April 2017

CNS Global Incidents and Trafficking Database

Tracking publicly reported incidents involving nuclear and other radioactive materials

2016 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

At the 2016 Nuclear Security Summit, world leaders called nuclear and radiological terrorism "one of the greatest challenges to international security."[1] However, there are no plans to hold additional summits, and prospects for sustained international cooperation at the highest level on nuclear and radiological security are uncertain. Ongoing conflicts worldwide, whether in Syria or Yemen, Mali or Ukraine, complicate security efforts in many countries. There is a continuing risk that other countries, facing leadership changes or fiscal constraints, might deprioritize nuclear and radiological security funding.

Yet the threat remains undiminished: the revelation in early 2016 that Islamic State operatives were monitoring a Belgian nuclear power plant suggests that terrorists continue to explore ways to access nuclear and other radioactive materials or sites.[2] As in previous years, almost half the incidents in the 2016 database would be suitable for use in a radiological dispersal device (RDD).[3] Clearly, radioactive materials, perhaps even including nuclear materials, are still within the reach of malicious individuals or groups.

In 2016, The James Martin Center for Nonproliferation Studies' (CNS) review of open source reports found a total of 143 incidents of nuclear or other radioactive materials outside of regulatory control, which occurred in 19 countries. Since CNS began tracking incidents in 2013, researchers have identified a total of 683 incidents occurring in 48 countries.

Incidents involving nuclear materials (uranium, plutonium, and thorium) are of special concern. In 2016, ten of these incidents occurred but none involved weapons-usable nuclear material. There were 53 reported incidents involving nuclear materials between 2013 and 2016.

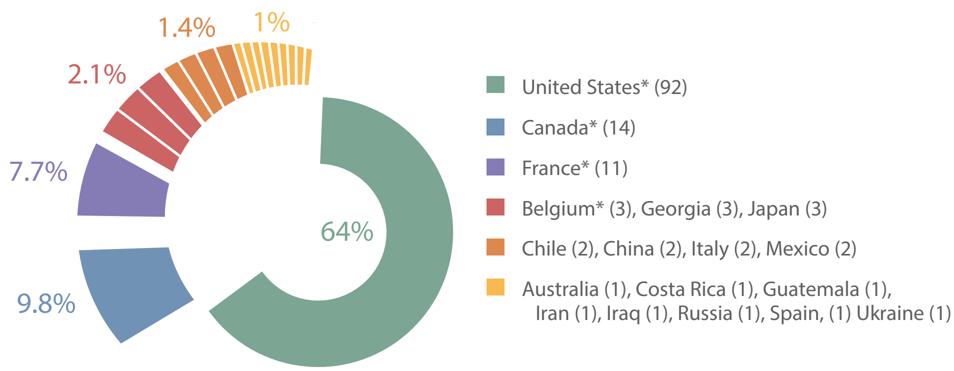
In 2016, few recorded incidents involved the most dangerous radioactive materials. The IAEA has a five-point categorization system for radioactive materials and sources, where a Category 1 source poses the greatest danger to human health. In addition to the type of radioactive material involved, the amount of material present in a source frequently affects what category it falls under. No reported Category 1 incidents and only three Category 2 source incidents occurred in 2016. From 2013 to 2016, four cases involved a Category 1 source, and 24 involved a Category 2 source. Although Categories 3-5 materials are considered by the IAEA to present a lower risk, in high enough quantities they still pose a significant risk. These lower category materials constituted the majority of 2016 incidents.

The 2016 data reinforces the trends identified in previous editions of the annual report. The consistency of these findings over four years lends additional weight to the policy recommendations expressed below.

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

The total incident count varies widely by country. This is partly because of countries' highly variable reporting and transparency. Very few countries routinely and systematically report all incidents involving the loss of radioactive material to the public. Those that do routinely publicly report incidents have the bulk of the incidents in this database: 86.7% of 2016 cases (124 incidents) occurred in the United States, Canada, France, Belgium, and Japan, the six countries that most routinely publish incidents online. CNS database entries from other countries are derived from case-by-case official reports or unofficial media accounts.

Figure 1. Reported Incidents for 2016



*The United States, Canada, France, Japan, South Korea and Belgium all systematically and publicly report incidents involving nuclear and other radioactive material.

The IAEA maintains a confidential Incident and Trafficking Database (ITDB), which is generated from voluntary reporting by countries. However, what countries report to the ITDB varies widely and there is no legally binding obligation to report the loss of even the most dangerous radioactive materials and sources to the ITDB. The IAEA publicly releases only a statistical summary of the ITDB, not details of individual incidents. Fragmented reporting, both in countries' confidential reports to the IAEA and in their public disclosures, makes it impossible to get an accurate picture of nuclear and radiological security worldwide.

Policy Recommendation: Develop a common standard for incident reporting which requires reporting Category 1 and 2 incidents; encourage wider reporting transparency

Past reports recommended that states adopt a universal reporting standard. However, a common standard is not enough if it remains entirely voluntary. At a minimum, governments should be legally required to report losses involving the most dangerous Category 1 and 2 radioactive materials. Greater public transparency in all reporting would enable analysts outside of the IAEA to better identify areas of concern and develop tailored policy solutions.

Key Finding 2: Transportation creates greatest vulnerabilities

Thefts made up around 27% of the 2016 incidents. Roughly 55% of these thefts occurred while the material was being transported. In most of these cases, it is unclear whether the thieves were specifically looking to steal radioactive material, or if it was incidental to vehicle or other equipment theft.

Among the thefts, the four cases of attempted illicit sale of radioactive material in 2016 are of greatest concern, as they demonstrate a continued interest by criminals in trafficking radioactive materials for profit. Three of the cases occurred in the country of Georgia, where two involved the attempted sale of depleted uranium, and the third involved the smuggling of cesium-137. A case in Ukraine involved the attempted sale of radioactive materials, including at least one strontium-90 source.

Policy Recommendation: Improve physical security measures; 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. State regulators should continue encouraging greater use of electronic tracking of vehicles and prototype radio frequency identification device (RFID) technology. Most states with dangerous sources already do this with Category 1 sources. However, enhanced security for Category 2 sources is not as universal. The creation of an IAEA Technical Guidance (T) document on the subject would encourage best practices sharing. State regulators should also make it illegal for users of radioactive materials to leave Category 1-3 sources unattended in vehicles.

Key Finding 3: Humans fail

Human failure played a role in 62 reported incidents in 2016, including most cases of loss and many incidents of theft. In many instances, published standards were not respected or were incorrectly applied, pointing to an insufficient security culture.

Policy Recommendation: Improve security culture

Weak security culture remains a problem. Regulatory agencies (or licensees themselves) should conduct personnel audits, assess existing protocols, and improve training and work conditions. Employees should also be trained to understand the reasons behind rules and regulations. Some progress of note is being made. The IAEA is creating guidance for states on developing security cultures within organizations responsible for nuclear or other radioactive materials, and the World Institute for Nuclear Security (WINS) provides resources to industry to improve security culture.

Key Finding 4: Alternative technologies exist

Many incidents involved devices which used radioactive materials for which there are non-radioactive options available (e.g., some cancer treatment machines).

Policy Recommendation: Encourage material replacement efforts

Where appropriate alternatives exist, policymakers should accelerate the replacement and end new manufacturing of devices containing radioactive material. A 2008 report from the National Academy of Sciences concluded that non-isotopic devices exist to fulfill nearly all Category 1 and 2 radioactive material applications.[4] For example, linear accelerators (LINACS) can be used to replace cancer treatment machines that use radioactive colbalt-60, and there are non-radioactive x-ray devices that could replace cesium-137 blood irradiators. However, progress implementing replacement efforts remains slow due to high costs, lack of awareness, and doubts about effectiveness.

Conclusions

The possibility of malicious actors obtaining nuclear or other radioactive material remains a significant threat. Governments, international organizations, and industry can improve security over nuclear and other radioactive materials by increasing reporting and its transparency to the public, investing in electronic tracking technologies, making devices containing radioactive materials easier to secure and transport, using alternative technologies to radioactive materials where feasible, and improving security culture.

I. Introduction

The consequences of a terrorist incident involving nuclear or other radioactive materials range from highly disruptive (in the case of a radiological dispersion device) to catastrophic (in the case of a nuclear device). The international community has launched numerous initiatives to reduce the risk that nuclear and other radioactive materials will fall into malicious hands. The Nuclear Security Summits, the last of which was held in 2016, were a forum for world leaders to meet, share best practices, and make formal commitments to improving nuclear security. Although the IAEA will continue to hold ministerial conferences on nuclear security, the end of the summit process may deprioritize efforts to improve the security of nuclear and other radioactive materials worldwide. This makes tracking incidents involving nuclear and other radioactive material more important than ever to increasing awareness of the threat and informing policymakers of options for ameliorating it.

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 that is generated from publicly available data and news reports, and which is freely available to anyone. This differs from the official Incidents and Trafficking Database (ITDB) maintained by the IAEA, which is generated exclusively from voluntary member state reporting, and whose full data is only available to the participating states' governments and certain international organizations.

The CNS database contains detailed information 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. The entire database is available for download by anyone at www.nti.org/trafficking.

The 2016 database contains 143 incidents. Trends remain consistent with data collected between 2013 and 2015.

- Losses represent about 37% of incidents, with 58 losses recorded
- Thefts constitute approximately 25% of incidents, with 40 cases reported
- Approximately 31% of incidents occurred during transport, with 45 cases reported.

As in previous years, the 2016 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, despite the fact that 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 nuclear and radiological terrorism. An improvised nuclear explosive device (IND) requires the acquisition of large (kilogram) quantities of weapons-usable nuclear material, such as highly enriched uranium or separated 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, such as half-life, radioactivity, portability, dispersibility, and availability.[5]

Nuclear Material

Between 2013 and 2016, reported cases involving nuclear material—defined as various forms (or isotopes) of uranium, plutonium, and thorium—accounted for 7.8% percent of the incidents in the database (53 cases). Of these, 10 cases took place in 2016. The breakdown of cases by isotope is presented in Table 1.

Table 1. Reported Incidents involving nuclear materials

Nuclear materials	Incidents, 2016	Incidents, 2013-2016
Uranium, total cases:	**8**	**42**
Depleted	5	16
Natural	0	7
Low-enriched uranium (LEU)	0	1
Highly-enriched uranium (HEU)	0	1
Unknown enrichment	3	17
U-233	0	0
Plutonium, total cases:	**0**	**4**
Plutonium-238 (Pu-238)	0	2
Plutonium-239 (Pu-239)	0	0
Unknown plutonium isotope	0	2
Thorium (Th), total cases:	**2**	**7**
Total, all nuclear materials:	**10**	**53**

In all but one of the reported cases from 2016 that involved nuclear materials, the material has been recovered. In case #2016643, a contractor for Oak Ridge National Laboratory mis-shipped depleted uranium, and four barrels of the depleted uranium remain missing.

The 2016 database contains no incidents involving weapons-usable nuclear material. It is unclear whether the low number of reported cases involving weapons-usable nuclear material is attributable to overall adequate security measures for such materials, or if cases are going unreported. Of the nuclear material trafficking cases that have been reported over the past four years, the majority have dealt with depleted uranium and non-weapons-usable material, such as scrap metal taken from abandoned nuclear facilities. For example, on April 18, 2016, Georgia's security agency reported the arrest of six men of Georgian and Armenian origin who were attempting to sell an unknown quantity of depleted uranium for $200 million (#2016607).

Although a high degree of attention is placed on all cases concerning weapons-usable material, it continues to be difficult to accurately assess the status of global nuclear security, due to the unknown number of unreported or undetected incidents.

Other Radioactive Material

The majority of cases reported in the CNS database involved non-nuclear radioactive material. While useless for an IND, some of this material would be suitable for a radiological device. In a radiological dispersion device (RDD), radioactive material is spread to contaminate an area of air, land, or water (e.g., through conventional explosives or an aerosol dispersion system such as a crop duster). The major consequences of an RDD would likely be public panic and a lengthy and expensive cleanup effort that could render important areas uninhabitable for a period of time (e.g., Manhattan), rather than extensive casualties.[6] Although many types of radioactive materials exist, only about a dozen exhibit the characteristics that qualify them as a serious RDD security threat, namely high radioactivity, portability, dispersibility, and availability.[7]

Between 2013 and 2016, 329 unique incidents, or 47.8% of cases, involved material of principal RDD concern. In 2016 alone, 68 cases (47.55%) involved materials of principal RDD concern (See Table 2). At least 153 incidents in the 2013 to 2016 dataset involved more than one radioactive material. It is therefore plausible that a terrorist RDD design would involve at least two materials of concern, which could complicate post-attack identification and remediation measures.

Table 2. Reported Incidents by material type[8]

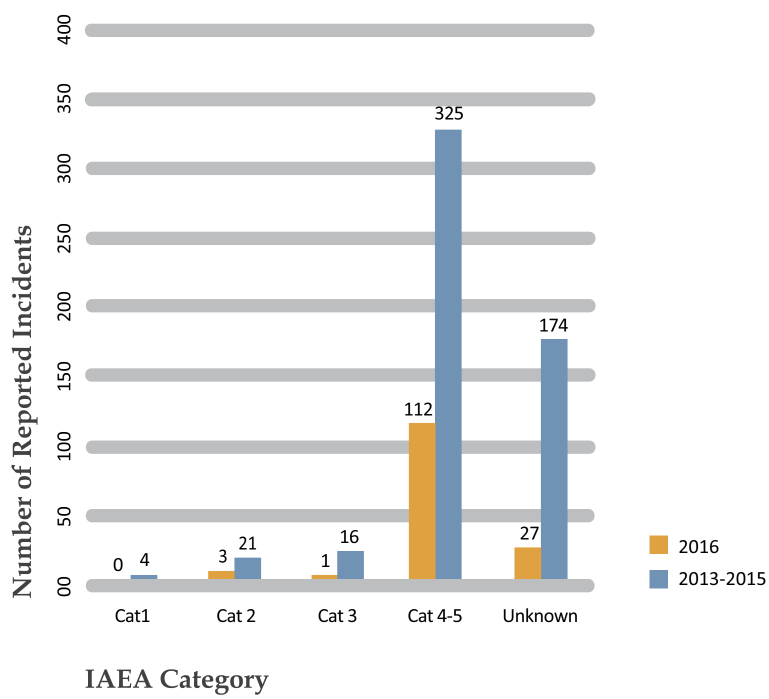
Material of principal RDD concern	Incidents, 2016	Incidents, all years
Cesium-137 (Cs-137)	39 to 40	191 to 194
Americium-241 (Am-241)	30 to 32	154 to 159
Iridium-192 (Ir-192)	8	41 to 42
Radium-226 (Ra-226)	5 to 6	32 to 36
Cobalt-60 (Co-60)	2	26
Strontium-90 (Sr-90) and its decay product, Yttrium-90 (Y-90)	8	21
Californium-252 (Cf-252)	0	4
Selenium-75 (Se-75)	1	3
Plutonium-238 (Pu-238)	0	2 to 4
Plutonium-239 (Pu-239)	0	0 to 2
Ytterbium-169 (Yb-169)	0	1
Thulium-170 (Tm-170)	0	0
Subtotal[9]	93 to 97	474 to 491
Total unique cases	**68 to 70**	**329 to 342**

A malicious actor with access to radioactive material could also misuse the material by exposing individuals to the radiation it emits, for example, by hiding an exposed source near a target.[10] By definition, and unlike an RDD, a radiological exposure device (RED) does not involve the dispersal of material and hence will not lead to widespread contamination.

An additional set of radiological terrorism or criminal threats involves what one group of experts has dubbed "inhalation, injection, and immersions (I^3) attacks."[11] These attacks involve a radioactive substance being forced into a victim's body to deliver a direct internal dose of radiation. Numerous radioactive materials that are not a serious RDD security threat are highly effective poisons if used in such a manner. This is because low-penetrating radioactive materials, namely alpha-emitters such as polonium-210, pose a minimal threat when outside the human body but are lethal even in minuscule quantities once internalized. This fact underscores the need to ensure that all radioactive material is well-regulated regardless of whether it is suitable in quantity or quality for an RDD or RED.

The IAEA categorizes radioactive sources according to their potential harm to human health 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).[12] 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, a large number of cases in the CNS database do not have a listed IAEA category. Of those that were categorized, few involve the most dangerous categories of radioactive materials. Figure 2 shows the breakdown of reported incidents by IAEA category.

Figure 2. Incidents by IAEA Category



Most cases with an assigned IAEA category involved Category 4 or 5 sources. Across the four-year reporting period, a total of four cases involved a Category 1 source; 24 incidents involved Category 2 sources; and 17 incidents involved Category 3 sources.

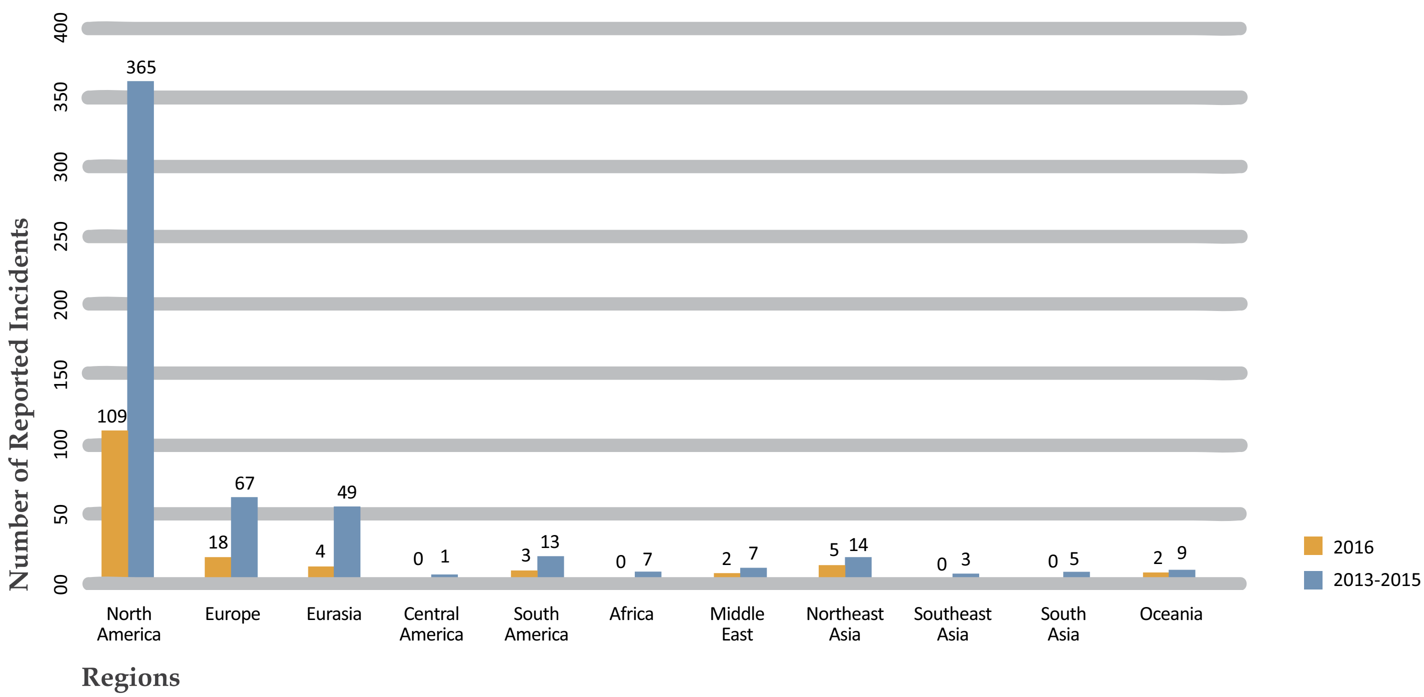
In 2016, no incidents involved a Category 1 source. Three incidents involved Category 2 sources, and one involved a Category 3 source. These four incidents involved industrial-use Iridium-192 sources and had been recovered by the time of reporting. The IAEA notes that recovery of the riskiest radioactive sources is given high priority and is often successful.[13] In response, terrorists might seek to acquire numerous low-category sources and cobble them together into an RDD, rather than attempting to divert more suitable Category 1 or 2 sources. An RDD constructed in this way, though likely to require intense clean-up efforts, would likely be less effective than one constructed from Category 1 or 2 sources.

III. Key Findings and Policy Implications

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

The CNS Database includes a total of 683 reported incidents in 48 countries, which occurred during the 2013 to 2016 reporting period. The newly added 2016 case subset consists of 143 incidents that occurred in 19 countries. The regional case breakdown is shown in Figure 3.

Figure 3. Reported Incidents by Region



A major reason for the disproportionate number of North American cases is that the region contains two of the six countries whose governments engage in systematic public reporting of individual incidents, the United States and Canada. Outside of North America, France, Belgium, Japan, and South Korea also systematically and publicly report incidents.[14] The cases from these six countries account for 86% of 2016 cases, and slightly fewer than 80% of the total cases between 2013 and 2016.

The Security Service of Ukraine publishes notices of trafficking cases, but does not publish non-trafficking losses.[15] Although in previous years Australia was listed among the countries which routinely publish detailed incident reports, the latest edition of Australia's end-of-year report covering 2015 incidents only included an aggregate number of cases, and there has thus far been no report covering 2016 incidents.[16] Such backsliding in transparency is counter to the need for countries to be more rather than less transparent about their incident totals.

In 2016, the United States reported the highest number of cases (92 cases, 64%); followed by Canada (14 cases, 9.8%); France (11 cases, 7.7%); Belgium/Georgia/Japan (3 cases each, 2.1% each); and Chile/China/Italy/Mexico (2 cases each, 1.4% each). Nine countries had a single case each in 2016: Australia, Costa Rica, Guatemala, Iran, Iraq, Peru, Russia, Spain, and Ukraine. See Figure 1 in the executive summary.

The incident distribution by country is roughly consistent with prior years, except that fewer Ukrainian and Russian cases were reported in 2016. The country breakdown for all 683 cases from the entire 2013 to 2016 database is as follows:

- U.S. (412 cases, 60%)
- Canada (54 cases, 7.9%)
- France (41 cases, 6.0%)
- Russia (19 cases, 2.8%)
- Ukraine (15 cases, 2.2%)
- Australia/Belgium/Japan (10 cases each, 1.5% each)
- Italy/Mexico/U.K. (7 cases each, 1.0% each)
- Georgia (6 cases, 0.88%)
- China/Kazakhstan/Poland (5 cases each, 0.73% each)
- Brazil/Chile/Moldova/South Korea (4 cases each, 0.59% each)
- Argentina/Israel/Lebanon/Peru/South Africa/Spain/Vietnam (3 cases each, 0.44% each)
- Algeria/Colombia/Costa Rica/Finland/India/Iran/Iraq/Lithuania/Macedonia/Slovakia/Sri Lanka (2 cases each, 0.29% each), and
- Austria/Belarus/Germany/Guatemala/Ireland/Latvia/Malta/Nepal/Nigeria/Sierra Leone/Turkey (1 case each, 0.14% each).

The majority of the cases over the past four years have consistently come out of comparatively wealthy industrialized democracies, which frequently have the most robust and transparent reporting mechanisms. The level of global reporting is noticeably inconsistent and presents a generally 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. However, in other cases, governments may not always catch incidents occurring on their territories, and if they do, they may choose not to publicly report them.

It is likely that many countries' security and regulatory agencies have internal data covering additional cases, but they do not consistently report this data to the public or the IAEA, especially for low-risk incidents and closed non-criminal cases. For example, Ukraine reported the results of two joint Ukraine-U.S. projects that retrieved ageing radiation sources from bankrupt enterprises. 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.[17] 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 20 times the number of cases in the entire CNS database.

Other governments may routinely report incidents to the IAEA confidentially, but such reporting is entirely voluntary, even for the highest risk radioactive materials and sources. Additionally, countries use their own discretion and interpretation to decide what types of incidents to report both publicly and to the IAEA's ITDB. For example, the United States systematically reports large numbers of missing tritium EXIT signs, while other high-reporting countries that presumably also use these ubiquitous devices do not.

Policy Recommendation: Develop a common standard for incident reporting which requires reporting Cat. 1 and 2 losses; encourage wider reporting transparency

There remains a need to address the information gap by creating a stronger common reporting standard for countries. Identifying and collectively agreeing on more detailed standardized criteria for what information should be reported would make reporting more consistent across countries, and could reduce countries' concerns about any possible repercussions from reporting incidents occurring on their territories. However, new standards must move beyond voluntary codes of conduct in regard to the most dangerous non-nuclear radioactive materials. Unless it becomes legally mandatory to report incidents involving the most dangerous materials, and information is made public at the soonest appropriate time, a common standard is not enough.

As one leading radiological security expert, George Moore notes, "[…] 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."[18] Moore recommends that states work through the IAEA to establish a mandatory reporting standard for Category 1 and 2 radioactive materials and sources. Given the immense danger posed by materials and sources in these categories, and their high suitability for radiological terrorism, there is a compelling argument for a legally binding reporting requirement, similar to the one that already exists for nuclear materials.

Improvements in the transparency of governmental incident reporting worldwide are essential to better understanding and improving the security of nuclear and other radioactive materials. When all countries publicly report incidents and trafficking cases based on the same criteria, analysts will be able to assess where security policies or practices can be improved.

Universal transparent reporting will not happen overnight, so at a minimum, agreeing on common standards for the types of incidents to report and agreeing to treat the losses of Category 1 and 2 materials as legally mandatory to report would be excellent first steps.

Key Finding 2: Transportation creates greatest vulnerabilities

Cases of theft and trafficking deserve special scrutiny because they involve a malicious individual deliberately attempting to circumvent security measures. Successful thefts involve serious lapses in the security of nuclear and other radioactive materials, even though thieves may not have specifically targeted these materials. For example, a thief may steal a truck without knowing that it is carrying radioactive materials, but such incidents nonetheless point to major transportation security vulnerabilities. Thefts accounted for 40 incidents (28% of cases) in 2016, and 167 incidents (25% of cases) in the overall 2013 to 2016 reporting period.

The CNS database categorizes thefts by type, including: theft from an individual; theft from a fixed site; theft from a vehicle (where the vehicle itself is not stolen); theft with a vehicle (vehicle stolen with source inside); and unknown. Theft cases are also categorized by whether at least one individual was attending the source at the time of theft, or whether the source was left unattended (See Figures 4 and 5). This granular categorization of thefts illustrates how thieves typically obtain sources. Knowing how many cases involved theft of an attended source provides a good estimate for the number of thieves that were undeterred by the presence of an individual, and therefore threatened or used violence, or were likely willing to do so.

Of the 170 thefts recorded between 2013 and 2016 in the CNS database, over twice as many thefts occurred during transit as from a fixed location (in cases where the information is known). In almost 90% of thefts, the material was left unattended (in cases where this information is known).[19] Radioactive materials therefore appear to be most vulnerable to theft during transit, and particularly when left unattended.

Trafficking

In 2016, there were 4 definitive cases of trafficking of nuclear or other radioactive materials. Three of these cases ended in arrests and it is unclear from available information how the fourth ended.

- On January 11, 2016, Georgia's security agency reported that it had arrested three men for attempting to sell an unknown quantity of cesium-137 for $100,000 (#2016578). The report did not state whether the men had a buyer for the material or where the material came from.

Figure 4: Types of Thefts

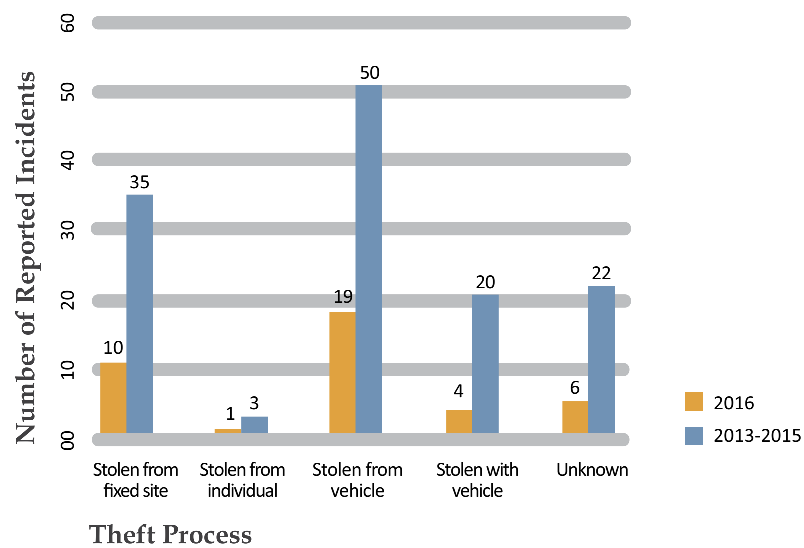
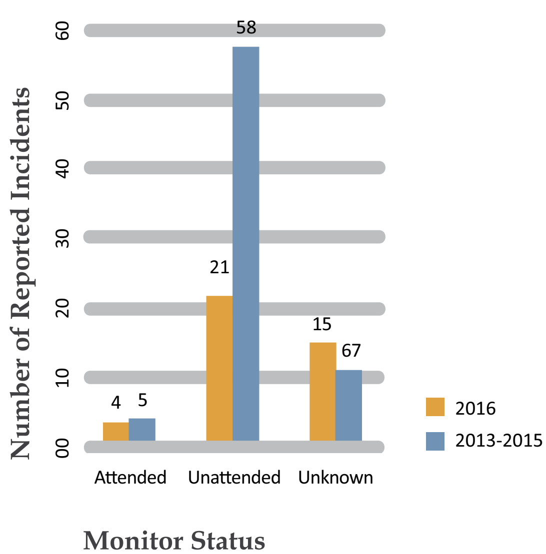


Figure 5: Whether an individual was present at the time of a theft



- In March 2016, Ukrainian authorities searched a warehouse belonging to an unnamed businessman and seized a crate containing radioactive materials, including at least one strontium-90 source (#2016613). The report indicated that the owner of the warehouse had plans to illegally sell the material. Ukrainian authorities did not state whether the individual had a buyer in place or where the material came from. The report also did not state whether the warehouse owner was arrested.
- On April 18, 2016, Georgia's security agency reported the arrest of six men of Georgian and Armenian origin who were attempting to sell an unknown quantity of depleted uranium for $200 million (#2016607). Authorities also located a specially designed container for transportation of significant quantities of uranium at the residence of one of the individuals arrested. Georgian authorities did not state where the material came from or whether the individuals had a buyer ready.
- On April 28, 2016, Georgian authorities announced they had arrested five men who were attempting to sell 1.665 kilograms of depleted uranium for $3 million (#2016608). As with previous cases, the Georgian security services did not release information regarding the origin of the material, nor did they state whether the individuals had a buyer in place.[20]

The three Georgian cases appear to have been the result of a crackdown by Georgian authorities on traffickers. While the reports are classified as separate incidents, their proximity and the fact that two of them involved the same material suggests that they may have been related. The Ukrainian case appears unconnected to the Georgian cases and involved entirely different material. At the moment, there is not enough information to state whether the individual involved was a part of a larger network or was acting independently.

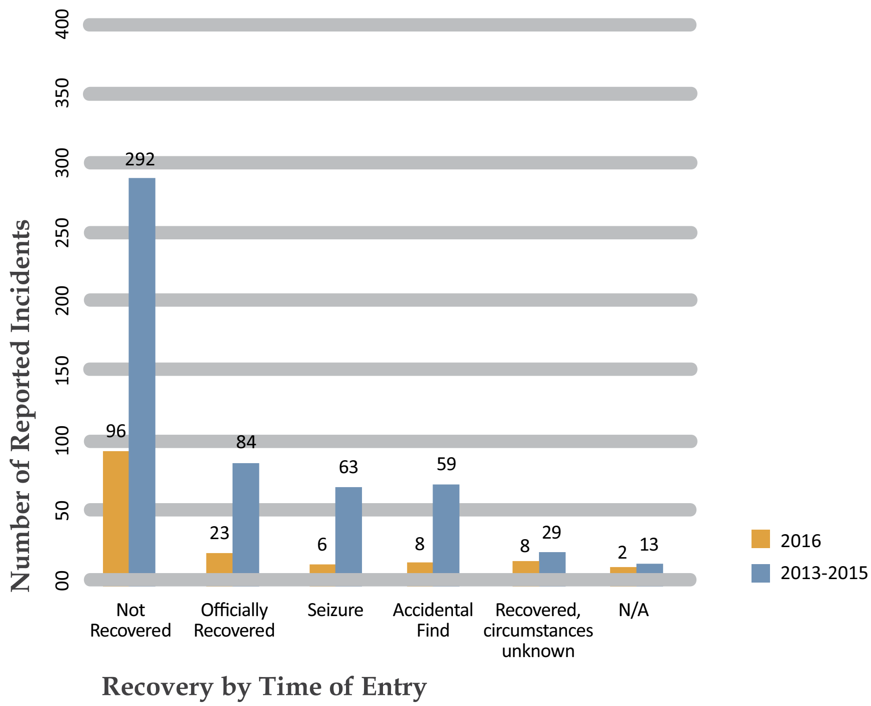
Recovery Data

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 that have fallen out of regulatory control, reporting whether they are recovered can be discretionary.

A recognized limitation of the CNS database is that entries are not routinely revisited once they are input, even in the unlikely event that updated information becomes 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 can only be interpreted as the minimum number of sources which were actually recovered. Figure 6 sorts incidents by whether the material was recovered, and, for those that were, the manner of recovery.

Recovery measures are often time consuming and expensive. Response measures included offering rewards for the device's return, notifying local vendors, alerting surrounding districts, informing local media, inventory searches, interviews, canvassing areas with detectors, and responding to anonymous tips. Sometimes radiation monitoring portals or the public detect a missing source by chance. Source recovery is an arduous process and not guaranteed to succeed. Given the high costs of recovery, it pays to invest in measures that prevent a source from falling out of regulatory control.

Figure 6: If & How Material Was Recovered



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

The difficulty and expense of official recovery efforts highlights the value of enhanced preventive measures, from the most basic physical security measures to electronic tracking technology. Much of the regulatory and policy focus remains on securing Category 1-3 sources, which are the most dangerous sources.[21] Following the 2014 Nuclear Security Summit, a group of 23 states committed to securing all Category 1 sources within their territories by 2016.[22] So far, 22 out of 23 states have followed through.[23]

A key part of this commitment was developing a system to track all mobile Category 1 sources. Most of the 23 states did so by developing electronic tracking systems.[24] In addition, the United States and South Korea have worked to expand their systems to track Category 2 sources within their territories.[25]

For example, in the United States in 2005, the U.S. Department of Energy commissioned Argonne National Laboratory to develop customized radio frequency identification (RFID) technology to continuously track nuclear and other radioactive materials during storage, transportation and disposal.[26] Employed in 2009, the ST-676 RFID tag employs sensors that "monitor the temperature, humidity and shock to which the tag is exposed."[27] Made to track and secure cargo containers, the RFID tag also includes a locking mechanism, acting as an additional security measure.[28]

The Mobile Source Transit Security System (MSTS), funded by the U.S. National Nuclear Security Administration, also employs radio frequency identification technology. Currently in the pilot stages, the MSTS uses Bluetooth, Wifi, and satellite-based GPS tracking to monitor portable well-logging equipment containing sealed radioactive sources including Cesium-137 and Americium-241.[29] Notably, the MSTS employs both an "etag," which is attached directly to the source's shield and includes a "built-in tamper-detection sensor," as well as an "rtag," used to measure levels of radioactivity within the vehicle and thereby detect the source's presence.[30]

There has been little activity globally to expand tracking technology to Category 3, 4, and 5 sources. Efforts have been hampered by the much larger number of devices in circulation in these categories. The vast majority of incidents recorded in the dataset involve Category 4 and 5 sources. Technologies such as GPS and RFID provide a relatively cheap means of tracking and securing Category 4 and 5 sources, which do not pose the same security risks as Category 1-3 sources. Though the security risks are much lower, devices containing Category 4 and 5 sources can be expensive to replace if lost or stolen. Those responsible for such devices may find it worth employing electronic tracking technology if only to save themselves money, thus also greatly enhancing radioactive materials security.[31]

An increase in the gap between "thefts with vehicle" (4 in 2016; 10 in 2015) and "thefts from vehicle" in 2016 (20 in 2016; 12 in 2015) indicates a greater need for direct source tracking rather than general GPS tracking for vehicles transporting radioactive sources. Cases in the 2016 dataset make clear that GPS tracking on the vehicle alone is not sufficient. When a truck containing a moisture density gauge with a sealed Cs-137 and Am-241 source was stolen off a construction site near San Juan, Puerto Rico, the vehicle was recovered within a day; however the source remains missing (#2015365). In such a case, direct source tracking would have been useful to recovering the device.

Additionally, regulatory agencies such as the U.S. Nuclear Regulatory Commission do not currently require the most dangerous radioactive materials to be attended while in transit. Standards and training concerning the security of radioactive materials while in transit are clearly inadequate, given the number of thefts that occur involving unattended materials and sources. Governments should seriously consider making it illegal to leave Category 1-3 radioactive materials and sources unattended while in transit. Enhanced training on this best practice paired with appropriate legal penalties could deter individuals from leaving Category 1-3 sources and materials unattended while in transit, thus mitigating the risk they will be stolen.

Key Finding 3: Humans Fail

IIn 2016, 62 incidents (43.3% of total cases) were at least partially caused by carelessness, inattention to appropriate procedures, or other behaviors that fall under the heading of "human failure." Primarily associated with cases involving lost nuclear or other radioactive material, human failure also contributed to four incidents of theft (10% of total).

This indicates the need for a stronger security culture. Improved training should impart to employees responsible for radioactive materials and sources an understanding of why following what may seem like arbitrary regulations is so important. Nearly all of the reported loss cases could have been avoided if the individuals responsible for handling the material had adhered to safety and security best practices while the material or source was in their care. Incomplete reporting and lax inventory controls are among the leading causes of reported loss cases. For example, in September 2016, a static eliminator gauge (used to eliminate built up static electricity) containing a Polonium-210 source was discovered missing after the licensee conducted a detailed inventory and was unable to find the device. The licensee stated that the device likely went missing five years before in 2011. The licensee was also unaware that reporting the loss was required (#2016689). Additionally, human failure while transporting sources was a leading cause of loss cases in the 2016 database. In these incidents, workers failed to follow proper protocols while transporting a device. For example, in April 2016 a radiography crew did not secure an industrial radiography camera in the tailgate of their pickup truck, and the device fell out of the back of the truck and landed in the road. The device was recovered after an individual who witnessed the event called the proper authorities (#2016602).

Inattention to security measures also contributed to 10% of thefts, many of which involved cases in which proper storage would have prevented the theft. Frequently, the stolen radioactive material or device was left unattended or improperly secured in a worker's car, or in an unsecure location at a job site. In one example, a technician returned home with a moisture density gauge containing a cesium and americium source in the backseat of the car. The next morning, the individual noticed that the car had been broken into and the device stolen. A few days later the device was found in a nearby vacant lot (#2016617).

Human failure also contributed to material loss through misrouted shipping. For example, in March 2016, 23 Ir-192 sources (Category 2) shipped from Burlington, MA to Prague, the Czech Republic failed to arrive. The package was eventually located at the Prague airport and successfully delivered to its intended destination (#2016573).

Policy Recommendation: Improve security culture

Human error is unavoidable. However, the rate at which errors occur and the consequences of these errors are controllable. Proper employee training that inculcates a respect for security regulations, an understanding of the rationale behind protocols, and proper working conditions help employees to follow regulations and can reduce human failure.

In 2008, the IAEA released a guide on nuclear security culture titled *Nuclear Security Culture: Implementing Guide.*[32] This guide focused exclusively on nuclear facilities and materials. Efforts are underway to broaden security culture to facilities and organizations in charge of non-nuclear radioactive materials. For example, the IAEA is in the process of drafting a report focusing on the broader application of security culture. This report, titled, Enhancing Nuclear Security Culture in Organizations Associated with Nuclear and/or Radioactive Material was released in July 2016 to solicit comments from member states.[33] The report is meant to serve as a guide for implementing a strong culture of security, not only in institutions responsible for nuclear materials, but also in those which possess other radioactive materials or sources. Regulatory agencies should encourage licensees to adopt these practices where appropriate.

The data shows that human failure is still a problem and that the security culture associated with the handling of low-category radioactive materials and sources is insufficient. Policies should focus on understanding why the application of existing material protocols for low-category sources is failing. While it may be that stricter regulations or punishments for noncompliance are necessary, the priority should be to understand why existing regulations are not being followed. Post-incident interviews are invaluable for determining what went wrong. However, no structured interview data exists in the public domain for incidents involving radioactive materials and sources. Regulatory agencies should therefore consider working to develop and publicize post-incident interview standards.

Key Finding 4: Material Replacement

Well over half of the total incidents captured in the entire 2013 to 2016 database involved radioactive sources or devices used in industrial and medical applications (320 and 102 cases, respectively, representing 62% of the total incidents). The 2016 cases followed the same trend, with 65% of incidents involving a radioactive source or device used for industrial or medical purposes, as shown in Figure 7.

Select industrial and medical applications sometimes require high doses of penetrating radiation. The IAEA Category 1 through 3 radioactive sources involved in documented incidents comprised either industrial or medical sources.

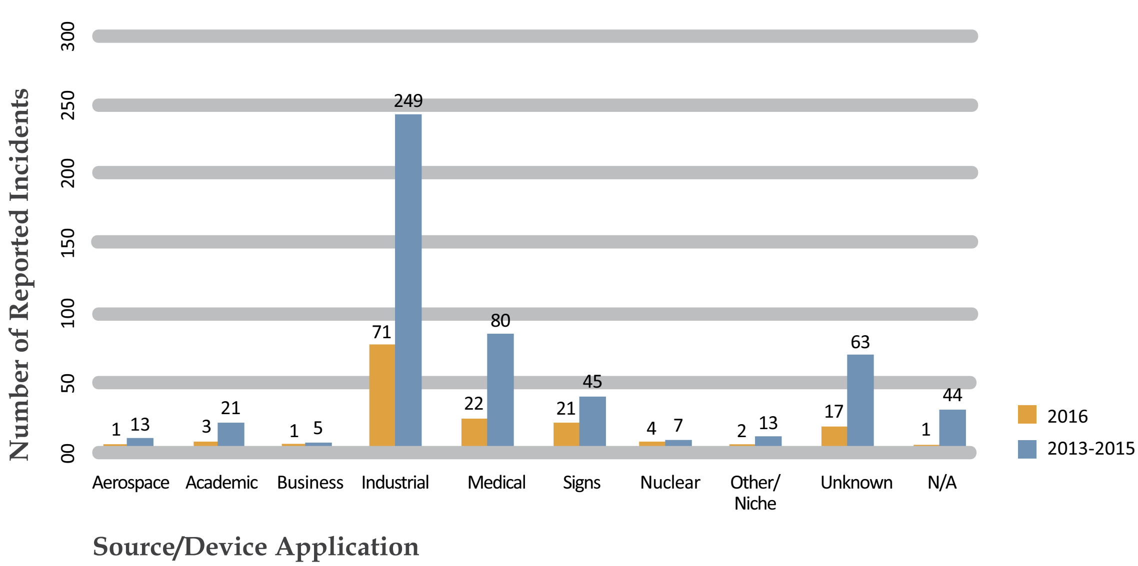
Policy Recommendation: Governments should encourage replacement efforts

Minimizing the use of dangerous radioactive materials (i.e. Category 1 and 2 sources) is among the most effective ways to reduce the likelihood of terrorists acquiring necessary materials for an RDD. According to a 2008 National Academy of Sciences (NAS) report, non-isotopic replacements "exist for nearly all applications of Category 1 and 2 [radioactive] sources."[34] For example, Cobalt-60 is often used in machines to treat cancer, but also poses a high terrorism risk. In December 2013, a truck carrying a large amount of Cobalt-60 was hijacked. Following an extensive manhunt, the perpetrators were arrested and the material was recovered. The Cobalt-60 had been intended for use in a radiation therapy machine. However, linear accelerators (LINACs), which do not involve a radioactive source, are suitable replacements and their risk of misuse is lower.[35] In higher GDP countries, LINACs have almost entirely replaced Cobalt-60 sources. In lower GDP countries, new strategies are needed. Since the publication of the *2015 CNS Trafficking Report,* a paper by Miles Pomper, Ferenc Dalnoki-Veress, and George Moore titled *Treatment, Not Terror: Strategies to Enhance External Beam Cancer Therapy in Developing Countries While Permanently Reducing the Risk of Radiological Terrorism* examined this problem.[36] In addition to Colbalt-60, Cesium-137 is a dangerous radioactive source regularly used in medical equipment, such as blood irradiators. However, there are now alternative technologies available to hospitals and healthcare providers. For example, in 2012, the U.S. Food and Drug Administration approved the use of non-radioactive x-ray devices for sterilizing blood, and there are currently two types of non-radioactive devices available.[37]

The United States has been working with the IAEA and other countries to explore available alternatives for high-risk radioactive materials. At the 2016 Nuclear Security Summit, the United States, along with twenty-seven other nations and INTERPOL, released a joint statement on *Strengthening the Security of High Activity Sealed Radioactive Sources (HASS)*. The statement reiterates that specific medical and industrial applications of dangerous sources may be replaced with "technologies based on sources of lower activity and, in some specific cases, no radioactive sealed sources at all."[38] International research and development projects are in pursuit of such technologies, with the goal of reducing the total number of Category 1 and 2 sources in use.

A 2014 Nuclear Regulatory Commission report highlighted a lack of awareness, concern over the cost, and concerns over effectiveness as major road blocks to adopting alternative technologies.[39]

Figure 7: Source or Device Application



Cost

A July 2015 *CNS Occasional Paper* outlined different methods for addressing cost concerns. These include direct government funding for the adoption of alternative technologies, tax breaks where it is viable, and adjustment of liability rates to reflect the danger of accidents or misuse involving radioactive sources and materials.[40] These approaches are especially appropriate for wealthier countries. For example, the National Nuclear Security Administration's (NNSA) Cesium Irradiator Replacement Program (CIRP) gives end-users, primarily hospitals, a financial incentive to replace Cesium-137 irradiators with x-ray irradiators and dispose of Cesium-137 irradiators at NNSA sites.[41]

In a December 2016 report, the U.S. National Science and Technology Council (NSTC) suggested financial incentives could overcome these concerns.[42] The 2016 NSTC best practices guide urges Federal agencies to establish grant programs to conduct the clinical trials needed for alternative technologies, to create internal policies against purchasing new high-activity source devices (where appropriate), and policies to phase out existing high-activity source devices.[43] The report also directs agencies to provide training on non-radioisotopic devices to increase the number of end-users able to transition and to facilitate the growth of the next generation of users.

Addressing cost in poorer countries is much more difficult. Most remaining cobalt-60 machines are used in middle and low income countries.[44] *Treatment, Not Terror* examined several strategies tailored to the developing world. The paper suggests a combination of approaches such as donor support, developing cheaper LINACs, selling refurbished LINACs at a lower cost, and encouraging regional bodies/states to buy in bulk.[45] The goal is to bring cancer treatment to lower income states while also reducing the risk of radiological terrorism.

Efficacy

In blood irradiation, x-ray and UV systems have proven to be viable replacements for Cs-137 irradiators. Newer models of x-ray irradiators are more streamlined, require no external cooling, and have longer operational lifespans. Some UV systems still require FDA approval for certain applications, and source end-users are reluctant to transition to alternative technologies.[46][47]

For well logging, a technique vital to the oil and gas industry which employs Category 2 and 3 sources, many non-radioisotopic technologies exist or are in development. However more must be done to make these technologies as efficient as devices containing Category 1 and 2 sealed sources.[48] The Department of Energy and U.S. national laboratories are working with the industry to try to overcome replacement barriers. One of the biggest challenges is the fact that "[…] well log analysis relies on a large body of data that has been accumulated...using Am-Be [radioactive] sources."[49] Similar quantities of data must be collected using non-radioactive sources for the industry to have the data to back up use of the new technologies.

Awareness

Government agencies and commercial developers of replacement technologies should make source end-users aware of the existence of alternatives. Government agencies can make use of internet-enabled platforms, including virtual meeting spaces and social media, to promote alternative technologies and to learn from source end-users.[50]

IV. Conclusion

As the CNS database enters its fifth year of collecting information on nuclear and other radioactive materials outside of regulatory control, it is clear that radioactive materials security efforts still have a long way to go. Inconsistent and opaque reporting standards across countries, human failure, inadequate physical security measures, and poor security culture are common themes found throughout the past four years of global incident data.
As discussed in Key Finding 1, most governments do not publicly report information on incidents that occur within their territory, which obscures the extent of the problem.

The frequency with which radioactive materials and equipment are misdirected, lost, or stolen is of serious concern. Furthermore, many of these incidents could have been prevented had commonsense security and safety measures been implemented, such as conducting regular inventories, properly securing items, and not leaving items unattended. Human failure played a significant role in the 2016 incidents. More effective training, particularly to foster a strong security culture among users of radioactive materials and sources, is vital to reducing these cases. Employing electronic tracking technologies such as RFID would in turn make it easier to track, and when necessary, recover radioactive materials and sources. Finally, national governments should consider making it illegal to leave the most dangerous radioactive materials unattended while in transit.

The most effective way to prevent radioactive terrorism is to prevent terrorists from accessing the necessary materials. Reducing the availability of the most dangerous radioactive materials and sources is especially crucial in this regard. Solutions exist to replace many of the most dangerous sources (Category 1 and 2) with safer alternatives. This vital next step in improving radioactive materials security would be practicable to implement if governments prioritize providing financial and regulatory incentives to facilitate device replacement.

Incidents involving nuclear or other radioactive materials outside of regulatory control represent a major public safety and security issue. Nuclear and radiological terrorism remains a serious global threat, and requires sustained engagement by governments, international organizations, regulatory agencies, and the businesses and individuals who are the end-users of nuclear and other radioactive materials.

V. Methodology

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

- The database includes incidents reported January 1, 2013 through December 31, 2016.
- CNS researchers conducted global searches in 14 major languages. Use of these languages also 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 subsequent subcategories are explained in the Category Definitions section of the database.

Past editions of the database identified “human negligence” as a cause for many incidents. Because “negligence” carries a specific meaning in criminal law that does not exactly correspond to all cases described in the report, CNS has elected to replace it with the term “human failure” as defined below. Incidents identified as linked to human failure are not classified as such in the database itself. Incidents are examined prior to writing this report to see if they are linked to human failure.

The following guidelines were used to determine whether human failure was a contributing factor in an incident:

- Human failure was defined as a lack of reasonable care or attention to maintaining control over radioactive materials, including any failure to follow relevant regulations or company procedures governing the use, storage, shipment, receipt, or disposal of radioactive materials.

- 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 events 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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