

**Development of Approach for Long-Term Management of Disused Sealed Radioactive Sources – 13630**

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**ABSTRACT**

Radioactive sources are used widely throughout the world in a variety of medical, industrial, research and military applications. When such radioactive sources are no longer used and are not intended to be used for the practice for which an authorization was granted, they are designated as ‘disused sources’. Whether appropriate controls are in place during the useful life of a source or not, the end of this useful life is often a turning point after which it is more difficult to ensure the safety and security of the source over time. For various reasons, many disused sources cannot be returned to the manufacturer or the supplier for reuse or recycling. When these attempts fail, disused sources should be declared as radioactive waste and should be managed as such, in compliance with relevant international legal instruments and safety standards. However, disposal remains an unresolved issue in many countries, due to in part to limited public acceptance, insufficient funding, and a lack of practical examples of strategies for determining suitable disposal options. As a result, disused sources are often stored indefinitely at the facilities where they were once used. In order to prevent disused sources from becoming orphan sources, each country must develop and implement a comprehensive waste management strategy that includes disposal of disused sources.

The International Atomic Energy Agency (IAEA) fosters international cooperation between countries and encourages the development of a harmonized “cradle to grave” approach to managing sources consistent with international legal instruments, IAEA safety standards, and international good practices. This “cradle to grave” approach requires the development of a national policy and implementing strategy, an adequate legal and regulatory framework, and adequate resources and infrastructure that cover the entire lifecycle, from production and use of radioactive sources to disposal.

**INTRODUCTION**

Radioactive sources have been in use since early 20<sup>th</sup> century, and up until about 1940, the main application was the use of radium sources in medicine. Since then, there has been a considerable increase in the number and diversity of sealed sources being used. Today, radioactive sources are widely used in medicine, research, industry, and agriculture. The majority of sources are small in physical size, with the only items of significant size being some industrial radiography units and

commercial irradiators. Despite their predominantly small physical size, radioactive sources can contain different radionuclides with activity levels in the MBq ( $10^6$  Bq) to PBq ( $10^{15}$  Bq) range. Regulatory and physical control of the majority of sources is ensured during manufacturing, distribution and normal use. When sources are no longer used and are not intended to be used for the practice for which an authorization was granted, they are designated as ‘disused sources’.

Regardless whether appropriate controls are in place during the useful life of a source or not, the end of this useful life is often a turning point after which it is more difficult to ensure control. Weak management of sources, or at worst a complete loss of control, has major implications for safety and security within a Member State, also potentially beyond its borders. Disused sealed radioactive sources (DSRS) warrant special attention because they present the largest pool of potential orphan sources (sources which are not under regulatory control, either because they have never been under regulatory control, or because they have been abandoned, lost, misplaced, stolen or transferred without proper authorization).

One example of the potential consequences of this occurred in 2010, when the University of Delhi in India instituted a campus-wide project to remove unused and unwanted objects. One of the objects identified for removal and disposal was an instrument that had been unused since 1985. It was auctioned in February to a scrap metal dealer and was delivered to the dealer in Mayapuri. No one realized that it contained Cobalt-60 sources. Sometime in March, the owner cut off a piece of a source for testing to identify the metal and gave it to another dealer, who put it in his wallet. By late March, the shop owner developed diarrhea and skin lesions, and in early April he was hospitalized with radiation sickness. The dealer who had taken the sample developed radiation burns on his buttock and later collapsed. By mid-April, a total of eight individuals were hospitalized with radiation injuries. One individual was transferred to another hospital where he died from multiple organ failures due to the high radiation exposure. Authorities recovered eight sources at the original shop, two at a nearby shop, and one from the dealer's wallet. Many of these were fragments of the original Cobalt-60 source.

To prevent DSRS from becoming orphan sources, the International Atomic Energy Agency (IAEA) encourages Member States to develop and implement comprehensive domestic solutions for end-of-life management of radioactive sources, with the expectation that they may remain in the State indefinitely; in which case they should be declared as radioactive waste and should be managed as such, in compliance with relevant international legal instruments and safety standards. The cradle-to-grave approach requires the development of a national policy and implementing strategy, an adequate legal and regulatory framework, and adequate resources and infrastructure that cover the entire lifecycle, from production and use to disposal. However, it has been observed that comprehensive regulatory infrastructure and radioactive waste programs can be weak or non-existent due to, e.g., low prioritization, lack of awareness or limited resources.

## **GLOBAL SAFETY REGIME**

International legal instruments, IAEA safety standards, and international good practices provide a framework referred to as the Global Safety Regime for achieving a high level of safety worldwide. At the core of the Global Safety Regime are activities undertaken by each country to ensure the safety and security of activities and facilities within its jurisdiction. National efforts should be augmented by inter alia international conventions that establish common obligations and mechanisms for ensuring protection and safety; codes of conduct that promote the adoption of good practices in the relevant facilities and activities; internationally agreed IAEA safety standards that promote the development and application of internationally harmonized safety requirements, guides and practices; and international peer reviews of the regulatory control and safety of facilities and activities.

### **International Legal Instruments**

The *Code of Conduct on the Safety and Security of Radioactive Sources* (the Code of Conduct), together with the *Guidance on the Import and Export of Radioactive Sources* (the Guidance), and the *Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management* (the Joint Convention) are important elements of the Global Safety Regime. Many States are in the process of transitioning from political commitments to the Joint Convention, Code of Conduct and the Guidance towards actual implementation of the articles and principles contained in these instruments. As the Secretariat for these instruments, the IAEA has been tasked by Member States to organize international meetings to exchange information on national experiences in this area. Additionally, Joint Convention review meetings and Code of Conduct open-ended meetings allow participating Member States to harmonize strategies and to adopt internationally agreed good practices for the management of sources. These international meetings are also useful for the exchange of information, to share experience and lessons learned, and thus contribute to the overall improvement of the safe and secure management of sources in participating countries.

### **IAEA Safety Standards**

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards. The publications by means of which the IAEA establishes standards are issued in the IAEA Safety Standards Series, which covers nuclear safety, radiation safety, transport safety and waste safety. In 2008, a long-term structure for the safety standards was adopted that would allow users to more easily identify those safety standards that are applicable to the specific facility or activity they are dealing with. The publication categories in the series are Safety Fundamentals, Safety Requirements and Safety Guides. They reflect an

international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation.

The Safety Fundamentals (SF-1), the General Safety Requirements (GSR) and the General Safety Guides are applicable to all facilities and activities. These are complemented by Specific Safety Requirements (SSR) and Specific Safety Guides (SSG), which are applicable to specified facilities and activities. In this collection of publications, the main provisions related specifically to end-of-life management of DSRS are included in References [1] through [8], and address the following:

- Requirement for financial provisions for management of disused radioactive sources [1]
- Requirement for prompt arrangements for the safety and control over radioactive sources, including financial provision, once it has been decided to take them out of use [2]
- Requirements that must be met during all of the stages in the development of a disposal facility [3]
- Guidance on a methodology for establishing a national strategy for regaining control over orphan sources and improving control over vulnerable sources [4]
- Guidance on management options for disused sources [5]
- Guidance on the management of radioactive waste and disused sources [6]
- Guidance on storage of radioactive waste and disused sources [7]
- Guidance on the borehole disposal of radioactive waste and disused sources [8]

Other IAEA Publications that are not part of the Safety Standards Series but that complement or are directly related include Safety Reports or TECDOCs which report on the application of the standards, provide practical examples or detailed methods for performing certain calculations or certain activities, or illustrate types of forms to be used in certain processes.

### **International Cooperation**

For a number of years, the main objective of international/regional cooperation has been to enhance safety and security of source management at large, emphasizing the need for safety and security culture, developing and implementing regulatory frameworks, and putting in place appropriate safety and security measures. The IAEA promotes international cooperation and sharing experience through a variety of mechanisms, including peer review missions, technical meetings, and other projects/programs.

Recognizing that States have the ultimate responsibility to ensure safety the IAEA offers Integrated Regulatory Review Service (IRRS) missions that take into consideration both regulatory technical and policy issues, by comparing the State's activities against IAEA safety standards and where appropriate, good practices in other States. IRRS missions provide a balance between technical and policy discussions among senior regulators and the opportunity to share regulatory experiences, harmonize regulatory approaches among States, and to create mutual learning opportunities among regulators. Regulatory technical and policy discussions take into account current issues coming from the State's self-assessment and resulting from the evaluation of technical areas.

In February 2012, the IAEA held a *Technical Meeting on Implementation of the Code of Conduct with Regard to Long Term Strategies for the Management of Disused Sealed Radioactive Sources* at the IAEA Headquarters in Vienna, Austria. The purpose of the meeting was to promote the safe and secure management of disused sources, with emphasis on sustainable and comprehensive long-term management strategies, and to build on recommendations from previous meetings. Among the conclusions of the meeting, it was recognized that there is no single comprehensive end-of-life strategy applicable for all States, and that strategies will reflect variations in: (i) the maturity of legislative and regulatory system; (ii) the presence of a nuclear power programme; (iii) the inventory and the characteristics of disused sources in the State; (iv) the financial and human resources available; and (v) whether the State is a supplier of radioactive sources.

In May 2012, The Fourth Review Meeting of the Contracting Parties of the Joint Convention was held at the Headquarters of the IAEA in Vienna, Austria. The Contracting Parties recognized the need to have strict control over sealed sources, and many Contracting Parties already have campaigns at a national level to collect orphan sources and bring them under control, and have also established strict registries, licensing systems or tracking systems of sources. Contracting Parties recognized that, where return to the supplier is not feasible, the Contracting Party must ensure appropriate management solutions are established. One of the improvements developed on was a proposal to improve the reporting of management of DSRS in order to give a comprehensive description of the legislative and regulatory system governing the management of DSRS.

### **Other Tools**

The IAEA has developed a number of tools to support the management and control of DSRS. These tools allow for the tracking, reporting, safety demonstration, and regulatory control of DSRS:

- Radioactive Waste Management Registry (RWMR)
- Net Enabled Waste Management Database (NEWMDB)

- Safety Assessment Framework (SAFRAN) Software Tool
- Regulatory Authority Information System (RAIS)

## **DISPOSAL OF DISUSED SOURCES**

At the end of their useful lifetime, it is possible in some cases to return DSRS to their original manufacturer for recycling. In many cases this is not possible and even though they may be ‘spent’ sources (i.e. no longer radioactive enough for their intended use), they still present a significant hazard. Even with the options of recycling and repatriation (some companies can recycle sources Cobalt-60 and Americium-241), disposal options must still be developed. As such, disused sources for which no recycling or repatriation options exist should be declared as radioactive waste and should be managed as such, in compliance with relevant international legal instruments, safety standards, and good practices.

Near surface disposal, which according to the IAEA waste classification scheme is suitable for low-level waste (as determined by the demonstration of safety including the safety assessment), can be a suitable option for DSRS with relatively low activities and half-lives less than approximately 30 yr. However, waste exceeding the acceptance criteria (radioactivity and half-life) for near surface disposal requires higher levels of containment and isolation than can be provided by near surface facilities. In Member States with a mature nuclear industry, possibilities for deep disposal may exist or, more often, may be planned. In reality, such States are relatively few in number. More often, States have radioactive waste, but lack the possibility of safe disposal for such waste.

One concept for DSRS disposal currently being promoted by the IAEA is the Borehole Disposal Concept. The system is a detailed, engineering level system that allows the safe and permanent disposal of DSRS in specially created boreholes. The system includes pre-disposal activities, in particular characterization and conditioning of disused sources, and is applicable to high activity sources. The Concept has been designed to provide a safe, economical, simple, and permanent solution for the long term management of DSRS. Owing to its relative simplicity, it can be implemented in countries that own the sources, but do not have the infrastructure needed to make them permanently safe.

In order to support Member State efforts in disposal site selection and facility licensing for DSRS, the IAEA has developed a post-closure generic safety assessment (GSA) of the disposal of DSRS in such boreholes. The intent of the GSA is to guide and support the demonstration of safety. The near field design evaluated in the GSA is based on a narrow diameter (0.26 m) design and using borehole drilling technology that is readily available in all countries. The design can accommodate disused sources of less than 110 mm in length and 15 mm in diameter. The sources are assumed to be disposed at least 30 m from the ground surface thereby significantly reducing the probability of

the waste being disturbed by human intrusion or other disruptive events and processes. The hydrogeological and geochemical conditions considered in the GSA and potentially influencing the near field were selected to represent a broad spectrum of site conditions. Site-specific safety investigation and assessment is still necessary to confirm that the site conditions, design and inventories fall within the GSA envelope of assumptions and data.

## **PATH FORWARD**

It is recognized that there is no single comprehensive end-of-life strategy applicable for all countries - strategies reflect variations in the maturity of legislative and regulatory system, the presence of a nuclear power programme, the inventory and the characteristics of disused sources in the country, the financial and human resources available, and whether the State is a supplier of radioactive sources. Many issues continue to remain unresolved with regards to sustainable, long-term management of disused sources, affecting return of disused sources to commercial suppliers, return to Country of Origin (repatriation), long-term storage, and disposal. Through various means, the Member States have made a number of recommendations to the IAEA for their consideration and implementation; which the IAEA takes into consideration in developing its programmes.

Despite the existence of guidance, experience, and technologies, disposal of radioactive waste in general remains an unresolved issue in most States, with placement of disused sources in a dedicated storage facility often a necessary step in their long-term management. Among the causes for the lack of progress in disposal are limited public acceptance, insufficient funding, and a lack of practical examples of strategies for determining suitable disposal options. Among the difficulties faced by the Member States include the lack of guidance for methodologies for choosing disposal options in consideration of volume, radiological properties, and other characteristics of disused sources, as well as examples of strategies for determining suitable disposal options.

The IAEA will continue its practice of providing forums for exchanges of information and lessons learnt; developing and maintaining safety standards and security guidance, and providing technical assistance and other resources. In addition, the IAEA has initiated the following projects:

In 2012 the IAEA, in collaboration with the European Union, initiated a project to support Member States develop capabilities and capacity for the management (including disposal) of DSRS. The 4-year project, entitled ‘Strengthening Cradle-to-Grave Control of Radioactive Sources in the Mediterranean Region,’ includes eighteen participating Member States from the Mediterranean Basin as well as several sub-Saharan African countries. Technical support is provided by IAEA staff from the Waste Technology Section of the Department of Nuclear Energy and the Waste and Environmental Safety Section and the Regulatory Infrastructure and Transport Safety Section,

both of the Department of Nuclear Safety and Security. Project Management is coordinated by the IAEA Department of Technical Cooperation. The expected outputs of the project include revised national policies and strategies, improved and licensed source management systems, consolidated human capabilities technical capacities, upgraded and reinforced national licensing and regulatory control, strengthened national regulatory framework, and increased political support and adherence to the Joint Convention and the Code of Conduct.

In 2012, the IAEA initiated a joint program (involving experts in security, safety, waste technology, and emergency response) using the IAEA Nuclear Security Fund to develop a comprehensive mechanism to support States' efforts to properly manage DSRS. To support such a program, four coordinating Sections with the IAEA, each having different expertise in disused source management, have been tasked to cooperatively develop a methodology to assist States specifically with end-of-life management of disused sources. The program goal is to help Member States address disused sources in a way that is comprehensive and sustainable. It will also consider how to assess the sustainability of long-term management techniques within a country from both a technical and cost perspective. Once a draft tool is available, it will be used in a developing MS to identify areas for improvement and possible areas in which external assistance may benefit better DSRS management. This program could also result in additional IAEA guidance, training, and the development of coordinated review missions, specific to end-of-life management.

## **CONCLUSIONS**

Sustainable management of disused sources requires a national policy and strategy, an adequate legal and regulatory framework, and adequate resources and infrastructure. The IAEA recognizes that a comprehensive effort is needed to work with MS to develop and implement effective and sustainable national strategies for the proper management of sources when they become disused or are no longer needed. To help Member States meet these objectives, the IAEA has developed extensive safety standards, security guidance and technical guidance, technological assistance plans, and other resources for disused sources management.

The IAEA supports international cooperation, exchange of lessons-learned and good practices, and International Conventions like the Code of Conduct and the Joint Convention. Practical assistance is being provided through the development of a cost-effective and safe technological option for the disposal of DSRS via the borehole disposal concept. In addition, IAEA provides numerous national-level, regional, and interregional projects through the Technical Cooperation programme and other extra-budgetary programs aimed at human capacity building, peer review of existing infrastructure, and direct assistance for DSRS repatriation.



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