Cobalt-60 Use and Disposal: An Established Pathway

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Abstract

Unfounded concerns exist about industrial cobalt-60 sources being stolen, lost, or abandoned. Implementation of many security measures since September 11, 2001 protects against the theft of cobalt-60 sources. The industry uses unique serial numbers to perform “cradle to grave” tracking of the cobalt-60 sources. And regulatory changes require owners of irradiators to provide substantial upfront financial guarantees to cover anticipated disposal costs in the unlikely event an owner abandons their sources.

Cobalt-60 plays a vital role in the sterilization of medical products and thus contributes to the healthcare and well-being of millions of people. After the installation of the initial load of cobalt-60, irradiators reload as needed to replenish the decay loss of 12.3% per year and to accommodate any growth in product volumes, usually 5-10% annually. Cobalt-60 is disposed of only when it has decayed to such a low level that it is no longer useful and with a half-life of 5.26 years it naturally decays into stable nickel-60 reaching background radiation levels in roughly 175 years. Of the 82,000 industrial sources in service today worldwide, the total physical volume occupied requiring disposal is very small at approximately 3.6 cubic meters (127 cubic feet).

The economic, environmental, and societal benefits associated with current industrial applications of cobalt-60 mandate its continued use and management in a secure, safe, efficient and cost effective manner. Irradiator owners, source manufacturers, and reactor sites generating cobalt-60, recognize the vital importance of cobalt-60, and their responsibility have together over many years developed methods to recycle cobalt-60, thus minimizing the amount of waste and have provided an effective pathway for its ultimate final storage or safe disposal.

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Who bears the burden?

The recent 2008 report by the US National Academy of Sciences (NAS) on “Radiation Source Use and Replacement” raises the question as to who bears the burden; and specifically deserving debate is the level of user responsibility for the costs associated with source disposal, and possible terrorist acts. Figure 1 illustrates the typical lifecycle of a cobalt-60 source and the participants in “cradle to grave” management. Below is a discussion of the participants, current status, and concerns with respect to industrial cobalt-60 sources.

**Regulatory:** The IAEA Code of Conduct on the Safety and Security of Radioactive Sources, and supplementary Guidance on the Import and Export of radioactive sources sets the international platform. As of July 4, 2008 a total of 92 countries made a political commitment to the Code of Conduct. Competent Authorities adopt these IAEA guidelines and use them to develop or update their national regulations and security measures. For example the USA Nuclear Regulatory Commission (NRC) under 10CFR tightly regulates, tracks, monitors and controls the use of industrial cobalt-60 sources used in gamma irradiators. Individual National Authorities may have their own rules for financial assurances and recordkeeping for source transfers and decommissioning.

**Reactor Site:** Power reactors produce over 75% of the world’s bulk cobalt-60 with the rest coming from speciality reactors, and cobalt-60 source manufacturers have reciprocal agreements in place with many reactors to handle spent cobalt-60. The owners of reactors recognize and accept the responsibility for the management of their waste in an environmentally, socially and financially responsible manner – believing it is important that future generations do not have to bear the cost of today’s operations.

**Source Manufacturer:** MDS Nordion and REVISS, the leading suppliers of cobalt-60 offer cobalt-60 return services. Recycling or reuse is the preferable option for sources returned to them. If disposal is the chosen option sources are stored until sufficient quantities warrant sending them to a waste management service provider, in all cases to a government regulated, highly secure operation. Source manufacturers seek to have long-term disposal agreements in place, thereby assuring users of the technology a method for returning sources no longer of value.

**Irradiator Owner:** In about 50 countries over 170 large-scale gamma irradiation facilities are currently in operation, and in total contain approximately 300 million of cobalt-60. Facilities may be licensed to contain 1 to 4 million curies (MCi) or more, but invariably initially contain less cobalt-60 to allow for growth over time. Owners of irradiators typically enter into supply agreements that include the provision for the return of sources to the supplier. After the installation of the initial load of cobalt-60, facilities routinely reload on an as required basis to replenish the decay (12.3% per year) and to accommodate any growth in product volumes, usually 5-10% per year. Irradiator designers construct the cobalt-60 source racks to accommodate this additional number of sources added over time, cognizant of the usual practice of returning sources after expiry of a 20 year
warranty. In most cases decommissioning procedures are straight-forward and simple with the transfer of the majority of sources to another irradiator and the few old, lower activity sources returned for recycling, final storage or disposal.

**How big is the disposal problem?**

Actually it is surprisingly small. The industry standard is a cylindrical cobalt-60 source with the dimensions of 11.1 mm (0.437”) in diameter and (451.6 mm (17.76”) in length. With approximately 82,000 sources in service worldwide the total physical volume which all of them would occupy is only 3.6 cubic meters (127 cubic feet). To put this volume into perspective, a small one car garage has the volume of 45 cubic meters (1600 cubic feet). An estimate shows that all of the cobalt pellets, slugs, wafers, discs, etc. produced up until 2003 could fit within, (in fact most likely the bottom 20%) of just one solid waste storage bunker located at Atomic Energy of Canada (AECL), Chalk River, ON, Canada. Thus the decay storage space needs and ultimate disposal of cobalt-60 is not significant relative to the nuclear power industry.

**How much does disposal cost?**

Persons need to take care when comparing different disposal options, since it can be misleading. In the NAS report it was noted that to dispose of just one cobalt-60 source (300ci) at the low-level Barnwell Disposal Waste Facility, in South Carolina, USA would cost about $130,000 US. This facility deals with the disposal of low-level radioactive waste that looks like ordinary trash (e.g. paper or fabric) and is ill-equipped to economically handle cobalt-60 sealed sources, hence the high price for it to handle something it is not set up to do. Nor will it ever be set-up, since it must be noted that this facility is slated to be closed in the next few years.

So how much does cobalt-60 source disposal cost? This varies with the negotiated agreements between REVISS or MDS Nordion, but it is safe to say that current charges for industry-standard sources in typical return quantities are in the order of several thousand US dollars per source (not the $13 million for 100 sources as would inferred by the NAS report). It is a modest percentage of the price of purchasing a new cobalt-60 source. It should also be noted that the removal and transportation are relatively small incremental costs, albeit increasing due to recent implementation of Code of Conduct regulations, but this may be mitigated somewhat if source returns are conducted together with an irradiator source replenishment.

Today more than 100 low- and intermediate-level radioactive waste (LILW) disposal facilities are, or have been operating, and more than 42 repositories are under some stage of development in the IAEA’s Member States. Costs will vary greatly between sites depending on many factors; some may offer affordable options for the disposal of cobalt-60 sealed sources. The acceptability of waste at a given repository is subject to criteria which include a concentration limit for the different types or groups of radionuclides in a waste package and the total activity. The disposal of radioactive waste is based on proven and well-demonstrated technologies and as noted in the IAEA report continued
attention is being given to costs of disposal, public acceptance and the possible establishment of
t regional-multinational repositories.

**What is being done to minimize waste?**

Cobalt-60 is disposed of only when it has decayed to such a level that it is no longer useful. When companies return sources, at say 20 years of age or more to the manufacturer, where technically and commercially viable, the cobalt-60 inner source material may be recycled and used in the production of new cobalt-60 sources that will be in service for another 20 years or more. Since these are new sources using a combination of recycled and new material that manufacturers produced under stringent controls, the manufacturer can offer a new source warranty.

While the concept of recycling material seems simple, it is more complex and inherently expensive than many realize for source manufacturers to undertake and maintain this capability. It is important that suppliers, users, political leaders and regulatory authorities work together to maintain an atmosphere where environmentally responsible initiatives, like cobalt-60 recycling, can flourish.

Occasionally discussed is the concept to send lower activity cobalt-60 to the reactor site for “recharging”. Consider the fact that engineers designed the process flow to handle inactive materials going into the reactor and active materials coming out, and not the reverse. Besides many reactors that produce cobalt-60 focus on the generation of electricity which is their primary raison d’être and use cobalt-59 to absorb a neutron in the reactor control mechanism, with the production of cobalt-60 viewed an important by-product. When all the technical, economic and safety factors are considered it becomes quickly evident that this is not a practical or even viable idea.

When the cobalt-60 is no longer usable, final disposal means the sealed source is placed in a safe, tightly-controlled location from which there is no intent to retrieve it or has decayed to the point where it is essentially a non-radioactive waste, e.g. cobalt-60 with a half-life of 5.26 years naturally decays into stable nickel-60 reaching background radiation levels in roughly 175 years. Compared to the time associated with the decay of high level nuclear power waste materials to decay over thousands of years, the issue with cobalt 60 is really one of long-term storage rather than disposal.

**What is being done optimize the use of cobalt-60**

There are efforts progressing to optimize radiation sterilization doses without compromising patient safety, thereby offering the potential to significantly lower currently sterilization doses. Lower doses reduce the amount of cobalt-60 required in many industrial irradiators (possibly by as much as 40 to 50%).

Mathematical modeling offers tremendous benefits for all owners and user of irradiation facilities. Many companies using radiation processing (X-ray, gamma or e-beam) want to better manage resources and optimize the use of this technology. Modeling enables faster time to market for irradiated product, plus improved quality systems and better-cost control.
Are there any alternatives to cobalt-60?

Alternative technologies to cobalt-60 gamma radiation exist, are well understood and used. In fact the diverse international membership of the iiA includes leading suppliers of machine-based radiation equipment, multinational healthcare companies, dosimetry producers and more than 90 percent of the world’s contract irradiation service providers, as well as the major cobalt-60 suppliers. Ultimately the selection of a technology to be employed for radiation processing depends on the type of products to be treated, location and economics.

Why decommission an irradiator?

As the irradiation industry has grown over the past decades it has evolved in favour of contract sterilization services. Many service providers today are technology neutral, offering technological solutions that best meet specific customers’ needs. To offer such a range of possibilities to customers around the world, service providers continue to expand their operations and construct genuinely global networks, replicating organizational requirements to ensure consistent, standardized service wherever they establish contract irradiation facilities.

Over 40 irradiators have been decommissioned to date, and a number of business reasons exist for this happening. As time passes, the changing requirements of customers can result in an older irradiator no longer being in a desirable location, or be able to physically or cost-effectively handle the volume and widely differing types of products requiring irradiation. The facility may have become cobalt utilization inefficient when compared to newer irradiator designs. It may require more maintenance, and suffer from increasing downtime.

What if a company goes bankrupt?

Currently gamma radiation is used for the sterilization of over 40% of the world’s single-use medical disposable products and is growing at a rate of 5 -7% per annum. Many medical devices have, at the very outset, been designed and produced with the intent of using cobalt-60 gamma irradiation for sterilization. Any change in the mode of sterilization for these products could require major raw material changes, and the costly redesign and validation of the device (including primary packaging) for many product families for an alternate sterilization process.

There is understandable concern over the scenario in which a company goes bankrupt or simply abandons the cobalt-60 sources in irradiator(s) it owns. Typically irradiators operate 24/ 7; there is virtually no excess processing capacity maintained in irradiators, most medical device companies practice just-in-time manufacturing, and sterile device inventories are in the order of 30 to 40 days. This product needs to be irradiated somewhere. In reality competitors jump at the opportunity to acquire this cobalt-60, while market factors dictate the final price, due to its high value for most of its working life cobalt-60 is viewed as an asset.

Another potential scenario which has generated concern is that of a source manufacturer becoming insolvent and ceasing to honour its source return commitments. Both the major suppliers (MDS Nordion and REVISS) are large, international and reputable companies operating profitable
businesses. At IMRP 2003 in Chicago, and on further occasions since then both companies announced substantial investments and increased production objectives to meet the growing demand for cobalt-60.

Both leading suppliers recognize that successfully balancing cobalt-60 supply with demand is challenging, requires significant investment, expertise and long-term cradle to grave commitment. But neither company ‘controls’ the national policy on radioactive waste disposal established by policy makers in their respective countries and must conform to the government regulations under which they conduct business. It is important to note that all current disposal pathways are under tight government control, secure and highly regulated.

Cobalt-60 provides a vital role in the world’s healthcare and industrial economy, which cannot be fully substituted by any other technology for many technical and economic reasons. By the year 2050, the number of the people in the world aged 80 or older will be six times greater than today thereby intensifying the demand for sterile and novel human healthcare combination drug-device products. The greatest risk to the future of gamma irradiation and hence the successful growth of these vital healthcare products is new regulation that increases costs, while not contributing any meaningful additional safety or security benefits.

Are government regulatory controls adequate?
Yes. Strictly regulated, rigorous safety controls apply to cobalt-60 throughout its lifecycle. A strengthening of the regulatory infrastructure is ongoing and evolving based on lessons learned and the need to protect the public from inadvertently accessing it, or terrorists gaining control of radioactive sources for malicious purposes. It is well recognized that the design of industrial irradiation facilities, stringent control over the shipping of source in massive containers, and the detailed safety and security plans irradiator owners have implemented ensure gamma irradiation continues to be safe and effective and make cobalt-60 virtually useless as a tool of terrorism.

Most regulatory authorities require financial assurances from users, thereby ensuring that neither they nor their taxpayers incur the financial burden of associated with cobalt-60 disposal and irradiator decommissioning. The concept of adequately funding these risks intuitively makes sense, and is supported by industry and is a common practice in most parts of the world.

The issue is whether regulatory requirements are placing an unfair burden on irradiator owners (and society) by establishing spuriously high up front funding figures, well in excess of what is adequate from a practical point of view. This occurs by factoring in disposal costs for all cobalt-60 sources, including those with a realizable asset value which would not sent for disposal, but resold in the event of a bankruptcy or abandonment. Even more damaging is using the total licensed capacity of the irradiator in such calculations, rather than what is actually installed, resulting in owners paying for decommissioning of empty spaces in the source rack for many years. The difference between funding for sources that would really require disposal, the disposal path chosen for the calculation and assuming a false worst case, as identified above, can be at least several hundred thousand dollars.
per irradiation facility. This will have an impact unnecessary negative on healthcare costs in the medium–to-long term.

Industry has consistently regarded safety and security as a top priority throughout its 50-year history; it has and will continue to fulfill that priority with regulatory rigour. Government and industry could do with fresh thinking on cobalt-60 use and disposal to balance the level of risk against the appropriate level of funding to protect the public, while at the same time continuing support for cobalt-60 usage for the benefit of society in order to prevent infection, illness and disease.

Figure 1: Typical Lifecycle for Cobalt-60 Sealed Sources

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3 Radioactive waste disposal: Global Experience and Challenges  
4 Advanced Statement to the National Academy of Sciences' Nuclear and Radiation Studies Board January 29, 2007