July 2019

CNS Global Incidents and Trafficking Database

Tracking publicly reported incidents involving nuclear and other radioactive materials

2018 Annual Report

Produced Independently for the Nuclear Threat Initiative by the James Martin Center for Nonproliferation Studies

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Acknowledgments

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Executive Summary

Three years have passed since the fourth and final Nuclear Security Summit (NSS), which marked the culmination of a multi-year global effort to strengthen security over nuclear and other radioactive materials. The IAEA has rolled out new technical documents on how states can improve security over nuclear and other radioactive materials,[1] and member states are increasingly incorporating those recommendations into their regulatory frameworks. In addition to creating high-level awareness of the threats, the summit process may have contributed to a reduction of the most serious incidents involving nuclear and other radioactive materials. The 2018 edition of the database recorded only four incidents involving the most dangerous materials (IAEA Category 1 and 2), tied with 2016 for the fewest in the history of the database. It is impossible to causally link this data point with the summit process—and other dangerous incidents may have gone unreported—but the data provides some reason for optimism.

Despite this progress, there are several indications that security over nuclear and other radioactive materials is dangerously declining in priority on the international agenda. No international forum has emerged to replicate the high-level attention paid to the issue by the NSS process, and further international cooperation in this realm appears unlikely. The deteriorating diplomatic relationship between the United States and Russia, the collapse of key decades-old arms control agreements, and uncertainty about the future of transnational entities and trade agreements make the global climate unfriendly to new nuclear security initiatives. Additionally, the United States has significantly decreased its nuclear security and nonproliferation budgets,[2] and International Atomic Energy Agency spending on nuclear security has decreased from its post-NSS highs.[3] And, this year's report finds that the overall number of incidents worldwide involving nuclear and other radioactive materials outside of regulatory control remains consistent and concerning.

In 2018, the James Martin Center for Nonproliferation Studies' (CNS) global, multi-language, review of open source reports found a total of 156 incidents of nuclear or other radioactive materials outside of regulatory control, occurring in 23 countries.[4] Since CNS began tracking incidents in 2013, researchers have identified a total of 1,040 incidents in 58 countries.

Incidents involving nuclear materials (especially certain isotopes of uranium and plutonium) are of special concern, because of the potential of such materials to be used in an improvised nuclear device (IND). In 2018, there were four reported incidents involving nuclear materials, a decrease from the eight unique incidents recorded in 2017. One 2018 incident was particularly serious: the loss of 1 gram of weapons-grade plutonium from a university laboratory in Idaho. While the incident did not involve sufficient material for an IND, it illustrates worrying gaps in the security of weapons-useable nuclear materials.

Non-nuclear radioactive materials incidents also carry significant safety and security concerns, as discussed in greater detail throughout this report. The IAEA categorizes radioactive materials 1-5, where Category 1 poses the greatest danger to human health and Category 5 poses the least risk. The IAEA's categorization system is based on the type of radioactive material involved, its activity level, and the relative danger posed by external (human) exposure to the material. Higher IAEA categorization also corresponds to materials of higher concern for misuse as radiological dispersal devices (RDDs).

Incidents involving the most dangerous materials, Category 1 and 2, are relatively rare in the CNS database. In 2018, zero Category 1 incidents were reported, and only three Category 2 incidents were reported, which tied with 2016 for the fewest Category 1 and 2 incidents reported. In total, from 2013 to 2018, four cases involved Category 1 sources, and 35 involved Category 2 sources. Although these numbers are low, it is impossible to know whether the relative scarcity of Category 1 and 2 cases is artificially low because of incidents going unreported.

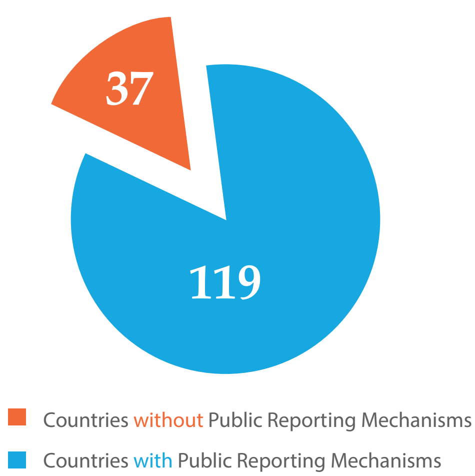
Category 3-5 materials are classified as presenting a lower risk than Categories 1 and 2. However, these materials can still pose significant safety and security risks, and are cause for public concern. The majority of 2018 incidents involved Category 3-5 materials, accounting for approximately 77 percent of total reported incidents. In 32 percent of cases, there was insufficient publicly reported information for CNS researchers to categorize the material.

With six years of accumulated data, consistent trends have emerged, which lend additional weight to the key findings and policy recommendations outlined below.

Key Finding 1: Voluntary reporting yields variable, low transparency results.

As in past years, CNS found that there were broad differences in the numbers of incidents reported across countries, with the U.S. reporting the most incidents. This says much more about the variations in reporting requirements across countries than it does about the actual number of incidents in each country. As shown in Fig. 1, the majority of incidents recorded in the 2018 database occurred in the six countries that have public reporting mechanisms.

Figure 1. Total Incidents, 2018



Although individual states may require internal reporting of incidents, only six countries publicly release those reports. Even the United States, by far the most prolific public reporting state, does not publicly report all incidents. For example, in an incident uncovered in 2018, Department of Energy (DOE) employees lost sealed plutonium and cesium sources while traveling. Since the sources involved were DOE rather than civilian in nature, they were not reported through Nuclear Regulatory Commission channels, and the incident was only uncovered publicly through investigative reporting.[5] Canada, another country that publicly reports incidents, only updates its database when a Category 4 or higher loss occurs. As a result, incidents involving Category 5 materials may be published months after they occur.

This problem is not limited to public reporting. The IAEA's Incident and Tracking Database (ITDB) remains confidential, and thus closed to outside researchers. However, it suffers from similar reporting inconsistencies.[6] States voluntarily participate in its reporting system and set their own standards for what to disclose to the organization. Even if incidents become publicly known, the IAEA may only record them in the ITDB if they were also reported to the IAEA by the state in question.

Policy Recommendation: Establish a common standard for incident reporting that requires reporting Category 1 & 2 losses; encourage public reporting of incidents involving military sources.

Past versions of this report have made this recommendation, but international progress has not been made on this front. At a minimum, the IAEA should establish a mandatory standard for all member states to report incidents involving the most dangerous Category 1 and Category 2 losses to the IAEA's ITDB. This would allow the Agency to identify problem areas and craft appropriate responses. Better still would be to publicly disclose these incidents. A well-informed public can both assist with materials recovery and bring nongovernmental expert analysis to bear to improve security practices.

Additionally, this edition of the report recommends that incidents involving Category 1 and Category 2 military-origin radioactive materials be reported with the same regularity and transparency as those involving civilian materials. Incidents involving military materials this year show that these incidents pose just as much of a concern as incidents involving civilian-origin materials. Just as reporting transparency can improve procedures and help instill a robust security culture in institutions, so too can a lack of transparency enable security issues to fester.

Key Finding 2: Transportation creates the greatest vulnerabilities, especially when materials are unattended.

As in past years, CNS researchers identified that an alarming number of incidents occur while nuclear and other radioactive materials are in transit. In 2018, 68 incidents (41% of total incidents) occurred during transport, consistent with similarly high rates in previous years.

Of the incidents that occurred during material transport, 25 were confirmed thefts, again consistent with previous years. In many cases, radioactive material theft may have been incidental to the thief's efforts to steal a vehicle or other valuable equipment. Nonetheless, the occurrence of thefts while material is in transit represents perhaps the most dangerous nexus for incidents in the database.

Policy Recommendation: Improve physical security measures while in transport; expand electronic tracking of dangerous radioactive sources.

Physical security improvements could help prevent losses and thefts during transit, especially of the most dangerous sources. There has been some progress on this front, but more work remains.

Most states with dangerous sources require electronic tracking of vehicles and containers holding Category 1 sources. Unfortunately, enhanced security for Category 2 sources is not as universal. States should require electronic tracking of Category 2 sources and, where appropriate, encourage its use for some lower category materials and sources as well.

Electronic tags to track the location of materials have become very inexpensive over the past few years. Most consumer smartphones have tracking capabilities which allow users to locate them if lost or stolen. An initiative of Malaysia's Atomic Energy Licensing Board attempts to leverage the ubiquity of smartphones to help track lost and stolen radioactive sources. Called the MyAtom mobile app, it was designed to assist first responders in locating sources and coordinating recovery. Apps like this may represent the future of radioactive materials security.[7]

Key Finding 3: Human failure is a security risk.

Human failure continues to contribute to the occurrence of a large percentage of incidents. In 2018, CNS researchers identified 98 incidents (63% percent of all incidents) in which those responsible for nuclear and other radioactive materials behaved carelessly or disregarded appropriate procedures. This designation is primarily associated with cases involving lost and misrouted nuclear or other radioactive materials, although it is also a factor in some cases of theft. In incidents such as these, safety and security measures were either not known, or willfully disregarded, resulting in the material falling out of regulatory control.

Policy Recommendation: Improve security culture at organizations responsible for nuclear and other radioactive material.

Past reports have recommended creating policies designed to improve security culture at organizations in possession of nuclear and other radioactive material. However, given that human failure was a contributing factor in more than half the 2018 incidents, weak security culture clearly remains a problem.

Licensees should train employees to understand the reasons behind rules and regulations rather than just the regulations themselves. This understanding would provide better motivation for following the rules. Regulatory agencies (or licensees themselves) should conduct personnel audits, assess existing protocols, and improve training as warranted. The forthcoming IAEA publication, *"Enhancing Nuclear Safety Culture in Organizations Associated with Nuclear and/or Radioactive Material"* will provide a much-needed resource to assist organizations in crafting a more robust security culture.

Key Finding 4: Viable alternative technologies exist for many applications of nuclear and other radioactive material.

Many incidents involved sources or devices for which there are viable non-radioactive technologies. Independent experts and governmental studies have identified viable alternatives for high-activity radioactive sources in many areas of the medical and industrial fields, and costs are becoming increasingly competitive as technology improves.[8]

Policy Recommendation: Encourage material replacement efforts.

Incidents involving nuclear and other radioactive incidents cannot occur when there are no such materials to be mishandled in the first place. This report has made this recommendation every year and has noted significant progress over time. Many high-income countries have made commitments to replace dangerous medical sources and the devices that employ them with devices that do not require radioactive materials, and are in the process of implementing them. For example, France and Norway have already replaced 100 percent of their cesium blood irradiators with alternatives, while Japan has reduced its own stock by 80 percent.[9]

Unfortunately, many non-radioactive devices remain expensive and require regular maintenance to function properly. Without assistance, this places them out of reach for many lower- and middle-income countries (LMICs). The international community is working to resolve this, and there has been some progress in providing LMIC countries with these technologies. For example, thanks to assistance from the IAEA, Zambia and Zimbabwe are expanding cancer treatment options, including installing radiation therapy machines that do not require radioactive material to function.[10]

2018 saw progress in the adoption of non-radioactive technologies for industrial uses. A UK Nuclear Security Science Network (NuSec) workshop identified the most promising alternative technologies to replace sealed radioactive sources in industrial radiography. Incidents involving material with industrial uses represent 46% of all incidents since 2013.

Conclusions

Despite progress in nuclear and radiological security, incidents of nuclear and other radioactive material falling out of regulatory control occur all too frequently. However, the international community can work to reduce the number and severity of these incidents. Governments should publicly report incidents using a unified standard, so that the scope of the problem can be understood and security experts can tailor strategies to address the problem. Given the frequency of security incidents occurring during transport, nuclear and other radioactive materials are at greatest risk when being transported. Governments should work to require the electronic tagging of the most dangerous materials to allow for easier recovery if they go missing. Private entities and organizations that are not required to employ electronic tracking should strongly consider doing so anyway, if only to mitigate the financial cost of losing expensive devices. Organizations responsible for nuclear and other radioactive materials management should work to improve security culture to ensure that rules and reporting standards are being followed. Finally, where viable alternative technologies exist, governments should work to replace devices employing radioactive materials to prevent incidents from occurring in the first place.

I. Introduction

In 2018, a team of researchers attempted to quantify the potential impacts of a very small (1 kiloton) nuclear device exploding in a major city.[11] Their conclusion is sobering: tens of thousands dead and injured, total destruction of the city's infrastructure, and a global economic depression leading to a rise in global poverty.[12] The consequences of a terrorist incident involving radioactive material, while less catastrophic, would include societal panic and economic disruption. An August 2018 incident in Malaysia, in which a lost radioactive source incident was misreported as a "radioactive dispersal device," hints at how serious a real incident of radioactive terrorism could become to maintaining public order. The false report caused a costly disruption in trade and required leaders to issue reassuring public statements.[13]

The United States acknowledged the threat of nuclear and radiological terrorism in its December 2018 *National Strategy for Countering Weapons of Mass Destruction (WMD) Terrorism,* which warned that there is a mounting risk of WMD terrorism, as criminal actors' capabilities and willingness to use WMDs increase. The paper identified several strategies to prevent WMD terrorism, giving top billing to denying terrorists access to WMD materials and reducing the global quantity of WMD-related material. Yet the urgency of the threat as expressed in these documents is not reflected in the actions or priorities of the U.S. government. The security of nuclear and other radioactive materials has suffered from a lack of attention in recent years at both the national and international levels. The U.S. Department of Energy's proposed 2019 budget slashes funding for securing vulnerable nuclear and other radioactive materials around the world.[14] The issue has also received less attention from the international community since the conclusion of the Nuclear Security Summit process.[15] Given the reduced salience of nuclear and radiological security at the head-of-state level, it is incumbent on non-governmental organizations and research institutions to fill the gap.

The CNS Global Incidents and Trafficking Database, prepared by the James Martin Center for Nonproliferation Studies (CNS) and funded by the Nuclear Threat Initiative (NTI), offers researchers and policymakers insights into the successes and failures of the global nuclear and radiological security regime. It is the only database of its type which is generated from publicly available data and news reports, and which is freely available to the public. In contrast, the official Incidents and Trafficking Database (ITDB) maintained by the IAEA is generated exclusively from voluntary member state reporting, and its full data is only available to participating states' governments and certain international organizations.

The CNS database contains detailed information drawn from open sources on incidents involving the loss of regulatory control over nuclear and other radioactive materials. Loss of control refers to both unintentional acts (such as loss or misrouting), and intentional acts (such as theft or attempted trafficking). Some incidents may also involve materials that were never under regulatory control but should have been. The information comes from official reports issued by national governments and the IAEA, as well as from media reports.

The level of detail in each entry is limited by the accuracy and comprehensiveness of the underlying reports. At a minimum, all entries include an incident report date, a location, and a unique, 7-digit entry code, which is used to identify them in this report (e.g., #2016643). Researchers have attempted to piece together additional details for each entry, including the type of material or device involved, its typical application, and details of its recovery. Anyone can download the entire database online at www.nti.org/trafficking.

The 2018 database has 156 incidents. Trends remain consistent with the data collected between 2013 and 2017.

- 58 losses were recorded, constituting 37% of all incidents.
- 45 thefts were recorded, constituting 29% of all incidents.
- 64 incidents occurred during transport, constituting 41% of all incidents.

As in previous years, the 2018 database documents several incidents involving the illicit trafficking of nuclear and other radioactive materials. Fortunately, trafficking incidents remain rare relative to the overall number of incidents recorded in the database; it is possible that more trafficking incidents occur but either go unreported or are not intercepted by law enforcement.

These trends and more will be discussed in greater detail in subsequent sections. The large number of cases documented, even though most countries do not publicly report incidents, underlines the global need for increased efforts to ensure that nuclear and other radioactive materials are used responsibly and securely—or, where possible, replaced altogether.

II. Materials and Data Overview

Securing nuclear and other radioactive materials is the first and most critical line of defense against both nuclear and radiological terrorism. An improvised nuclear explosive device (IND) requires the acquisition of large (i.e., kilogram) quantities of weapons-usable nuclear material, such as highly enriched uranium or plutonium. Whereas nuclear weapons are typically only made from uranium or plutonium, radiological weapons could employ a wide range of nuclear or non-nuclear radioactive materials, and do not require fissile material. Although many types of radioactive materials exist, only about a dozen exhibit characteristics that qualify them as serious security threats, in terms of their half-lives, radioactivity, portability, dispersibility, and availability.[16]

Nuclear Material

Between 2013 and 2018, 41 reported incidents involved nuclear material, accounting for 3.9% of all recorded incidents. For 2018, nuclear materials account for 3.2% of incidents.

Table 1. Reported Incidents Involving Nuclear Materials

Nuclear Materials	Incidents, 2018	Incidents, 2013-2018
Uranium, total cases:	**2**	**23**
Depleted	0	1
Natural	0	8
Low-enriched uranium (LEU)	0	1
Highly-enriched uranium (HEU)	0	3
Unknown enrichment	2	10
Plutonium, total cases:	**2**	**11**
Plutonium-238 (Pu-238)	0	2
Plutonium-239 (Pu-239)	2	5
Plutonium-241 (Pu-241)	0	1
Unknown plutonium isotope	0	3
Thorium (Th), total cases:	**3**	**12**
Subtotal, all nuclear materials:	**6**	**46**
Total Unique Cases:	**5**	**41**

In one major case involving nuclear material recorded in 2018, Idaho State University reported that it could not account for one of its nine grams of weapons-grade plutonium. The 1 gram in question was supposed to have been disposed of in 2004, but records do not indicate a confirmed disposal. The university was fined $8,500, and the weapons-grade plutonium was assumed to be unrecoverable. (Incident #2018008)

In another case, uranium of an unknown enrichment level was stolen from an industrial x-ray company. The material was later recovered thanks to an anonymous tip. (Incident #2018042)

Lastly, two Thorium-230 check sources (small radioactive sources used for calibration and monitoring) were stolen from a former naval base in June and have not been recovered. (Incident #2018144)

The two cases with unaccounted-for nuclear material pose minimal risk of diversion toward an improvised nuclear device (IND). While Idaho State University's weapons-grade uranium was not recovered, at only 1 gram it is far below the IAEA's significant quantity figure for plutonium, 8kg. (The IAEA defines a significant quantity [SQ] as "the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded.")[17] Th-230 is not suitable for use in a nuclear device.

Other Radioactive Material

In contrast to an improvised nuclear device (IND), which would require the acquisition of fissile materials such as HEU or separated Pu to construct, radiological weapons such as radiological dispersion devices (RDDs) can be made with a wide variety of radioactive materials. RDDs use conventional explosives to disperse radioactive material over a wide area. RDDs and other forms of radiological terrorism are frequently referred to as "weapons of mass disruption," because they generate widespread fears of radiation to instill terror and panic disproportionate to their lethality. If used at an economic hub such as a port, an RDD could cause immense disruption and terror in the general populace, and impose significant clean-up costs.

As seen below, between 2013 and 2018, roughly 50% of cases in the database involved at least one material of principal RDD concern.[18] Just over 70 such cases occurred in 2018 alone.

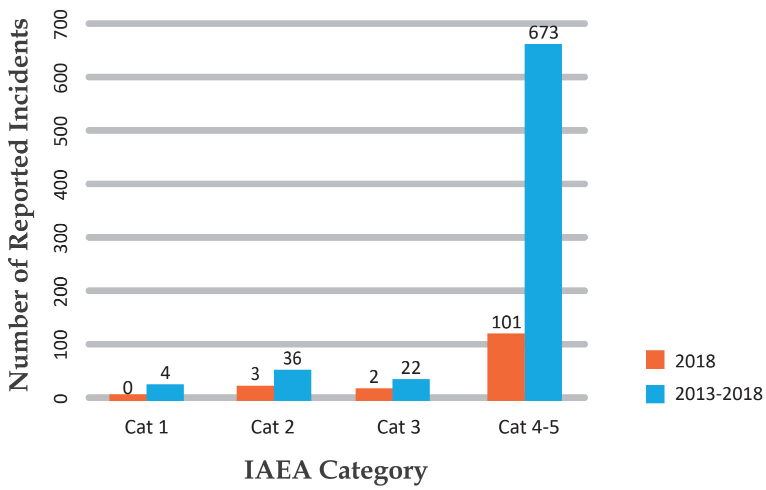
Table 2. Reported Incidents by Material Type

Material of principal RDD concern	Incidents, 2018	Incidents, 2013-2018
Cesium-137 (Cs-137)	37	280
Americium (Am-241)	40	247
Iridium-192 (Ir-192)	7	60
Radium-226 (Ra-226)	8	44
Cobalt-60 (Co-60)	4	24
Strontium-90 (Sr-90) and its decay product, Yttrium-90 (Y-90)	4	29
Californium-252 (Cf-252)	0	5
Selenium-75 (Se-75)	1	4
Plutonium-238 (Pu-238)	0	2
Plutonium-239 (Pu-239)	2	7
Ytterbium-169 (Yb-169)	0	1
Thulium-170 (Tm-170)	0	0
Subtotal	103	703
Total unique cases	**74**	**502**

Given the potential for significant societal disruption, and the large number of annual materials losses useable in radiological devices, radiological attacks pose a serious societal threat. However, to date, the most widely-publicized attacks using radioactive materials are what one group of experts have dubbed "inhalation, injection, and immersion (I^3) attacks".[19] These attacks have tended to target individuals for assassination, as opposed to large groups of people or high value areas. The most well-known example of this type of attack involved the assassination of Russian dissident Alexander Litvinenko using Polonium-210 in 2006.

The IAEA categorizes radioactive sources according to their potential harm to human health from estimated exposure on a scale of 1-5, as detailed in IAEA Safety Standards Series RS-G-1.9. Category 1 sources present the greatest health risk (e.g., a large quantity of cobalt-60, the source radiation in a radiation therapy machine), and Category 5 the lowest (e.g., the source radiation for X-ray fluorescence devices). This grading system is intended to assist states in allocating scarce human and financial resources to the highest priority risks. Most countries use this categorization scheme to develop national-level regulations, but non-governmental reports on incidents relating to radioactive material frequently do not report the category of the materials in question. For this reason, many cases in the CNS database do not have a listed IAEA category. Of those that were categorized, few involve the most dangerous Category 1 and 2 materials. Figure 2 shows the breakdown of reported incidents by IAEA category.

Figure 2. Incidents by IAEA Category

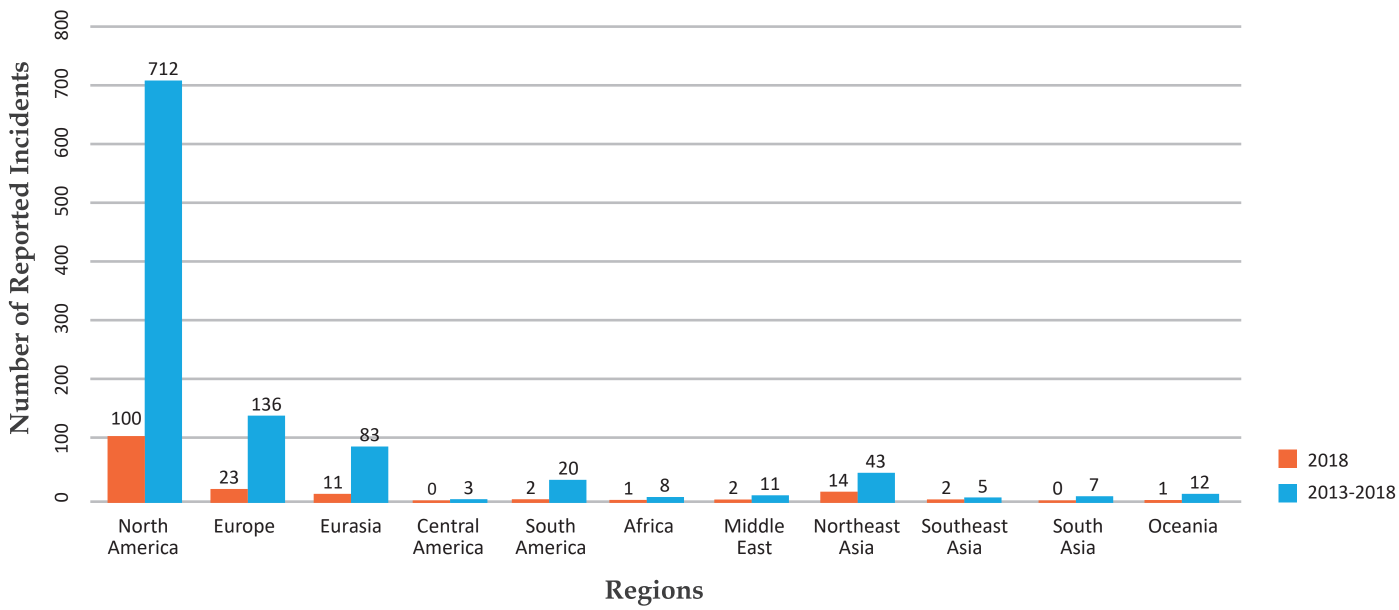


III. Key Findings and Policy Implications

Key Finding 1: Variable reporting transparency yields variable, low transparency, results

The CNS Database includes a total of 1,040 incidents, which occurred in 58 countries during the 2013 to 2018 reporting period. The newly added 2018 case subset consists of 156 incidents occurring in 23 countries. The regional case breakdown is shown in Figure 3.

Figure 3. Reported Incidents by Region



A disproportionate number of reported cases come from North America, because the United States and Canada have two of the most robust and transparent reporting systems in the world. Other countries with strong public reporting standards are France, Belgium, South Korea, and Japan, all of which are represented in this year's incidents database. While these countries all have relatively high numbers of nuclear and other radioactive materials, sources, or devices subject to regulatory control, they are not the only such countries, and their predominance in the database is primarily attributable to their robust reporting standards. In 2018, 76% of all reported incidents occurred in the six countries with the highest public reporting standards, consistent with past years.

Reporting standards vary widely; most countries do not routinely report incidents to the public. Some countries, such as Mexico, publicly report incidents involving dangerous radioactive materials to alert the public of potential danger, and to enlist their help in recovery efforts.[20] Ukraine's Security Service reports incidents involving smuggling, attempted illicit sales, and trafficking of nuclear and other radioactive materials, but does not report other types of incidents such as losses.[21] Other countries have no public reporting mechanisms whatsoever; all incidents from these countries recorded in the database have been culled from media reports.

Even countries with strong reporting standards do not necessarily report all incidents. In the United States, the Nuclear Regulatory Commission (NRC) reports many incidents that would go unreported in other countries, such as stolen exit signs or smoke detectors, which only contain trace amounts of radioactive material. More significant incidents can also fall through the cracks. For example, in September 2018, a World

War II-era radium deck marker was found under a stretch of newly-built condominiums in San Francisco on the site of a former naval shipyard that the U.S. Navy, the city, and multiple government agencies had long maintained was clear of radioactive contamination.[22] Because the incident involved a long-discarded source, it was not reported through normal NRC channels.

As in past years, in 2018 the United States reported the most incidents of any single country:

- United States (86, 55.1%)
- Canada (12, 7.7%)
- France (11, 7.1%)
- Russia (8, 5.1%)
- Japan (7, 4.5%)
- China (6, 3.8%)
- Ukraine (4, 2.6%)
- Finland (3, 1.9%)
- Belgium, Chile, Mexico, Spain (2 incidents each, 1.3%)
- Burkina Faso, Hungary, Kuwait, Lebanon, Malaysia, Netherlands, New Zealand, the Philippines, South Korea, Switzerland, United Kingdom (1 incident each, 0.6%)

The distribution of incidents is broadly consistent with past years. In 2018, researchers found incidents in several countries for the first time in the history of the database: Burkina Faso, Hungary, Kuwait, the Netherlands, New Zealand, and the Philippines.

SPOTLIGHT 1

How many incidents does the CNS Global Trafficking Database miss?

There's no way to know what we don't know, but the results of two joint Ukraine-U.S. projects suggest that the number might be bigger than we realize.

The Ukraine-U.S. joint projects retrieved aging radioactive sources from bankrupt enterprises, many of which had been abandoned or left unsecured in landfills. According to Ukrainian authorities, 14,755 spent radiation sources, representing a total activity of 1.27 petabecquerel (PBq, a measurement of radioactivity), were collected between 2009 and 2015.[23] Because the incidents were aggregated when publicly reported, it is impossible to incorporate them into, or individually cross-check them with, incidents in the CNS database. However, if each individual source had been publicly reported as a single event, this total would represent more than 14 times the number of cases in the entire CNS database and over four-and-a-half times the total number of incidents in the IAEA's confidential database.[24]

The level of global reporting has wide regional variance and presents an incomplete picture. There are a variety of factors that could explain the scarcity of reports in certain regions. In some cases, there are fewer nuclear and other radioactive materials in a particular region, and therefore one would expect fewer incidents. However, in other cases, governments may not always catch incidents occurring in their jurisdiction, and if they do, they may choose not to report them. Many countries possess internal incident data that is not reported to the IAEA or the public in a timely fashion, or at all. This can result in delayed or aggregate reporting, which further complicates efforts to determine the total number of incidents. Some countries report incidents to the IAEA confidentially, but choose not to inform the public. In addition, many countries have different standards for what they choose to report in the first place, making it difficult to definitively account for the total number of nuclear or radiological incidents.

Policy Recommendation: Develop a common standard for incident reporting which requires reporting Cat. 1 and 2 losses; encourage reporting of incidents involving sources of military origin.

A stronger common reporting standard would help address the information gap that currently exists, and would facilitate the development of better security policies. This year, El Salvador and Liechtenstein joined the ITDB as participating states, bringing the total number of participating states up to 136 and improving reporting transparency.[25] While this is encouraging, several IAEA member states still do not participate, including several that possess a nuclear infrastructure and/or are countries of concern for trafficking and terrorism, such as Angola, Egypt, Myanmar, North Korea, Syria, and Turkmenistan.

Since 2013, the CNS annual reports have advocated the adoption of a legally binding international instrument that would mandate reporting of incidents involving IAEA Category 1 and 2 radioactive materials. While voluntary instruments such as the IAEA's Incident and Tracking Database (ITDB) play an important role in incident reporting, they are not adequately comprehensive or transparent. Many states still do not participate in the ITDB, and even participating states may elect not to report an incident, or may fail to do so in a timely manner.

George Moore, a former senior analyst in the Office of Nuclear Security[26] at the IAEA, has noted that "there is no binding international instrument that requires states to report the loss of regulatory control over hazardous radioactive sources or significant amounts of radioactive materials."[27] Moore recommends that states work through the IAEA to establish a mandatory reporting standard for Category 1 and 2 radioactive materials and sources. Given that Category 1 and 2 incidents comprise only a small proportion of total incidents, it should not pose an undue burden if member states are required to report them. Still, it is politically difficult for the IAEA to impose an obligation, no matter how light, upon member states.

This edition of the CNS Global Incidents and Trafficking Report makes an additional recommendation meant to improve reporting transparency: incidents involving sources of military or government origin should be routinely and publicly reported through channels like those which exist for civilian incidents. In the United States, this would mean reporting losses, thefts, and other incidents involving military and government sources through the Nuclear Regulatory Commission's Event Notification system, or some equivalent clearing house. Two incidents in the United States in 2018 involved such sources. The first incident, in which two sealed radioactive check sources were stolen from two Department of Energy employees while on business travel, was one of the more egregious examples of human failure and poor security culture. The other, in which a radium deck marker was found at a condominium construction site on a former decommissioned military installation in San Francisco (#2018133), resulted in public concern, as the site had previously been declared free of radioactive contamination.[28]

A common reporting standard would give a more accurate and complete picture of incidents involving nuclear and other radioactive materials. It is difficult to know where security policies can be improved when we don't know where all the gaps are. In addition, there is precedent for such legal instruments. The Convention on Early Notification of Nuclear Accidents, adopted in 1986 after the Chernobyl disaster in the USSR, mandates the prompt reporting of nuclear incidents that may physically affect another state. More recently, the International Convention on the Suppression of Acts of Nuclear Terrorism entered into force in 2007, following the September 11, 2001 and other terrorist attacks, encouraging cooperation among states to prevent the misuse of nuclear and other radioactive materials. Rather than wait for another disaster to spur legal change, the IAEA and its member states would do well to encourage at least Category 1 and 2 incident reporting as soon as possible.

Given the persistence of cross-border trafficking in nuclear and other radioactive materials, there is a compelling case for the international community to view incidents involving the most dangerous Category 1 and 2 sources as transnational threats that necessitate an international response. Incidents such as the one that took place in June 2018 (#2018078), in which Ukrainian security forces apprehended six members of an international smuggling ring trafficking in radium-226, shows that nuclear and other radioactive material security transcends national borders.

Key Finding 2: Transportation creates vulnerability to theft

The IAEA has identified nuclear and other radioactive materials as being most vulnerable to loss or theft while in transport.[29] The CNS Global Incidents and Trafficking Database bears this out: since 2013, over half of all incidents of theft have been associated with a vehicle. Incidents of theft highlight how nuclear and other radioactive materials can be vulnerable to malicious actors even when not intentionally targeted.

In 2018, 45 incidents involved theft, constituting approximately 29 percent of all incidents. From 2013 to 2018, the database recorded 259 incidents involving theft, constituting approximately 25 percent of all incidents.

Figure 4. Types of Theft

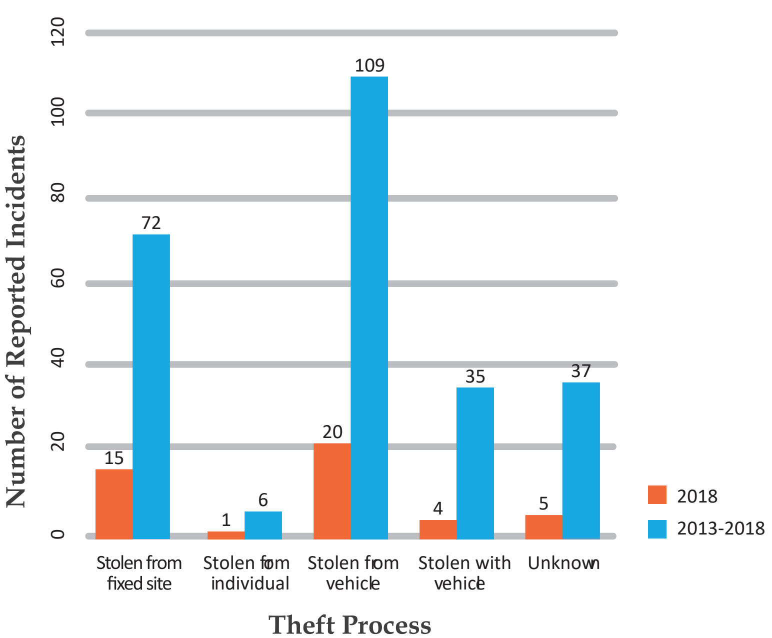
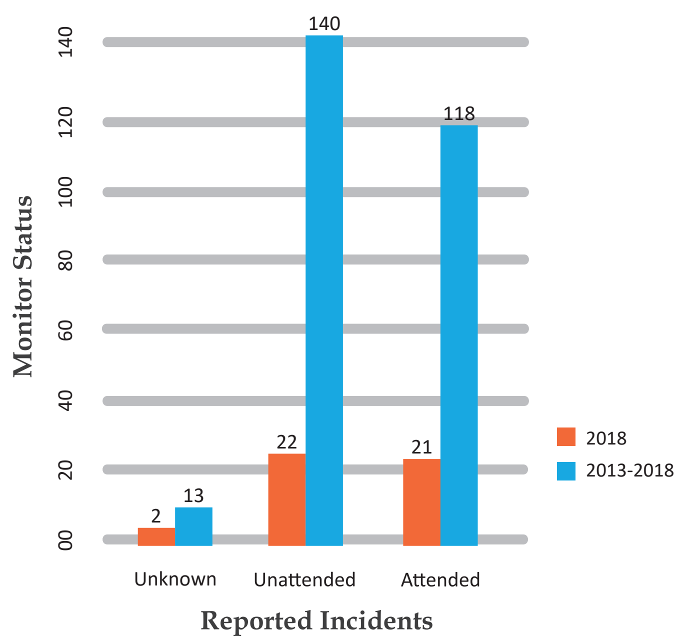


Figure 5. Monitor Attendance During Theft of Material



This makes 2018 the year with the most incidents of theft since the database began in 2013, outpacing the 42 incidents of theft recorded in 2016. While not a huge increase over previous years, the uptick in incidents of theft, both in absolute terms and as a proportion of all incidents, is concerning.

To highlight the vulnerabilities of nuclear and other radioactive materials to malicious actors, the CNS database categorizes thefts into five categories: theft from an individual, theft from a fixed site, theft from a vehicle (where the vehicle itself is not stolen), theft with a vehicle (where the vehicle is stolen with the material inside), and theft under unknown circumstances. Theft cases are further categorized by whether at least one individual was attending the source at the time of theft (see Figures 4 and 5).

Of the 259 thefts recorded between 2013 and 2018, 140 occurred when the device involved was in transit, 77 occurred at a fixed location, and 42 occurred under unknown circumstances. Only 13 devices were confirmed attended at the time of theft, while 128 were unattended, which suggests that the presence of an individual is a strong deterrent and security measure. In the remaining 118 incidents, it was unclear whether the device was attended or not. Assuming a similar ratio holds for these incidents, it can be inferred that devices are more vulnerable to theft when unattended, as such instances make up roughly 90% of recorded thefts.

Most thefts involving vehicles feature devices with radioactive sources being stolen *from* a vehicle, as opposed to being stolen *with* the vehicle (109 vs. 35). In the latter cases, the vehicle was likely the primary target of theft, whereas in the former, thieves were more likely interested in the devices themselves. This distribution leads us to conclude that, while better safety and security practices can prevent devices from being left unattended in vehicles, greater emphasis should be placed on securing the sources themselves and preventing their removal from vehicles, as well as on adding tracking technology to assist in locating stolen devices.

Trafficking

In 2018 five definitive cases of intentional trafficking of nuclear and other radioactive materials were recorded. While this represents only a small percentage of all recorded incidents, it must be remembered that more cases likely occur, but go undetected or unreported.

- Incident #2018078: Ukrainian security services arrested six individuals believed to be part of an international radioactive

SPOTLIGHT 2

Rules of the Road

Two 2018 incidents that occurred on opposite sides of the globe illustrate how even basic physical security measures on the part of end users can make all the difference. In September, a truck belonging to a private industrial firm was stolen during a fill-up at a gas station in West Virginia (#2018156). The truck contained a radiography camera with a Category 2 iridium-192 source. The truck was recovered by state police, and, because the camera was properly secured, it was recovered intact and without any signs of having been disturbed.

This contrasts with a serious incident that occurred in Malaysia in August 2018 (#2018136), in which a piece of radiographic equipment was either lost or stolen from the back of a pickup truck while in transit between the cities of Seremban and Shah Alam. When the vehicle arrived at its destination, the tailgate was found to have been lowered and the radioactive source was missing. Although there was no evidence that the radioactive material had been used for malicious purposes, local news media exacerbated the incident by mischaracterizing it as the loss of a "radioactive dispersal device (RDD)."[30] This mischaracterization sparked panic in the area, requiring government officials to issue calming statements. The incident also resulted in costly enhanced border checks, and despite all of this the device still was not located.[31] This incident illustrates how inadequate security measures can cause societal harm even when the material is not exploited by a nefarious actor. It also shows how employing very simple security measures, such as locking up sources in the vehicle and installing GPS tracking devices, can prevent serious consequences.

materials smuggling ring. The individuals were arrested after attempting to sell police an unspecified quantity of radium-226 in a sting operation. It is unclear how the individuals acquired the material.

- Incident #2018079: Ukrainian security services seized a device containing radioactive material from an individual who planned to sell and mail the device to an unnamed EU country.

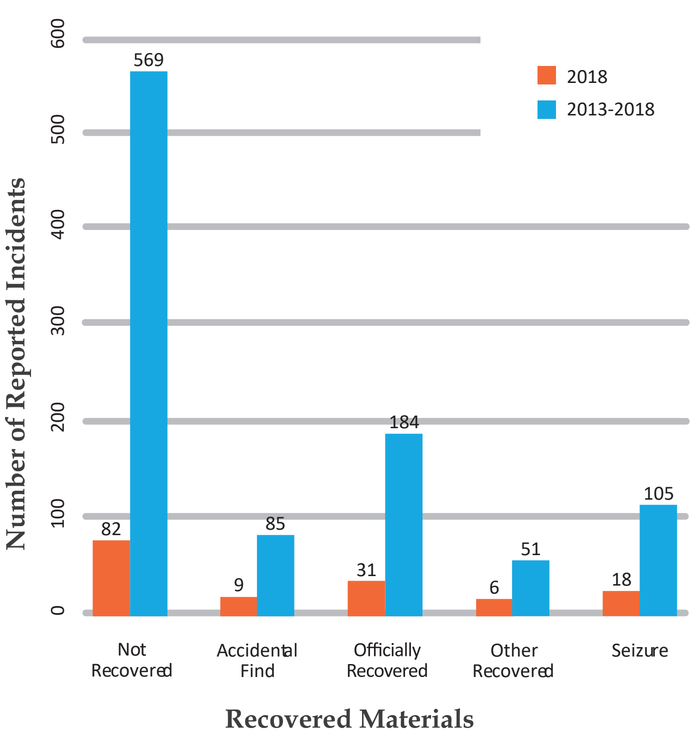
- Incident #2018080: Four scrap metal dealers in the Netherlands were arrested after authorities determined they were illegally selling radioactive scrap metal used in ballast blocks on ships.

- Incident #2018191: Sheremetyevo airport customs in Russia found a “yellow, radioactive mineral” in a package arriving from Italy. A criminal investigation is underway, and the stone was presumably confiscated.

- Incident #2018190: Customs officials in Orenburg, Russia confiscated 292 “medical medallions” from an entering truck driven by a Kazakhstani citizen. The medallions were reportedly being smuggled into the country and registered gamma radiation 20 times in excess of the background level. A criminal investigation is underway on charges of “illegal movement of potent, poisonous, toxic, explosive, radioactive substances, radiation sources, or nuclear materials across the border.”

From this limited number of cases we see that instances of trafficking, when reported, are detected and addressed by domestic law enforcement. The trafficking of radium in the first case suggests industrial or antiquated medical isotopes, reinforcing this report’s call for increased security over nuclear and other radioactive materials in those fields. The third incident also indicates a weakness in the scrap metal processor’s internal security structure, which should have prevented the sale. While the end use is unknown in all cases, the primary motivation behind most trafficking cases appears to be profit.

Figure 6. Were Materials Recovered?



Recovery Data

The CNS database tracks whether materials outside of regulatory control are recovered, and, if so, how. The data is likely incomplete because recoveries are rarely reported in the press. In addition, although it is mandatory in some countries to report materials outside of regulatory control, reporting their recovery can be discretionary.

A recognized limitation of the CNS database is that entries are not routinely revisited once they are entered, given the low likelihood that updated information will become available. For example, a source entered as lost and unrecovered would remain flagged as an unrecovered case even if it were eventually reported found two years later. Therefore, the recovered incidents in the database only represent the minimum number of sources that were recovered. Figure 6 sorts incidents by whether the material was recovered, and, for those that were, the manner of recovery.

Given the dangers associated with nuclear and other radioactive materials, recovery of stolen devices or sources may necessitate personnel trained in radioactive decontamination and waste disposal. Many sources, if damaged or opened intentionally, could contaminate the surrounding environment and/or harm exposed individuals. Law enforcement investigations involving nuclear and other radioactive materials are complicated by the need to implement radiation safety procedures to protect personnel and the general populace. Law enforcement can issue information about lost material and increase chances for an accidental find, but the small size of many radioactive materials and sources makes searching for them time-consuming and difficult. In 2018, CNS recorded 9 incidents where the material was accidentally found, 31 incidents where the material was officially recovered, 18 in which it was officially seized, and 6 in which it was recovered under unspecified circumstances.

Policy Recommendation 2: Improve physical security measures while in transport; expand electronic tracking of dangerous radioactive sources.

Since the publication of the first CNS Global Incidents and Trafficking Report in 2013, there has been progress in national attention devoted to the physical security of nuclear and other radioactive materials. Perhaps as a result of commitments made by states at the 2014 Nuclear Security Summit (NSS), there has not been a known incident of theft involving a Category 1 source since 2013. In the past year, countries have undertaken national initiatives aimed at improving the physical security of these most dangerous sources using electronic monitoring. However, the continued prevalence of thefts involving lower-category materials and the rarity of their recovery suggests that end users should prioritize basic physical security and consider electronic tracking for some of these items.

Two 2018 examples from Asia highlight significant government investment in improving electronic tracking and physical security measures for nuclear and other radioactive materials. In early 2018, Malaysia's Atomic Energy Licensing Board (AELB) rolled out its new MyAtom mobile app.[32] The app, currently only accessible by national authorities and first responders, tracks nuclear and other radioactive materials, displaying their locations around Malaysia in order to improve interagency coordination in response to incidents involving such materials.[33] Combined with the AELB's new training courses on environmental radiation monitoring,[34] Malaysia has increased its capacity to detect and respond to incidents involving nuclear and other radioactive materials.

In Japan, the Atomic Energy Commission, citing security concerns, directed hospitals and companies with radioactive sources to improve their security practices in advance of major international sporting events in 2019 and 2020.[35] These directives reportedly included installing security cameras at radioisotope storage sites, and furnishing security personnel with proper communication devices and training.[36] Increased investment in physical security, combined with enhanced capacity to track and recover lost or stolen sources, vastly improves public safety by preventing incidents and mitigating the effects of those that occur.

Key Finding 3: Human Failure Is a Security Risk

In 2018, 87 incidents (58% of total incidents) were at least partially caused by carelessness, inattention to appropriate procedures, or other behaviors that could be reasonably classified as "human failure." Human failure is primarily associated with lost or misdelivered nuclear or other radioactive material. However, it can also include cases of theft where human failure is a clear contributing factor, and five such cases occurred in 2018.

The high frequency of human failure in incidents since 2013 suggests the need for a stronger security culture in the organizations that handle nuclear and other radioactive materials, sources, and devices. Many incidents could have been prevented if the individuals handling such materials had simply known and followed best practices for safety and security. For example, an auto parts wholesaler in Mississippi lost a

SPOTLIGHT 3

Security Culture Is Not Just Academic

Human failure is often closely tied to institutional failure. Institutions that fail to promote a strong security culture among their employees and staff are especially vulnerable to incidents of nuclear and other radioactive material falling outside of regulatory control. This problem is not limited to small industrial or commercial organizations handling low-activity radioactive sources; even large organizations handling weapons-grade nuclear material can fail to instill appropriate security culture.

For example, in May 2018, Idaho State University was fined $8,500 for misplacing one gram of weapons-grade nuclear material. While one gram is not enough material for an improvised nuclear device (IND), loss of regulatory control over any amount of fissile material is a grave concern. The material was scheduled to be disposed of in 2004, but no documentation could be found to confirm that this occurred (Incident #2018008). Idaho State University is not a small-scale industrial or commercial end user; it has a well-regarded nuclear engineering program that works closely with the Department of Energy's Idaho National Laboratory. Additionally, the university generally has a good record with the Nuclear Regulatory Commission.[37]

This incident also resembles a major case study from the 2017 CNS Global Incidents and Trafficking report, wherein a professor at the University of Nevada at Las Vegas was responsible for the loss of 1.4 grams of highly enriched uranium (Incident #2017165). The implications are clear: all organizations which handle nuclear and other radioactive material, whether large or small, simple or sophisticated, must promote a strong security culture.

static eliminator containing a Polonium-210 source. This incident was reported in February 2018, but the loss occurred sometime in 2015, a lapse rendering recovery of the source highly unlikely. Apparently, someone used the device once, but it did not work well, so he said that it "must be lost" and "is probably in the dump somewhere." (Incident #2018023)

In another case reported in 2018, a moisture density gauge was stolen from a company vehicle. Technicians reported the incident to their supervisors, who then waited two days to report the incident. (Incident #2018057) A stronger security culture could have prompted the supervisors to report the incident immediately.

Policy Recommendation: Improve security culture

Some human error is unavoidable. However, the frequency and severity of such errors can be diminished with a robust security culture. Proper employee training that inculcates respect for safety regulations, understanding of the rationale behind protocols, and appropriate procedures for working with radioactive materials can reduce human failure.

The IAEA recognizes the importance of instilling a strong security culture in organizations that work with nuclear and other radioactive materials and has published several implementing guides to help member states establish strong nuclear and radiological security cultures. In 2008, the IAEA published a guidebook, *Nuclear Security Culture: Implementing Guide,* which emphasizes the role of security culture in preventing security incidents.[38] The IAEA also drafted a technical guide in 2016, *Enhancing Nuclear Safety Culture in Organizations Associated with Nuclear and/or Radioactive Material,* which is expected to be released in 2019.[39] Additionally, the World Institute for Nuclear Security (WINS) coordinates with the IAEA to provide resources to industry to improve security culture.

These IAEA documents offer guidance for improving security and fostering a robust security culture tailored to the needs of organizations and institutions that use nuclear and other radioactive materials. One consistent theme in these materials is the necessity of awareness training; that is, ensuring that personnel who are responsible for handling potentially dangerous materials are educated about the consequences of poor security practices. This is another factor which bolsters the case for increased transparency in incident reporting: an understanding of the frequency and severity of incidents involving nuclear and other radioactive material may incentivize personnel to take appropriate precautions. This points to an important reason the CNS Global Incidents and Trafficking Database adds value: as the only open-source database of security incidents involving nuclear and other radioactive materials, it can serve as a clearinghouse for cautionary examples to assist organizations in crafting an effective security culture plan.

Key Finding 4: Viable Alternative Technologies Exist

Materials with industrial or medical applications constitute a high percentage of reported incidents. In 2018, 93 of the 156 recorded incidents (about 60%) involved radioactive sources or devices with industrial or medical applications. This figure is in line with previous years: there have been 633 such incidents since the database started in 2013, for an average of 105.5 per year. Given that medicine and industry account for over half of all incidents in the database, replacement efforts should focus on these two fields.

Table 3. Incidents by Industry

Industries	Incidents, 2018		Incidents, 2013-2018	
Aerospace	5	(3.2%)	23	(2.2%)
Academic	4	(2.6%)	44	(4.2%)
Business	1	(0.64%)	7	(0.67%)
Industrial	69	(57.7%)	485	(46.6%)
Medical	24	(15.4%)	148	(14.2%)
Signage	15	(9.6%)	95	(9.15%)
Nuclear	2	(1.3%)	20	(1.9%)
Other/niche	3	(1.9%)	27	(2.6%)
Unknown	32	(20.5%)	142	(13.7%)
N/A	1	(0.64%)	49	(4.7%)
Total Incidents:	**156**		**1,040**	

Policy Recommendation: Governments should encourage replacement efforts.

Replacement of materials that could be used in radiological terrorism remains the best way to permanently reduce risk. Fewer radioactive materials in circulation—especially in low-security settings such as hospitals—means fewer opportunities for losses, accidents, or thefts. While there has been encouraging progress in materials replacement, problems of cost, concerns about efficacy of non-radioactive alternatives, institutional complacency and inadequate awareness continue to hinder replacement efforts.

Radioactive materials have wide applications in medicine, construction, food, and radiation detection. However, they also pose a substantial terrorism risk given their potential use in RDDs. According to the U.S. Department of Health and Human Services' Radioactive Emergency Medical Management, the most dangerous common radioactive materials are cesium-137, americium/beryllium-241, strontium-90, and cobalt-60,[40] which featured in approximately 23%, 26%, 3%, and 2.5% of incidents respectively for 2018 (totaling 59 unique incidents). These sources are often stolen from ill-secured devices used in construction or medicine, with examples from the past year including the theft of numerous Cs-137 and Am/Be-241-based moisture density gauges, the theft of seven Cs-137 and Sr-90 sources from the former Naval Air Station Brunswick (Incident #2018144), and 50 iodine brachytherapy seeds disappearing from a Hot Lab in Newark, DE (Incident #2018063).

Fortunately, countries are increasingly aware of the risks inherent to these radioactive materials, and are implementing increased security measures, such as those in Malaysia and Japan mentioned in Key Finding 2. However, as these security measures carry significant costs, transitioning away from technology that relies on radioactive materials provides a safer, and possibly more economical, tactic for reducing the risk of loss or theft.[41]

A 2018 U.S. Nuclear Regulatory Commission task force report highlights ongoing U.S. replacement efforts for medical isotopes in blood irradiation,[42] one of the most common medical applications of Category 1 and 2 sources.[43] Cs-137 blood irradiators can be replaced with cheaper x-ray-based counterparts, but institutional complacency, lack of awareness, and capital costs represent a significant barrier to countries and institutions that have already invested in Cs-137 units.

In order to address these barriers, the NNSA's Cesium Irradiator Replacement Project (CIRP), under the Office of Radiological Security (ORS), provides removal and disposal services for Cs-137 blood irradiators, as well as financial assistance for purchasing, installing, and maintaining new x-ray irradiators, to participating institutions.[44] In March 2018, CIRP helped the University of California replace the majority of its Cs-137 blood irradiators.[45] This replacement effort covered almost half of the Cs-137 blood irradiators in California, while helping university facilities improve security, reduce long-term operation costs, and increase their operational capacity. According to the NNSA publication, transitioning to x-ray irradiators reduces operational costs by obviating or diminishing the need for source disposal and expensive security systems. Certain participating institutions reported an increase in their ability to process blood.[46] The California initiative follows other international efforts already widely reported; France and Norway have replaced 100% of their cesium sources, while Japan has reduced its own stock by 80%.[47]

Besides Cs-137 blood irradiators, the U.S. Nuclear Regulatory Commission Task Force on Radiation Source Protection and Security has identified Co-60 teletherapy devices as a major medical application of Category 1 and 2 sources.[48] The report indicated linear accelerators (LINACs) as a preferred non-isotopic replacement, but conversion from Co-60 teletherapy machines to LINACs also faces financial obstacles, particularly in lower-middle income countries (LMICs). Based on the 2018 NRC report, Co-60 teletherapy machine replacement efforts are less active than those for blood irradiators. The 2018 NRC report listed the FDA's approval of a new model of LINAC, but did not mention any current replacement efforts focusing on blood irradiators.[49]

The ORS complements these replacement efforts with its 2020 Cities Initiative, which focuses on "enhancing radiological security in major U.S. cities by 2020 by providing security enhancements to sites that house high-activity radioactive materials and training to law enforcement professionals responsible for responding to a theft of these materials."[50] Between pursuing material replacement efforts and improving security culture, the U.S. has reduced the risk of incidents involving nuclear and other radioactive materials, providing a good blueprint for future progress.

Outside the United States, the IAEA is partnering with hospitals in removing financial obstacles to radioactive material replacement. Ongoing cooperation between the IAEA and national governments facilitates the transition away from radioactive sources, with the IAEA providing support for purchasing and installing non-isotopic devices.[51] In May 2018, Mother Teresa Hospital in Tirana, Albania installed its second LINAC with assistance from the Albanian government and the IAEA, greatly expanding its cancer treatment options and capacity.[52] Zambia and Zimbabwe, among other African nations, are also expanding their cancer treatment options by installing LINACs with IAEA assistance.[53] IAEA support for newer, safer technologies represents a positive trend that, if properly directed, can help expand replacement efforts to additional regions of the world.

SPOTLIGHT 4

New Initiatives in Industrial Radiography

Previous editions of this report, and numerous replacement initiatives, have focused on non-radioactive alternatives in the medical field, and specifically replacement options for Cs-137 and Co-60. However, given the high frequency of industrial gauges in incidents, CNS researchers investigated alternative technologies in the oil and gas industries, which widely use Cs-137, Co-60, Am/Be-241, and Cf-252 in well logging equipment.[54]

A major development in alternative technology for industrial radiography occurred in 2018, when the UK Home Office identified the use of radioactive material in well loggers as a national security issue. Due to this designation, the Atomic Weapons Establishment (AWE) and the Nuclear Security Science Network (NuSec) hosted a workshop in 2018 aimed at exploring alternative technologies and how to facilitate transition in the field.[55] Out of 24 potential replacement technologies, members of the public sector, industry, and academia identified acoustic technologies, pulsed neutron generators, nuclear magnetic resonance (NMR), data analytics, and x-rays as the most promising alternatives, and outlined plans for their future implementation.[56]

The AWE/NuSec workshop represents encouraging progress, as the oil and gas industries that make heavy use of well-loggers have been hesitant to adopt new technologies, for fear that conversion to non-isotopic instruments will render historical calibration data useless. A 2010 study by the U.S. Department of Energy found that non-isotopic alternatives with additional unique sensing functions exist for Am/Be-based well loggers, but that full conversion to non-isotopic technologies was hampered by strong industry biases against regulation and in favor of the use of radioactive technologies.[57] The presence of members of industry at the AWE/NuSec workshop signifies their willingness to work towards transitioning away from radioactive sources, which will help secure another major industry against diversion.

Cost

Programs such as the ORS's CIRP encourage replacement of Cs-137 irradiators in U.S. institutions by providing expertise and financial support.[58] This support is critical, as installation, maintenance, and disposal costs can amount to $100,000-$200,000 per device.[59] The CIRP initiative could be expanded to help other countries in their own conversion efforts, or serve as a framework for domestic initiatives.

X-ray blood irradiators have a lower purchase price than Cs-137 irradiators. However, high transition costs represent a significant obstacle for countries already invested in cesium models.[60] Substantial IAEA support for adoption of non-radioactive cancer treatment technologies helps mitigate these obstacles, as the cases in Albania,[61] Zimbabwe, and Zambia demonstrate.[62]

Besides increasing financial support for conversion efforts, reducing new technology costs also removes barriers for lower- and middle-income countries (LMICs) transitioning to non-isotopic medical devices. The overall cost of installation and maintenance for a LINAC is at least twice that of Co-60 or Cs-137 teletherapy machines.[63] U.S. company Varian offers LINAC models designed for LMICs that feature slightly reduced up-front costs and far lower maintenance expenses.[64] Single-energy LINACs represent another cheaper alternative, with current trials showing them to be of comparable efficacy to normal LINACs.[65] However, some LMICs are have been reluctant to purchase them, seeing the devices as inferior technology.[66] Both these alternative technologies demonstrate viability for widespread transition away from radioactive sources in medicine despite high costs. Efforts continue to eliminate barriers to their adoption, but at present the IAEA still recommends Co-60 or Cs-137 machines for LMICs because of their lower cost and ease of use, representing an institutional obstacle to full adoption of non-radioactive medical devices.[67]

Efficacy

While some California medical providers have reported an increased ability to process blood after switching from Cs-137 irradiators to non-radioactive technologies,[68] alternatives for many other Cs-137-reliant devices still face technological hurdles to widespread adoption.[69] Some research labs have reported differences between data collected by Cs-137 machines and non-radioactive alternatives, which presents conversion difficulties.[70]

This concern is particularly acute in the oil and gas industry, as detailed above, where differences in data collected between cesium-based tools and non-radioactive alternatives constitute a significant barrier to wider adoption.[71] Continued study of differences between the two types of devices would aid these transition efforts, and hopefully boost adoption of non-isotopic sources in other fields.

Awareness

The above initiatives represent a trend of greater awareness regarding nuclear and other radioactive materials replacement, but further actions should be taken. Awareness of large-scale replacement opportunities increases when parties such as governments and technology manufacturers clearly identify initiative partners in their publications.[72] The IAEA can help raise awareness by focusing its support for cancer treatment technology on non-nuclear options like LINACs, instead of Co-60 or Cs-137 radiotherapy machines.

IV. Conclusion

With the release of the CNS trafficking database's sixth annual report, the 2018 incident data reinforces consistent trends identified in previous editions. Many states that participated in the Nuclear Security Summit (NSS) process have enacted policies which make good on their NSS commitments, while the IAEA continues to provide technical guidance and assistance in establishing stronger nuclear and radiological security cultures in its member states. However, lack of global urgency and de-prioritization of the issue threatens to erase or dilute the progress achieved by the NSS process.

Reflecting these consistent trends, the policy recommendations of this CNS Global Incidents and Trafficking report echo those of previous editions:

- Encourage uniform, systematic, and transparent global reporting;
- Use technology to enhance physical security;
- Improve organizational security culture; and,
- Replace radioactive materials with less dangerous alternatives, where possible.

These measures will help communities around the world to enjoy the benefits of nuclear and other radioactive materials where viable alternatives do not exist, while reducing the risk of safety and security incidents, and especially nuclear or radiological terrorism.

V. Appendix

For a complete methodology overview and dataset, please refer to the full database at www.nti.org/trafficking.

- The database includes incidents reported January 1, 2013 through December 31, 2018.
- CNS researchers conducted global searches in 11 major languages. Use of these languages enabled in-depth native language searches for incidents.
- Researchers used a variety of information sources, including countries' regulatory agencies, national and local news reports, and country-specific search engines.
- The database includes twenty categories describing each incident. The categories and their subcategories are explained in the Category Definitions section of the database.
- Previous editions of the report counted duplicate sources of the same enrichment level or isotope as separate incidents for the "all nuclear materials" subtotal. To avoid the overrepresentation of these incidents, the 2018 report counts duplicate sources from the same incident as only one incident. As such, figures from the "Nuclear Materials" and "Other Radioactive Materials" sections may be inconsistent with past versions of the report.

The 2013-2015 editions of the database identified "human negligence" as a cause for many incidents. Because "negligence" carries a specific meaning in U.S. criminal law and civil litigation that does not exactly correspond to all cases described in the report, in 2016 CNS replaced it with the term "human failure" as defined below. Incidents identified in the report as linked to human failure are not classified as such in the database itself, but are examined under the following guidelines to determine whether human failure was a contributing factor:

- Human failure is defined as a lack of reasonable care or attention to maintaining control over nuclear and other radioactive materials, including any failure to follow relevant regulations or company procedures governing their use, storage, shipment, receipt, or disposal.
- The circumstances surrounding how material fell out of regulatory control had to be described in the incident report in order to link an incident to human failure. If insufficient details were given, the role of human failure was deemed unknown.
- All incidents classified as "loss" were deemed due to human failure unless the circumstances surrounding loss of control involved a natural disaster or other event outside the control of the individual(s) responsible, such as a health event.
- Incidents classified as "delivery failure/misrouting" were deemed due to human failure if a shipment was delivered to the wrong address or location; was labeled improperly; contained more or less material than was specified in the invoice; was the result of a communication breakdown; or relevant individuals did not otherwise follow the proper procedures for shipping, receiving, or opening radioactive materials.
- In cases classified as "theft/stolen material," the incident report had to specifically mention whether the user failed to follow relevant regulations or company protocols at the time the theft occurred.
- Cases falling into all other categories listed under "Type of Incident" were linked to human failure if the incident report mentioned activities that fit the type of behavior detailed above.

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