California's Radiological Threat Reduction Initiative

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Abstract

The Nuclear Threat Initiative (NTI) has been working with various entities throughout the State of California to bring awareness to the threat of high-activity radiological sources, as well as build support for the protection and/or removal and replacement of these sources with safe and effective alternative technologies. Considerably more prevalent than nuclear materials, radiological sources are used throughout the world for medical, industrial, agricultural, research, and other purposes. California, specifically, has a significant number of irradiators used for medical and research purposes that contain cesium-137, a highly-radioactive isotope that exists in a dispersible salt powder form. Replacing these irradiators with certified alternative x-ray technologies of equivalent effectiveness, where possible, would thereby significantly reduce the threat of these dispersible cesium sources being used to create a 'dirty bomb.' Over the past year, strategic partnerships were built with the Office of the Governor of California, the California Department of Public Health, and the University of California system, which has led to a series of four workshops throughout the state. These workshops have included participation from the executive offices of the various University of California branches, the University of California Office of the President, California Governor Edmund G. Brown Jr., the California Department of Public Health, many of the medical workers and researchers that use cesium irradiators, along with senior NTI and Department of Energy National Nuclear Security Administration (DOE/NNSA) Office of Radiological Security leadership. This work is being done as part of a broader initiative to create permanent threat reduction by removing, replacing, and disposing of cesium-based irradiators throughout the United States.

Executive Summary

Blood and research irradiators are important tools used by both the medical and research communities on a daily basis. The material commonly used to make these irradiators so effective is a highly-radioactive isotope known as cesium-137. Although certain characteristics of cesium-137 present several benefits relative to other similar isotopes for medical and research irradiation, its physical properties and high source activity make it an ideal candidate for a radiological dispersal device (RDD), or 'dirty bomb.' Fortunately, there exist safe and arguably equivalent alternative technologies for both medical and research purposes that utilize x-ray radiation instead of the gamma radiation of radioactive isotopes.

Introduction

As part of a broader national effort to reduce the radiological risk of cesium-based irradiators, the Nuclear Threat Initiative (NTI) successfully launched a radiological initiative with the State of California in 2017. California has the largest number of high-activity cesium-137 devices in the United States, estimated at over 100. More than half of these devices are cesium blood irradiators, which could be replaced with existing U.S. Food and Drug Administration (FDA)-approved alternative technologies. The remainder are cesium research irradiators which may also be replaced in many circumstances with alternative technologies, although for research purposes, these alternative x-ray irradiators do not have to undergo the rigorous FDA approval process. Under this effort, NTI is partnering with the Office of the Governor of California, the California Department of Public Health, the Office of the President of the University of California (UC), and other federal and state partners. Since May 2017, NTI has sponsored four Radiological Security Workshops throughout California to raise awareness of the radiological security threat, as well as seek input from participants regarding additional efforts that could be undertaken to further reduce the risks posed by radioactive sources.

Through these efforts, NTI, along with its federal and state partners, have (1) successfully raised awareness state-wide of the threat of cesium sources, (2) engaged extensively with the medical and research communities of California to address questions and concerns about switching to alternative technologies, and (3) secured the commitment of several major source users throughout the state to begin the process of transitioning away from cesium irradiators. A major milestone was reached in early 2018 when Janet Napolitano, President of the University of California system, requested a commitment from the chancellors of each UC campus to participate in this effort of removing and replacing all cesium-based irradiators under their control – nearly half of the cesium irradiators in California.

Isotope of Greatest Concern

Considerably more prevalent than nuclear materials, radiological sources are used throughout the world for medical, industrial, agricultural, research, and other purposes. Cesium-137 is one such source that is used for both medical and research purposes. Found primarily in both blood and research irradiators, but also used to a lesser extent in calibration of instrumentation and dosimetry, cesium-137 is a high-activity source typically found as salt powder-form cesium chloride. According to the Nuclear Regulatory Commission, cesium-137 is a desirable source for these uses due to "its desirable single energy spectrum (662 keV), long half-life, low cost, and moderate shielding requirements relative to other nuclides."[1]

[1] "Request for Comments on the Draft Policy Statement on the Protection of Cesium-137 Chloride Sources and Notice of Public Meeting," Nuclear Regulatory Commission, June 29, 2010, https://www.gpo.gov/fdsys/pkg/FR-2010-06-29/pdf/2010-15734.pdf

However, cesium-137 also poses significant health risks. In 2005, the International Atomic Energy Agency (IAEA) released a categorization table of radiological sources. Sources are ranked from Category 1-5 based on the 'danger' of the source, or "the radionuclide specific activity of a source which, if not under control, could cause severe deterministic effects for a range of scenarios that include both external exposure from an unshielded source and internal exposure following dispersal of the source material," with Category 1 being the most dangerous and Category 5 being the least dangerous. Because of its levels of source activity and penetrating radiation, along with its relatively long half-life, water solubility, and highly-dispersible form, cesium-137 chloride as used in blood and research irradiation is considered by the IAEA to be a highly-dangerous Category 1 source.[2]

Its high source activity, water solubility, and highly-dispersible form make cesium -137 an ideal candidate for use in a radiological dispersal device (RDD), also known colloquially as a 'dirty bomb.' RDDs are created by pairing a conventional explosive with any amount of radioactive material – a much less technically-demanding design than an improvised nuclear device (IND). While the immediate effects of an RDD would be much less lethal than an IND, the widespread availability of radiological sources, along with the potential for significant long-term economic effects, make an RDD an attractive option for terrorists. Although very few people would be killed in the initial blast of an RDD, if detonated in a highly-populated urban area such as Los Angeles or San Francisco, one cesium chloride source from an irradiator has the power to irradiate several city blocks, causing potentially billions of dollars in economic disruption due to widespread panic, infrastructure overload, and business closures.[3]

California is estimated to have more than 100 cesium-137 irradiators, making it the state with the largest number of these sources. Of these, more than half are blood irradiators that can be replaced with existing FDA-approved alternative technologies. The remaining devices are research irradiators, for which alternative technologies also exist, although they are not required to undergo the rigorous FDA approval process. While concerns remain about equivalent functionality of alternative x-ray devices for some research applications, alternative technologies

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[2] "Categorization of Radioactive Sources," International Atomic Energy Agency, 2005, https://www-pub.iaea.org/MTCD/publications/PDF/Pub1227_web.pdf

[3] In 1985, accidental exposure to a cesium chloride source in Goiânia, Brazil led to the deaths of four people, internal and external contamination of 249 people, and the monitoring of approximately 112,000 people. It took until mid-1988 for cleanup and relatively normal operations to resume, and the incident resulted in approximately 3,500 m^3 of waste due to building destruction and environmental cleanup. With a current urban-area population more than
10 times that of Goiânia in 1985, and the added dispersion of a conventional explosive, an RDD incident in Los Angeles would undoubtedly be many orders of magnitude worse.
"The Radiological Incident in Goiânia," International Atomic Energy Agency, 1988, https://www-pub.iaea.org/MTCD/publications/PDF/Pub815_web.pdf

are considered to be roughly equivalent for blood irradiation purposes.[4] These alternative x-ray technologies have significant safety and security benefits, however, as they require far less security and shielding, eliminate the liabilities inherent in operating a high-activity radiological source, and do not require the same expensive and extensive disposal process necessary for radiological sources.[5] As of today, there are three types of x-ray blood irradiators that are FDA-approved for sale and use in the United States, and at least five manufacturers producing and selling various x-ray research irradiator models.

Threat Reduction Efforts in California

Since 2016, the Nuclear Threat Initiative has been deeply involved in domestic radiological security efforts around the country. In 2016, Emory University in Atlanta teamed up with NTI and DOE/NNSA to replace a cesium blood irradiator with an x-ray irradiator. This effort led to the project lead for Emory University, Dr. Patty Olinger, receiving the Medical Innovation Award at the 2016 Nuclear Industry Summit.[6] Not long after, NTI and DOE/NNSA began working with hospitals throughout New York City to encourage them to follow suit. In October 2017, NNSA's Acting Deputy Administrator for Defense Nuclear Nonproliferation David Huizenga, New York City Department of Health and Mental Hygiene Commissioner Dr. Mary Travis Bassett, and NTI co-chair former Senator Sam Nunn, formally announced a city-wide initiative to transition from blood and research irradiators using high-activity sources to alternative technologies.[7] The majority of the hospitals in New York City have since provided pledges to remove and replace their cesium irradiators over the next several years.

Following the success of these initiatives, NTI, along with DOE/NNSA, made the decision to advocate for similar efforts in the State of California. In 2017, NTI co-sponsored two workshops in cooperation with the Office of Governor Brown and the California Department of Public Health – one in the Los Angeles area (May 2017) and one in the San Francisco area (September 2017). These meetings were attended by representatives of the executive offices of the various University of California branches, the University of California Office of the President, California Governor Edmund G. Brown Jr., the California Department of Public Health, law enforcement and emergency response personnel, along with senior NTI and DOE/NNSA Office of Radiological Security (ORS) leadership.

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[4] Dodd B. and Vetter RJ, "Replacement of 137Cs irradiators with x-ray irradiators," *Health Physics*, February 2009, https://www.ncbi.nlm.nih.gov/pubmed/19125053

[5] "Preventing a Dirty Bomb: Resources for Hospitals and Research Centers," Nuclear Threat Initiative, February 22, 2018, http://www.nti.org/analysis/articles/preventing-dirty-bomb-resources-hospitals/

[6] Sam Nunn, "Remarks by Sam Nunn at Nuclear Industry Summit 2016," Nuclear Threat Initiative, March 30, 2016, http://www.nti.org/analysis/speeches/remarks-sam-nunn-nuclear-industry-summit-2016/

[7] "NSA and partners launch project to reduce use of radioactive source-based devices in New York City," National Nuclear Security Administration, October 12, 2017, https://www.energy.gov/nnsa/articles/nnsa-and-partners-launch-project-reduce-use-radioactive-source-based-devices-new-york

Through these workshops, a set of recommendations were formed. High-level recommendations included:

- Encouraging more California hospital and medical facilities to take part in NNSA's

  Voluntary Security Upgrade Program[8] in order to further improve radiological security in California

- Engaging with senior management and "decision makers" of facilities that house cesium sources in order to advance radiological security efforts, including highlighting liabilities of housing cesium sources in the absence of proper insurance coverage

- Sharing information and data on previous experiences with the use of alternative technologies

- Conducting additional research and encouraging the development of further studies on the comparative effectiveness and reliability of cesium and x-ray irradiators

In addition, participants of the workshop highlighted the desire for additional market competition for alternative technologies (as noted above, only three types of x-ray blood irradiators have been FDA-approved for sale and use in the United States), additional security and threat awareness, and further training and exercises in the State of California on proper safety and security of high-activity radioactive sources.

More recently, NTI and the University of California (UC) co-sponsored two similar technical workshops at two separate campuses (UC-Los Angeles and UC-San Francisco) on January 29-30, 2018, to encourage hospitals and research facilities within the University of California educational system to consider converting to x-ray technologies. The UC system owns and operates nearly half of the total cesium irradiators in the State of California, making them, by far, the largest single user of cesium sources in the state and a major target for the state-wide radiological threat reduction initiative. As the majority of these irradiators are used for research purposes, these workshops were focused primarily on the UC research community. The workshops included presentations from experts in the various fields that use irradiation for research purposes, as well as panel discussions, question and answer sessions, and the

[8] From NNSA: "ORS works with organizations to evaluate partners' existing security systems, and provide protection upgrades, guidance, and training to enhance the security of high-activity radioactive sources. ORS collaborates with partner organizations worldwide on sustainable security, including implementation of regulatory development, security planning and training, transportation security, response planning and training, and the strengthening of inspection and enforcement regimes."
Office of Radiological Security, National Nuclear Security Administration, https://www.energy.gov/nnsa/office-radiological-security-ors

opportunity for cesium users to connect with several of the manufacturers of alternative technologies.

As a result of these workshops, Janet Napolitano, President of the University of California system, issued a letter to the Chancellors of the UC campuses requesting that they work with their researchers to implement the systemwide effort to reduce risk by removing disused cesium irradiators and replacing those needed irradiators, where feasible, with x-ray irradiators through the Department of Energy National Nuclear Security Administration's (DOE/NNSA) Cesium Irradiator Replacement Project (CIRP).[9]

To effectively accomplish this task, the UC Office of the President created a systemwide Radioactive Source Replacement Working Group consisting of UC Office of the President representatives along with faculty from each of the UC system campuses. The Working Group held meetings in early 2018 to determine the feasibility of this request, taking into account the varied uses of cesium research irradiators across the UC system. Through various comparative studies, presentations, and discussions, the Working Group concluded that x-ray irradiators could effectively replace their cesium counterparts in many applications on their campuses, with some notable exceptions, and laid out a path forward for users looking to make the switch. President Napolitano has requested that campuses make an initial decision on switching by September 2018, allowing them several months to review the existing data and literature, as well as conduct or commission studies of their own. It is also expected that more comparative studies will be undertaken once more x-ray irradiators are purchased and brought into use.

On a national level, the U.S. House of Representatives has recently passed an amendment to the National Defense Authorization Act supporting the acceleration of the replacement of cesium blood irradiator sources. This amendment sets a goal for the full elimination of cesium blood irradiator usage nation-wide by December 31, 2027. To do this, it asks for a report within 180 that identifies the annual funds necessary for the DOE/NNSA Cesium Irradiator Replacement Program and Off-Site Source Recovery Program[10], which will be the federal programs used to facilitate this transition.[11]

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[9] From NNSA: "Under NNSA's voluntary Cesium Irradiator Replacement Program (CIRP), ORS partners with commercial licensees to replace their cesium-137 irradiators with X-ray irradiators. Through CIRP, NNSA provides a financial incentive toward the purchase of an X-ray irradiator, contingent on the disposition of the cesium-137 irradiator at the site. Disposition is facilitated through NNSA's Offsite Source Recovery Program." Malika Tallbi, "Cesium Irradiator Replacement Preserves Health Benefits, Promotes Radiological Security," *DNN Sentinel*, National Nuclear Security Administration, Vol. II, No. 1, October 2017, https://www.energy.gov/sites/prod/files/2017/10/f37/DNN_Sentinel_VolII_No1_optimized2%5B1%5D.pdf

[10] From NNSA: "The Off-Site Source Recovery Program (OSRP) is a U.S. Government activity sponsored by the National Nuclear Security Administration's (NNSA) Office of Global Material Security and is managed at Los Alamos National Laboratory through the Nuclear Engineering & Nonproliferation Division. OSRP has an NNSA sponsored mission to remove excess, unwanted, abandoned, or orphan radioactive sealed sources that pose a potential risk to national security, health, and safety."
Off-Site Source Recovery Program, National Nuclear Security Administration, http://osrp.lanl.gov/

[11] "Amendment to Rules Committee Print 115-07 Offered by Mr. Panetta of California," National Defense Authorization Act for Fiscal Year 2019, May 18, 2018 https://amendments-rules.house.gov/amendments/PANETT_037_xml518181053365336.pdf

Conclusion

Towards the goal of nation-wide permanent reduction of the threat of high-activity radiological sources, NTI, along with federal and state partners have found success in the State of California over the past year. By taking separate approaches towards the medical and research communities, workshops organized by NTI and its partners have effectively started important discussions, attempted to address questions and concerns, and allowed current cesium irradiator users the chance to interact and discuss alternative technologies with x-ray device manufacturers.

As NTI and DOE/NNSA focus their radiological security efforts on additional cities and states, current users of alternative x-ray technologies are encouraged to share the data that they collect, as well as develop further comparative studies that can be shared among the medical and research communities. While several comparative studies already exist from users at institutions such as the Baylor College of Medicine[12], University of Wisconsin-Madison[13], and Mount Sinai Medical Center[14], further data and information, along with the continued development and adjustment of x-ray irradiators by the manufacturers, will allow for an easier and more comfortable switch away from cesium-based irradiators for medical and research users in the near future. In addition, NTI has developed a webpage dedicated to educational materials for hospitals and researchers looking to make the switch, and can be found at http://www.nti.org/hospitals.

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[11] From NNSA: "The Off-Site Source Recovery Program (OSRP) is a U.S. Government activity sponsored by the National Nuclear Security Administration's (NNSA) Office of Global Material Security and is managed at Los Alamos National Laboratory through the Nuclear Engineering & Nonproliferation Division. OSRP has an NNSA sponsored mission to remove excess, unwanted, abandoned, or orphan radioactive sealed sources that pose a potential risk to national security, health, and safety."
Off-Site Source Recovery Program, National Nuclear Security Administration, http://osrp.lanl.gov/

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[13] Gibson BW et al., "Comparison of Cesium-137 and X-ray Irradiators by Using Bone Marrow Transplant Reconstitution in C57BL/6J Mice," *Comparative Medicine*, June 2015, https://www.ncbi.nlm.nih.gov/pubmed/26141441

[14] Erik Bakken et al., "Cost-Benefit Analysis of Switching from Cesium-Chloride Blood Irradiators to X-ray Blood Irradiators," University of Wisconsin-Madison, 2013, https://www.lafollette.wisc.edu/images/publications/cba/2013-irradiators.pdf

[15] Jacob Kamen, "Mount Sinai Experience in Reducing and Removing the Risks of Malicious Use of Radioactive Materials," Nuclear Threat Initiative, June 5, 2017
http://www.nti.org/media/documents/Mount_Sinai_Experience_paper_6-5-2017.pdf

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