Managing the Risks of Legacy Radioactive Sources from a Security Perspective

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Abstract. The safety and security risk posed by highly radioactive, long-lived sources at the end of their normal use has not been consistently well-managed in previous decades. The Brazilian Cs-137 accident in 1986 and the Thailand Co-60 accident in 2000 are prime examples of the consequences that ensue from the loss of control of highly dangerous sources after their normal use. With the new international emphasis on security of radioactive sources throughout their life cycle, there is now further incentive to address the management of risks posed by legacy, highly dangerous radioactive sources. The ANSTO South-East Asia Regional Security of Radioactive Sources (RSRS) Project has identified, and is addressing, a number of legacy situations that have arisen as a result of inadequate management practices in the past. Specific examples are provided of these legacy situations and the lessons learned for managing the consequent safety and security risk, and for future complete life-cycle management of highly radioactive sources.

1. Introduction

Radioactive sources have been used extensively throughout the world for decades in medicine, industry, research, agriculture, the military and education. The safety risks associated with normal use and with accidents involving such sources have been known, and to varying extents addressed, for many years. This includes the development and implementation of relevant radiation protection standards and practices, with most countries adopting the international norm in the relevant International Atomic Energy Agency (IAEA) Safety Standards [1, 2]. However, there has been considerable variability among countries in the controls exercised over radioactive sources, most often because of the level of resources of the state regulatory or radiation safety infrastructure. While many countries are improving their capacity to safely manage radioactive sources, the variability in control and safety management of radioactive sources in previous decades can still present problems today. Examples of the consequences of lack of adequate controls include serious accidents involving death and injury such as at Goiânia, Brazil [3] and Samut Prakarn, Thailand [4], both situations involving abandoned highly radioactive medical radiotherapy sources. Less active radioactive sources have been inadvertently transported with other materials or smelted in recycled scrap metals, the main consequences being inconvenience and costs. In most countries where sources have been used since they became readily available in the 1960s, there are still vulnerable or orphan source situations with the potential to create problems such as these. This legacy from the historical supply and use of such sources without adequate consideration for their end-of-life management requires better recognition and resolution by all concerned.

Today the legacy radioactive source issue is compounded by the need to manage radioactive sources from a security perspective. The IAEA Basic Safety Standards only make passing reference to security requirements, stating that “sources shall be kept secure so as to prevent theft or damage” [1]. There was little other applicable guidance available except by adapting that for the physical protection of nuclear material [5], although its application to practices involving radioactive sources was problematic, given the different nature and uses of the two classes of material. There was a belief among the radiation protection community that because radioactive sources were by their nature hazardous materials, no person would risk their own health or that of others by intentionally circumventing radiation protection arrangements. This state of mind meant that only inadvertent or accidental misuse had to be prevented or mitigated. For reasonable people and situations, radioactive sources were assumed to be “self-protecting” and were secure if they were safely managed. Since September 2001 there has been a growing recognition of the threat of malicious use of radioactive sources intended to cause serious consequences such as public radiation exposure and contamination

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and disruption of normal society from a radiological dispersal device. This realisation has caused the international community to examine how to better manage radioactive sources, particularly to protecting sources from people – security; rather than protecting people from sources – safety. Reviews and analysis based on actual experience of poorly controlled sources identified the need for action using risk management approaches [6, 7]. The IAEA developed an action plan to improve radioactive source security management around the globe [8]. The *Code of Conduct on the Safety and Security of Radioactive Sources* [9], developed in 2000 and updated in 2003, described the principles of source security management along with those already established for radioactive source regulation and safety. This was followed in 2004 by the supplementary *Guidance on the Import and Export of Radioactive Sources* [10]. Ninety-two countries have made statements of intent to implement the principles of the Code, and 46 countries for the supplementary Guidance [11]. However these remain non-binding instruments. Furthermore, there is currently no detailed international standard that provides governments with practical guidance as to how to secure their radioactive sources.

To address the need for radioactive source security, some governments have provided resources and implemented national programs and bilateral and multilateral regional activities [12, 13]. Since July 2004, the Australian Government, through the Australian Nuclear Science and Technology Organisation (ANSTO), has implemented the Regional Security of Radioactive Sources (RSRS) Project to minimize the likelihood and consequences of unauthorized or malevolent use of radioactive sources within countries of South East Asia and the Pacific. From the outset, the RSRS Project joined with the U.S. Department of Energy's National Nuclear Security Administration (USNNSA) Global Threat Reduction Program in a range of activities to improve the effectiveness of control and security of radioactive sources in the region. The RSRS Project is working with countries to:

a) Improve national infrastructures, such as strengthening legislative and regulatory controls to include security provisions for radioactive sources;
b) Appropriately apply standards and requirements for the physical protection and security management of radioactive sources, and undertake related professional development to implement these requirements in a sustainable way;
c) Develop capability and expertise by the provision of radiation detection equipment and related training for orphan source searches and for emergency response; and
d) Identify and address situations involving vulnerable or orphan radioactive sources.

In achieving these outcomes, a major aim of many of the RSRS Project activities is to prevent radioactive sources falling out of appropriate control at the end of their useful lives, or to bring them into safe and secure control if they have not been appropriately controlled in the past. Such legacy source situations represent both a safety and security risk, although recognition of the security risk and what to do about it is relatively new.

2. Legacy Source Situations in South-East Asia and the Pacific

ANSTO RSRS Project activities have encountered the following situations where radioactive sources are a legacy of past activities and where the current control, safety and security of such sources makes them vulnerable to accidents, theft or misuse.

2.1. Papua New Guinea

There is considerable use of radioactive sources in Papua New Guinea (PNG) in the mining industry for radiography and gauging. However, there is no legislative basis or formal regulatory oversight for the purposes of control, radiation safety or security of these sources. Both the Department of Mining and the Department of Health provide some oversight of radioactive source importation, but neither department has defined legislative authority for these activities. The Category 2 radiography sources and Category 3 (and lower) gauge sources used in PNG mines and industry are assessed to be adequately controlled by the international companies operating under their asset management and quality-assured safety programs. Whilst this situation is not desirable as it does not satisfy international standards [1, 2, 9], it currently provides a reasonably adequate basis for industrial radioactive source security risk management in PNG.

Some radioactive sources managed within the PNG government health sector are more vulnerable, as the example of a disused 50 TBq Co-60 teletherapy source at the publicly funded and operated ANGAU Memorial Hospital in Lae demonstrates. This radiotherapy facility was established in the 1970s as part of an Australian international aid program, with the source last replenished in 1993 with Co-60 supplied by ANSTO from its Lucas Heights reactor in Sydney. Partly because of the age of the facility, and partly because of the lack of PNG government health funding, when the source became clinically unusable in 2001 the cancer treatments lapsed. The source was then stored in dilapidated conditions with minimal staff oversight and no regulatory control. In 2005, the RSRS Project became aware of the situation during routine source security outreach work. As this source was manufactured and supplied by Australia, Australia's commitment to the *Guidance on the Import and Export of Radioactive Sources* and Australian legislation allowed ANSTO to accept the return of the source, even though there was no contractual requirement imposed when the source was originally supplied. The source was repatriated to Australia by the RSRS Project for safe and secure long-term storage at Lucas Heights in December 2005. This operation cost over AU$100000, and would have cost substantially more had the Royal Australian Air Force not provided a Hercules aircraft for transport of the source.

2.2. Cambodia

There is no safety or regulatory infrastructure for radioactive sources within Cambodia. The Ministry of Industry, Mines and Energy (MIME) formed the Office of Atomic Energy (OAE) in 2006 to provide some technical capacity and focus, but it has no enabling legislation or authority to exercise controls or standards for safety or security of radioactive sources in Cambodia consistent with international norms [1, 2, 9]. The extent of national radioactive source usage or storage is unknown as a survey to compile a national inventory has not yet been performed (see Cambodian presentation in [14]). However, the extent of medical use of highly radioactive sources in Cambodia is satisfactorily known. A large public hospital in Phnom Penh currently has an operating oncology department with one Co-60 teletherapy unit and one Cs-137 brachytherapy after-loader. This hospital has periodically undertaken radiotherapy since 1960 using equipment and radioactive sources provided by the former Soviet Union. There appears to be no other medical use of radioactive sources within Cambodia.

In early 2005, a hospital medical physicist observed localised elevated radiation levels arising from outside the oncology department building during a routine survey. A surface radiation hot-spot was identified about two metres from the building. In March 2005 the hospital staff partially excavated this hot-spot and placed a quantity of shielding material within the excavation and five concrete blocks on the surface, so that the near-surface dose rate was less than a few tens of μSv/h. The area has been fenced and a warning sign in Khmer erected. Subsequent investigation by ANSTO staff indicates that the buried orphan radioactive source is most likely one or more Co-60 teletherapy sources used at the hospital before the Cambodian civil war of 1975-1981. The source appears to have been buried in an unshielded condition. The isotope has been spectroscopically determined as Co-60, and from dose rate measurements (over 13 Sv/h in bore holes made adjacent to the source) and reasonable assumptions on soil shielding and geometry, the current activity is estimated to be a few TBq.

In addition to this high-activity source, a comprehensive field radiation survey of an area about 5000 m^2 surrounding the oncology department building discovered 31 low-activity Co-60 brachytherapy sources with a total activity of 18 MBq buried near the surface. ANSTO staff have radiologically and physically characterised these sources and placed them into storage at the hospital. There are no identifying marks on these sources regarding their origin. All these found radioactive sources, as well the unearthed high-activity source, are orphan sources in that the hospital and other Cambodian government authorities are not currently claiming responsibility for their ownership or their longer-term safe and secure management.

2.3. Vietnam

Vietnam has over 20 cobalt-60 teletherapy units, with some of these units and sources supplied during the 1990s through international aid donation, including from Australia at a time when Australian Co-60 therapy units were being replaced by linear accelerators. These sources which have now decayed so they are no longer of clinical use, remain at hospitals around the country often in unsatisfactory conditions for long term storage from either a safety or security perspective. As with many countries, a national policy or program for management of disused sources or radioactive waste management is yet to be fully developed and implemented in Vietnam. Further, there has not been active recovery of the sources by the supplying countries, Australia included. While both the currently in-use and disused sources are under regulatory control, the Vietnamese regulator is relatively young, only being formally separated from the main atomic energy operating organisation in 1998. In the last few years, several laws and regulations on radiation safety and radioactive source security have been produced and are now being implemented. Vietnam is thus recognising and addressing its legacy source issues.

2.4. Situations involving low-activity sources

One of the most common vulnerable source situations encountered by the RSRS Project involves low-activity sources, typically Category 4. While these sources do not individually present a significant safety and security hazard, when aggregated they can present as a higher, Category 3 risk, particularly when there is no formal regulatory oversight. Examples of where low-activity disused sources are in vulnerable situations as encountered during ANSTO RSRS Project activities include:

a) Fifty disused Cs-137 brachytherapy needles, each with activity ranging up to a few GBq (total Category 4), in Papua New Guinea being stored in dilapidated conditions.
b) Sixteen disused Ra-226 brachytherapy needles up to one GBq each (total Category 4) being stored in a Fiji hospital. One of the sources is missing.
c) At least three disused Cs-137 Am-241/Be and Cs-137 moisture/density gauges being stored in Fiji (each Category 4).

Orphan source situations continue to be detected in the region by other agencies. In October 2007, staff from the Philippine Nuclear Research Institute (PNRI) responded to a radiation alarm detected on a shipping container in the port of Manila bound for Indonesia when it passed through a portal monitor installed under the US Megaports program [15]. The resulting search discovered an unshielded 760 MBq Cs-137 source abandoned among the scrap metal within the shipping container.

3. Managing Legacy Sources

Each of the identified legacy source situations throughout South East Asia and the Pacific represents varying levels of safety and security risk, with different characteristics and potential solutions. However, there are some interrelated or common matters in these situations. Factors that need to be considered in proposing viable solutions for legacy source situations include:

a) application of international standards and guidance, including security provisions, on disused sealed source management;
b) national or local safety and regulatory infrastructure to identify and address legacy source situations, including any political and legislative constraints;
c) existing national resources and capability, including multinational or trans-national cooperation, for providing effective end-of-life management for legacy sources; and
d) the potential public health, safety and security risks, and public perceptions, weighed against costs and benefits.

3.1 Application of appropriate standards and guidance

These sources were originally supplied in accordance with then international standards, albeit standards which did not adequately recognise or address end-of-life management. While the goodwill of the donors and the subsequent medical benefit provided by these sources is not in question, the arrangements and considerations surrounding the original donation did not take into account the

necessary management of the sources following their clinically useful life. Records of the donations from Australian organisations show that while radiation protection during use was considered when installing these sources, no adequate foresight was given to what domestic regulatory, safety or security standards the sources would be subject to, nor the management of the sources at the end of their useful life. Similarly, the disused gauges currently being stored in Fiji were supplied commercially with no arrangement for their return at the end of their useful life, nor verification that they could be managed appropriately in-situ according to international standards at such time. In many of these cases, the current responsible agency or source owner is not in a good position to ensure adequate resources to satisfy standards for safety and security.

These sources were originally supplied in accordance with then international standards which however did not adequately recognise or address end-of-life management [1, 2]. The IAEA *Code of Conduct on the Safety and Security of Radioactive Sources* and the supplementary *Guidance on the Import and Export of Radioactive Sources* now recommend that all exporters consider whether sources they provide will be adequately managed by the recipient throughout their life-cycle. The International Source Suppliers and Producers Association (ISSPA) has developed a Code of Good Practice that addresses these concerns [16]. Satisfactory implementation of this commitment will reduce or eliminate the likelihood of sources becoming uncontrolled in the future. However a similar commitment and effort from the international radiation protection community is required to support countries in addressing existing, and to assess potential, vulnerable source situations. This is particularly the case for category 1 and 2 radioactive sources, as they present higher safety and security risks.

One means to progress such a commitment is to provide appropriate international guidance and standards to apply to legacy situations, particularly from the viewpoint of security. The IAEA produced technical guidance on the security of radioactive sources throughout their life cycle in an interim document for comment in June 2003 [17]. However, a specific security standard based on comments received from this technical guidance document is yet to be published by the IAEA. These requirements would apply to legacy sources and provide a greater impetus than at present to address vulnerable source situations. As reported at the June 2007 Code of Conduct review meeting, it appears that the extent of implementation of security provisions for radioactive sources, legacy included, remains low in a number of countries [14]. Early finalisation of practical standards and/or guidance from the IAEA would enable countries to better secure their legacy radioactive sources.

3.2 Regulatory authority and capability

For countries that have well-resourced and established regulatory agencies or other institutional capability in radioactive waste and disused source management, it is reasonable to expect that satisfactory and sustainable management of legacy source situations can be achieved. RSRS Project activities in Indonesia, Vietnam and the Philippines have assisted in identifying and developing the appropriate national requirements to provide authority for, and provisions to implement, the safe and secure management of disused sources at more centralised facilities. These facilities include the BATAN Radioactive Waste Management Facility in Serpong, the PNRI Radioactive Waste Storage Facility in Manila and the Vietnam Atomic Energy Commission (VAEC) Disused Source Store in Da Lat. While these facilities provide a potential legacy source management pathway, the areas of legislative authority and technical capability were identified as needing development.

Obtaining appropriate legislative authority for the management of vulnerable sources requires specification of arrangements for safety and security, including provisions to establish the necessary human, equipment and financial resources covering any conditioning, packaging, transport and storage. A series of regulatory working group meetings were held with experts from each national agency, ANSTO and USNNSA programs to turn these requirements for source security into provisions to be included in updated or new legislation or regulations. These trilateral working groups also addressed the provision of the appropriate authority to manage and store disused sources if other mechanisms such as return to the original supplier or manufacturer were not available. As a result, legislation or regulations covering vulnerable source management are now in place in Indonesia, the

Philippines and Vietnam. A key consideration in drafting these regulations was to ensure that sources would not simply be transported from one site to another that did not satisfy safety and security provisions for storage. As such, the regulations contain security and physical protection requirements on how legacy sources must be stored.

To complement this legislative authority, national agencies must have the ability to assess and respond to vulnerable source situations when they arise. To this end, the USNNSA program has provided radiation detection equipment to search for orphaned sources and, together with the RSRS Project, has provided training in the use of the equipment and search techniques to Indonesia, the Philippines, Vietnam, Thailand and Cambodia.

This dual approach of providing legislative authority and technical capability improves the capacity of these countries to respond to legacy source situations. This was evidenced by the aforementioned case where PNRI staff responded to a radiation alarm on a shipping container in the Port of Manila. Using the equipment, techniques and their revised regulatory authority developed with assistance from the RSRS Project, they were able to locate, prepare and transport an orphaned source to their storage facility. Acting under the authority of their newly established legislation, they thereby autonomously effected secure management of an orphaned source.

3.3 Absence of regulatory or safety infrastructure

Not all legacy source situations can be managed independently by each country. In a number of countries, there is no regulatory or radiation safety infrastructure within which to adequately develop management of legacy sources. These situations need more direct assistance from the international community to provide a safe and secure resolution.

This was the case in PNG described above where ANSTO repatriated a disused Co-60 teletherapy source in 2005. This high-activity (Category 1) source was being stored with no effective control. Effective management could only be achieved through international shipment to an appropriate country. In this case, the Co-60 source was manufactured by ANSTO, giving a mandate under Australia's commitment to the IAEA *Code of Conduct on Safety and Security of Radioactive Sources* to return the source to ANSTO for safe and secure storage.

The improved end-of-life management outcome for this legacy source demonstrates that international assistance programs can achieve practical outcomes for identifying and dealing with legacy sources in developing countries. However, this remediation was contingent on a number of factors. Due to the high-activity and remote location of the teletherapy source, finding a willing transport operator to move it from Lae to Sydney was problematic. The Royal Australian Air Force provided a Hercules aircraft to transport the source at no direct cost, thus providing a significant saving on an already expensive operation. The second, and perhaps more problematic factor, was the origin of the source. Australia, like many countries, has restrictive legislation that prohibits the import of radioactive waste or disused sources for storage or disposal that are not of Australian origin [18]. If the source had not been supplied by ANSTO or its origin was not known, it could not have been transported to and kept in Australia. As PNG does not currently have the capacity to domestically manage such sources safely and securely, it would have remained in place as a highly vulnerable source. While both of these factors were resolved satisfactorily in this case, the situation highlights the challenges that can be faced in providing suitable management of legacy sources in developing countries. A practical risk-based approach that recognises the capacity of the local safety and regulatory infrastructure is needed from the international community to overcome both legislative and logistical barriers to proper management of legacy sources.

The effect that these barriers can have on adequate management of legacy sources is also seen in considering the buried source detected in Cambodia. Like PNG, this situation involves a high-activity (Category 2) legacy source in a poorly controlled situation with no in-country safety or regulatory infrastructure or resources to provide effective management. There is strong anecdotal evidence that the source was supplied by the former Soviet Union. While it may be possible to confirm the origin of

the source upon its excavation, this will not necessarily assist in identifying a satisfactory end-of-life management pathway as there is almost certainly no contractual obligation to take the disused source back. The ability of many countries, including Australia, to provide a long-term storage or other disposition option for the source would be restricted by their domestic legislation. If a long-term solution is to be found to minimise the safety, environmental and security risk posed by this source, the international community needs to commit to better practical arrangements regarding its long-term storage.

3.4 Working with Source Suppliers

One further solution to legacy source issues is for organisations and governments to work more closely with the source suppliers. ISSPA has indicated that they are willing to work with the industry to provide solutions to these situations [19]. There are many legacy sources where the manufacturer is known, but the source was provided before contracts routinely provided for return of the source to the manufacturer. The low-activity sources in PNG and Fiji fall into this category. While return of these sources to the manufacturer for conditioning or storage would provide an effective management pathway, the financial cost of this solution needs to be addressed. Much of this burden could be alleviated if the suppliers developed more proactive campaigns to foster the return of such legacy sources, with the international community providing the necessary resources, including financial, for their packaging and transport to the supplier. As most current suppliers are now required to take back their newly provided sources, it is not unreasonable that older sources returned in this fashion could be incorporated into their storage or recycling programs, provided costs associated with retrieval and transport to the supplier are covered through alternate means. This arrangement could apply even when a source's origin is unknown or if the original supplier is no longer in business. The international radiation protection community could work to establish a viable management program for these orphan sources, particularly in countries where there is insufficient capacity to otherwise mange these sources safely and securely. A factor in the risk-cost-benefit evaluation for taking such modest actions now rather than later is the ability of current government programs such as the ANSTO RSRS Project to leverage resources for retrieval and transport from a security viewpoint. This could occur even when the assessed risk is small, thus avoiding the nuisance associated with low activity sources becoming uncontrolled and the related poor public perceptions.

4. Conclusion

In recent years, the radiation protection community has made significant efforts to address the need to better manage the security of radioactive sources in addition to existing safety practices. Measures such as the IAEA *Code of Conduct on Safety and Security of Radioactive Sources*, the associated import/export guidelines and the ISSPA Code of Good Practice at least provide the relevant principles for controlling radioactive sources from both safety and security perspectives. The security provisions of these measures now apply to sources that are currently in use or proposed to be used. In these situations it is expected that proper recognition and implementation of the requirements for adequate safety and security will be provided during and after the use of the source.

However, this situation does not necessarily apply to legacy sources, particularly when the sources are not, or were never, under some form of satisfactory control or responsible ownership. By actively engaging source regulators, owners and operators on source security matters, international programs such as the ANSTO RSRS Project are identifying and remedying legacy source situations and developing a more practical means of determining who is responsible for management of such sources. There are still a number of challenges or impediments to effective management of legacy sources that need to be addressed by the international community. These challenges, and suggestions for ways in which the international community can address them, include:

1. **Active engagement of lesser developed countries on legacy sources issues.** Legacy source situations by their very nature can be difficult to recognise, characterise and address. Many countries do not have the necessary technical resources or regulatory, safety and security capacity to do so. Active and on-going engagement of these countries by the international community is needed to identify legacy sources and provide viable management pathways.

2. **Completion of an international standard on radioactive source security.** Many countries are in the process of implementing legislation, regulations and guidance enabling them to provide effective control and security provisions for high risk radioactive sources including at the end of their useful life. However, agreed international standards and technical guidance on physical protection and security management of these sources have not yet been promulgated, except in an interim form in 2003. The IAEA needs to finalise its radioactive source security standards and guidance and better integrate these with radiation protection standards and guidance.
3. **National and international framework to assist management of legacy sources.** Legacy source situations where there is neither a satisfactory domestic management pathway nor a manufacturer, supplier or another country prepared to accept the source have been identified. The international community needs to consider flexibility in national legislation and regulation that currently prevents acceptance of legacy sources from others to provide more effective control and security of these sources.
4. **Co-operate with source suppliers in legacy source remediation.** A number of legacy source situations have been identified where there are only a few high risk sources in country and the original supplier or manufacturer is known, but due to the sources' age there is no contractual requirement to accept their return. Commitment from international suppliers, or relevant other national agencies, to accept these radioactive sources into their recycling or reclamation programs would provide a cost effective way of controlling and securing these sources. Where there are insufficient domestic resources to fund the packaging and transport of these sources to the supplier, the international community should meet these costs based on a considered mid- to long-term cost-risk-benefit evaluation.

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