Stronger Efforts are Needed to Improve the Control of Radioactive Sources: An IAEA Perspective - 8395

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ABSTRACT

High activity radioactive sources provide great benefit to humanity through their utilization in agriculture, industry, medicine, research and education, and the vast majority is used in well-controlled environments. None-the-less, control has been lost over a small fraction of those sources resulting in accidents of which some had serious – even fatal – consequences. In order to improve the existing situation, concerted national and international efforts are needed and, to some degree, are being implemented to strengthen the safety and security of sources in use, as well as to improve the control of disused sources located at numerous facilities throughout the world. More efforts must also be made to identify, recover, and bring into control vulnerable and orphan sources. The IAEA has been involved in efforts to bring about better control of radioactive sources for many years but since the events of September 2001 the amount of effort put into this area has increased considerably. This paper highlights IAEA work in this regard. This paper also discusses in some detail the overall nature of the problem with regards to disused sources and points out how there is still much to do in both improving the existing situation and ensuring the sustainability of control over radioactive sources for the future.

INTRODUCTION

The IAEA has been involved in improving the control of sealed radioactive sources almost since its inception. As the production and use of sources has increased, so too has the amount of disused sources. Accidents and incidents involving radioactive sources indicate that the existing regime for the control of sources needs improvement. Additionally, today's global security environment requires more determined efforts to properly control radioactive sources. Consequently, the current international and national regimes must be strengthened in order to ensure control over sources that are outside of regulatory control (orphan sources), as well as for sources that are vulnerable to loss, misuse, theft, or malicious use. Besides improving the existing situation, appropriate norms and standards at the national and international levels must continue to be developed to ensure the long-term sustainability of control over radioactive sources.

ACCIDENTS AND INCIDENTS

Despite their predominantly small physical size, sources contain very high concentrations of radioactivity. Industrial and medical sources are typically in the GBq to PBq range. The radiation emitted from the sources is usually intense, requiring reliable encapsulation for operational use and heavily shielded containers for storage. Owing to their small physical size, they are easily lost or misplaced if not properly managed. This is a particular problem when items of industrial or medical equipment containing sources become obsolete and are replaced, or simply scrapped, or when the sources weaken and need to be replaced. In all these circumstances, the sources are said to be 'disused'. Poor management practices in many parts of

the world have meant that disused sources have been found stored in exposed and unprotected locations and are consequently sometimes in poor condition, perhaps even leaking. There have been accidents and incidents recorded in the last 40 years involving fatalities as a result of sources being used in an inappropriate manner and being inadvertently mishandled by the public [1].

When a source is exposed, both people and the surrounding environment can be affected. Injuries from unprotected exposure to a radiation source can be devastating, both for the immediate victims and the community at large. Most countries that use radiation sources have regulations in place to control their use, and the sources themselves have protective shielding to prevent exposures, but accidents continue to happen. The causes for these accidents, while complex, more often than not involve someone finding a source that was lost, or worse, one that was not properly controlled. This is generally the exception rather than the rule as many thousands of sources are safely used throughout the world on a daily basis.

National regulations and international standards governing the manufacture and use of sealed radioactive sources (SRS) ensure that the source is safe when used as intended. In fact, prior to a major accident involving a sealed source in Goiania, Brazil in 1987 [2], it was widely believed that these regimes were effective in ensuring safety.
The Goiania accident, caused by a ruptured ^{137}Cs source (50.9 TBq (1375 Ci)) from an abandoned and later dismantled teletherapy device, resulting in in four fatal exposures, 28 cases of radiation burns, significant environmental contamination in the affected area, and large-scale socio-economic disruption, was the first of several accidents in the 1980s to 1990s that challenged the view that regulations and management systems of that time were effective to ensure safety. The IAEA has issued a series of reports on these accidents and lessons learned from them.
A sample of the findings of some of the reports is given below:-

- "The Radiological Accident in Istanbul" [3]. A serious radiological accident occurred in Istanbul, Turkey, in December 1998 and January 1999 when two packages used to transport ^{60}Co teletherapy sources were sold as scrap metal. The persons who purchased the two packages opened them and broke open the shielded containers, thereby unknowingly exposing themselves and several others to radiation from at least one unshielded ^{60}Co source. The persons who dismantled the containers suffered from acute radiation syndrome. Altogether, eighteen persons were admitted to hospital, out of which ten exhibited clinical signs and symptoms of acute radiation exposure.
- "The Radiological Accident in Lilo" [4]. The radiological accident described in this report took place in Lilo, Georgia in 1997, when sealed radiation sources were abandoned by a previous owner at a site without following established regulatory safety procedures. As a consequence, 11 individuals at the site were exposed for a long period of time to high doses of radiation which resulted *inter alia* in severe radiation induced skin injuries.
- "The Radiological Accident in Yanango" [5]. In February 1999 a serious radiological accident occurred in Yanango, Peru, when a welder picked up an ^{192}Ir industrial radiography source and put it in his pocket for several hours. This action resulted in his receiving a high radiation dose that necessitated the amputation of one leg. His wife and children were also exposed, but to a much lesser extent.

- "The Radiological Accident in Samut Prakarn" [6] A serious radiological accident occurred in Samut Prakarn, Thailand, in late January and early February 2000 when a disused ^{60}Co teletherapy head was partially dismantled, taken from an unsecured storage location and sold as scrap metal. Individuals who took the housing apart and later transported the device to a junkyard were exposed to radiation from the source. At the junkyard the device was further disassembled and the unrecognized source fell out, exposing workers there. Altogether, ten people received high doses from the source. Three of those people, all workers at the junkyard, died within two months of the accident as a consequence of their exposure.

These reports that highlight the lessons learned can be obtained from the IAEA. For more information on how to order the reports go the web site "www.IAEA.org".

ORPHAN SOURCES

The above-listed examples of accidents involving radioactive sources all have one commonality – the sources that were involved were all orphan sources. Radioactive sources that are not under good regulatory control can result in a number of undesirable consequences including human health impacts, socio-psychological impacts, political and economic impacts, as well as environmental impacts. Disused sources represent the largest pool of vulnerable and potential orphan sources. History has shown that many accidents involving orphan sources come about because sources that are no longer in use are eventually forgotten, with subsequent loss of control years later. To this end, it is beneficial from both a safety and security viewpoint for all disused sources to be identified and to undergo proper disposition. One of the difficulties is that sources do not usually become disused abruptly but, instead, their frequency of use decreases slowly over a period of time. In addition, licensees are discouraged from proper disposition of disused sources by the cost involved, by the bureaucracy of doing so, or by the lack of an available disposal option. The regulatory regimes in many countries and also the transport regulations are becoming ever more stringent and it is sometimes impossible for a country with limited resources and expertise to repatriate disused sources to the country of origin. This often means that these sources are candidates for becoming orphaned.

Regional and national campaigns to improve the overall control of radioactive sources have been found useful in significantly reducing the numbers of disused sources that can potentially become orphaned, or to dispose of these sources properly. The IAEA has developed strategies that can be used by countries to regain control over orphan sources and assists our member states by funding the development of a verified inventory and also by training people to go out on search and secure missions. Provision of suitable searching equipment also forms part of this assistance.

INTERNATIONAL STANDARDS AND GUIDANCE

The IAEA is tasked with producing and updating Safety Standards, Technical Documents and security related publications [7]. These include the Basic Safety Standards [8] and many other publications. The non-legally binding international undertaking, the Code of Conduct on the Safety and Security of Radioactive Sources [9] and its associated Guidance on the Import and Export of Radioactive Sources [10] are particularly relevant to the international control regime.

The objectives [11] of the Code of Conduct on the Safety and Security of Radioactive Sources (the Code) are to:

- Achieve and maintain a high level of safety and security of radioactive sources;
- Prevent unauthorized access or damage to, and loss, theft or other unauthorized transfer of, radioactive sources, so as to reduce the likelihood of accidental harmful exposure to such sources or the malicious use of such sources to cause harm to individuals, society or the environment;
- Mitigate or minimize the radiological consequences of any accident or malicious act involving a radioactive source.

The Code was endorsed by the General Conference of the IAEA in 2003. Since then, 90 States have made a political commitment to the Code in line with resolution GC(47)/RES/7.B. The supplementary Import/Export Guidance was endorsed by the General Conference in resolution GC(48)/RES/10.D. To date, 45 States have notified the Director General of their intention to act in a harmonized manner in accordance with the Guidance. The Board of Governors and the General Conference of the IAEA also endorsed a mechanism for a voluntary, periodic exchange of information among States on their implementation of the Code and Guidance. The Code of Conduct has been a great achievement with wide political adherence which is leading to factual implementation. International appraisal can be one of the follow up mechanisms to see how member states are meeting the guidance given in the Code of Conduct and the Safety Standards. The IAEA has been implementing appraisal missions for many years which have resulted in assessing how countries around the world control their sources. In addition to assessing the countries' respective capabilities, these missions also provide a set of recommendations on how the countries can improve their domestic programs for the control of sources.

To support the implementation of international regimes and standards, the IAEA is developing a series of documents which provide guidance for the prevention and detection of, and response to, theft, sabotage, unauthorized access and illegal transfer or other malicious acts involving nuclear and other radioactive substances and their facilities. This series, which follows a structure that is similar to the Safety Standards, is known as the "Nuclear Security Series" (NSS) (see [7]). One of the upcoming publications in the NSS will be the "Security of Radioactive Sources – Implementing Guide" which provides specific recommendations for the improved control and security of disused sources.

The technical Departments of the IAEA are also continuously producing technical documents that assist Member States in the operational aspects of dealing with radioactive sources. An example is the publication titled "Management of spent high activity sources (SHARS)" [12]. These and many other publications assist not only the IAEA's Member States but also other States in their quest to better control and secure sealed radioactive sources.

INTERNATIONAL CONVENTIONS

The following list of international conventions has relevance for the safety and security of radioactive sources.

- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.
- Convention on Nuclear Safety.

- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.
- Convention on Early Notification of a Nuclear Accident.
- International Convention for the Suppression of Acts of Nuclear Terrorism (Nuclear Terrorism Convention.)

As yet there is no internationally binding Convention on the Safety and Security of radioactive sources. However, the non-legally binding Code of Conduct enjoys world-wide support as shown above. It is also important that the import and export and control of radioactive sources be done in a harmonised manner.

NATIONAL REGULATORY INFRASTRUCTURES

The achievement and maintenance of a high level of safety and security in the use of radioactive sources depend on there being a sound legal and governmental infrastructure within a country. A large part of the IAEA´s statutory mandate is the establishment, and promotion, of advisory international standards and guides. The IAEA has a strong focus on assisting member states to upgrade their regulatory infrastructures to meet the international requirements of the various conventions, Safety Standards and the Code of Conduct [8], [9], [10]. The Safety Standards series of publications follows a hierarchical structure with "Fundamentals", "Requirements" and "Guides". See references [13] (Fundamentals), [8] (Requirements), and [14], [15] (Guides) for examples of these publications. The appraisal services offered by the IAEA can be used to benchmark regulatory infrastructures against these publications as well as international instruments. Recently the IAEA has expanded this by assisting member states in promulgating regulations specifically aimed at the security of radioactive sources.

The European Union countries are all bringing out new regulations to meet the criteria brought out by the EU in the so-called "HASS" Directive [16]. Council Directive 2003/122/EURATOM on the control of high-activity sealed radioactive sources and orphan sources (known as the "HASS Directive") was introduced to provide a regulatory framework for the control of sealed radioactive sources that have the potential to cause harm if they are not adequately controlled.

All these international and national efforts are definitely making an impact in improving the manner in which radioactive sealed sources are controlled throughout their life cycle. It is still however true that the regulatory regimes of certain countries are not as well established as they could be due to a variety of reasons including, economic, skills shortages, regional instability, lack of political will and a lack of understanding of the significance of the problem. It is in these countries that the IAEA provides the most support.

DIRECT TECHNICAL ASSISTANCE

Through training courses, expert missions, fellowships, scientific visits, and equipment disbursement, the Technical Cooperation (TC) Programme of the IAEA provides the necessary skills and equipment to establish sustainable regulatory and technical capabilities in the counterpart country or region. The programme also includes projects specifically focussed on improving the way in which states manage their radioactive sources whether they be still in operation or disused. A notable success of this Programme was the conditioning and safe storage of old radium sources in over 50 countries (see Figure 1 below). This project is still on-going. A

standardised methodology was developed and expert teams were trained in different regions of the world. These expert teams then conducted the operations after the States had collected the radium sources and brought them to a central location.

Fig 1. Radium sources safely conditioned in one of the IAEA Member States.

The end result was radium sources stored in a retrievable fashion in drums that are suitable for long term storage. An important aspect of this work is that the final disposal of the radium sources has not been precluded as the sources can be retrieved from their packaging if necessary.
The IAEA has provided technical assistance to recover and condition disused radioactive sources for many years but these activities were normally of a limited scope and were funded through the TC Programme as described above. The attacks in September 11 2001 triggered an awareness of the possibility of radioactive material being used maliciously. Those attacks proved the adversary is not concerned with his / her own well-being. One can logically extend this possibility to the adversary being self-exposed to an unshielded source (such as a radiological exposure device), or to detonating a "dirty bomb". The developed world and in particular the United States then started funding the IAEA's Nuclear Security Fund that had been set up in support of the IAEA's Nuclear Security Plan. The objective of the Nuclear Security Plan is to achieve improved worldwide security of nuclear and other radioactive material in use, storage and transport by supporting Member States in their efforts to establish, maintain and sustain effective national nuclear security regimes.
The escalation of the IAEA activities to improve the control over radioactive sources began in 2002. Following the meeting of the IAEA, Russian Federation-MINATOM (now ROSATOM) and US-DOE (NNSA) in June 2002, a Steering Committee and Project Management team were established. This venture became known as the "Tripartite" Initiative. Although the initiative was officially launched in January 2003 the implementation of the initiative began in the second half of 2002. The USDOE contributed financial resources of approximately US$ 1 million as well as in-kind contributions in the form of expertise, equipment and technical solutions. The Russian Federation ROSATOM made an in kind contribution of technical information, expert advice, equipment and technical solutions. The IAEA provided administrative services for the Steering Committee and contributed project management expertise. Countries of the former Soviet Union (FSU) that were targeted, included Armenia, Azerbaijan, Belarus, Estonia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan and Uzbekistan. Source recovery and disposition

projects were completed in all of the above mentioned countries. Under this initiative, the IAEA project teams have managed the dismantling and transport of radioactive sources with a total activity of 2120 TBq (57251 Ci) into safe and secure storage. The devices and storage areas where the sources were found were all vulnerable to malicious acts and posed a high risk of possible accidents. The amount of radioactive material secured in a safe and sustainable manner is significant. The risk of accidents and the availability of radioactive materials for malicious use have been substantially reduced by this cooperative effort that could be used as a model for further international cooperation. While the IAEA teams were dismantling devices and transporting the sources to safe and secure storage, the US-DOE (NNSA) teams were upgrading the physical protection of irradiators and teletherapy machines in the same region. Once the "Tripartite" initiative came to an end, the IAEA work was expanded to include countries in the regions of South-Eastern Europe, the Middle East and Northern Africa. Funding for the projects launched in these countries came from a variety of donors including the EU, the United Kingdom and Canada to name but a few.

The EU Joint Action is of particular note as these donations to the Nuclear Security Fund have been used during three so-called cycles. Cycle 3 is currently being implemented and a fourth cycle is being negotiated. The projects completed so far have improved the control of radioactive sources in many countries. The EU Joint Action is a broad based action involving improving the legal infrastructure of countries, upgrading the physical protection of nuclear facilities and radioactive sources, dismantling and transporting disused sources to safe and secure storage and illicit trafficking.

An example of one of the projects conducted under the auspices of the EU Joint Action is the dismantling of three large irradiators in one of the countries of South-Eastern Europe and the transport of the sources to safe and secure storage at the national radioactive storage facility. One of the irradiators that has been dismantled can be seen in Figure 2.

Fig 2. Cs-137 irradiator used for research purposes (before dismantling).

An important aspect of sources recovery work is to make sure that the end destination, whether it is an interim store or a centralized national facility for long term storage, is secure. It is therefore important to conduct this work in conjunction with experts who can judge the adequacy

of physical protection measures at the end points. If the physical protection of the storage facility is not adequate, it should then be upgraded.

FUTURE FOCUS AREAS

It is clear that sealed radioactive sources will continue to be manufactured and used throughout the world in ever increasing numbers. It is therefore important to control their use and disposition throughout their entire life cycle. The IAEA should focus their activities on the areas of the source life cycle where the sources are most vulnerable to a break down of control. This is usually when the sources become disused for whatever reason. In the experience of the authors, loss of control can be brought about by some common problems, including:–

- Political instability in a Region or Country leading to economic hardship.
- Natural decay of the radio-isotope making the device unfit for purpose.
- Lack of proper maintenance leading to a breakdown of the device.
- Withdrawal of manufacturer support (when a newer model comes on to the market).
- Replacement by other technologies (eg. Linear accelerators replacing teletherapy devices).
- Etc.

In order to prevent this, closer cooperation should be encouraged between international organizations such as the IAEA, national authorities, users and the manufacturers or suppliers of the sealed radioactive sources. The establishment of the source manufacturer's organization (ISSPA) has been a major step forward in this regard. The IAEA can facilitate cooperation between the various stakeholders. The IAEA's on-going promotion of the "Code of Conduct" and the associated "Import Export Guidance" [9], [10] will bring about better control of sources in countries that adopt this guidance.

It is vital that suitable end-points are identified for the final disposition of disused sources. Ultimately this should be the disposal of disused sources in a suitable geological repository. Unfortunately not many radioactive waste repositories accept the disposal of disused sources. The vast majority of disused sources are placed in storage for an undetermined period with no end-point in mind. These storage locations need to be suitably protected from a security point of view and also be under a rigorous safety regime. The liability issue of the on-going management of source stores needs to be borne in mind and funding should be set aside for the maintenance of an adequate safety and security regime.

The IAEA's work on disposal of sealed radioactive sources using the so-called "BOSS" (**B**orehole Disposal **o**f **S**ealed **S**ources) technology may result in an actual disposal operation in the near future. This involves the disposal of sealed radioactive sources in a borehole. An international peer review team have scrutinized this technology in 2005 and concluded that "the IAEA/ Necsa borehole disposal concept (BOSS) has been demonstrated to be a safe, economic, practical and permanent means of disposing of disused radioactive sealed sources (DSRS). The BOSS should be considered a viable option for management of these sources today".

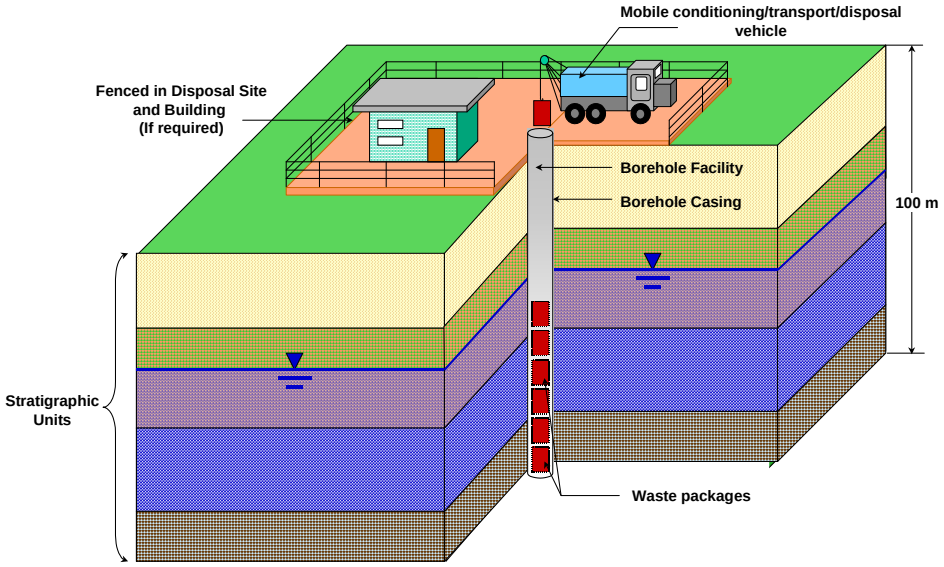

Fig 3. The BOSS concept for the disposal of disused sealed radioactive sources [17]

Permanent disposal of sources is obviously one of the best solutions for protecting sources from persons who would wish to use them for malicious purposes.
Another technology, developed by Necsa in conjunction with the IAEA is described in another paper at this conference. This is the mobile hot cell that allows the removal and conditioning of high activity sources in the field. The IAEA plans to deploy this technology in Member States in the near future.
The IAEA's Safety Standards Series of documents provides an essential set of reference for anybody dealing with sealed radioactive sources, whether they are users, regulators, transport companies, or manufacturers. This series of documents is continuously revised and expanded.

CONCLUSION

The IAEA will continue to promote the better control of sealed radioactive sources throughout the world by addressing the constraints and problems inherent in the source life cycle. The IAEA's role as facilitator and promoter of best practices will be pursued. The ultimate goal is that States have effective and sustainable regulatory and technical infrastructures in place, thus having their own capability to ensure that radioactive sources used for beneficial purposes are safe and secure throughout their life-cycle.

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