SAND2018-12478C

RADIOLOGICAL SECURITY THROUGH CESIUM IRRADIATOR REPLACEMENT IN THE UNITED STATES

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Abstract

The radioactive cesium chloride (CsCl) used in cesium irradiators is highly attractive for use in Radiological Dispersal Devices, commonly known as “dirty bombs”. This is due to the ease of dispersal of the soft CsCl powder, the inherent bonding properties of CsCl, and the difficulty of decontamination after dispersal. The paper will summarize the U.S. Department of Energy’s National Nuclear Security Administration’s (DOE/NNSA) efforts to address the risk of CsCl through the Cesium Irradiator Replacement Project (CIRP). CIRP is part of the NNSA’s domestic strategy to manage the risk that CsCl could be used in a malicious act of radiological terrorism by supporting the adoption and development of non-radioisotopic alternative technologies and thus achieving greater security by reducing the number of high-activity radioactive sources vulnerable to theft of other misuse. Participants in CIRP procure an alternative technology device and NNSA eliminates the risk of their CsCl source by federally-funding its removal and disposal through the Off-Site Source Recovery Project (OSRP). As of October 19, 2018 sixty-two irradiators have become disused and their sources removed and dispositioned by OSRP through participation in CIRP. In addition, over seventy devices are expected to become disused and be removed in 2019 through CIRP. CIRP incentivizes users to adopt x-ray irradiators and have their newly disused CsCl sources removed by fully funding the source removal and disposition and by reimbursing a portion, typically 50%, of the cost of the x-ray irradiator. NNSA is further working to address the security concern posed by disused sources by working to increase source transportation and disposal capacity to meet the increased demand due to CIRP. NNSA and partners are designing and fabricating containers that can be used by industry, research, and government entities to ship additional radiological materials safely and securely.

1. INTRODUCTION

“Isotopes that can make life-saving blood transfusions and cancer treatments possible…could be used to build a bomb that would spread radioactive material…and should provide impetus for governments, the medical community and industry globally to immediately secure all such materials or replace them with alternative technologies.” This statement by former United States Senator Sam Nunn articulates the need for enhanced radiological security and the adoption of alternative technologies as a security strategy. The security of radioactive

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cesium chloride (CsCl) is of primary concern due to its widespread use in IAEA Category 1 and 2 quantities, and the anticipated level of disruption from its use in a terrorist attack. For these reasons the United States Department of Energy's National Nuclear Security Administration (DOE/NNSA) prioritizes the security of CsCl sources, including through the Cesium Irradiator Replacement Project (CIRP), which assists cesium source users in replacing their CsCl-based irradiators with alternative technology devices, such as x-ray irradiators, and dispositioning the disused source.

CsCl is primarily used for two applications: the irradiation of blood prior to transfusion, and in a variety of biological and materials research studies. Blood is irradiated to prevent Transfusion-Associated Graft versus Host Disease (TAGvHD), a rare but usually fatal complication from blood transfusion. According to the U.S. Food and Drug Administration, the radiation dose to prevent TAGvHD should be "2500 cGy[1] targeted to the central portion of the container and 1500 cGy should be the minimum dose at any other point" [1]. Research irradiators are widely used to perform a variety of research studies. Examples include studies of the response of materials to radiation exposure and medical research using cells or small animal subjects. NNSA estimates that approximately 400 cesium blood irradiators and 315 research irradiators are currently in use in the United States based on data collected by the Nuclear Regulatory Commission (NRC).

The United States (U.S.) government has established a strong political foundation for radiological security through the use of alternative technology. The 2005 Energy Policy Act directed the NRC to work with the National Academies of Sciences, Engineering, and Medicine to review current uses of radiation sources and to identify technically and economically feasible replacements [2, 3]. In 2008, the National Research Council of the National Academies' Committee on Radiation Source Use and Replacement released its report recommending that the U.S. Government take steps in the near term to replace CsCl radiation sources with lower-risk alternatives. The Energy Policy Act of 2005 also established the Radiation Source Protection and Security Task Force, which noted in its 2014 report that "all [member agencies] support efforts to further reduce security risks by developing alternative technologies as replacements" [4]. The "United States National Progress Report" delivered at the 2016 Nuclear Security Summit included a commitment to "partner with industry to replace 34 cesium blood irradiators with non-radioisotopic alternative technologies by 2020" [5], a goal that was achieved in early 2018. The most recent political support is included in the John S. McCain Fiscal Year 2019 National Defense Authorization Act, which set a goal for the National Nuclear Security Administration of "eliminating the use of blood irradiation devices that rely on CsCl by December 31, 2027" by working with licensees that voluntary partner with the NNSA to replace their cesium blood irradiators [6].

2. THE RISK POSED BY CESIUM CHLORIDE

Radiological terrorism with cesium chloride could take many forms, but all fall into the following three categories:

a) Radiological Dispersal Device (RDD), also known as a "dirty bomb": using an explosive or other means to disperse the CsCl over a large area.
b) Radiological Exposure Device: hiding the CsCl source in a public place where it will expose a large number of people to harmful levels of radiation.
c) Poison: adding the radioisotope to food or water that may be ingested by humans.

While each of these types of attacks could result in deaths, none of them are likely to cause a large number of prompt fatalities. The major consequences of radiological terrorism are the psychological impacts on the targeted population and the economic impact of closing the contaminated area and decontamination.

The economic impact of a RDD can be divided into direct recovery costs, the impact on affected businesses, and the costs associated with the long-term public perception of the contaminated area. The direct recovery costs can include public evacuation and relocation, health care, surveys of the damage and contamination, decontamination of the area including destruction of anything that cannot be decontaminated, and disposal of waste. CsCl binds with surfaces and can easily penetrate into materials such as concrete. Given the 30.2-year half-life of the Cs-137 in CsCl, areas directly affected by a release of CsCl would be contaminated for substantial amounts of time.

[1] Gray (Gy) is the standard unit for absorbed radiation dose. 2500 centi-Gray (cGy) is equivalent to 25 Gy.

CsCl poses a significant hazard to those exposed to it; primarily through ground shine (i.e., external exposure to the gamma radiation emitted from contaminated surfaces). Inhalation and ingestion may also contribute during the period immediately following an attack. Radioactive CsCl is circulated in bodily fluids and delivers a whole-body dose to those exposed internally. The impact of a major RDD incident on businesses includes the loss of Gross Domestic Product from affected businesses and from reduced spending by affected consumers. The perception-based costs may persist for many years and include unwillingness to live or work in the contaminated area, to invest in the area, or to purchase products produced in the area. NNSA estimates these costs to reach multiple tens of billions of dollars for a major RDD attack.

Radioactive CsCl is widely viewed as the radioisotope of greatest concern in the United States. According to the 2008 U.S. National Academy of Sciences (NAS) report, "the presence of these sizable sources in areas that are potentially attractive targets is a major factor making radioactive cesium chloride such a concern" [7]. CsCl is usually manufactured in a powder form that is highly dispersible and water-soluble. Cesium chloride also tends to penetrate deeply into materials, increasing the amount of destruction required for decontamination. For these reasons, the NAS report recommends the elimination of "all Category 1 and Category 2 cesium chloride sources in the United States and, if possible, elsewhere" [7].

3. THE UNITED STATES NATIONAL NUCLEAR SECURITY ADMINISTRATION AND ALTERNATIVE TECHNOLOGIES

3.1. Radiological Security Strategy

One of the missions of NNSA is to prevent the use of high-activity radioactive sources in a radiological dispersal device or other acts of terrorism against the United States and its allies. This first-line-of-defense program works within the United States and with partners in more than 80 countries around the world. To accomplish this mission, NNSA partners with a wide variety of stakeholders including government regulatory authorities, licensees, site safety and security personnel, local and national law enforcement, industry, non-profit organizations, and international organizations. NNSA uses three strategies to ensure the security of at-risk radioactive sources:

a) Protect high-activity radioactive sources by enhancing physical security.
b) Remove and disposition disused radioactive sources.
c) Reduce the global reliance on high-activity radioactive sources by promoting the adoption and development of non-radioisotopic alternative technologies.

3.2. Radiological Security through Alternative Technologies

The NNSA is leading the United States' efforts to manage radiological security risk through the use of non-radioisotopic alternative technologies. When an institution replaces their high-activity radioactive sources with alternatives or acquires alternatives in lieu of radioactive sources, the risk of radiological terrorism utilizing radioactive sources from that institution is eliminated. For this reason, NNSA prioritizes radiological security through the use of alternative technology as a long-term, sustainable security strategy. To implement this strategy, NNSA facilitates the exchange of information among its partners and stakeholders on the status, capabilities, and adoption considerations for alternative technologies.

NNSA and radioactive source users in many industries have found that technology developments in recent years have improved the performance of many alternative technologies. For some applications of radioactive sources, however, the available alternative technologies are not able to meet economic, operational, or technical requirements. For these applications NNSA utilizes its research and development programs and partners with external organizations to promote or conduct research, development, testing, and evaluation of novel technologies that could serve as radioactive source alternatives in the future. In addition to these approaches, NNSA also works with other U.S. government agencies, foreign governments, and international organizations to analyze and recommend regulatory and policy approaches that promote radiological security through alternative technology development and adoption.

NNSA recognizes that not all users of high-activity radioactive sources can switch to alternative technologies, even if a viable commercial alternative is available. For those users, NNSA mitigates the security risk of their sources by assisting with the removal of disused sources and by providing an extensive package of physical security products and services, including equipment, consultations, facility modifications, and training for safety and security staff and local law enforcement.

3.3. The Cesium Irradiator Replacement Project

NNSA directly supports the replacement of high-activity radioactive source-based devices with non-radioisotopic alternative technologies through financial incentives and source removal programs. Within the United States NNSA offers CRIP, a voluntary program for users of CsCl-based self-shielded irradiators who are interested in replacing their cesium irradiator with a non-radioisotopic alternative, e.g. an x-ray irradiator. Through CIRP the NNSA provides cost-sharing on the purchase of the x-ray irradiator, typically 50% of the purchase price, and removes and disposes of the CsCl irradiator at no cost to the user. NNSA requires a complete transition to alternative technology, i.e. the CsCl irradiator removed and the alternative installed and verified operational, before providing its cost-sharing incentive. As a Federal program with limited funding, NNSA must prioritize the selection of irradiators to be replaced. NNSA prioritizes based on impact to radiological security, including considerations for the source activity, the device location, the device's current security strategy, and the replacement project's likelihood to inspiring future device replacements. NNSA also supports the replacement of cobalt-60-based irradiators and unique situations on a case-by-case basis.

3.4. The Irradiator Replacement Trend in the United States

Many medical facilities in the United States have made the decision to replace their cesium- or cobalt-based irradiators with x-ray alternatives in the past two years. The CIRP has played a key role in this trend, but the maturation of x-ray irradiation technology and the increased regulatory requirements for high-activity radioactive sources in recent years have also driven users to switch to x-ray irradiators.

CRIP was initiated in 2015 and saw exponential growth in the number of participating institutions in 2017 and 2018. As of October 19, 2018 CIRP has partnered with source users to replace 62 irradiators. By October 2019 NNSA expects to replace and additional 70 devices. Volunteers and funding permitting, NNSA plans to continue replacing 70 irradiators per year until 2027, when all of the high-activity cesium irradiators in the country would be replaced. This large-scale approach will satisfy the NNSA goal set forth in the Fiscal Year 2019 National Defense Authorization Act [6].

Two regional irradiator replacement initiatives highlight the irradiator replacement trend. The first is in the city of New York, where the Department of Health and Mental Hygiene is partnering with NNSA, the Nuclear Threat Initiative, and New York hospitals and universities to replace around 80% of the city's CsCl irradiators with x-ray devices by the end of 2020. This includes all of the blood irradiators in the city and the majority of the research irradiators. Similarly on the west coast, the University of California is in the process of replacing more than 90% of the irradiators across their ten campuses and five medical centers with x-ray alternatives. Since most of the University of California's irradiators are used for research, this level of commitment shows that many biological research studies can be effectively conducted with the use of x-ray irradiators.

4. CESIUM CHLORIDE REMOVAL AND DISPOSITION

Disposal of high-activity cesium sources in the United States is a challenge that exacerbates the risks associated with CsCl described in Section 2. Commercial disposal in the US is limited but recent changes in 2015 U.S. NRC Branch Technical Position on Concentration Averaging and Encapsulation has provided greater access to higher activity sources. Unfortunately, many disused and unwanted Category 1 and 2 sealed sources remain at licensed facilities despite the 2015 NRC update. NNSA's Off-Site Source Recovery Project (OSRP) recovers these sources in the interest of national security, public health, and safety. Since 2001, OSRP has removed more than 3,500 Category 1 and 2 sources[2] from U.S. industrial, educational, healthcare, and government facilities.

The radiological terrorism risk reduction that results from irradiator replacement through CIRP is not realized until the disused CsCl source is properly removed and dispositioned. Cesium irradiators that are replaced

[2] Note that a single radiation emitting device may contain multiple sealed radiation sources.

through CIRP are prioritized for removal by OSRP, who works with the licensee to identify a removal timeline that meets their operational needs. For example, many blood centers need to have their new x-ray irradiator installed before their old cesium irradiator is removed to avoid downtime in their blood processing capability. As another example, some hospitals and universities that use radiation for biological research need to run the cesium and x-ray irradiators side-by-side for a few weeks or months to validate the x-ray machine before the cesium irradiator can be removed.

Historically, the timely disposal of U.S. radioactive sources was a hindered by the lack of approved transportation containers that could move sources from the licensee to the secure disposal facility. Since 2009, however, NNSA completed the development, testing, and certification of two new transportation containers: the 435-B container and the 380-B container. The 435-B container is relatively lightweight, easy to transport, and capable of transporting a wider variety of radioactive devices than other containers. The 380-B container is able to transport unique devices that are very challenging for the containers that are currently available. The 435-B performed its first source removal in March 2018 at a hospital that replaced a CsCl irradiator through CIRP. The 380-B will be delivered in July 2019. These containers will enable the shipment of nearly all CsCl devices that are used commercially in the U.S. In addition, these new containers will enable OSRP to meet the demand for CsCl irradiator disposal through CIRP, as described Section 3.5. Recently CIRP has approximately doubled the number of sources removed per year through OSRP.

NNSA will also provide the IAEA with a 435-B container to help facilitate the removal and transportation of high activity sources and assist both the IAEA and Member States in addressing end of life management issues associated with disused sources. In addition to the package, NNSA will also supply the IAEA with the necessary ancillary equipment needed to operate the package, provide assistance with certification outside of the U.S., and provide assistance in maintain the package. NNSA expects the package will be delivered to the IAEA in the first quarter of 2019.

5. EDUCATION AND OUTREACH FOR U.S. IRRADIATOR REPLACEMENT

NNSA partners with U.S. state and federal nuclear regulators, non-profit organizations, industry organizations, international organizations, and institutions that use radioactive CsCl to hold educational workshops, webinars, and technical information exchanges for CsCl users that may consider enhancing their physical security or switching to an alternative technology. These educational events provide information on NNSA programs that offer assistance with irradiator replacement, the status and capabilities of commercially available alternative technologies, technology selection and replacement considerations, and lessons learned from other institutions that have replaced their cesium irradiators with x-ray devices.

One key example of successful regional outreach and education is with New York City. New York is a leader in radiological security, having been a terrorist target in the past and recognizing it will likely be targeted again in the future. NNSA has partnered with New York City over the past eight years on a thorough approach to physical security and law enforcement response training. In recent years, however, the emphasis has shifted to cesium irradiator replacement. NNSA partnered with the Nuclear Threat Initiative, the New York City Department of Health and Mental Hygiene, and New York City hospitals and universities to hold four educational meetings and workshops for CsCl source users. A workshop held in the summer of 2016 featured presentations from researchers and blood centers that successfully switched from CsCl to x-ray irradiators. A recording of the workshop is available online [8]. The result of this educational engagement is the first U.S. city-wide initiative to replace cesium irradiators with alternative technologies. As of October 19, 2018 about 1/3 of New York City's cesium irradiators were replaced through CIRP. By the end of 2020 NNSA anticipates replacing around 80% of these devices through CIRP, including 100% of the city's blood irradiators. "We applaud New York City's effort to work together to phase out high activity radioactive sources," said NNSA's then Acting Deputy Administrator for Defense Nuclear Nonproliferation David Huizenga at a Fall 2017 press conference announcing the initiative. "It has been at the forefront of U.S. efforts to enhance radiological security and serves as an example for other major cities. We are proud to support the city's permanent threat reduction effort and we greatly appreciate its leadership in the prevention of radiological terrorism" [9].

NNSA contributed to an equally successful outreach and education campaign in the state of California. NNSA partnered with the Nuclear Threat Initiative, the California nuclear regulator, and the University of California President's Office to hold four educational meetings and workshops for CsCl source users over the past two years. Similar to the workshop in New York City, the University of California hosted two workshops in January 2018 with presentations on the risk of radiological terrorism, the experiences of researchers and blood centers that have replaced their cesium irradiators, and the technical considerations for irradiator replacement. A recording of the event is available online [10]. As a result of this education campaign, the University of California is implementing the removal or replacement of more than 90% of its Category 1 and 2 source-based irradiators, including 100% of the blood irradiators, with x-ray devices through CIRP.

6. CONCLUSION

High-activity radioactive cesium chloride (CsCl) sources pose a national security risk due to their potential to be used in a Radiological Dispersal Device. Replacing irradiators that use CsCl with non-radioisotopic alternative technologies is an effective approach to eliminate the security risk of CsCl sources. The U.S. National Nuclear Security Administration (NNSA) assists domestic CsCl source licensees who volunteer to replace their cesium irradiators through the Cesium Irradiator Replacement Project (CIRP). There is a strong trend in irradiator replacement in the United States, as demonstrated by the replacement of 62 irradiators through CIRP in the past few years. NNSA plans to continue using irradiator replacement as a primary domestic cesium security strategy, with the aim of meeting the goal set by the U.S. Congress to replace all cesium irradiators in the U.S. by the end of 2027. NNSA work to enable transportation and secure disposition of these sources, as well as work educate CsCl source licensees about irradiation technology and device replacement considerations will continue to be key to the success of this security strategy.

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