Transportation safety risk for source recovery versus consequence of leaving radioactive sources in place and vulnerable due to limited transport options or denial of shipment

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Potential risks associated with transportation safety of recovered radioactive sources in normal commerce are rhetorically compared to the latent risk of not recovering disused radioactive sources due to limited transport options or outright denial of shipment. It is essential, during each phase of the recovery process, to ensure secure, timely, cost effective and reliable means to return vulnerable radioactive sources to safe and protected locations by land, sea and/or air transport. In some cases, only limited transport options exist or denials of shipment may occur that impede the recovery process. Risks associated with normal transportation of recovered sources are considered less significant than the risks related to leaving disused radioactive sources at their original location.

Keywords: Transportation risk, Source recovery, Denial of shipment

Introduction

The Off-Site Source Recovery Project (OSRP) at Los Alamos National Laboratory (LANL), as part of the National Nuclear Security Administration's (NNSA) Global Threat Reduction Initiative (GTRI), recovers and manages disused and unwanted radioactive sealed sources that present a risk to health, safety and national security; and sources for which few or no disposal options currently exist.

Sources containing radioactive plutonium, americium, californium, cesium, cobalt, curium, radium and strontium have been recovered from medical, educational, agricultural, research, industrial and government facilities. Since 1997, GTRI/OSRP has been able to recover over 22 400 sources from 834 sites in 49 States, the DC area, Puerto Rico and over 930 more from several foreign countries. This represents recovery of over 28 600 TBq (774 770 Ci) of radioactive material during this period (all recovery totals as of 26 July 2010).

The problem of disused, or otherwise unwanted, radioactive material widely distributed around the world is recognised as a global threat. Unused long lived radioactive sources are the residual product of industry, medicine and scientific research. These unwanted sources create a supply of hazardous material which could be incorporated into a weapon of terror; or may simply present a health and safety threat to the public and the environment if left unattended.

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There are several root causes to the legacy radioactive source problem which are not addressed in this discussion. However, one of the most unfortunate obstacles to a seemingly simple solution (i.e. expeditious, efficient and cost effective elimination of the threat posed by unwanted radioactive sources by moving them to a safe and secure location) is the restricted or limited transportation mechanisms available to move such materials from a place of high vulnerability to safe and secure locations. Therefore, any difficulty in shipping these at-risk sources may result in the sources remaining at-large – with potential adverse effects to national security, public health or the environment.

The question thus becomes whether the potential risks associated with transportation safety of recovered radioactive sources in normal commerce are greater than or less than the latent risks of not recovering the disused radioactive sources due to limited transport options or outright denial of shipment.

In-depth analyses with specific examples require additional research and are beyond the scope of this emblematic overview.

Radioactive source distribution

Since their development, radioactive sources have been distributed around the world for peaceful uses in medicine, industry, agriculture, research and in common consumer products. Radioactive sources are prevalent in hospitals, irradiation facilities, construction companies, universities, factories, oil field industry and even homes throughout the world.[1]

Millions of small radioactive sources (containing radium 226, cesium 137, etc.) exist around the world, each

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1 Collections of small radioactive sources may not be securely stored

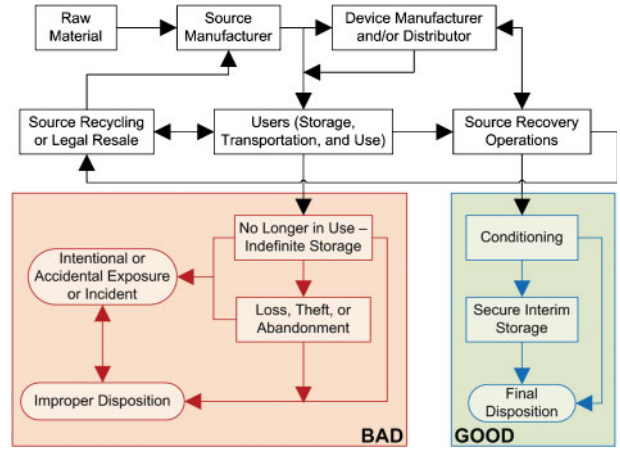
2 Devices containing high activity radioactive sources may end up in unsecure locations

containing small amounts of radioactivity.[2] Individually they pose little risk to national security, public health or the environment. However, potential danger to public health, the environment or security increases if these sources are consolidated in large numbers at a single location without proper protection (Fig. 1).

Larger, higher activity sources are also prevalent. Estimates indicate that more than 10 000 medical teletherapy units are located at hospitals throughout the world for treatment of cancer.[2] Such devices often contain hundreds of TBq (many thousands of Ci) of cobalt 60 each. Blood irradiators use hundreds of Ci of cesium 137 to kill antibodies in blood products to prevent host versus graft disease. It is estimated that between 1000 and 2000 blood irradiators exist worldwide.[3]

Approximately 500 000 sources were distributed to European Union Member States over the past 50 years and about 110 000 remain in use.[4] Most of the remainder were returned to manufacturers; or sent to secure interim storage or disposition. However, the sources in this arena at greatest risk of being lost from regulatory control are the estimated 30 000 disused sources held in storage at users' premises throughout the European Union Member States.[4] Sources outside the European Union or US may be at higher risk. The International Atomic Energy Commission (IAEA) estimates that 110 countries fail to impose adequate controls over radiological sources (Fig. 2).[5]

A definitive number for radioactive sealed sources distributed worldwide is not currently known, nor easily obtainable. A survey conducted in 2003 found that a total of about 7·8 million radioactive sealed sources were in use worldwide for various applications.[6] Since only 49 out of 127 IAEA member states responded to



3 Lifecycle of sealed sources: diagram was inspired by other generic source lifecycle diagrams, such as those appearing in Refs. 1, 4, 7 and 8

the General Accounting Office (GAO) survey, the actual number of sources may be much larger.

It is even more difficult to determine the precise number of radioactive sources that have been lost, stolen, abandoned, illegally transferred or improperly dispositioned. The full extent of the global threat from excess and unwanted radioactive sealed sources cannot be accurately quantified. Unfortunately, the problem is dynamic and it is not getting any smaller.

Source lifecycle

The lifecycle of radioactive sealed sources begins with raw materials and manufacturing, and should terminate with final disposition. A proactive cradle-to-grave management approach is one way to monitor status/location of radioactive sources.

Figure 3 attempts to convey possible stages in the lifecycle of a sealed radioactive source.

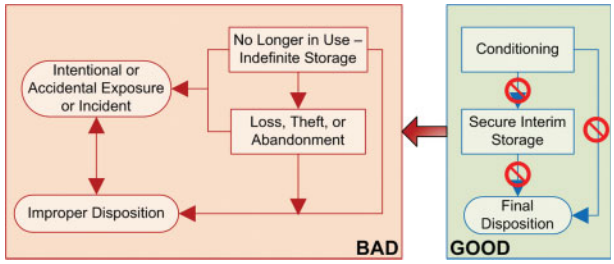
Vulnerability of sources at each stage in the lifecycle varies. Intentional misuse, theft or accidental loss may occur at any point in the lifecycle during storage, transportation or use. However, when sources are no longer in use (e.g. relegated to indefinite storage), the potential for loss, theft, abandonment, improper disposition and/or an unfortunate incident seems more likely. Therefore, a key issue for management of radioactive sources is to identify exactly when they become unwanted or disused. When sources are unwanted, they should be returned to the manufacturer or sent for disposition; or source recovery operations for threat reduction purposes should be initiated.

In the simplified graphic model in Fig. 3, three lifecycle terminus options exist: safe, secure and legal final disposition on the 'good' side; improper disposition; intentional or accidental exposure or incident on the 'bad' side.

The arrows represent transportation and flow of the source from one stage to another. If transportation is hindered due to denial of shipment, sources cannot proceed to the next stage of their journey and may never reach final disposition.

Denial or delay of shipment

Denials of shipment of radioactive material negatively influence the recovery of disused, unwanted or abandoned



4 Denial of shipment leaves unwanted sources in 'bad' situation

sources of radiation for risk mitigation purposes. Impediments to this recovery process lead to delays in returning at-risk radioactive sources to safe and protected environments and leave them in a potentially 'bad' situation as represented in Fig. 4.

If recovery shipments cannot be made or are delayed (as indicated by the ⏀ symbol in Fig. 4), the hazards associated with the radioactive sources at the storage location are not reduced and move from the 'good' side of the lifecycle to the 'bad' side where proper disposition is unlikely. Therefore, the material becomes subject to possible loss, theft, abandonment, improper disposition and/or an unfortunate incident.

Ensuring efficient and cost effective means of domestic and international shipment of excess, unwanted or abandoned sources of radiation for risk mitigation purposes is vital to global threat reduction and the health and safety of people around the world. Therefore, shipments of radioactive sources for risk mitigation purposes should not be denied (or delayed) assuming that the packages are prepared in accordance with established transportation regulations and carried in compliance with established international hazardous material codes. Denial of such recovery shipments of at-risk radioactive sources is not in the public interest.

Comparing risks

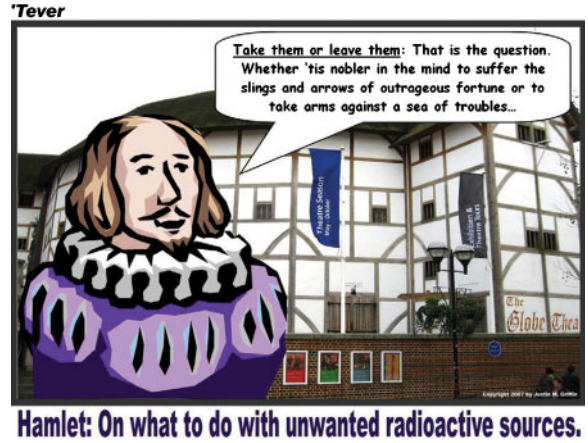
Is the potential risk associated with transportation safety of recovered radioactive sources in normal commerce greater than or less than the latent risks of not recovering excess, unwanted or abandoned radioactive sources and leaving them in place?

> *Take them or leave them…'That is the question. Whether 'tis nobler in the mind to suffer the slings and arrows of outrageous fortune or to take arms against a sea of troubles…'* (Quotation from Hamlet's soliloquy in Act III, Scene I of Shakespeare's play 'Hamlet, Prince of Denmark.')

For this discussion we rhetorically ask whether it is better to 'take arms against a sea of troubles' by transporting them in the public domain; or to 'suffer the slings and arrows of outrageous fortune' by leaving at-risk sources unrecovered (Fig. 5).

Recovery transportation risks – 'take them'

As alluded to by the arrows between boxes in Fig. 3, production and use of radiation sources inevitably involves transport in the public domain. When sources are no longer in use they must also be shipped through the public domain to safe and protected interim storage or final disposition.



5 Hamlet on what to do with unwanted radioactive sources

There are some inherent risks associated with normal, incident free transport (e.g. radiation dose to transport workers). Although risks such as these are important in some cases, for the purpose of this document risks from incident free transport are assumed to be minimal. Transport of this sort simply results in successful movement of radioactive source(s) from one location to another without negative impact to people, property or the environment along the shipping route.

Occurrences during transport may have different outcomes depending on the severity of the accident or incident, the type/magnitude of failure of package integrity and the radiological and physical characteristics of the material conveyed.[9] Despite herculean efforts to ensure safe transport of radioactive sources related to packaging, potential for accidents or incidents in transit does not equal zero.

The nature of the safety requirements incorporated into established transport regulations for shipment of Class 7 cargo ensures high levels of protection of the public and the environment. In fact, radioactive material has been shipped within the US for over 50 years with no occurrences of death or serious injury from exposure to the radioactive cargo.[10] Despite this fact, fears of potential accidents/incidents which result in loss of package containment and subsequent dispersal of radioactive material into the environment often taint public or political opinions against transport of Class 7 cargo. This is a 'perception' issue, not a real radiation safety issue when the sources are packaged compliantly.

As previously stated, potential for accidents or incidents during transport does not equal zero, but can this be quantified? We have to look at past performance.

In the US, approximately 2 800 000 shipments of radioactive material occur every year.[11] Thus over a 10 year period, about 28 million shipments take place. Historical records for the 10 year period from 1997 through 2006 show that the US recorded a total of 163 875 reportable domestic transportation related incidents (involving all modes of transport and all classes of hazardous material cargo). These incident reports to Department of Transportation (DOT) are required by 49 CFR Part 171, Sections 15 and 16. Of these, only 147 involved shipments of radioactive cargo.[12] Most of these incidents were classified by DOT as minor vehicular accidents (such as fender

benders) which did not cause adverse effects to the Class 7 packages.

Although accidents or incidents are inevitable, past performance indicates that the odds are quite low. Perhaps one out of every 200 000 shipments of radioactive cargo may result in an accident. If an accident does transpire, an actual radiation hazard may not occur since the packages used for Class 7 cargo are designed and tested to survive accident conditions without release of the radioactive constituents.

Risks of not recovering unwanted sources – 'leave them'

Recently, international cooperative efforts have been undertaken to upgrade the security of specific facilities around the world and to put more effective security controls and regulations in place.[13]

If unused sources are stored in a secure environment before proper disposition, source recovery may not be necessary. Unfortunately, internationally organised secure in place efforts may have little effect on radioactive sources which have fallen through the cracks of regulatory control or sources that have otherwise not been relocated to a centralised repository. Furthermore, disused sources containing long lived radionuclides, even though properly conditioned, cannot be stored indefinitely.[14]

This may include millions of sources currently used or stored at individual facilities around the world for medical, industrial, agricultural or research purposes (each with various levels of regulatory control and oversight). Similar to the 2003 GAO report, the NATO Advanced Research Workshop on International Approaches to Securing Radioactive Sources Against Terrorism also estimates that there are at least 8 million radiological sources worldwide.[5] All radioactive sources currently in use will reach the end of their useful life someday, and will require proper disposition.

Because limited transport options exist or denials of shipment occur to impede the recovery process, some at-risk sources may inevitably be left behind. Since safety, security and control standards at these locations may be less than desirable, the risk of loss, theft, abandonment, improper disposition and/or an unfortunate incident involving these lingering sources is not reduced. Over the years, lost, abandoned, stolen or improperly dispositioned sources have caused unfortunate radiation contamination incidents and deaths around the world – sometimes accidental, sometimes intentional. According to a database compiled by researchers at Stanford University's Institute for International Studies, 830 entries were recorded in their 'Database on Nuclear Smuggling, Theft, and Orphan Radiation Sources', as of 2002.[15] This included 643 nuclear smuggling incidents (including thefts), 107 cases of orphaned sources and more than 80 cases involving fraud or malevolent acts using radioactive material to commit murder, deliberate exposure and blackmail and to poison food and water supplies.[15] According to the IAEA Illicit Trafficking Database, 1562 confirmed incidents were reported between 1993 and 2008. Of these 336 incidents involved unauthorised possession and related criminal activities, 421 incidents involved reported theft or loss and 724 incidents involved other unauthorised activities and events.[16]

6 Incidents can occur if radioactive sources (or devices such as these teletherapy heads) are not properly dispositioned

At least some of these known incidents may have been prevented if the sources were moved to a safe and secure environment before they were lost, abandoned, stolen or misused (Fig. 6).

Furthermore, the likelihood of an attack using a radiological dispersal device (i.e. dirty bomb) created using lost, abandoned or stolen radioactive sources is also still a major concern. In 2002, Jose Padilla was arrested for planning to use a dirty bomb in the US; and by 2003, British officials also determined that Al-Qaeda had gained the expertise and possibly the materials to build a crude dirty bomb.[17]

When comparing potential transportation risks to risks caused by leaving disused, unwanted or abandoned radioactive sources in place, the answer seems clear. If safe management of radioactive sources is not guaranteed where the unused sources exist, it is less risky to 'take them' than it is to 'leave them'.

Conclusions

The full extent of the global threat from excess and unwanted radioactive sealed sources cannot be accurately quantified. This dynamic problem changes as new sources are distributed around the world and old sources outlive their usefulness.

Since late 2001, the US and the European Union have contributed large sums of money at home and internationally to secure and/or recover at-risk radioactive sources.

Sources that are no longer in use (e.g. relegated to indefinite storage) are more vulnerable to intentional misuse, theft or accidental loss. Therefore, it is important to identify exactly when radioactive sources are no longer used or are unwanted. When sources become unwanted, they should be returned to the manufacturer or sent for disposition; or source recovery operations for threat reduction purposes should be initiated.

Ensuring reliable and affordable means of domestic and international shipment of excess, unwanted or abandoned sources for risk mitigation purposes is vital to global threat reduction and the health and safety of people around the world. Denial of such recovery shipments of at-risk radioactive sources for threat reduction purposes is not in the public interest.

Without going into elaborate examples or scenarios, one can assert that the risks during normal transportation

of radioactive sources for threat reduction purposes are less than latent risks associated with leaving disused, unwanted, abandoned or otherwise unsecured radioactive sources in place. If enduring security and management of radioactive sources cannot be guaranteed for disused sources where they currently exist, logic dictates that source recovery operations be conducted to relocate excess and unwanted sources to a safe and secure location for threat reduction purposes.

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