a regional basis and last up to two weeks.
5. Networks. An important activity is to establish and maintain networks of knowledgeable institutions and organizations that can be accessed by member states.

One of the particular challenges experienced by many Member States is the management of legacy wastes arising from past practices related to the use and manufacture of radioactive material. This paper will describe the principle IAEA activities focused on addressing the wide variety of legacy waste issues.

LEGACY WASTE

Current practices in the nuclear industry such as energy production and its supporting processes (mining, conversion, enrichment, deconversion, fuel fabrication, spent fuel handling), medical and industrial isotope production, operation of research reactors, hospitals, university etc. all have well-regulated and established predisposal waste management programs and commonly deploy good waste minimization practices. Many of these waste programs are operated by

commercial entities that either self-perform the tasks or let contracts to commercial service providers.

However, whereas the majority of the newly generated waste streams described above are generally well regulated and controlled there is a class of waste known as legacy wastes that present unique challenges. Legacy waste is a catchall name for a range of wastes that have many different origins including historical and problematic wastes that was generated in the past that for a host of different reasons outlined below, does not have an established waste processing scheme or defined end-point. Examples of past practices that generated legacy waste include:

- Waste that was generated during national defence programs where the priorities of the time mandated storage of waste against future undefined strategies
- Historic waste from older storage and disposal facilities where both the facilities themselves and the waste have degraded or have failed to meet the performance specification
- Past research and development activities
- Problematic waste without a planned disposal route. These include wastes with reactive or potentially flammable components or non-radiological hazardous materials.
- Institutional wastes such as hospital and industry waste
- Disused sealed sources that are not covered by lease arrangements

The first two categories represent the largest volume and highest cost programmes. The schedules for dealing with some of these wastes are protracted, with examples such as the US DOE Hanford Waste Treatment Project and the UK Sellafield having liabilities that stretch many decades into the future. The last four waste categories generally represent volumetrically small quantities but in terms of risk are very large contributors. Sealed sources accidents, for example, have resulted in arguably the largest number of fatalities from nuclear activities. These wastes often become orphan wastes by virtue of social and national changes that mean records and ownership is often obscured.

Major Legacy Waste Challenges

It is one of the goals of the WTS to ensure that sufficient guidance is given to MS at the planning stage of any operation that will generate radioactive waste to ensure that final end-points are established and in place prior to the commencement of the waste generating activity. However, in the past there are many reasons why waste became a legacy liability. The major challenges that often lead to the creation of legacy waste include:

- Lack of process knowledge about the waste, resulting from loss of process data or knowledge or consolidating waste from many sources in one location (Tank, silo, storage or disposal facility)
- Waste from accidents such as Chernobyl and more recently Fukushima. The former has become a legacy problem and the latter is attempting to avoid become a legacy.
- Variable characteristics and quantities. The quantity issues are evident from comparisons with the defence programme wastes with the medical wastes

- Wastes that have been disposed or stored in unsatisfactory conditions that for example might include degrading unpackaged waste or disposal trenches leaking unacceptable levels of activity into the environment.
- Degrading waste storage or disposal packages
- Waste that was previously conditioned but with the passage of time no longer meets the constraints of disposal waste acceptance criteria (WAC)
- Mixed waste with hazardous materials present
- Unique waste from one-of-a-kind processes

IAEA ACTIVITIES RELATED TO LEGACY WASTE MANAGEMENT

Publications

The IAEA publishes a range of documents under its Technical Report Series and Nuclear Energy Series to provide guidance and information related to many aspects of nuclear energy including radioactive waste management and decommissioning. The information in this series builds on expertise of representatives from Member States participating in technical working groups and consultancies. The publications are designed to assist MSs that are either implementing or planning nuclear activities.

Many of WTS publications cover various aspects of legacy waste management, for example:

- Retrieval and Conditioning of Solid Radioactive Waste from Old Facilities
- Upgrading of Near Surface Repositories for Radioactive Waste
- Locating and Characterizing Disused Sealed Radioactive Sources in Historical Waste

However due to the large number of publications available and in order to simplify access to key technical information related to the predisposal management of radioactive waste, a new initiative to consolidate existing and state-of-the-art technical information in a series of eight predisposal handbooks.

- Characterization of Radioactive Waste, Waste Forms and Packages
- Compilation of decontamination techniques and technologies and their application
- Treatment of low and intermediate level liquid waste
- Treatment of low and intermediate level solid waste
- Treatment of radioactive gaseous waste
- Conditioning of low and intermediate level liquid and solid waste
- Processing of high level and spent nuclear fuel declared as waste
- Storage of radioactive waste and conditioned waste packages

It is the intention that these handbooks will provide MS with access to key information related to the identification, selection, design and implementation of waste management schemes for all types of waste inventories.

Two recent topical publications may be of interest to many Member States with only small legacy waste inventories:

- Mobile Process Systems for Radioactive Waste Management

- Modular Design of Processing and Storage Facilities for Small Volumes of Low and Intermediate Level Radioactive Waste including Disused Sealed Sources

Both these publications provide information on alternative technical solutions for waste owners who do not have the need or capacity for large, monolithic waste management facilities. The deployment of mobile waste processing systems has the advantage of lower capital cost, easy replacement, shared or temporary use and reduces the decommissioning burden once the processing is completed. Alternatively, modular designs allow the flexibility for the establishment of more complex processing schemes (for example, characterization, treatment and conditioning) but with all the advantages of the mobile processing systems.

Coordinated Research Projects

Coordinated Research Projects (CRPs) are tools to encourage information exchange and cooperation on research and development activities in MS on selected topics of common interest. CRPs usually run for 3-4 years and involve participants from between 10-15 countries. In addition to ongoing dialogue and sharing of information, the IAEA organizes periodic research coordination meeting usually held annually to update progress and promote discussions. At the end of the project, the results of the CRP as published as agency reports.

Due to their cross-cutting and wide-spread nature, issues associated with legacy waste are often the subject of CRPs.

The processing of irradiated graphite to meet waste acceptance criteria is the subject of a recently completed CRP. Radioactive graphite arising from the decommissioning of certain nuclear reactors is a problematic waste stream in many MS and is often stored awaiting the development of a suitable disposition route. There is currently a worldwide inventory of approximately 250 000 tonnes of radioactive graphite comprising graphite moderators and reflectors that will require a management solution. The CRP, which involved participants from 24 organizations from 10 MS, explored innovative and conventional methods for graphite characterization, retrieval, treatment and conditioning. The execution of the CRP promoted the exchange of advanced information on the on-going research and development activities and highlighted a number of unresolved scientific and technical issues such as the need to:

- Improve the scientific understanding underpinning the creation, chemical form, location and release behaviour of radionuclides in the irradiated graphite matrix
- Improve the understanding of speciation and its impact on transport models
- Ensure that sampling programmes are statistically representative of the totality of the graphite to be disposed
- Develop novel alternative dismantling and treatment strategies

Although this CRP is new complete, many of the participants are continuing their networking and information activities via a new IAEA initiative known as GRAPA – the international project on irradiated graphite processing approaches

A new CRP on the subject of the management of long-lived alpha bearing waste is being launched in 2016/2017 to promote cooperation and information exchanged between MS with similar alpha waste challenges particularly those with relatively small inventories of alpha waste. Many MS have long-lived alpha bearing waste that were generated as part of historic activities (for example, cold war weapons production), reprocessing of spent fuel, decommissioning and other activities. These wastes are in a wide variety of forms (solid, liquid and gaseous) and often require segregation from other categories of waste prior to processing and disposal. Alpha bearing wastes pose a particular radioactive waste management challenge due in part to their inherent radiotoxicity, chemistry and because the presence of long-lived radioisotopes means the resulting conditioned waste form needs to be protective of the environment for several thousand years and requires deep geological disposal. Over the years, many long-lived alpha bearing waste treatment and conditioning techniques have been developed but for many MS with only small alpha waste inventories innovative and fit-for-purpose solutions are still required. As a consequence, many MS still have alpha waste inventories with no identified treatment and disposal paths. The opportunity therefore exists to develop more efficient waste processing schemes and waste forms to reduce costs, expedite schedules and reduce the risk associated with long-lived alpha bearing waste management operations. The purpose of this CRP is to understand the scope of MS's long-lived alpha bearing legacy waste streams and provide a forum in which to bring together researches, technology providers and nuclear waste owners and operations to identify promising solutions for the challenges posed. The expected output from this CRP will be a summary of the current status and trends in alpha waste characterization, treatment, conditioning and waste form performance, suggestions for processing schemes for legacy waste inventories and by conducting a gap analysis, identification of potential topics for future research and development.

Technical Coordination Projects

The direct assistance of predisposal expertise to member states is provided through projects managed by the IAEA's Department of Technical Cooperation with technical support provided by the WTS staff. Many of the MS seeking IAEA assistance in the predisposal management of radioactive waste do so because of legacy waste management issues due to past activities related to past activities associated with the development of nuclear fuel cycle programs, research reactor operations and disused sealed radioactive sources. Many of these countries either no longer have or never established a comprehensive radioactive waste management infrastructure and so seek assistance from the IAEA in areas ranging from waste management strategy and planning, inventory assessment, technology identification and selection, development of waste processing and storage capabilities. This assistance is usually delivered in the form of technical expert advice, capacity building by provision of training courses, topical workshops, scientific visits to waste management facilities and organizations, hands-on training fellowships at established facilities and institutions and procurement of equipment.

Some examples of these legacy waste clean-up projects are given below.

Example 1: Management of Legacy Waste at the Vinča Site, Serbia

In the mid-1950s the then Government of Yugoslavia built the Vinča Institute near Belgrade to provide nuclear research services. Two research reactors were established: a zero power research reactor to provide criticality research data (RB reactor) and another for high power irradiation services for a variety of experiments (RA reactor). The research reactor was shut down in the 1980s and in 2004 the Serbian government initiated decommissioning of the RA reactor and associated nuclear facilities at the Vinča site. In addition to repatriation of the spent research reactor fuel to the Russian Federation and the general decommissioning activities, a major component of the initiative is the retrieval and processing for storage of waste generated during Vinča site operations and as a result of national programs to the collect and centrally store disused sealed radioactive sources (DSRS) from all over the Republic of Serbia. The inventory of several thousand drums of raw and conditioned waste, unpackaged waste, decommissioning waste and DSRS is currently stored in unsatisfactory conditions and requires retrieval, processing and repackaging for long-term storage in a newly built storage facility.

Fig. 2. Legacy Waste Storage Facilities at the Vinča Site

As part of a European Commission Instrument for Pre-accession initiative, the IAEA in conjunction with the Vinča site operator, Public Company Nuclear Facilitiy of Serbia (PC NFS) developed a technical specification to retrieve, process and store the current inventory for that formed the basis of a request for proposal with eventual contract award going to consortium, Tecnubel – IRE Elit who have extensive experience in solid waste and DSRS management. Capacity building is a key component of the contract scope which involves the contractor training the local PC NFS work force in various aspects of waste and DSRS management so that they can continue in the longer term to independently provide DSRS search and recovery efforts throughout Serbia and potentially the surrounding countries. As mentioned earlier, one of barriers to dealing with a legacy waste inventory is the uncertainty associated with lack of a final end point, in this case established waste acceptance criteria (WAC) for low-level waste disposal. As the Republic of Serbia does not yet have a WAC the contractor proposes to use state-of-the-art retrieval, sorting, segregation and size reduction equipment to process and repackage the waste into a number of generic categories (compactible, combustible, non-compactible, free releasable waste) that will not preclude future processing scheme. The key to the safety of this processing and repackaging effort will be a robust characterization effort which will lead to the establishment of a detailed inventory

and waste tracking system to ensure that information related to the classification and categorization is recorded and retained in a form that it can be utilized by operators in the future when LLW disposal WAC are established and keep future waste processing efforts to a minimum.

TC Example 2: Management of Chernobyl Accident Legacy Waste

The IAEA has been involved in the post-accident clean-up of the Chernobyl site for many years and continues to provide sustained support in conjunction with other bodies, such as the European Commission.

The role of the IAEA on this project is largely oversight and review as well as both advisory activities and technical support for processing the waste. Work the IAEA has participated in includes:

- Review of the integrated strategy for radioactive waste management
- Development, review and optimization of Waste Acceptance Criteria
- Management of Tritium containing waste
- Assisting with processing liquid waste containing both organic materials and transuranics. This waste consists of 20,000 m^3 of accumulated operational waste and annual arisings of some 1,600 m^3 of waste from the shelter, plus dealing with any associated secondary waste.
- Reviewing decontamination techniques with potential use on large items of equipment and structures
- Assistance with specific immobilization processes, for example filter Perlite TRU sludge
- Upgrading the Solid Processing Facility
- Assessment of storage facilities
- Assisting with the safety case for waste disposal

Fig. 3. Chernobyl Nuclear Power Plant Site

This multi-group approach has been used to support the Fukushima accident and valuable lessons learned have been passed on to the Fukushima team. The sheer breadth of activities has required WTS to deploy a deep and wide understanding of the technologies and approaches that might be applied and evaluating options and selecting the optimal solution.

It is envisaged that this support will continue well into the future as there are significant challenges still remaining, related to the spent fuel, the melted reactor core (lava) and the associated debris.

Ultimately the reactor building, the damaged core and the reactor building will need to be rendered both safe and secure through decommissioning activities.

The IAEA and WTS will play a key role in ensuring that the lessons learned from this and other major accidents will be incorporated in future planning and in tackling any future accidents should they occur.

TRAINING COURSES AND WORKSHOPS

There are many areas of common interest in predisposal and one tool the WTS uses to disseminate information is to provide topical training courses to inform participants from MS that need information and guidance on predisposal best practices in areas such as:

- Waste characterization
- Retrieval and processing of legacy waste
- Upgrade of waste processing and storage facilities
- Multilateral approaches to radioactive waste management

Many of these events are managed through the TC department. A recent week long workshop on the management of problematic waste was organized for European participants in the Russian Federation. The workshop took the form of expert lectures on the best management approaches to dealing with problematic wastes followed by group exercises looking at addressing real life problem scenarios devised by the experts. The scope included a variety of problematic wastes included irradiated graphite, plutonium contaminated materials (for example rusted metal surfaces in glove boxes), organic liquids (for example oils, scintillation liquids, tributyl phosphate, kerosene), materials containing both radioactive and toxic compound (for example, beryllium mercury, asbestos) and highly reactive materials (for example, alkali-based alloys). Potential treatment solutions presented included vitrification, encapsulation in geopolymers and cements, chemical, electrochemical, mechanical and laser-based techniques for decontamination of metal and concrete surfaces, including the management of the generation of secondary waste from deployment of these techniques. Topics for past workshops have included 'Organization and technologies for recovery and reconditioning of old 'historic' wastes' and 'Experience in corrective actions at near surface repositories'

Other training courses have covered topics from development of waste management strategies and plans, development and use of waste acceptance criteria, selection of technical options for processing packaging, and storage, modular design and mobile processing facilities for small inventories.

NETWORKS

The WTS has established a number of networks to support the sharing of knowledge and expertise. LABONET is a cross-cutting network focused on the sharing of international experience in the application and development of procedures and techniques for the characterization of low and intermediate-level waste and packages. The primary objectives of LABONET are to:

- Support organizations or MS with less advanced nuclear programs with the characterization of radioactive waste by making available the relevant skills,

knowledge management practices and approaches from MS with mature operating nuclear facilities and characterization laboratories
- Develop an expanded range of training and demonstration activities with a regional or thematic focus providing hands-on, user-orientated experience and the dissemination of proven analytical procedures
- Facilitate sharing and exchange of knowledge and experience amongst organizations with operating characterization facilities, in pursuit of best practices and long-term knowledge management
- Create a forum in which expert's advice and technical guidance may be provided on the Agency's programme in the area of waste management

Topics related to legacy waste characterization have been the subject of sessions at several of the annual meetings as there is continued interest from MS in techniques to characterize legacy waste packages and waste forms for potential disposal.

CONCLUSIONS

WTS activities have a particularly important role to play in allowing the IAEA to meet its objective of promoting the safe and peaceful uses of nuclear energy. Waste is an inevitable product of nuclear activities and at present is one of the aspects of the nuclear industry that continues to concern governments, regulators and stakeholders alike. To ensure that sustainability of all peaceful uses of nuclear energy is critical that any waste produced has a well-defined plan to ensure its safe management and ultimate disposal. It is also essential that existing legacy waste inventories are effectively managed and clear end-points established.

The IAEA's Waste Technology Section provides a source of information and guidance to assist MS with establishing 'cradle to grave' waste management strategies and plans for to ensure future waste arisings are minimized and safely managed as well as providing a resource of technical information and best practice on how to address the issue of legacy waste inventories.