LA-UR 07-3686 Nefarious Uses of Radioactive Materials

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The November 2006 death of Alexander Litvinenko through the ingestion of ^{210}Po (polonium-210) has reignited the debate concerning the possibility of future malicious use of radioactive materials. However, before making any assumptions about the impact of this incident, based upon the media frenzy surrounding the case, it would be prudent to look at past incidents in order to put it in perspective. This paper uses several moderately restricted and open-source databases, and open-source case research to determine the effectiveness of the research community's ability to trace and trend past radiological diversion from regulatory control.

Background:

Although the investigation of the Litvinenko case is ongoing, there are a significant number of past cases of diversion of radioactive materials that could be referenced to assist trending and investigating future radiological threats. A large variety of disturbing and rarely reported cases of interest arose throughout the process of this research, and several unusual cases were unreported the databases.[1]

One of the most disturbing cases was a child abuse case in 1972 and involved a father placing ^{137}Cs pellets in his 13-year-old son's headphones, in his pillow, and in a sock next to his genitals while he slept, for a total of eight exposures, causing severe lesions and castration. The child underwent over 16 operations with numerous skin grafts. The motives of this case were unknown, and the assumption was that the father was mentally disturbed

[1] Some details of cases are purposely omitted by request from the database providers or out of concern for the privacy and security of those involved in the incidents.

after a recent divorce.[2] This case did not appear in any of the databases, and as a result of this research, has now been added to a couple of them.

Another case unreported in the databases involved a woman who attempted to self-inflicted an abortion using a medical x-ray unit. Although Pennsylvania state records on the case were impossible to procure, knowledge of the event was obtained through a research paper and conversations with the author of the paper, who was a former expert in the radiation control program in Pennsylvania.[3]

An attempt to murder an associate using a gamma emitter occurred in China in 2002 when a disgruntled worker placed ^{192}Ir pellets in the ceiling panels above a business rival. This incident caused acute radiation symptoms in 74 hospital staff members, including a near miscarriage, and an untold fate for the targeted business man and his associates.[4] The initial symptoms experienced by the intended victim were severe and included memory loss, fatigue, loss of appetite, headaches, vomiting, and bleeding gums.

All of the databases in this research cited one of the most ironic methods of revenge. It occurred in 1999 when a lab technician smeared a radioactive substance (Phosphorous-32) on his lab partner's chair because he uncouthly believed that because his lips were tingling that his she had tried to poison him first.[5]

In 1996, in Suffolk County, New York, two men were charged with conspiracy to commit murder using five canisters of radium that had been seized by authorities. This case

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[2] Collins, V. P., and M.E. Gaulden. "A Case of Child Abuse by Radiation Exposure." In: The Medical Basis for Radiation Accident Preparedness. KF Hubner, and SA Fry, Eds. 1980. New York: Elsevier North Holland Inc.

[3] Lubenau, Joel O., and Daniel J. Strom. "Safety and Security of Radiation Sources in the Aftermath of 11 September 2001." Aug. 2002. Health Physics. Vol. 83. No. 2.

[4] Hamid Mohtadi and Antu Murshid, "A Global Chronology of Incidents of Chemical, Biological, Radioactive and Nuclear Attacks: 1950–2005." National Center for Food Protection and Defense. July 7 2006.

[5] "Lab rage radiation fallout." Australia. Hobart Mercury. 21 Aug. 1999.

was a plot to assassinate two county officials, with the plan being to contaminate the victims' homes, cars, and food.[6]

Even the media, which has incessantly swarmed the Litvinenko case, as if it were a new phenomenon, is not always innocent. In an October 1992 case, a few plutonium "buttons" were reputed to be placed by journalists in a hotel room in Sofia Bulgaria. The presumed motive was that a journalist put the sources in the room to create false headlines.[7]

Murder as a motive is also not unique to the Litvinenko case. One fascinating case occurred in an unstated "Western" state and involved a scientist planting a powerful radioactive source inside his supervisor's watch as a means of gaining a promotion to his supervisor's position upon his death.[8]

Foreign Language Sources:

In addition to English-based open-source material, information was obtained from Russian source material. For example, a Russian medical journal shed light on the type of source that was used to kill Vladimir Kaplun in 1993. Although most of the databases reported the Kaplun incident, they were unable to pinpoint the actual radioactive source used to murder him. However, the Russian medical journal provided intricate details, such as the fact that isotope used was a cesium source was placed inside the back of his seat, resulting in exposure to internal organs and death due to profound blood loss from multiple ulcers in the stomach. The Russian journal provided an entire medical case history, with

[6] "Two Individuals Charged with Conspiracy to Commit Murder Involving Radioactive Material (Radium)." U.S. Nuclear Regulatory Commission Preliminary Notice of Event or Unusual Occurrence. PNO-I-96-043. June 14, 1996.

[7] Mohtadi, Hamid, and Antu Murshid. "A Global Chronology of Incidents of Chemical, Biological, Radioactive and Nuclear Attacks: 1950-2005." National Center for Food Protection and Defense. Jul. 7, 2006.

[8] Lyudmila, Zaitseva, and Kevin Hand. "Nuclear Smuggling Chains: Suppliers, Intermediaries, and End-Users." American Behavioral Scientist. Vol. 46. No. 6. Feb. 2003.

diagrams, that could not be found in any other source material.[9] Not too long afterward, a similar attempt occurred at another office in Irkutsk.[7]

Another Russian source provided unique cases involving the placement of radioactive material in a boss's hat, radioactive ink blotter placed on a banker's desk, and children stealing radioactive pellets and subsequently dying of radiation poisoning.[10]

The abovementioned cases are a mere sampling of far more cases that go back to the 1960s—with varying intentions and radioactive materials, that were uncovered during the course of this research.

Attractiveness of radioisotopes:

Isotope	Type	Emits	Half-Life
H-3 (helium)	Industrial	β	12.3 y
P-32 (phosphorous)	Medical	β	14.3 d
Co-60 (cobalt)	Industrial	γ, β	5.3 y
Ge-68 (germanium)	Medical	γ, β	18.9 min
Sr-90 (strontium)	Industrial	β	28.8 y
I-125 (iodine)	Medical	β	9.7 d
I-131	Medical	γ, β	8.0 d
Cs-137 (cesium)	Industrial	γ, β	30 y
Ir-192 (iridium)	Industrial	γ, β	73.8 d
Po-210 (polonium)	Industrial	α, γ	138 d
Ra-226	NORM*	α, γ	1600 y
Th-232	NORM	α, γ	1.4×10^{10} y
U-235 (HEU**)	Nuclear	α, γ	7×10^{8} y
U-238	NORM	α, γ	4.5×10^{9} y
Pu-239	Nuclear	α, γ, n	24110 y
Am-241	Industrial	γ, α	432.2 y

* NORM - Naturally occurring radioactive material
**HEU - Highly enriched uranium
Emitters: α: Alpha, β: Beta, γ: Gamma, n: Neutron

Table 2: Characteristics of Radioisotopes from Various Databases

[9] Gogin, E.E., et al. " A Case of an Attempt on the Life of an Individual by the Use of a Gamma Irradiator." Moscow, Russia. Terapevticheskii arkhiv. Vol. 66. Issue 7. pp. 89–91. 1994.
[10] Kharlamova, Tatyana. "Dzhini Iz Butylki Vpushchen. Shutit S Nim Ne Stoit." Moscow, Russia. Rossiskaya Gazeta. p.8. 28 May 1996

When discussing the misuse of radioisotopes, it is important to understand the reasons why certain isotopes are more attractive than others for specific purposes. A gamma emitter's ability to penetrate most materials and its relatively long half-lifee are attractive features for someone seeking a deadly source that will not have to be in direct contact with the intended target. Radiography and teletherapy sources are examples ofstrong gamma emitters. Industrial radiography sources are fairly common and are susceptible to theft because of their relatively small size. Moisture/density gauges, which typically contain combinations of ^{137}Cs (cesium), ^{252}Cf (californium) or AmBe (americium/ beryllium), are also common and small. According to the databases used in this research, gamma sources are the most commonly misused radioactive material, and cesium—a common industrial source—has been the most frequently reported misused radioisotope in all but one of the databases. According to the IAEA, "radioactive sources used in industrial radiography, radiotherapy, industrial irradiators, and thermoelectric generators are those that are the most significant from a safety and security standpoint."[11] Many of the most severe cases of misuse found in the databases were perpetrated by a person with either direct access to the material or the ability to get a license to obtain material. Direct access to the material makes industrial sources the most vulnerable and desirable targets for misuse. Although the handling and transport of gamma emitters may also be dangerous to the perpetrator—such as a terrorist—a terrorist is likely to be risk averse to the consequences of exposure to radiation without a barrier. Depending on the activity level of the sources, shielding can also be achieved with minimal difficulty, thus sparing exposure to the perpetrator.

The few cases of suicide (see Figure 2) found in the databases demonstrate the unusual choice of gamma emitters as a suicide method. It is unclear why someone would

[11] "Inadequate Control of World's Radioactive Sources." IAEA Press Release 2002/09.Vienna. June 24, 2002.

choose to commit suicide in this manner, unless the thought was simply that high enough amounts of radiation are deadly. One suicide, listed in Johnston's Archive, in the USSR in 1960, it took a man 18 days of incessant pain to finally die. In actuality, external exposure to an extremely high dose of radiation from a source such as cesium would first result in extreme confusion and nervousness, nausea, vomiting, diarrhea, loss of consciousness, and burning sensations of the skin.[12] At very high doses, these symptoms might last from a few minutes to a few hours, and after a brief latency period, would soon be followed by the patient going into convulsions and then into a coma. However, at lower lethal doses death might not occur (depending on the dose) until days or even weeks after the initial exposure.

Isotopes used in nuclear medicine procedures are mostly beta and alpha emitters, which have relatively short half-lives so they don't remain in the patient's body for much longer than the procedure. Their short half-lives also make the alpha and beta emitters harder to stockpile until enough has been accumulated for the desired misuse. Additionally, alpha and beta emitters used in nuclear medicine procedures do not have the penetration capability of gamma emitters and typically only emit radiation into a specifically targeted area. Therefore, the short half-lives, impenetrability, and specific nature of emission of alpha and beta sources make them fairly unattractive for misuse. The databases reflected this position, showing very few cases using medical isotopes.

The databases cite multiple incidents of the ingestion of radio-nuclides, such as ^{32}P (phosphorus); however, mortality resulting from the ingestion of any alpha or beta emitters was extremely rare. On the other hand, in the now-notorious Litvinenko case, ^{210}Po was used with the rare goal of internal contamination. Polonium worked well because it was mainly an alpha emitter with a half-life that was longer than the typical nuclear medicine isotope,

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[12] "Acute Radiation Syndrome, a Fact Sheet for Physicians." Centers for Disease Control and Prevention. May 28, 2007. Website: http://www.bt.cdc.gov/radiation/arsphysicianfactsheet.asp .

although it was still measured in days. Polonium was also difficult to detect in the patient's body, making treatment and detection very complicated tasks. Therefore, although the difficulty of detection and the longer half-life of polonium made it an ideal medical isotope for murder, it remains unclear how such a rare substance was acquired and whether this isolated case sets a precedent for future use. What is clear is that although the misuse of medical isotopes is not uncommon, for the time being, it appears the intentional misuse of alpha and beta emitters has, fortunately, resulted in more injury than death.

The Databases:

The following open-source data resources were used to compile a general history of the malevolent use of radioisotopes:

- Illicit Trafficking Database (ITDB)—International Atomic Energy Agency (IAEA);
- Database on Nuclear Smuggling, Theft and Orphan Radiation Sources—Defense Science and Technology Organization (DSTO);[13]
- Weapons of Mass Destruction (WMD) Terrorism and Chemical, Biological, Radiological, and Nuclear Incident and Response Databases—Center for Nonproliferation Studies (CNS);
- Johnston's Archive Database of Radiological Incidents and Related Events—compiled by Wm. Robert Johnston; and
- A Global Chronology of Incidents of Chemical, Biological, Radioactive and Nuclear Attacks: 1950–2005.[14]

[13] DSTO database maintained by Friedrich Steinhaeusler and Lyudmila Zaitseva, Division of Physics and Biophysics, University of Salzburg, Austria. May 2007 (restricted access).
[14] "A Global Chronology of Incidents of Chemical, Biological, Radioactive and Nuclear Attacks: 1950–2005."

Database	Total Number of Cases
ITDB [xiii]	577
DSTO	816
CNS WMD/Rad	32
Johnston's	8
Global Chronology	45

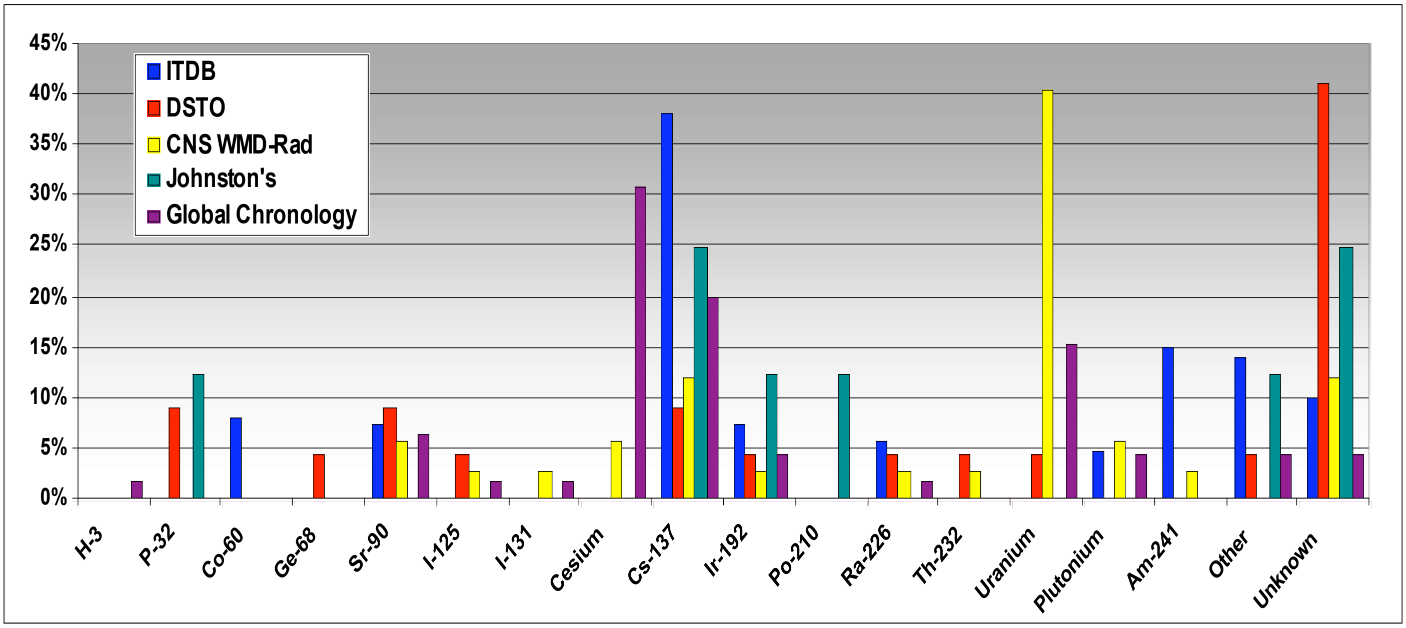
Table 1: Total number of cases in each database

The above databases were evaluated using several specific criteria. The first criteria evaluated (Figure 1) were the specific material characteristics, put into categories that were based upon the type of radioactive source material used in each incident: material category, type of emitter, and half life.[15] The second criterion was based upon the perpetrator's intent for the use of the radioactive material (see Figure 2). For this research, Dr. Jeffrey Bale's definition of terrorism was used to determine whether or not a case should be categorized as having terrorist intent or not.[16] The exception to his definition was that threats without substantiated evidence of radioactive source-material acquisition were excluded because it would have made it difficult to distinguish real misuse from the numerous hoaxes.

Based upon the various discrepancies in the organization and availability of information from the databases, few concrete conclusions could be drawn from this research. However, several possible trends are noteworthy. With the exception of the DSTO database, most databases reported that cesium, especially ^{137}Cs, and uranium were the most commonly reported misused radioactive isotopes (See Figure 1).

[15] Refer to Figure 1 for a listing of the radioisotopes and their commonality of misuse in each database.
[16] Dr. Bale is a professor at the Monterey Institute of International Studies, and his definition of terrorism is the following: "The use or threatened use of violence directed against victims selected for their symbolic or representative value, as a means of instilling anxiety in, transmitting one or more messages to, and thereby manipulating the perceptions and behavior of a wider target audience."

Radioactive material categorized as "other" (mixed sources) or "unknown radioactive material" came in a distant second in all of the databases. The high rate of "other" and critically "unknown radioactive materials" reported in all of these databases is disconcerting



and reflects a general lack of detailed information on radioactive source incidents.

Figure 1: Isotope percentages reported in each database

Although the ITDB did not provide specific information on the numbers or details of the incidents, it did provide percentages of misused radioactive sources. When compared to the other databases, the ITDB percentages, for the most part, did not reflect similar patterns of radioactive source material misuse. The exception was cesium, which the ITDB confirmed as the most commonly misused isotope. As the ITDB did not provide any data on the intent of the perpetrator, the quality of its individual cases could not be compared with the other databases. Additionally, although the DSTO had the highest number of cases, the authors of this research were only given access to cases involving direct malevolence and thus could not incorporate data on the much higher number of incidents of theft and trafficking that comprise the bulk of cases in the DSTO.

Each database has differing requirements for case reporting. Therefore, attempting to determine the ultimate intent of the end-user in each case was also difficult (see Figure 2). The CNS and the Global Chronology databases both focus their case reporting on cases with a more generalized focus, reporting higher incidents of theft, terrorism, and unknown intent; whereas Johnston's Archive focuses heavily on cases involving casualties and does not include theft in its case reporting. The DTSO reports the highest numbers of theft, even more than the ITDB, and the highest number of cases of revenge/harm and murder. However, unlike CNS, DTSO and Global Chronology both report a lower number of terrorist incidents. Three cases of radioactive sources being used for suicide make up nearly half of the incidents reported in Johnston's. However, at the same time, suicides are not reported in most of the other databases. The exception is Global Chronology, which reports one suicide, making up only two percent of its caseload.

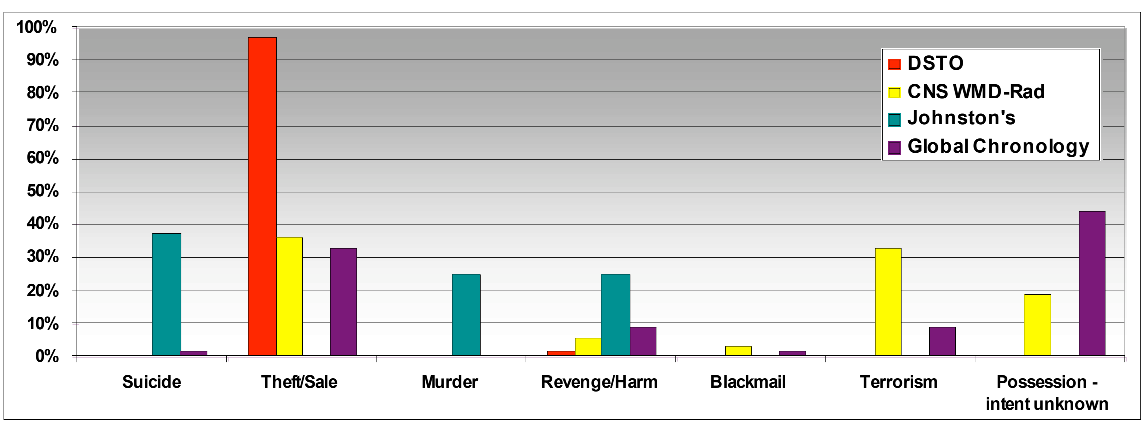


Figure 2: End-user intent percentages reported in each database

There was a disconcertingly high rate of incidents with unknown intent and unknown radioactive material in nearly all of the databases. This either reflects a dearth in the availability of detailed accounts of the incidents or poor investigation on the part of the database managers into the details of the events reported. The variance in case reporting made each database unique and vital to assembling an overall spectrum of the history of radiological material misuse. However, there is no guarantee that the case reporting of these few databases encompass all of the possible types of radioactive material misuse.

Inherent Weaknesses of Databases:

The most poignant observation from this research was the discrepancies in the quality of identical case reporting across the databases. Cases of overlap was to be expected and perhaps desired, but the fact that one case may show an isotope while the other has the end-user's intent poses a strong argument for the creation of secure comprehensive resource that would permit the database managers to share open-source data on these events. The significant differences and weaknesses between the databases were the following: (1) Uneven and unclear reasoning for start dates of database entries. (2) Variance in the reporting of incidents. (3) Unclear or lack of detailed information on the isotope type or perpetrator intent for material. (4) Number and type of incidents in databases.

(1) The starting dates for database entries, for no clear reason, varied widely. For example, Johnston's Archive cites its earliest case as being a suicide in 1960, whereas the DTSO cases start as late as 1993 with the murder of Vladimir Kaplun. Looking at these year ranges, one would think that Johnston's Archive, having the greatest longevity, would have the most cases and that DTSO would have the least. However, the opposite is true, with Johnston's Archive listing only eight total malicious radioactive incidents, whereas DTSO, spanning a much shorter time period, lists 22 malevolent cases and in far greater detail.

(2) Another important factor that restricts the research community's ability to trend cases was the inconsistency of incident reporting. Taking the same two databases compared above, it might appear that Johnston's Archive, having so few cases, would be relatively useless. However, five of the eight cases in Johnston's did not overlap with any of the other databases and, therefore, provided the only data available on those incidents. For example, a 1994 case involving the radiological poisoning of the food and drink of a fellow graduate student 30 times over a period of two years by a colleague in Taiwan should have fallen under the purview of all of the databases. It occurred within the timeframe of all of the databases; yet it only appeared in Johnston's Archive. The same reasoning applies to the fact that Johnston's Archive was the sole reporter of suicides.

All of the databases had a significant amount of overlap. For example, the combined average of overlap for all of the databases was around 30%. CNS had the highest amount of overlap, with 42.5% of its cases being reported elsewhere. However, most overlapping cases were covered in greater detail in one database and less in another. Overlapping cases should be scrutinized by all database managers to ensure the fidelity of their cases and to enhance the overall case reporting. The variance in restrictions to access to each database should not hinder the more restricted databases, such as the CNS, from receiving the benefit of enhancing their existing case backgrounds.

(3) Another issue that blocked progress in assembling data was a lack of detailed information on the incidents. The ITDB/DSTO databases are mostly restricted and, therefore, this research had to rely upon the more generalized data provided by a facts and figures sheet that the ITDB publishes annually on its website and correspondence with the DSTO database manager for a limited malevolent case listing. The ITDB gave the percentages for the amounts of specific isotopes involved in illicit trafficking and the

numbers on total incidents and "high risk dangerous"[17] incidents (see Figure 3), but it did not provide details about the intent of the perpetrator who used the radioactive material.[18] Prevention of access to end-user intent may be essential to preventing the idea of spreading ideas for terrorists to conduct their attacks and therefore some restrictions in this area are essential.[19]

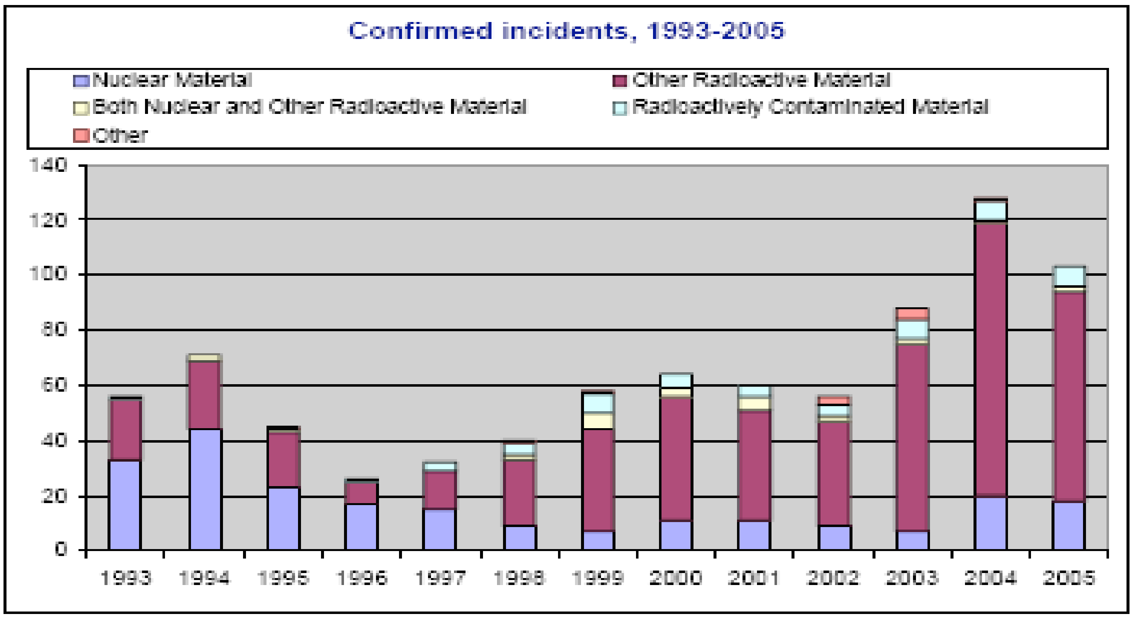


Figure 3: ITDB **c**onfirmed incidents from 1993 to 2005.[20]

The lack of specific information and the fact that nearly all the sources used in this research restricted public access highlights the sensitivity of the information related to radiological incidents and does not reflect a fault of the databases themselves. In fact, in

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[17] ."Categorization of Radioactive Sources." IAEA RS-G-1.9. Radioactive sources belonging to Categories 1, 2, and 3 are considered "dangerous" (i.e., having the potential to cause deterministic health effects if uncontrolled or used for malicious purposes).

[18] "Illicit Trafficking and Unauthorized Activities Involving Nuclear and Radioactive Materials." IAEA Fact Sheet. 2005. May 11, 2007. Web site: http://www.iaea.org/NewsCenter/News/2006/traffickingstats2005.html

[19] For an excellent example of this see how an unclassified report by Charles Ferguson was considered by terrorist as a viable means towards creation of a dirty bomb: Coll, Steve. "The Unthinkable." New York, NY. The New Yorker. p.2. 12 March 2007.

[20] (Reprinted from "Illicit Trafficking and Unauthorized Activities Involving Nuclear and Radioactive Materials." IAEA Fact Sheet. 2005.)

most cases the databases do not disclose this information as a service to government agencies who request that the information remain confidential. Nevertheless, with the exception of the ITDB, which relies solely upon state reporting of incidents, all of the databases rely upon open-source reporting of their data. Therefore, the lack of uniform reporting of identical incidents points should at least encourage the sharing of information between databases.

(4) Another inherent weakness in most, if not all, of the databases was the total number and type of incidents reported. As was mentioned earlier, the fewest number of cases in a database were found in Johnston's Archive, which reported only eight cases over a considerable period of time. The discrepancies between the total numbers of incidents reported may appear insignificant; however, considering the small overall number of cases of malicious use of radioactive materials, these differences are important. A good example of how poor reporting of a small number of cases can affect the quality of the data is that CNS and Global Chronology, both with a large number of cases, do not list even one murder. However, a total of four murders were found in the cumulative results of all of the other databases. It should also be noted that four murders contradicts most media reports and even research articles, which, when discussing the rarity of the Litvinenko case at most cite only two radiological murders in the past. The CNS database provided one of the highest numbers of incidents. However, after threats and hoaxes were eliminated from that data, it brought the CNS total number down to a size similar to that of most of the other databases.

Finally, the accessibility to the resources for this research varied. Johnston's Archive and Global Chronology are the only two databases accessible-to-the-public. However, because some cases in Johnston's and Global Chronology either overlapped incorrectly or did not exist in caseloads of the restricted databases, it would be instructive for the more restrictive databases to attempt to at least harmonize their cases with databases on the public domain. The only caveat to this is that the veracity of the information in each case should be determined before altering existing caseloads.

Strengths of Databases:

Although inconsistencies in overlap and other variances have been described as being weaknesses in the databases, they can also provide strength to the data through those differences. As a result of not all databases use the same criteria for vetting cases into their caseloads, some databases find cases that otherwise would not have been discovered in others. For example, Johnston's database limits itself to cases involving casualties and so cases of theft and other diversion activities are left out. At the same time Johnston's narrow focus on casualties provides the most comprehensive information on suicides. The CNS database provides information on hoaxes, which might also be useful in tracking threats or the attractiveness of isotopes. Overall, the strength of all of these databases is their unique case reporting and the fact that they are operating on a scarcity of open-source information.

The Way Forward:

Although the focus of this research was on the general misuse of radioactive materials, it is important to note that reports on illicit trafficking of these same materials have been on the rise since the 1990s.[21] The IAEA confirms this fact, stating that most of the high-risk "dangerous" incidents have occurred in the past six years.[22] As illicit trafficking is a form of misuse of radioactive material, any significant rise firmly establishes the need for increased vigilance of radioactive material diversion. Additionally of concern, is the possibility that poor reporting and weak detection capabilities in the past, coupled with

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[21] Severe, William, R., Balatsky, Galya, I., and Eaton, Stacey, L. "Illicit Trafficking of Radioactive and Nuclear Materials." Nuclear Safeguards, Security, and Nonproliferation: Achieving Security with Technology and Policy. Burlington, MA: Butterworth-Heinemann, ch.22. 2008.

[22] "Illicit Trafficking and Unauthorized Activities involving Involving Nuclear and Radioactive Materials."

heightened post-Cold War awareness of radioactive materials trafficking, technological advances in detection that may also account for the current rise in reporting of illicit trafficking. Nevertheless, the fact that numerous cases exist at any time is a cause for concern.

Considering the devastating effects of 9/11 and the enhanced international focus on the threat of radiological dispersal devices, it would be prudent to consider the outcome of this research as a signal to increase support and funding for existing databases on radiological misuses and for those databases to better communicate with one another. As a result of the sensitivity of the information, it might be necessary to maintain the current confidentiality of most of these events. However, this should not deter the creation of a vetting method acceptable to all the databases that would allow the sharing and restricting information.

After looking at the severity of the exposures and the odd motivations of the above cases, it is apparent that a focus on long-lived gamma emitting sources that fall out of government control should be of utmost priority. Investigation into the large swath of unknown isotopes and unknown end-users should also be done to ensure a capability to develop trends for radiological diversion events. There have been a wide variety in the cases of misuse and very few cases with grave consequences, therefore it is highly unlikely that future radiological source misuse will be predictable. However, sharing data between multiple databases should be an obligation similar to that of tracking a serial killer's movements. You may not know when or where an incident may take place, but patterns will hopefully develop in the long run. Hopefully the reason for the lack of a trending capability will remain a sparse scattering of cases of radiological misuse.

The methodology of using ^{210}Po to poison Alexander Litvinenko sent shock waves around the world. Fortunately, this type of case is rare, and hopefully it will be the last time the international community will have to deal with such a tragic event. As one author pointed out about a case from as far back as 1972, "Even Agatha Christie and Ellery Queen have not introduced the public to radiation as a potential lethal weapon."[23] Alexander Litvinenko and, lamentably, several others before him have initiated the public to unusual misuses of radiation.

[23] "A Case of Child Abuse by Radiation Exposure." In: Hubner KF, and SA Fry eds. The Medical Basis for Radiation Accident Preparedness.