CREDIBILITY OF THE THREAT FROM A RADIOLOGICAL DISPERSAL DEVICE BY TERRORISTS WITHIN THE UNITED STATES

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A radiological dispersal device (RDD) employed within the United States (US) could cause injury or death, create public panic, incur large cleanup costs, and disrupt governance and commerce. Shortly after the attack on September 11, there was much speculation within media and government about the threat of an RDD employed within the US. Although media interest eventually turned to other news, the question remained: "How credible is the threat of an RDD employed by terrorists within the US?" This research compared five case studies to analyze motivations, RDD effects, accessibility of radioactive materials, and obstacles to RDD employment. The five case studies include Al Qaeda's pursuit of RDDs or nuclear devices; a Chechen rebel radiological attack in Ismailovsky Park; the attempt by the "Radiological Boy Scout" to construct a breeder reactor; the Samut Prakarn, Thailand cobalt-60 accident; and the Chernobyl reactor accident. Trends emerging from cross-case analysis identified challenges and opportunities from a terrorist perspective. The study concluded that improved intelligence and investigations, improvements in radiological source security, and the deployment of a detection architecture have so far deterred RDD employment. However, to prevent a future RDD attack, support of programs to prevent or thwart radiological terrorism should continue.

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ABSTRACT

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A radiological dispersal device (RDD) employed within the United States (US) could cause injury or death, create public panic, incur large cleanup costs, and disrupt governance and commerce. Shortly after the attack on September 11, there was much speculation within media and government about the threat of an RDD employed within the US. Although media interest eventually turned to other news, the question remained: "How credible is the threat of an RDD employed by terrorists within the US?" This research compared five case studies to analyze motivations, RDD effects, accessibility of radioactive materials, and obstacles to RDD employment. The five case studies include Al Qaeda's pursuit of RDDs or nuclear devices; a Chechen rebel radiological attack in Ismailovsky Park; the attempt by the "Radiological Boy Scout" to construct a breeder reactor; the Samut Prakarn, Thailand cobalt-60 accident; and the Chernobyl reactor accident. Trends emerging from cross-case analysis identified challenges and opportunities from a terrorist perspective. The study concluded that improved intelligence and investigations, improvements in radiological source security, and the deployment of a detection architecture have so far deterred RDD employment. However, to prevent a future RDD attack, support of programs to prevent or thwart radiological terrorism should continue.

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ACRONYMS

A	Radioactive Emission Activity
AEC	Atomic Energy Commission
Bq	Becquerel
Ci	Curie
CRS	Congressional Research Service
D	Dangerous Radioactive Activity Level
DNDO	Domestic Nuclear Detection Office
EPA	Environmental Protection Agency
GAO	Government Accountability Office
GNDA	Global Nuclear Detection Architecture
GTRI	Global Threat Reduction Initiative
IAEA	International Atomic Energy Agency
KGB	Komitet Gosudarstvennoy Bezopasnosti
KSE	Kamol Sukosol Electric
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
OAEP	Atomic Energy for Peace
RDD	Radiological Dispersal Device
Sv	Sievert
US	United States
WMD	Weapons of Mass Destruction

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CHAPTER 1

INTRODUCTION

Introduction and Background

In the 2005 fictional HBO video, *Dirty Wars,*[1] London reeled after terrorists detonated a radiological dispersal device (RDD) in the heart of the city. The device consisted of a van packed with explosives and large sources of alpha and gamma radiation. First responders, limited by radiation exposure limits, struggled to assist casualties; overwhelmed medical facilities struggled to maintain control as large groups of contaminated individuals sought medical attention; and police struggled to maintain order as public panic set in and people circumvented barricades in an attempt to flee from the area, inadvertently avoiding decontamination. Meanwhile, United Kingdom and London officials were overwhelmed attempting to oversee response efforts and address the public. All people had to evacuate portions of the city rendered unusable-possibly for years.[2] Although *Dirty Wars* was fiction, could terrorists feasibly employ an RDD in the United States (US) today and would they?

With terrorist groups and disturbed individuals able to gain dangerous knowledge and build power through influence via the internet, it is more important than ever to accurately assess national vulnerabilities. During times of budget austerity, resources for RDD detection, prevention, and response will likely be limited. As a result, it is not fiscally feasible to prepare fully for every possible type of attack. Policymakers must carefully consider preventative measures and responses. Therefore, it is more necessary than ever to accurately assess the likelihood of attacks using RDDs. The focus for this paper will be on assessing the probability of an RDD attack, otherwise known as a “dirty bomb,” within the US and its territories.

Currently, there is an inconsistency among experts about whether or not individuals, autonomous cells, or hierarchical terrorist organizations would actively pursue and employ an RDD. Most opinions range from surprise that an attack has not yet occurred[3] to a doubt about their employment while generally acknowledging the presence of a threat.[4] In an attempt to quantify the perceived probability in 2005, Senator Lugar, Chairman of the Senate Foreign Relations Committee, published the results of a survey that questioned 80 professionals within government and industry related to security and nonproliferation. They asked the likelihood of an RDD attack in the next five years or the next ten years. The committee averaged the subjective responses from the various countries to produce an average risk. The Senate Foreign Relations Committee identified the risk of an RDD attack in the next five years and 10 years to be 27 percent and 40 percent, respectively.[5] Conversely, that also means there was a prevailing opinion that it was more likely that terrorists would not employ an RDD. Despite the public attention RDDs were receiving at the time, the majority of survey participants were right. The other important thing to note is that they indicated the probability of an attack would increase over time. According to the Congressional Research Service (CRS) in a 2004 Report:

> Some experts believe that terrorists could, without great difficulty, obtain radioactive material and construct an RDD, while others assert that radiation sources intense enough to cause casualties in an RDD attack would be injurious to the terrorists during acquisition and use. Most experts agree that few casualties would be likely to result from an RDD attack, generally only among those very close to the device, but many disagree on how attractive an RDD would be to a terrorist.[6]

In August 2004, just four months after the CRS published this report, British officials arrested plotters planning to employ a dirty bomb utilizing americium obtained from smoke detectors.[7] Officials thought it extremely unlikely the device would be potent enough to cause radiation sickness. However, there remain conflicts of opinion, as others argued that the device could incite panic by activating sensitive radiation sensors and there could be long-term residual contamination.[8]

Problem Statement

Despite the potential impacts associated with employment of an RDD, there is currently no comprehensive study to assess the likelihood and risk of RDD use within the US and its territories. Therefore, planners and policymakers make decisions to allocate limited resources to counter an RDD based on expert assessments that range from negligible threat to high risk—probable threat. These assessments lack a common framework for assessing risk. With disagreement between experts on the risk of an RDD, there is a potential that leaders will fail to maintain radiological security and detection systems, anticipate RDD use, and act to deter RDD employment.

Purpose

The purpose of this study is to:

1. identify trends, opportunities and challenges to terrorists motivated to obtain and implement an RDD;
2. compare the effects of an RDD to the effects desired by terrorists; and
3. analyze the ability of a terrorist organization to obtain suitable radioactive materials.

Research Design

This multiple case study compared five case studies related to either radiological terrorism or accidents and incidents involving radioactive sources that occurred outside of regulatory control. This study analyzed each case independently against four elements and then analyzed the five cases in a cross-case analysis to identify trends, opportunities, and challenges used to create recommendations to prevent RDD employment within the US. The case studies analyzed were a variety of incidents occurring both inside and outside of the US. The focus of this paper was on the risk of an RDD attack within the US. Therefore, the analysis of global incidents, which identified radiological effects and terrorist motivations, were consistent with the effects and motivations to use an RDD within the US.

Chapter 2 established the foundation of existing knowledge related to terrorist motivations, effects of an RDD, the accessibility of radiological isotopes, and the obstacles to the employment of an RDD. Sources were primarily from technical and governmental publications. The information presented in chapter 2 provided the basis for each factor.

The first factor was terrorist motivation. This factor included the motivations of these categories of actors: secular and religious hierarchical terrorist organizations, autonomous cells, and individuals.

The second factor was effects. Effects for the purposes of this paper were the physical effects from a radiological source exposure, panic, and cost of cleanup. This section presented the International Atomic Energy Agency’s (IAEAs) radiation source categories, which measure the strength of a source compared to what the IAEA believes to be dangerous levels. The section established a standard to compare the effects of specific sources to terrorist motivations.

The third factor discussed in chapter 2 was accessibility. This section identified the types of likely isotopes used in an RDD, their category level, common uses and storage areas, and the security of these types of sources. It addressed accessibility due to poor security and loss or theft both within the US and worldwide.

The fourth and final factor discussed in chapter 2 was obstacles. Obstacles included the risks of detection either by intelligence and investigation or by nuclear radiation detectors. Obstacles also included the identified difficulties of shielding and transporting hazardous radiological materials. These factors hinder the planning, transportation and employment of an RDD by terrorists.

Research Question

Primary Research Question

How credible is the threat of an RDD employed by terrorists within the United States?

Secondary Research Questions

The secondary research questions are:

1. What are terrorist motivations?

2. What are the effects of an RDD?

3. How accessible are hazardous radioactive isotopes?

4. What are the obstacles preventing the creation and employment of an RDD?

Assumptions

The US is a potential target for terrorists; therefore, US leaders should consider the threat of an RDD. As part of the assessment of threats and countermeasures necessary for an RDD, this study assumed that characteristics for RDD use or attempted use around the world would have commonalities with characteristics for RDDs potentially employed in the US. This assumption was necessary due to the limited RDD use in the US at the time of the study.

Terrorists have the knowledge and capability to create a conventional explosive event. Al Qaeda showed an explosive capability within the US when members bombed the World Trade Center in 1993.[9] Individuals have shown a capability to produce and employ explosive devices within the US. One example is the 1995 Oklahoma City Bombing, where Timothy McVeigh detonated a bomb hidden within a Ryder truck in front of the Alfred P. Murrah Federal Building.[10]

Definition of Terms

For definition of terms used throughout the paper, see the glossary.

Limitations

Based on the limited experience with RDDs within the US, the case studies draw from incidents across the world. In order to keep this publication available to the widest audiences, this study is limited to unclassified, open sources. As a qualitative study based in part on the lack of consistent data across all of the case studies, the generalizability of the study's outcomes is dependent on the context of future potential incidents in relation to those of the case studies within this paper.

Scope and Delimitations

Limits of Study

To keep the scope of the paper within limits of time and size, the content was limited to five case studies. It did not include consequence management, or threats from state actors. Therefore, this study did consider incidents such as the planned seizure and improvised explosive detonation of a Russian nuclear submarine by the Chechen Armed Forces Chief of Staff, Islam Khasukhanov,[11] or the radioactive poisoning of former *Komitet Gosudarstvennoy Bezopasnosti* (KGB) Officer, Alexander Litvinenko.[12]

Significance of Study

The threat of an RDD attack is a portion of the broader conceptual security threat framework, including prevention and consequence management planning. This study addressed prevention, but did not include prevention planning and consequence management. Increased fidelity on RDD employment risks and probability has the potential to provide value to the entire framework through a deeper level of understanding.

Additionally, assessing the risk posed by an RDD threat can guide decisions on whether to create, continue, or discontinue programs related to preventing the employment of an RDD. Such programs may include maintaining or upgrading detection devices, security programs, and policies for obtaining and using radiological sources, or public awareness. The next chapter will describe the current literature on factors related to the development and employment of RDDs within the US.

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[1] *Dirty Wars*, directed by Daniel Percival (Home Box Office Films, BBC Production, 2005).

[2] *Dirty Wars*.

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CHAPTER 2

LITERATURE REVIEW

The primary research question was: How credible is the threat of an RDD by terrorists within the United States?

Additionally, this study addressed the secondary research questions:

1. What are terrorist motivations?

2. What are the effects of an RDD?

3. How accessible are hazardous radioactive isotopes?

4. What are the obstacles preventing the creation and employment of an RDD?

This literature review compiled information primarily from government organizational research, testimony to Congress, and reports to Congress to provide supporting evidence for use while analyzing the case studies. For topics not represented in a government report or publication, this chapter used sources from books, news reports, or magazine articles. Preferred sources had first-hand knowledge or conducted interviews with referenceable sources that had first-hand knowledge, to lessen the likelihood of errors occurring from content changes and multiple interpretations as information passed from source to source.

This chapter analyzed the current literature related to the research topic in the order of the secondary research questions. Motivations, for the purpose of this study, were the desired result of terror attacks that contribute to political goals. Three categories for terrorists used throughout the study were hierarchical organizations, autonomous cells, and individuals or lone wolves. The analysis discussed these categories separately due to their distinct structure and motivations. Next, the analysis described the effects of

RDDs, followed by an assessment of the dangers associated with various isotopes and their accessibility. The accessibility section discussed how available radioactive isotopes were that could likely be used in an RDD. Finally, the chapter assessed the obstacles related to RDD construction and employment.

Hierarchical Organization, Individual, and Autonomous Cell Motivations

Hierarchical Terrorist Organizations

Hierarchical terrorist organizations have a clear leader and subordinate relationship.[1] They have more access to resources through funding and networks, but carry risk through their networks as well. Hierarchical organizations cannot survive without networks, but networks are more susceptible than individuals to deception and detection.[2] Because they are a hierarchy, organizational rule governs as opposed to individuals who can move on their own motivations.[3]

Religiously Oriented

Religiously oriented groups religiously govern and motivate the organization. They are not concerned with public support and they prefer attacks that inflict as many casualties as possible in order to further their goals. In this manner, the killing of non-believers is acceptable. According to the US Army Training and Doctrine Command, these types of religiously inspired attacks have risen 43 percent between 1980 and 1995. Nearly half of the active terrorist organizations were religiously oriented in 2004, [4] making this category the primary focus for RDDs within hierarchical organizations.

Secular Organizations

The motivations for secular organizations are different from religiously oriented organizations. Secular organizations require the support of the populace; therefore, mass killings negatively alter the public's perception of them as a rational organization, disgruntled over legitimate grievances. For this reason, secular organizations do not benefit from spectacular events with mass killings. Instead, they use targeted attacks against political or economic targets to achieve resolution for their grievances.[5] Since injury or death to civilians as the result of an RDD employment could damage secular organization legitimacy and public support, secular organizations were not an analytical focus.

Individual Terrorists

Contrary to how hierarchical organizations operate, individual terrorists, or lone wolves, are unaffiliated individuals who operate independently under leaderless resistance. Under hierarchical organizations, individual operatives work alone but remain under the direction and authority of the organization.[6] Jose Padilla, an individual operative who gained permission from Khalid Sheikh Muhammed to conduct an RDD attack within the US,[7] is an example of an individual operative of a hierarchical organization, but not an individual terrorist. Individual terrorists operate without direct leadership or a hierarchical organization support network. Contrary to hierarchical organizations, these individuals benefit from their autonomy through operational security, but do not have the same access to funding and resources. Therefore, individual terrorists often conduct attacks through inexpensive means. Individuals seek attacks that are spectacular, in order to capitalize on the use of media to enhance the effect of the attack.[8]

According to Kaplin, the author of *Lone Wolf and Autonomous Cell Terrorism*, there are two types of individual terrorists: the Islamic lone wolf and non-Islamic lone wolf. The goal of Islamic lone wolf terror attack violence is “spectacular operations with large body counts.”[9] The purpose is to elicit media attention globally and spread their ideological message. Conversely, Kaplin claims that for non-Islamic lone wolves, longevity is more important than spectacular attacks. As a result, attacks are part of an ongoing process. Therefore, remaining alive after the attack in order to continue to further the overall plan is a consideration that factored into operations.[10] It then follows that for an RDD to be a useful tool for a non-Islamic lone wolf, the emplacement and initiation must be survivable and the event must move the lone wolf’s agenda closer to his or her ultimate goal. Conversely, for an RDD to be a useful tool for an Islamic Lone Wolf, an RDD must be a spectacular event that resonates globally.

Autonomous Cells

According to Kaplin, autonomous cells are a small collection of individuals who temporarily cooperate in the pursuit of similar goals, but with each individual operating independently. Since autonomous cells are a collection of lone wolves, they operate similarly. Therefore, they do not have a hierarchy, central leadership, or an associated support network.[11] Literature on autonomous cells is limited, so the following deductive assumptions enable continued research. If an autonomous cell is a collection of individuals, then the motivations of autonomous cells are the same as the motivations of individual terrorists. Therefore, for Islamic Autonomous Cells, an attack must be a spectacular event that resonates globally. For non-Islamic Autonomous Cells, the RDD must further the agenda of the overall process and must be survivable for the emplacer.

Additionally, it is reasonable to deduce that autonomous cells face similar challenges to hierarchical organizations when coordinating and communicating, but on a smaller scale.

Radiological Dispersal Device Employment Motivations

The motivations previously described for hierarchical organizations, individuals, and autonomous cells addressed the overall terrorist motivations for each category of terrorist, but not for the use of RDDs specifically. However, a CRS document on RDDs, *A Brief Primer*, identified motivations specifically tied to the employment of an RDD. These motivations included goals beyond mass killings and spectacular attacks in order to propagate a message. According to the CRS, the use of an RDD would meet six goals for a terrorist organization: immediate death and injury, public panic, recruitment, asset denial, economic disruption, and long-term illness.[12]

The first motivation is immediate death and injury. Depending on source strength and concentration, the majority of immediate deaths and injuries would be from the explosive event.[13] This motivation exists in all terrorist categories except secular hierarchical organizations.

The five additional motivations specific to an RDD are public panic, recruitment, asset denial, economic disruption, and long-term illness.[14] Many of these motivations are interrelated. For example, public panic can result in economic disruption and increase terrorist recruitment. Even a small amount of radioactive material has the potential to cause panic. It can exacerbate economic disruption, response, and recovery efforts. People fearful of radiological sickness may ignore expert assessments and abandon an area otherwise safe. An example would be the employment of a small RDD at an airport or within a subway. Tied to a successful attack that incites public panic are the benefits of increased recruitment. Media and social media propagation after an attack affects public panic and proportionately influences recruitment. In the same way, asset denial can cause economic disruption. An RDD implemented at a key piece of economic or social infrastructure, like a railway, port, Congress, or football stadium, could cause people to abandon the affected areas and disrupt government or commerce. An RDD employed on Wall Street, at a port, or at another economic institution could significantly influence the economy. For example, if a disruption in trade due to the employment of an RDD occurs, imports, exports, or tourism are affected until the area can be cleaned up or an alternate means can be established. Related to public panic is long-term illness. [15] Radiation sickness can occur over months.[16] It is not hard to imagine how pictures within social and mainstream media could fuel public panic as injuries began to surface on survivors of the explosive event.

Effects of a Radiological Dispersal Device

Effects of radiation exposure depend greatly upon many different factors, including the cumulative time of exposure, the concentration of radiation, the amount absorbed, the type of radiation, the type of absorption, and tissue affected.[17] This study used the International System of Units whenever possible. Exceptions exist for measurements provided in the old standard of units. Onset of radiation sickness depends upon the amount of radiation that is absorbed. Absorbed doses above 1 Gray (Gy) can result in radiation sickness.[18] A gray is the amount of radiation absorbed by biological tissue. It is not the measure of how effective a particular type of radiation is on biological tissue. The Sievert (Sv) is the effectiveness, where Gy is the quantity. The Sv is the absorbed dose, Gy, multiplied by an effectiveness factor specific to each radiation type:

alpha, beta, and gamma.[19] According to the Mayo Clinic, some of the symptoms of radiation sickness include; nausea, fever, dizziness, hair loss, bloody vomiting and bloody stools. Table 1, from the Mayo Clinic, shows typical symptoms with their associated amounts of absorbed dose and times of onset of particular symptoms.[20]

Table 1. Mayo Clinic signs and symptoms of radiation sickness

	Mild Exposure	**Moderate Exposure**	**Severe Exposure**	**Very Severe Exposure**
	1-2 Gy	**2-6 Gy**	**6-9 Gy**	**10Gy or Higher**
Nausea and vomiting	Within 6 hours	Within 2 hours	Within 1 hour	Within 10 minutes
Diarrhea	---	Within 8 hours	Within 3 hours	Within 1 hour
Headache	---	Within 24 hours	Within 4 hours	Within 2 hours
Fever	---	Within 3 hours	Within 1 hour	Within 1 hour
Dizziness and disorientation	---	---	Within 1 week	immediate
Weakness and fatigue	Within 4 weeks	Within 1-4 weeks	Within 1 week	Immediate
Hair loss, bloody vomit and stools, infections, poor wound healing, low blood pressure	---	Within 1-4 weeks	Within 1 week	Immediate

Source: Mayo Clinic Staff, “Radiation Sickness,” September 29, 2015, accessed February 6, 2016, http://www.mayoclinic.org/diseases-conditions/radiation-sickness/basics/symptoms/con-20022901.

Radiation Categories

The IAEA, an entity of the United Nations Organization, established the following radiation categories to provide an industry standard on the "safe, secure, and peaceful use of nuclear technologies."[21] The activity ratio used by the IAEA to analyze radiation emissions with respect to the level considered dangerous is Radioactive Emission Activity (A)/ Dangerous Radioactive Activity Level (D). "A" is the radioactivity level representative of activity and "D" represents the radioactivity level that the IAEA considers to be dangerous.[22] The IAEA defines the dangerous level to be the absorption of 2.5 Gy per hour within two centimeters of the source.[23] It is important to note that the dangerous level is not the same as the normal background radiation level. The dangerous level is source and quantity specific. If the activity level is greater than what the IAEA considers the dangerous level, the A/D ratio will be more than 1. The activity and dangerous levels measurements are in Becquerel (Bq) or Curie (Ci). One Bq is equal to 3.7×10^{10} Ci. The IAEA ratio is the measure of potential radiation within a substance. Therefore, the quantity of the source affects the activity level. Neither Bqs nor Cis represent the rate of emission or type of radiation.[24] It is analogous to potential energy, in the sense that it measures the total potential radiation inside a particular type of source with a specific quantity.

Category 1

Category 1 sources are sources that are $A/D \geq 1000$. This means that the activity of the particular source is 1000 times or more active than the 2.5 Gy per hour source that can cause moderate radiation sickness within one hour.[25] Radioisotope thermoelectric generators, irradiators, teletherapy sources, and fixed multi-beam teletherapy sources (gamma knives) use category 1 sources.[26]

These sources are "extremely dangerous to the person."[27] Exposure to these sources for several minutes causes permanent injury, while exposure to these sources for more than several minutes can cause death. Personnel more than a few hundred meters away from a category 1 source will experience no negative health effects.

Category 2

Category 2 sources are sources that have an Activity Ratio: $1000 > A/D \geq 10$. This means that the activity of the particular source is between 10 and 1000 times more active than the dangerous level defined by the IAEA. Industrial gamma radiography and high—medium dose rate brachytherapy use category 2 sources.[28]

These sources are "very dangerous to the person."[29] Exposure to these sources for more than a few minutes can cause permanent injury. Exposure of several hours to days could cause death.[30] This source would not cause immediate health risks to persons more than 100 meters from the source.

Category 3

Category 3 sources are sources that have an Activity Ratio: $10 > A/D \geq 1$. This means that the activity of the particular source is either equal to or 10 times more active than the dangerous level defined by the IAEA. Fixed industrial gauges that incorporate high activity sources and well logging use category 3 sources.[31]

These sources are “dangerous to the person.”[32] Exposure for some hours could cause permanent injury. Exposure for days to weeks has a rare potential to be fatal. This source would not cause immediate health risks to persons a few meters away.[33]

Category 4

Category 4 sources are sources that have an Activity Ratio: $1 > A/D \geq 0.01$. This means that the activity of the particular source is less than one up to 100 times less active than the dangerous level established by the IAEA. Low dose rate brachytherapy sources (except eye plaques and permanent implants); industrial gauges that do not incorporate high activity sources, bone densitometers, and static eliminators use category 4 sources.[34]

These sources are “unlikely to be dangerous to the person.”[35] Exposure to this source is unlikely to cause permanent injury. There is a rare potential that someone in direct contact with the source for several hours or someone in close proximity to the source for several days, up to weeks could become temporarily ill.[36] “This amount of radioactive material, if dispersed, could not permanently injure persons.”[37]

Category 5

Category 5 sources are sources that have an Activity Ratio: $0.01 > A/D$ and $A >$ exempted. This means that the activity of the particular source is equal to or less than 100 times less active than what is dangerous, as defined by the IAEA. Low dose rate brachytherapy eye plaques and permanent implant sources, x-ray fluorescence devices, electron capture devices, Mossbauer spectrometry sources, and positron emission tomography use category 5 sources.[38] These sources are “most unlikely to be dangerous to persons."[39] "This amount of radioactive material, if dispersed, could not permanently injure anyone."[40]

Environmental Protection Agency Radiological Standards

The 2003 CRS report proposed that the Environmental Protection Agency (EPA) standards on radiological exposure exaggerated RDD effectiveness. Where the IAEA categorized hazards based on potential radiation emission, the EPA categorized risk based on human health risk from absorbing radiation measured in Sv. The EPA standard placed contamination limits at a 1:10,000 chance of developing cancer. This is what the EPA considers the risk of long-term illness. To put this into perspective, the CRS highlighted an analysis conducted by Stevin Koonin, provost of the California Institute of Technology. He asserted that contamination of a particular, but non-specified radioactive source of less than a fraction of a gram, spread over a square mile, would make the area uninhabitable by the 1992 EPA standard. However, in this scenario, for every 100,000 people exposed, only four would develop lifetime cancers above and beyond the 20,000 cases of cancer expected from other causes.[41] As early as 2000, the Government Accountability Office (GAO) identified a disagreement in standard during testimony to the Subcommittee on Energy and Environment, Committee on Science, United States House of Representatives, on the scientific basis for the radiation standards and limits.[42] According to the Department of Health and Human Services, Radiation Emergency Medical Management, the 2013 EPA standards for exposure were .05 Sv for all occupational exposures, annually and .1 Sv for protecting valuable property or public welfare, within a lifetime and a lifetime dose of .25 Sv for lifesaving or protection of large populations. For public exposures, at .01 Sv residents can shelter in place. For anticipated exposures of .02 Sv within the first year and .05Sv in subsequent years, the EPA recommends civilian evacuation.[43]

Availability of Radiological Source Materials

Isotopes

According to the Institute for Defense Analysis, the most likely sources for use in an RDD are cobalt-60, strontium-90, iodine-131, cesium-137, iridium-192, plutonium-238, and americium-241, due to their ability to produce acute radiation injury.[44]

All of these isotopes emit radiation in the forms of alpha, beta, or gamma radiation. Some sources emit a combination of forms of radiation. Alpha and beta particles are a relatively low threat to absorption while outside the human body. As little shielding as a dead layer of skin can stop alpha particles. Beta particles require slightly more shielding because they are lighter and faster than alpha particles. [45] Thick clothing can block most beta particles.[46] However, once inside the body through inhalation, ingestion or other means, these particles ionize cells. Depending on the material and amount of ionizing radiation absorbed, this can cause tissue damage, radiation illness, or in severe cases, death. Gamma rays require much greater shielding as they penetrate much further and through skin.[47]

The half-life of a radiological isotope is the amount of time it takes for half of a particular isotope to decay to another isotope.[48] This is not the same as the amount of time that it takes an isotope to no longer be dangerous.[49] The half-life is an indicator of how quickly an isotope decays.

Cobalt-60

Cobalt-60 is a category 1 or lower gamma source depending upon quantity in use, meaning that it can be more than 1000 times the dangerous level established by the IAEA.[50] Medical and industrial applications use cobalt-60. Because it is a strong gamma source and has a relatively long half-life of five years,[51] it is an optimal candidate for use in an RDD.

Strontium-90

Strontium-90 is a category 1[52] beta source.[53] It is a commercially produced isotope, used in medical or industrial applications.[54] Strontium-90 occurs as a fission product in nuclear waste, produced when uranium fuel is spent.[55] It has a relatively long half-life of 29 years.[56] In order for it to be an effective agent for an RDD, the device would have to result in air dispersal of particles sufficiently small to inhale, in order to produce optimal damage.

Iodine-131

Iodine-131 is a category 2[57] gamma and beta source[58] used in the treatment of cancers.[59] It has a very short half-life of eight days, is very soluble, and because it prefers to bind with other elements, it “does not stay in its pure form once released into the environment.”[60] It is a purple, gaseous, fission byproduct, of a nuclear reaction.[61] As a gamma emitter, its radiation can be easily absorbed by human tissue. As a beta emitter whose absorption is best through inhalation or ingestion, its gaseous state is dangerous to persons. People can easily inhale the gaseous form. Iodine-131 has the propensity to turn directly from a solid into a gas when heated, known as sublimation.[62] Iodine-131 has the potential to be an ideal candidate for a radioactive source within an RDD due to its propensity to sublimate when heated and its ability to irradiate through either beta or gamma emissions.

Cesium-137

Cesium-137 is a category 1 source[63] with a strong gamma and a beta emission.[64] It is a fission product and a component of nuclear waste produced when uranium fuel is spent.[65] It has applications in both medical and industrial applications.[66] Because of its relatively long half-life of 30 years[67] and its strong gamma radiation, it is a good candidate for use in an RDD.

Plutonium-238

Plutonium-238 is a category 1[68] alpha source.[69] Due to its heat production during radioactive decay, plutonium-238 fuels pace makers and thermoelectric generators to power space operations.[70] It, like all plutonium, is fissionable. It can capture fast moving neutrons[71] and subsequently undergo fission by splitting into neptunium-239 and a beta particle.[72] However, plutonium-238 is not the fissile isotope, able to capture slow moving neutrons, like plutonium-239.[73] Therefore, plutonium-238 is not in nuclear weapons. Plutonium-238 is a rare substance, only produced within a reactor. The only reactor within the US capable of producing plutonium-238 shut down in the 1990s. All plutonium-238 since had been bought from Russia, but Russia has recently stopped its production of plutonium-238.[74] Therefore, the US planned to resume production of plutonium-238 at Oak Ridge National Laboratory, Tennessee.[75] Consequently, this would be a difficult source for terrorists to obtain in sufficient quantities for an RDD. Being an alpha source in a solid state, plutonium-238 would require grinding or some other form of processing to support dispersion of particles small enough for inhalation. The rarity of the source and alpha decay, requiring inhalation or ingestion for absorption, makes it a less than ideal source for an RDD.

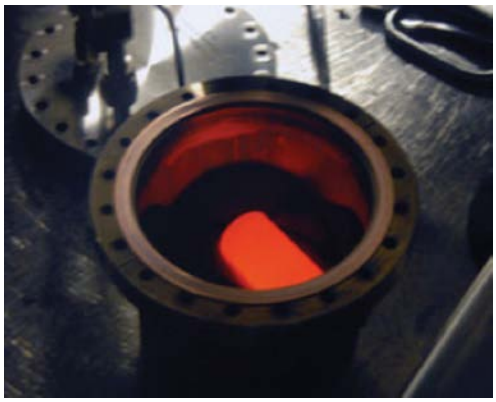

Figure 1. Plutonium-238

Source: National Aeronautics and Space Administration, "What is Plutonium 238?" NASA Fact Sheet, accessed April 28, 2016, https://solarsystem.nasa.gov/rps/docs/APP%20RPS%20Pu-238%20FS%2012-10-12.pdf.

Americium-241

Americium-241 is a category 2[76] alpha and gamma source.[77] It has a long half-life of 432 years and is a product of plutonium-241 decay; americium-241 is present within most common smoke detectors.[78] It is a weak but readily available source and terrorists used it in multiple RDD attempts.

Additional Isotopes of Importance

Radium-226 is an alpha, beta, and gamma-emitting source. It has a long half-life of 1,600 years. It is a rare isotope, with no known appreciable sources remaining. Found in both uraninite and pitchblende, a quantity of one gram of radium-226 is typical for seven tons of pitchblende. Alternate radionuclides, such as cobalt-60 often replace radium-226 due to safety and activity levels. Radium-226 alpha radiation interacts with beryllium to produce neutrons.[79]

Plutonium-239 is a fissile isotope used in nuclear reactors and nuclear weapons. It decays by alpha radiation to uranium-235. A particular sample of plutonium-239's viability as a weapons grade nuclear material depends upon the amount of uranium-240 within the sample. The longer plutonium-239 remains within a reactor, the higher the concentrations of uranium-240 and the less likely the material will be successful producing a fission reaction within a nuclear weapon.[80]

Uranium-235 emits alpha radiation to decay to thorium.[81] It is used in nuclear reactors and produces a fission reaction within a nuclear weapon. Uranium occurs naturally throughout the Earth's crust as a mixture of uranium-238 and uranium-235. About 99.3 percent of naturally occurring uranium mixtures is uranium-238. The remaining 0.7 percent is uranium-235. Enrichment increases the percentage of uranium-235 within a mixture. For uranium mixture use in a reactor, it must be enriched to at least 4 percent uranium-235,[82] but for use in a weapon, the mixture must be enriched to contain at least 90 percent uranium-235.[83]

Security and Accountability

Radioactive source security and accountability contribute to the potential availability of a source. Terrorists can obtain access to sources that emerge or escape from regulatory control, from loss or theft due to improper security, storage, transportation, all of which increased due to risks from insider threats. Vulnerabilities to source security exist both within and outside the US and its territories.

Accidents, Theft, and Loss

With many of the radioactive isotopes being produced within a reactor, guarded in accordance with governmental regulations, and sold only to authorized licensees, it seems intuitive that there would not be many sources out of governmental control. However, according to the IAEA fact sheet, there were at least 2,477 incidents of nuclear and radioactive material found or reported outside of governmental regulation as of 2013. Of those incidents, at least 664 incidents were due to a theft or loss from a facility or during transportation. According to the IAEA, these losses suggested vulnerabilities in the security of nuclear and radioactive materials. [84]

US Source Security

In 2012, the GAO reported on actions needed by US Agencies to secure potentially vulnerable nuclear and radiological materials. The report petitioned Congress for further enforcement of the President’s 2009 initiative to secure and account for all US radioactive material around the world. The presidential directive r equired accountability and security within four years. The GAO issued this report one year prior to the four-year deadline of the 2009 initiative.[85] Requests for enforcement by the GAO suggested that the Nuclear Regulatory Commission (NRC), hospitals, and industries were not making sufficient progress.

The NRC Security Order directed increased security controls through security procedures, equipment, and personnel access that will detect an intruder and delay them long enough for a response and apprehension. The NRC did not design security controls to prevent insider theft. The NRC Security Order is intentionally nonspecific. Policymakers did not want to financially burden licensees. Therefore, responsibility of securing radiological sources lay with the individual licensees. The NRC Security Order mandated that, at a minimum, "licensees limit access to radiological sources and develop a documented program to detect, assess, and respond to unauthorized access."[86] The orders did not specify the types of physical security required. For example, the policy excluded cameras, alarms, and types of locks from the mandated controls. Also, the NRC did not require additional physical security if a licensees staffs a room at all times.[87]

To improve physical security, the National Nuclear Security Administration (NNSA) implemented the Global Threat Reduction Initiative (GTRI). The GTRI was a Domestic Material Protection Program available to all US facilities that contain high activity radiological sources. The program offered training to hospital personnel and law enforcement along with security equipment upgrades. The program was voluntary and the NNSA funded the training and upgrades. However, once the three to five year warranty expired on the security upgrades, hospitals and medical facilities were responsible for maintaining the equipment. The annual cost for maintenance per site, estimated by the NNSA, was less than $10,000 annually. As of 2011, the NNSA completed upgrades for more than 300 facilities. It had plans to upgrade the remaining 1,200 facilities considered high risk by 2025. The average cost of each upgrade was $317,800 per building.[88]

The NRC gave licensees the freedom to establish screening and access standards when determining trustworthiness and reliability of employees granted access to highly active radiological sources. Background checks routinely screened employee interview data, such as employment, references, and academic history. A criminal background check from the Federal Bureau of Investigations was not required and there was no regulation for specific criminal actions to restrict an employee access. It was a subjective analysis by a licensee to grant access. Therefore, NRC regulation authorized licensees to grant access to personnel with criminal records. This created a risk of an insider threat that resulted in unescorted access to radioactive sources by personnel with criminal records. In one case, a licensee gave access to an employee convicted of making terroristic threats.[89]

Hospital and Medical Facility Security

In 2012, the GAO visited 25 out of the 1,500 hospitals and medical hospitals within the US and its territories with highly radioactive sources. All of the sites had completed inspections from either the NRC or its state regulatory inspectors.[90] The GAO evaluated the sites within seven US states and the District of Columbia against US standards to develop recommendations. They also interviewed 20 state regulatory officials and representatives from federal agencies, such as the Department of Defense, the NRC, and the Department of Energy.[91] The NRC, along with the NNSA and state regulatory officials were responsible for radiological source regulations and security within the US.[92]

Of the hospitals and medical facilities that the GAO inspected, they found personnel responsible for security of sources that did not feel adequately trained, did not have an understanding of the program controls, and did not feel comfortable giving security inspections. The GAO found minimally secured sources. One example was a blood irradiator containing a cesium-137 source secured by a door with a single combination lock. Employees wrote the combination on the doorframe. Additional examples showed vulnerabilities in security of equipment containing sources of cesium-137 near loading docks with either a door secured only by a swipe card or windows that were unalarmed and unsecured. In some cases, licensee granted access to more than 500 personnel for equipment containing sources not secured to the floor. In fact, one was on a cart with wheels.[93]

Of this small sampling size, 1.5 percent of all US hospitals and medical facilities, the report highlighted many examples of security vulnerabilities in physical security, personnel access, and screening for trustworthiness and reliability. All of these sites had passed recent inspections under the same operating conditions. There were ongoing efforts to improve security through the Global Threat Reduction Initiative, which would continue until at least 2025. Similar vulnerabilities were not isolated to hospitals and medical facilities. Industrial radiological source security experienced many of the same issues.

Industrial Radiological Source Security

There were two types of high activity sources used within industry: mobile and stationary sources. Each source posed different challenges to security. Licensees secured mobile sources in vehicles and not in a secure building, under licensee control. This presented a challenge to licensees when operating at public work sites or during hotel stays. Under NRC regulation, some security controls during storage included two separate chains or cables to secure the source, each affixed with its own lock. The vehicle containing the source must be locked and disabled when used as a temporarily storage site. The regulations, challenges of storing, and security vulnerabilities of stationary sources were the same as those reported by the GAO for hospitals and medical facilities in their 2012 report.[94]

Both the stationary and mobile sources were vulnerable to security risks from outsider and insider threats. There have been multiple incidents of outsider threats. An example of an outsider threat incident occurred when thieves stole a mobile source, containing a camera with 34 curies of Iridium-192 from a hotel parking lot. Officials never recovered the source or identified whether the target was the truck carrying the source, or the camera that housed the source. Another incident occurred at a construction site when an individual posing as an inspector attempted to gain access to a source.[95] Outsider threats are only half of the overall threat. Industries and hospitals obey the same regulations and experience the same issues of determining trustworthiness and reliability when considering employee access to radiological sources.[96] They also have the same challenges training employees on security and responsibilities. Therefore, the insider threat in industry remains a risk to radiological source security, and hence accessibility.

Foreign Source Security

Obtaining radioactive material is difficult for terrorists.[97] Since the black market is unregulated, terrorists are subject to fraud when they locate a smuggler willing to sell radioactive material.[98] Just because radiological material is difficult to obtain, does not mean that it is impossible. In Russia, for example, radioactive material security deteriorated after the fall of the Soviet Union, in 1991.[99]

In a 2002 GAO report to the US Senate Emerging Threats and Capabilities Subcommittee, the GAO identified 20 incidents of recovered weapons-grade material from smugglers. The incidents occurred between 1992 and 2001. Of the 20 incidents, 13 originated in Russia, two more suspected out of Russia, one originated in Germany, and four were from unspecified countries of origin.[100] Since 2002, the US has greatly invested in increased security and detection capabilities of radioactive sources worldwide.[101]

In an attempt to assist Russian and former states of the Soviet Union to increase security of radiological sources, nuclear devices and nuclear technology, Congress approved funding for nuclear nonproliferation and threat reduction. Beginning in 2002, President George W. Bush recognized the threat from readily available radiological sources throughout Russia. These sources were available due to the improper disposal of radiological waste from research facilities and from improper security of existing sources. Congress funded the Department of Energy to identify potential radiological waste sites and other sites lacking adequate security where theft was possible. The Department of Energy then prioritized those sites and where applicable, increased security. Beginning in fiscal year 2006, Congress began funding called the Second Line of Defense. The program funded the Department of Energy to increase Russian detection and interdiction efforts in order to prevent smuggling of radiological sources across Russian borders. Funding continued throughout both Bush and Obama administrations. Congress funded more than $1 billion in fiscal year 2012 alone for the purposes of nuclear nonproliferation and threat reduction in Russia and the former Soviet states.[102]

In spite of efforts to increase security of radiological sources worldwide, terrorists still have the opportunity to obtain radioactive sources through insider threat and blackmail. A man hired in 2009 to inspect welds within the Doel Nuclear Power Plant reactor, Belgium, died in 2014 while fighting for the Islamic State.[103] In 2015, during the investigation of a man with ties to the Islamic State, Belgian police discovered a video tape tracking the movements of a Belgian nuclear center's senior researcher and his family. Investigators believed that the Islamic State was planning to kidnap one of the researcher's family members to use them for ransom in order to obtain radioactive material.[104] With over 2,400 incidents of radiological sources outside of regulatory control, and persistent vulnerabilities in security, there are many points of access for determined individuals to procure radioactive materials. The implication is that some other factor or factors are obstructing the implementation of an RDD.

Obstacles

There are three primary obstacles keeping terrorists from employing RDDs with available materials. The first factor is state, federal, and foreign intelligence and investigations. The second factor is detection through the Global Nuclear Detection Architecture (GNDA). The final factor is the difficulty in handling radioactive materials.

Intelligence and Investigations

The US and foreign intelligence and investigations are obstacles to the employment of an RDD. Intelligence and investigations were responsible for numerous discoveries of sources outside of regulatory control. Similarly, intelligence and investigation were responsible for discovering and preventing multiple RDD plots before their employment.

Between 1992 and 2001, police of multiple nations recovered 12 out of 13 sources of weapons grade plutonium and uranium outside regulatory control. All of the material originated out of Russia. Russian police discovered material for five of the 13 incidents. However, not all of the material remained inside Russia. Lithuanian, German, and Czech Republic police discovered material for four incidents. Bulgarian security interdicted the last source at a border crossing.[105]

There were seven additional incidents, for a total of 20 incidents, of weapons grade material outside of regulatory control whose country of origin was either from a country other than Russia or an unknown country. Police recovered material from five of these incidents. Of the remaining two incidents, radiation detection and material testing were responsible for recovery.[106]

Foreign police efforts are not the only intelligence activities and investigations preventing attacks and recovering material. US investigations stopped RDD plots too. In 1999, officials arrested an Algerian man, Ahmed Ressam, in Port Angeles, Washington, with improvised explosive device components. He confessed to officials that he was intending to detonate bombs at the Los Angeles International Airport.[107] Al Qaeda relied on its network to coordinate and fund operations, but the use of a network created an obstacle for their operations, to include the employment of an RDD.

Detectors

Due to their high levels and type of radioactivity, most radiological sources ideal for RDDs are much easier to detect than the alpha emitting weapons grade radioactive material.[108] Additionally, radioactive sources are easier to detect at a border crossing or transportation site than chemical or biological agents. Terrorists can hide chemical and biological agents from area monitoring detectors by shipping items in airtight, sealed containers. To hide radioactive sources from monitoring, terrorists must shield the source. However, particularly in the case of gamma emitters, shielding makes them easier to detect by x-rays. Additionally, the heat signatures from radionuclides that produce heat during decay remain visible in infrared detectors.[109] Radiological detection is the responsibility of the Domestic Nuclear Detection Office (DNDO).

Bush established the DNDO in 2005 within the Department of Homeland Security with the responsibility for synchronizing the pre-existing, uncoordinated security and detection programs largely operated by the Departments of Energy, Defense, and State. The DNDO created the GNDA as a single, multilayered, system of systems.[110] The GNDA focused only on the "detection opportunity" and not on the larger system, which includes deterrence, counter proliferation, or response activities.[111] The GNDA capitalized on existing programs and organized efforts into a multilayer system: interior, exterior, and border.[112] In this way, if the GNDA did not detect a nuclear weapon or radioactive source in one layer, there was a possibility of detection in a subsequent layer. In FY06, the DNDO assessed that 72 programs totaling more than $2.2 billion in funding comprised the overall GNDA.[113] Some of these programs included security or detection at sublayers. The sublayers included foreign origins, foreign transit, foreign borders, transit to the US, US borders to include ports, US origin sites, regional areas around potentially targeted areas, and potential target areas.[114] In this manner, radioactive material from overseas could potentially encounter more detection opportunities than one originating within the US.

Some of the current detection technologies are radiation pagers, radiation portal monitors, radioactive isotope identification devices, and radiographic imaging systems. Each system has a limitation, requiring continued research in detection. Radiation pagers are lightweight, about the size of a piece of paper and inexpensive. They detect elevated levels of radioactivity, but do not identify where it is coming from. Radiation portal monitors are large, moderately expensive sheets of plastic that detect elevated radiation levels from vehicles, but similar to the radiation pagers, they do not identify the radioactive source. In addition, due to the use of radioactive sources in everyday commercial items, the radiation portal monitors have created many false alarms, which slow commerce through these points. The radiographic isotope identification devices are gamma spectrum detecting handheld devices, which function well in ideal conditions. However, they too have several limitations to include durability, weight, short range of detection for low radioactive sources, vulnerability to shielding, and the requirement for periodic cooling by liquid nitrogen or other mechanical means. The radiographic imaging system displays images created by high-energy photons. The images display dense objects, not measured radiation levels. However, this system fails to segregate radiological sources when mixed in with other objects of varying size and density.[115] The detection of sources and disruption of plots is not the only challenges terrorists face when attempting to employ an RDD. Terrorists are subject to the same hazards of radiation that they are trying to exploit.

Shielding

In order to build, store, transport, and emplace an RDD, terrorists must work in close proximity to the radiological sources. For each type of radiation, the way to best employ the source within an RDD creates a shielding hazard for the user. For example, in order for terrorists to disperse an alpha or beta source in small enough particles for inhalation, terrorists must first grind up the material or produce a gas. However, grinding sources or heating them into a gas creates an inhalation hazard for the terrorist. A concentrated, powdered source can be very hazardous. In the Goiaina, Brazil incident, a scrapyard worker discovered a canister containing powdered cesium discarded from a cancer treatment center. The material inside was a bright, sparkling blue, so he brought the canister around town to show to fellow residents. Residents passed the canister from "home to home." The incident resulted in the death of four people, radiation exposure to more than 200 people, and the leveling of 85 houses.[116] A terrorist without proper handling skills would be under considerable risk.

Similar handling hazards exist from gamma radiation sources. A gamma source of sufficient quantity to cause illness or death within a few minutes of exposure once dispersed would conceivably have the same or worse effects on an RDD builder, transporter, or emplacer. In fact, the builder, transporter, or emplacer would be in close proximity to a more concentrated gamma source than victims exposed after radiation source dispersal. The effects would be amplified as their absorption of radiation, due to proximity and length of exposure, would be higher. However, with correct shielding or sufficient standoff, terrorists could overcome these obstacles.

Summary

This chapter explored the extant literature related to the motivations of terrorist organizations, the effects of radioactive sources likely used in RDDs, the accessibility for individuals to those sources, and the obstacles to obtaining and using source material for an RDD. Religiously oriented terrorist organizations, individual terrorists, and autonomous cells are motivated to produce deaths through spectacular attacks in order to advance their goals. There are five additional terrorist motivations, specific to an RDD: public panic, economic disruption, recruitment, asset denial, and long-term illness.

The physical effects of an RDD are radiation sickness and possible death. The severity of radiation sickness and amount of time to develop symptoms depends on the amount of radiation absorbed. Absorption is dependent upon many factors. The cumulative time of exposure, concentration of radiation, amount absorbed, type of radiation, type of absorption, and tissue affected, are all factors effecting absorption.[117] There is a possibility for lifetime cancers from exposure.

Radiological sources have been available due to loss and theft. There have been more than 2,400 incidents of nuclear and radioactive sources outside of regulatory control. In spite of ongoing efforts to increase security worldwide, vulnerabilities still exist in the security of radiological sources.

Obstacles hindering the employment of an RDD are intelligence and investigation, detection through the GNDA and challenges handling and transporting radiological sources. The next chapter will describe the methodology to analyze five case studies based on these four factors of motivation, effects, accessibility, and obstacles.

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CHAPTER 3

RESEARCH METHODOLOGY

The primary research question was, "How credible is the threat of an RDD by terrorists within the United States?" In order to answer this question the study answered the secondary research questions relative to each of the case studies. The first analysis determined the motivations driving terrorist attacks by identifying whether the development of an RDD had been a motivation in the past or if there had been any previous attempts to employ an RDD. Next, this study analyzed the effects of an RDD to identify whether the effects coincided with the desired outcome of terrorist motivations. The analyses of the case studies addressed the availability of hazardous radioactive isotopes. If there are is no accessibility of radioactive sources sufficient for an RDD, then there can be no threat of an RDD attack. This study then identified obstacles that prevented the employment of an RDD. This helped identify why terrorists have not successfully employed an RDD and created areas for recommendations to prevent an RDD attack.

Case Study Research Methodology

This study used Creswell's case study research methodology[1] to evaluate the research questions. The general, but not prescriptive structure of case study research methodology is an entry vignette, an introduction, a description of the cases and their context, development of the issues, details about the selected issues, assertions and a closing vignette.[2]

Creswell's methodology provided a framework to present multiple real events as case studies with the entry vignette, an introduction, and description. However, the methodology did not facilitate a compare—contrast analysis between the factors of terrorist motivation, effects of an RDD, availability of materials, and obstacles impeding the employment of an RDD in order to answer the secondary research questions. To analyze the secondary research questions, this study integrated Wolcott's methodology of describe, analyze, and interpret[3] into Creswell's methodology. Describe was a common step in both Creswell and Wolcott's case study and was the point at which the two methodologies merged. After the description, Wolcott's analysis replaced Creswell's development of the issues and details about the selected issues. The analysis separated the factors of terrorist motivation, effects of an RDD, availability of materials, and obstacles impeding the employment of an RDD. This framework enabled comparison of those factors for a meta-analysis of each case study. Wolcott's interpretations replaced Creswell's step of assertions in order to provide understanding and meaning of the findings. The analysis concluded with a cross-case analysis that identified similarities and differences between the cases in order to answer the primary research question.

The case study research methodology used table 2 for descriptive presentation of data, analysis of that data, and interpretive synthesis of that analysis to draw conclusions. The graphic portrayal of key observations for each of the cases against the four factors related to the secondary questions would support the cross-case analysis and conclusions resulting from that analysis.

Table 2. Cross case analysis matrix

	Motivation	Effects	Accessibility	Obstacles
Case 1: Al Qaeda's pursuit of WMDs				
Case 2 Chechen Rebel Radiological Source in Izmailovsky Park				
Case 3 David Hahn's Breeder Reactor				
Case 4 Samut Prakarn, Thailand Cobalt-60 Accident				
Case 5 Chernobyl				

Source: Created by author.

Significance of Case Studies

Each of the five case studies chosen for this thesis had a different contribution of factors for later analysis. These factors included terrorist organizations; plans of radiological terrorism; employment of radiological terrorism; an individual; a non-dispersed, radiological accident; and a large, dispersed radiological accident. All of the case studies included incidents of radiological materials outside of regulatory control.

Case Study 1 was Al Qaeda's Pursuit of Weapons of Mass Destruction (WMDs). This case study was of significance to the overall study because it showed hierarchical terrorist group motivations to implement an RDD and the obstacles impeding the employment of an RDD.

Case Study 2 was the Chechen rebel emplacement of a radiological source in Moscow's Izmailovsky Park. This case study gave significance to the overall study because it showed a capability for use by hierarchical terrorist organizations and highlighted some of the motivational challenges to the employment of an RDD.

Case Study 3 analyzed the actions of David Hahn, the Radioactive Boy Scout. This case study was significant to the overall study because it showed the accessibility of radiological sources to motivated individuals.

Case Study 4 was the Samut Prakarn cobalt-60 accident. This case study was significant to the overall study because it showed the effects of radiological sources on humans and how those effects could contribute to terrorist motivations. Additionally, it showed the effects of a non-dispersed (concentrated) source.

Case Study 5 was the Chernobyl accident. This case was significant because it showed the effects of large quantities of radioactive materials. Through the steam explosion that dispersed the radioactive contents into the atmosphere, the accident at Chernobyl was an enormous RDD.

Cross-case Analysis

The cross-case analysis combined the individual analysis from each case study, and compared them across the four factors of motivation, effects, availability, and obstacles. The analysis compared the effects to the motivations and the obstacles to the availability. The results of the cross-case analysis answered the secondary research questions and provided data to assess trends, terrorist opportunities, terrorist challenges, and recommendations related to the primary research question.

Emerging Conclusions on Trends and Terrorist Opportunities and Challenges

The results of the cross-case analysis identified trends, terrorist opportunities, terrorist challenges, and recommendations. The synthesized trends, terrorist opportunities, and terrorist challenges produced recommendations and areas for further study. Analysis of the secondary research questions provided the answer for the primary research question.

Summary

This chapter described the qualitative methodology employed in the study merging the case study methodologies of Creswell and Wolcott. The framework of the case study methodology used in this paper was: entry vignette, description and context, analysis, and interpretations. Each case study contributed unique factors that broadened the analysis. These factors included terrorist organizations; plans of radiological terrorism; employment of radiological terrorism; an individual; a non-dispersed, radiological accident; and a large, dispersed radiological accident. This thesis analyzed each case study individually, then collectively as a cross-case study analysis to answer the secondary research questions. Answers to the secondary research questions provided the analyzed data required to answer the primary research question. This paper synthesized the chapter 2 Literature Review, the individual case analysis, and cross-case study analysis to produce trends, terrorist opportunities, and terrorist challenges to the employment of an RDD. Analysis of the five case studies, through this methodology, generated recommendations for future planners. Chapter 4 will describe the analysis of the case studies and the cross-case analysis.

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CHAPTER 4

ANALYSIS

Entry Vignette

In the HBO video *Dirty Wars*, terrorists detonated a large RDD within London, England. A hierarchical terrorist organization worked through a network to transport radioactive material into London. A transporter succumbed to radiation poisoning, alerting officials that there was a potential radiological threat. The terrorist group also encountered challenges to radiation exposure assembling the radioactive device. Meanwhile, London anti-terrorism units attempted to track down the cells, but before they could, terrorists detonated an RDD within the city. Ultimately, London anti-terrorism units captured the network lead and killed two suicide bombers before they could initiate a second device. The fictional film highlighted motivations, effects, and obstacles faced by terrorists in the planning, transportation, production, and employment of an RDD. These themes appeared in case studies related to radiological terrorism and radiological accidents. Similar factors of motivation, effects, accessibility, and obstacles have affected the ability of a terrorist organization or lone wolf to employ an RDD within the United States today.

Introduction

The primary research question was: How credible is the threat of an RDD employed by terrorists within the United States?

Additionally, secondary research questions are:

1. What are terrorist motivations?

2. What are the effects of an RDD?

3. How accessible are hazardous radioactive isotopes?

4. What are the obstacles preventing the creation and employment of an RDD?

Five case studies formed the basis for analysis: Al Qaeda's Pursuit of Radioactive Sources or Nuclear Devices, Chechen Rebels' Radiological Terrorism, the Radioactive Boy Scout, the Thailand Junkyard Cobalt Accident, and the Chernobyl Accident. This chapter will assess each case using the methodology described in chapter 3 against the factors of motivation, effects, accessibility, and obstacles in the use (or misuse) of radioactive isotopes in order to address the primary research question.

Case Study 1: Al Qaeda's Pursuit of a Radiological Source or Nuclear Device

Description and Context

Since the 1993 bombing of the World Trade Center by Khalid Sheikh Muhammed's nephew, which killed six and injured over 1,000 people,[1] Al Qaeda has maintained itself as an ongoing threat to the US.[2] Terror attacks have evolved in size, scale, and complexity, as exemplified by the coordinated attacks on September 11, which resulted in more than 2,900 deaths,[3] and the bombings in East Africa, which killed more than 200 people and wounded 4,500.[4] Al Qaeda's attacks have targeted civilians to produce large amounts of casualties and fear. Nuclear or radiological terrorism was another means of interest to Al Qaeda to produce casualties and fear. According to RAND, documents found in Afghanistan outline Al Qaeda's ultimate goal of developing or buying a nuclear weapon. RDDs were the preliminary step.[5]

Al Qaeda had the means to collect radioactive sources sufficient for an RDD. After the fall of the Soviet Union in 1991, rigid control over nuclear weapons and materials broke down for the next 10 years.[6] Rumors of nuclear weapons and radioactive sources circulated.[7] In September 1997, Peter Jouvenal, a British camera operator who had previously interviewed Osama Bin Laden, reported a group of Afghans selling Russian nuclear material approached him. In Mazar-e-Sharif, near the Russian border, smugglers presented several boxes. The Russian box labels annotated U235 150g, PU 239 50g, MO-9999 r OCT 98, CCCP (Soviet).[8] Terrorists could use these weapons grade, fissile materials for nuclear munitions.[9] However, the quantity described was insufficient, by several orders of magnitude.[10]

Many of these sales were hoaxes to sell radioactive waste in the place of weapons grade fissile material.[11] The isotopes plutonium-239 and uranium-235 decay primarily by alpha decay.[12] Recall a thin layer of clothing or a layer of dead skin is sufficient to guard against alpha radiation. However, Al Qaeda operatives watching over the encased material reported symptoms of radiation sickness, including hair loss. Al Qaeda members believed the reports of plutonium and uranium sales to be an “elaborate scam.”[13] One incident verified that Bin Laden bought nuclear waste instead of nuclear material.[14] If Bin Laden was intent on producing RDDs, the radioactive waste would have been readily available, but he pursued weapons grade material and claimed to have the means to test for it.[15] If the radioactive waste they acquired as a result of the scam produced radiation sickness, Al Qaeda had the capability to build an RDD.

In 1998, when tensions between the US and Iraq were escalating due to Iraq’s expulsion of weapons inspectors in November 1997, Bin Laden and several of his top officials signed a statement issuing a fatwa against the US to all Muslims. The statement identified three grievances. The first grievance was the alleged poor treatment of Muslim people by U.S forces within Kuwait, and that the US used the Arabian Peninsula as a launching point to attack other Muslims in Iraq.[16] Second, the statement proclaimed a "great devastation inflicted on the Iraqi people by the Crusader-Zionist alliance."[17] The devastation Osama Bin Laden referred to was the First Gulf War and the "Highway of Death." The document claimed more than 1 million lives in losses and claimed the US continued to create additional conflict.[18] The third and final grievance was for US support to Israeli occupation of Palestine, to include Jerusalem. Osama Bin Laden felt this land was sacred Muslim ground.[19]

In December 1998, an ABC News Reporter asked Bin Laden if he was trying to obtain chemical or nuclear weapons, to which Bin Laden replied non-categorically, "Acquiring weapons for the defense of Muslims is a religious duty."[20] He did not specifically mention radiological devices. An implication is that if acquiring weapons were a religious duty, then RDDs used in the defense of Muslims would be advantageous.

It was clear Bin Laden was interested in a nuclear program. He met with the retired senior Pakistan nuclear scientist Dr. Sultan Bashir-ud-din Mahmood in 2000 and 2001 to obtain information on their nuclear program. Mahmood had asserted that the purpose of the visits was purely innocent, that he met with Bin Laden and Mullah Omar, the Taliban Leader, to gain support for his charitable organization.[21]

A letter addressed to Al Qaeda's WMD project manager Abu Khabbab, dated January 12, 2001, in Kabul, described how to make explosives, deadly chemicals such as ricin, and improvised nuclear devices. One of the documents, in Arabic, English, German, and Urda, illustrated how to make an improvised nuclear device designed to compress weapons grade plutonium into a critical mass. In theory, compressing the weapons grade plutonium would lead to a nuclear explosion.[22] Experts observed that the devices would not work, and that the author had knowledge of the initiation of such devices, but not the manufacturing required.[23] In the absence of a nuclear explosion, these devices would operate as an RDD, scattering the fissile material.

According to author and FBI advisor, Paul Williams, the Russian Federal Security Service notified US officials in 1998 the Chechen mafia had sold 20 “nuclear suitcases” to Bin Laden in Grozny.[24] The alleged “nuclear suitcases” were portable nuclear devices, designed inside of a suitcase. Available open source literature could not confirm the existence of such suitcases. However, both the US and Russia created small nuclear devices during the Cold War, to be carried by Special Forces. The US version of a portable nuclear device was the B-54 special atomic demolition munitions, called “backpack nukes.”[25]

Bin Laden reportedly paid $30 million and two tons of heroin (value of $700 million) for the suitcases. The Chechen mafia allegedly purchased the suitcases in 1996 from former *Komitet Gosudarstvennoy Bezopasnosti* (KGB) officials after the fall of the Soviet Union. According to Williams, Israeli intelligence officials supported the claim.[26] Stanislav Lunev, a Russian intelligence officer and defector, stated to the US Congressional Committee on National Security in 2000 that he learned in 1997 of the suitcases’ existence. As many as 80 nuclear suitcases were missing.[27] William’s book, *Osama’s Revenge*, claimed that in 2001, officials reported the missing suitcases to the President that at least two of the suitcase nuclear devices “had reached Al Qaeda operatives in the United States."[28] According to his source list, this information came from an article by Naveed Miraj from the Frontier Post, Islamabad.[29] The article stated the device is only eight kgs (17 lbs) with two kgs (four lbs) of fissionable plutonium. The same article claimed that Al Qaeda had 70 small capsules of a deadly biological agent that when released would cause large-scale deaths, with the agent capable of burning human tissue to the bone.[30] Reported just two months after 9/11, it appeared this report may have been either propaganda or entirely fabricated.

Authors and news agencies speculated much over the actual existence of these suitcase nuclear devices.[31] In an ABC report, the assistant director of the FBI's WMD Directorate and former head of the Los Alamos National Laboratory Chemistry Division outlined what it would take to build and maintain a suitcase nuclear device. He assessed it takes at least "22 pounds of plutonium or 130 pounds of uranium to create a nuclear detonation"[32] This is much more than the four pounds plutonium-239 in the devices claimed to be in existence by the Frontier Post. These weight estimates do not include the weight of conventional explosives required to initiate the chain reaction.[33] Because it requires less material to initiate a nuclear reaction, plutonium would seem the likely choice. However, plutonium-239 is much harder to obtain than uranium. Unlike uranium, plutonium-239 does not occur in nature, but is produced within a reactor.[34] However, uranium sufficient for a fission reaction must be enriched to increase the amount of uranium-235 within the uranium mixture.[35] It would be very difficult for terrorists to obtain plutonium-239 or enriched uranium. Sufficient quantities would have to come from a state program and each state has their own "chemical fingerprint," making source origins attributable, if not traceable.[36]

If Al Qaeda purchased the suitcase nuclear devices, they would require continual maintenance. Estimates claimed that without continued maintenance and periodic overhauls, the devices would not function as designed in as little as three months.[37] Some scientists asserted that for a smaller device, more maintenance would be required due to the effects of radiation on electrical components.[38] It remains unverified whether or not Chechen rebels actually sold suitcase nuclear weapons. However, if Al Qaeda did purchase the suitcases and did not continue the required maintenance, they could still use the devices as expensive RDDs.

To give an example of how difficult this would be, of all the loose material recovery incidents between 1992 and 2001, the total amount of uranium found was 35 pounds; the quantity of plutonium found was 0.88 pounds.[39] If terrorists consolidated all of the weapons grade nuclear material recovered between 1992 and 2001; they still would not have had enough to build a nuclear fission device.

In June 2002, Suleiman Abu Ghaith, Al Qaeda's official spokesperson, outlined why Al Qaeda believed it had the right to kill or injure up to four million Americans: to reach parity for Muslims killed in the Persian Gulf, Palestine, the Philippines, Somalia, Sudan, Chechnya, and Afghanistan. Specifically, Al Qaeda held the US responsible for supporting Israel occupation of Palestinian land for 50 years. According to Abu Ghaith, the occupation resulted in five million Palestinians exiled and an additional 260,000 Muslims killed, 180,000 wounded, and 160,000 crippled. He held America responsible for the death of 1,200,000 Muslims; 500,000 of which Abu Ghaith claimed were children who died due to UN sanctions following the First Gulf War.[40] These numbers were prior to Operations Iraqi Freedom and 15 additional years of operations within Afghanistan.

Even though Al Qaeda was actively pursuing a nuclear fission device, RDDs received a much lower priority. In 2002, Al Qaeda recruit Jose Padilla met with the 9/11 mastermind,[41] Khalid Sheikh Muhammed to obtain Al Qaeda's approval to initiate an RDD attack within the US. Muhammed was hesitant; he urged Padilla to pursue a plan to blow up apartment buildings using natural gas.[42] He and another senior Al Qaeda official expressed concern about the plan's practicality and Padilla's ability to avoid detection and capture.[43] Muhammed's hesitation possibly generated from an incident the United Press International reported in 2001. Israeli officials caught a Pakistani terrorist associated with Al Qaeda attempting to enter Israel with a backpack containing nuclear material in an unspecified quantity and configuration.[44] There was limited direct reporting on this event. Other articles and books relating to this incident were based on articles and literature from original United Press International reporting.

In order to produce large amounts of casualties, Al Qaeda showed interest in obtaining WMD. During Vice Admiral Jacoby's February, 2003 statement to the Senate Select Committee on Intelligence, he informed them of Al Qaeda and similar terrorist groups' pursuit of chemical, biological, radiological, and nuclear capabilities and expressed concern for the ease of assembling RDDs and the potential availability of material.[45]

Table 3. Case Study 1 analysis: Al Qaida's pursuit of RDDs or nuclear devices

Case	Motivations	Effects	Accessibility	Obstacles
Case 1: Al Qaeda's pursuit of RDDs or Nuclear Devices	1. Parity for 4 million dead	RDD has not been employed by AQ. Consequently: 1. Only case of injury due to radioactivity was an operative guarding material	1. Obtained radiological materials from Chechen rebels	1. Intelligence and Investigations
	2. Spectacular attack to advance political and ideological goals through fear	2. No public panic generated.	2. "Nuclear suitcases" that could be used as RDDs	2. Deterrence created from effective interdiction
	3. Economic disruption to advance political and ideological goals			

Source: Created by author.

Al Qaeda had an interest in RDDs and employment of such a device was within their capabilities.[46] If Al Qaeda had the means, then why has there not been an RDD attack? Some analysts suggested they only want spectacular events. An RDD would pale in comparison to the casualty count resulting from the attacks on 9/11.[47] Some believe Operation Enduring Freedom interrupted operations.[48] Others believed Al Qaeda had the motivation and the means, but not the opportunity.[49]

Table 3 indicates how the four factors of motivation, effects, accessibility, and obstacles affected the ability of Al Qaeda to develop and employ an RDD.

Motivations

Al Qaeda's motivation to conduct terror attacks was to achieve parity for the deaths of four million Muslims. They used multiple large-scale explosive attacks like the bombings at the World Trade Center and East Africa Embassy Attacks[50] in an attempt to advance their political and ideological goals through fear. By Al Qaeda's repeated attacks on the World Trade Centers, they showed intent to cause economic disruption.

Effects

There was no RDD, so there were no effects from employment. Al Qaeda used explosive devices to inflict mass casualties in an attempt to reach parity. Their interest in nuclear devices supported their desire to satisfy the motivation for mass deaths to generate fear. The same motivation was not present for an RDD. Since the majority of injury and death would come from the explosive event, the most significant effects from the addition of radiological material to the explosive event would be long-term illness.

Accessibility

Al Qaeda had opportunities to obtain radiological material from Chechen rebels. However, they were interested in obtaining weapons grade, fissile material to construct an improvised fission bomb. If Al Qaeda had purchased nuclear briefcases from Chechen rebels, without continual maintenance, they would function as an RDD.

Obstacles

The effectiveness of both intelligence and investigations created deterrence as shown by Muhammed's hesitation to support Padilla's plot. His reasons for reluctance were confirmed when Padilla was arrested in Chicago in 2002. Since his arrest, Congress approved funding for increased detection and security. The GTRI increased security within the US, the NRC increased security worldwide, and the DNDO established the GNDA. These increased security and detection measures increased the effectiveness of deterrence.

Al Qaeda had the knowledge and the materials to use an RDD. The main obstacles to Al Qaeda's employment of an RDD within the US were intelligence and investigations. These two obstacles created a deterrence to Al Qaeda to employ an RDD.

The obstacles that effected Al Qaeda RDD operations were intelligence and investigations. The US and forces abroad have had success through intelligence and investigation, by interrupting Al Qaeda attacks. When Jose Padilla briefed his plot to construct and detonate a dirty bomb, Muhammed's apprehensiveness to support the plot was apparently well founded. Officials arrested Padilla in Chicago in 2002, with $10,000 in Al Qaeda cash. Similarly, Israeli officials captured an Al Qaeda associate attempting to transport an RDD across the Israeli border.[51]

Established in 2005, the increased capabilities of the GNDA made transporting a source undetected more difficult. It was not specified but likely that border officials discovered the possible RDD at the Israel border due to detection equipment or a search of the individual's vehicle. The GNDA was successful in synchronizing autonomous programs into an architecture that focuses on detection and security both within the US and worldwide. Initiatives such as the NNSA's GTRI resulted in increased security for sources within the US and advancements in the GNDA have improved detection.

The increased security, combined with the effectiveness of intelligence and investigations may be why Muhammed was concerned with the practicality of Jose

Padilla’s RDD plot. This created deterrence among Al Qaeda to plot an RDD attack. His concerns were founded when Padilla was arrested, enforcing the effect of deterrence.

Summary

The employment of an RDD was not the preferred choice for Al Qaeda to use to reach parity for the death of four million Muslims. Since there was no RDD employment, there were no effects from an RDD. They had the means, but not the opportunity. However, analysis of evidence suggested that Muhammed was willing to support the employment of an RDD but he and other officials had concerns about feasibility and wanted Padilla to use natural gas explosions instead. RDD employment may present itself as an opportunity, but apparently was not a priority. A weapon or attack that would cause significant loss of lives, like a nuclear attack, crashing an airliner, or detonating gas bombs in an apartment building, appeared to be their priority. The obstacles of detection, security, intelligence, and investigation created deterrence that prevented the employment of an RDD.

Case Study 2: Chechen Rebel Radiological Source in Izmailovski Park

Description and Context

In November, 1995, Shamil Basayev, a former Russian sympathizer turned top Chechen Guerilla Commander, guided a reporter from Russia’s Independent Television Channel to a radioactive source hidden under leaves in Izmailovsky Park, in Moscow. Shamil Basayev had been involved in attacks ranging from the 1991 Russian airplane highjacking, the 1995 raid on a Russian village, and the 1999 bombing of a Russian barracks.[52]

In 1995 and 1996, Shamil Basayev threatened the use of RDDs. He felt Russian officials and the Russian people were not taking his threats seriously. Basayev intended to show his capability for radiological terrorism, so he hid a radiological source near the entrance to Izmailovsky Park.[53] Cesium-137 is a fission product, the byproduct of spent uranium fuel.[54] The package was about six inches by one foot by two feet. Weighing around 70 pounds, it appeared that a dense material, like concrete, encased the source. Additionally, he also displayed containers with Cesium-137, Cobalt-60, or Strontium-90 at a conference in Shali, Chechen Republic.

There was a breakdown in radiological source security in Russian in 1991.[55] Shamil Basayev clearly had at least two radiological sources and claimed to have three more. Two of those sources, Basayev claimed to be attached to explosives, hidden within Moscow and ready to detonate at any time.[56] Their existence was unlikely. Basayev never employed or displayed any RDDs. RDDs were found within Chechnya, but not until years later near a railroad.[57]

Officials identified the radioactive source that Chechen rebels placed near the entrance to Izmailovsky Park as Cesium-137.[58] It has the potential to be a Category 1 source, depending upon quantity. It was approximately 70 pounds with packaging, but only a very small portion inside of the package was the Cesium source.[59]

According to reporters on site, their detectors read radiation levels at 100 times more than the ambient level normally present in Moscow.[60] Moscow's ambient radiological level three years prior to the attack, in 1992, was between five and 17 microroentgens per hour.[61] For the worst case, if the ambient remained the same, and the detected level is accurate as compared to the ambient level, then the source measured

1700 microroentgens per hour. One roentgen of radiation in non-bony, biological tissue is approximately equal to .87 Rad.[62] This is not precise, but can be indicative of the level of absorption. Therefore, the highest potential dose is 15 micro Gy per hour. Ignoring the decaying strength of the source over time and the body's ability to recover, it would take more than seven years for a person standing next to this source, to absorb enough radiation to display mild radiation sickness exposure symptoms.[63] It follows that research of this topic found no evidence of people reporting radiation sickness due to the source.

In Moscow, there had been several identified areas of elevated radioactivity hot spots. Hot spots were so prevalent that German and Finnish embassies kept Geiger counters on hand. It affected business as well. Russian research facilities created the hot spots through improper disposal of nuclear waste. They dumped the waste both on their own property and throughout Moscow. In 1992, officials even found radioactive waste in a children's playground. Between 1982 and 1992, the team cleaned up 650 hotspots from Moscow alone.[64] An additional cleanup effort funded $15.3 million in 2011 and 2013 to clean up 18 more contaminated sites. With this much radioactive contamination around Moscow, radioactive sickness due to radiological terrorism may be difficult to identify versus the environmental contamination.

Religiously oriented, hierarchical organization leader, Shamil Basayev, used attacks and threats to achieve his political goal: the Russian withdrawal from Chechnya.[65] He wanted to show that he could hurt the Russian people.[66] The displays were not effective in persuading the Russian government to withdraw from Chechnya, so Basayev changed methods. Jeffrey Bale, contributor to the Nuclear Threat Initiative, believed that an RDD or nuclear strike would have infuriated Russian officials and incited a devastating retaliatory attack.[67] Chechen rebel fear of retaliation may have deterred the use of an RDD. With Russia having a nuclear capability, Chechen rebels had to fear Chechnya annihilation.

At the time of this incident in 1995, there had not been any previous explosive attacks from Chechen rebels on Russian targets. Even the June 14, 1995 hospital attack in Budyonnovsk, Russia where rebels held more than 1000 hostage and killed more than 100 lacked an explosive element.[68] The bombing attacks attributed to Shamil Basayev began in August 1999 with the four apartment building bombings within Russian cities. He denied responsibility for these attacks. Many of the subsequent attacks included suicide bombings and attacks on trains, subways and other public gatherings.[69]

All of the rebel attacks killed more than 10 people. The largest casualty producing attack was the September 1, 2004 attack on a school in Beslan, Russia. [70]The attack resulted in the death of 331 civilians.

In December 1998, just months before Chechen Rebels demonstrated their capability to employ explosives, there was a spike in radiological incidents. The Chechen Security Services reported finding a radioactive substance affixed to an explosive mine near a railroad. It was not disclosed how the source was found or the type or quantity of the source.[71] Additionally in September 1999 just after the apartment bombings by Chechen Rebels, thieves attempted to steal radioactive materials from the Radon Special Combine Factory in Grozny, Chechnya. The two thieves only held the source container for a few minutes, attempting to remove it from the factory. Due to radiation exposure, a half hour later, one thief died, and the other collapsed, requiring hospitalization. Russian officials arrested the survivor. They did not report any updates of his status.[72]

Table 4. Case Study 2 analysis: Chechen rebel radiological source in Izmailovski Park

Case	Motivations	Effects	Accessibility	Obstacles
Case 2: Chechen Rebel Radiological Source in Izmailovsky Park	1. Coercion through mass casualties; cause Russian force withdrawal from Chechnya	1. Source more than 100 times the normal background radiation level, but no measurable effect on people	1. Obtained radioactive sources	1. Few impediments to acquisition or transportation
	2. Create public panic; demonstrate Chechen radiological capability that will cause Russian withdrawal	2. Failed to incite fear and panic	2. Poor radiological security after the 1991 fall of the Soviet Union	2. Fear of Russian retaliation may have created deterrence
		3. Death and injury due to explosive device (in other attacks)	3. Radiological waste dumped throughout Moscow	

Source: Created by author.

Motivations

Basayev was intent on the Russian force withdrawal from Chechnya. His method was the use of spectacular attacks to produce mass Russian civilian casualties to incite public fear and panic. He showed a capability for radiological terrorism and threats of RDDs to coerce Russian officials to withdraw from Chechnya. However, he lacked an explosive capability until 1999.

Effects

The source was 100 times the background radiation; with the highest potential dose of 15 micro Gy per hour, it would take more than seven years to case radiation sickness. This source was several orders of magnitude below the threshold established by the IAEA as dangerous.[73] Similarly, the EPA threshold for occupational exposure is 0.5 Gy total. It would take more than three years to reach this dose. Consistently, no reports indicated any casualties from the incident. Russian civilians, familiar with potential for radiation sickness due to the presence of radioactive waste throughout Moscow, did not panic. The attack failed to incite the fear that Basayev was trying to generate.

Accessibility

Basayev acquired radioactive sources. These were sources accessible due to the deteriorated security of radiological sources after the fall of the Soviet Union in 1991. Additionally, sources were available throughout Moscow. It would only take a Geiger counter to locate improperly disposed nuclear waste.

Obstacles

There was little in the way of physical deterrence to obtain and transport the source. This incident was prior to the NRC initiative that aided in the increased security of radiological sources abroad. The State Department did not receive significant Congressional funding to increase security measures in Russia and Eastern Europe until 2001.[74] However, the lack of desired effects created deterrence in the absence of public panic or physical effects from the placement of the source, which persuaded Basayev to change tactics.

Summary

The Chechen rebels had the motivation, the radiological means, and the opportunity. What they appear to have been lacking at the time was the explosive means. One consistency of Chechen Rebel attacks conducted under Basayev Shamil, was that they resulted in the death of no less than ten people. If Basayev's motivation was to push Russian forces out of Chechnya by creating fear through large number of casualties inflicted on Russian targets, then this non-explosive radiological attack was ineffective. Explosives in an RDD can enhance a fear effect by spreading contamination over a wider area. However, when his attempt to incite fear and panic by alerting news stations of the emplaced source failed. Basayev's lack of desired effects persuaded him to change tactics.

<u>Case Study 3: David Hahn, The Nuclear Boy Scout</u>

Description and Context

An article published in *Harper's Magazine,* "The Radioactive Boy Scout,"[75] was the source of much of the information in this case study. Other sources referenced linked back to the same *Harper's* article. Unlike subsequent articles from other publishers, this article was consistent with facts and dates.

David Hahn was a science enthusiast who used a passion for experimenting to cope with the pressures of adolescence and gain respect. Prior to the age of 10, he was a normal kid who played baseball and soccer, but when he was 10, his grandfather bought for him, *The Golden Book of Chemistry Experiments*.[76] It was after this that he developed an almost obsessive interest in science experiments. He learned through self-study, reading his father's college chemistry textbooks and additional books that he bought. His father encouraged his hobby by buying him laboratory equipment, like beakers. It was not apparent that he had sufficient knowledge or motivation to harm anyone with his radioactive isotope handling.

In 1991, Hahn set a goal on two things, becoming an Eagle Scout and achieving the atomic energy merit badge. To achieve the badge, Hahn created a diagram depicting nuclear fission and visited a hospital that utilized radiological medicine to learn about the application of radioactive materials in medicine. Hahn received the merit badge in 1991, but with his newfound knowledge, continued his pursuits of science experiments.

In 1994, David Hahn was a 17-year-old student who had a passion for science experiments. Attempting to build a breeder reactor in his mom's shed, his goal was finding energy sources and solutions.[77] A breeder reactor produces more fissionable material than it uses, while generating energy. When Hahn lacked the knowledge to build a breeder reactor, he reached out to the NRC, Department of Energy and various other governmental organizations and commercial industries for information. He originally received few replies and of little value. He tried again posing as a professor. He wrote as many as 20 letters a day. Later, he told the *UK Daily Mail* and *Harper's Magazine*, that the NRC gave him the information he needed. There is some discrepancy between two of the sources whether he mailed to obtain information on the building of the breeder reactor or the obtainment of sources, but both agree that he received the most valuable information from the NRC.[78] The only things he lacked were the materials.[79] From the information he received from governmental organizations and industry, Hahn believed he needed americium-241, radium-226, uranium-238, uranium-235, and thorium-232.[80]

He was able to purchase small samples of some isotopes by pretending to be a professor, but needed more material to conduct his experiments. For items and equipment that he could purchase without subterfuge, he was able to obtain funding by working at fast food restaurants, grocery stores, and a furniture warehouse.[81] Sufficient amounts of isotopes were not readily available to him through legal purchases.

With his earnings, Hahn wrote several smoke detector manufacturers and convinced one to send him 100 broken smoke detectors for one dollar apiece. Each smoke detector, containing a category 2 isotope, typically contains less than 3.7×10^4 Bq.[82] This is equivalent to a biological dose of one micro Sv per hour, which is .05 micro Gy per hour for alpha emissions.[83] It would take 200,000 hours, or more than 22 years of directly handling the contents of all 100 smoke detectors to show minor signs of radiation sickness. He was able to locate the small americium source within the smoke detector by writing to smoke detector companies until he found a helpful worker who explained where it was and what it looked like. Once extracted, Hahn used the americium from the smoke detectors to construct a neutron gun. It worked by emplacing americium inside a cavity drilled out of lead. He placed aluminum over the opening. Alpha decay from the americium interacted with the aluminum and released neutrons.[84]

With the neutron gun, Hahn intended to irradiate sources by bombarding atoms of fissionable material with neutrons. Next, Hahn needed fissionable material to irradiate with his neutron gun in order to make it more fissile. He chose uranium-235 because it is a weapons grade material used in atomic explosions. Therefore, he thought that it would be the most effective isotope. Since he could not buy uranium-235, Hahn decided to collect and refine it himself. He used his Geiger counter as a detection device and drove hundreds of miles in his Pontiac searching for rocks that emitted radiation. He was able to amass a quarter of a trunk full of uraninite, mostly from the shores along Lake Huron.[85]

What he most likely found was the oxidized pitchblende (U_3O_8) of the naturally, abundantly occurring uraninite (UO_2).[86] Uranium naturally decays to thorium, then to protactinium and on down the decay chain to ultimately end up at the stable element, lead. In each of these decays, the atom releases either an alpha or beta particle. In some cases, atoms release a gamma ray as the nuclides attempt to stabilize themselves. When using a Geiger counter, what is often detected are uranium's daughter radionuclides and not the decays from uranium itself. Therefore, a Geiger counter is not an accurate tool to determine sufficient concentration of uranium versus the abundance of its daughter radionuclides within the pitchblende.[87]

He did know, however, that he could not use the material in the pitchblende state, and he needed to isolate the uranium. Hahn believed that he could isolate the uranium from the pitchblende with nitric acid.[88] Although the process of grinding ore and using an acid, such as sulfuric acid or nitric acid is a common way of leaching uranium from pitchblende, a treatment of manganese dioxide, sodium chlorate, and salts is often required to first oxidize the uranium.[89] In fact, nitric acid is the best acid to leach uranium, but is not preferred due to its high cost and potential toxic risk to ground water.[90] When Hahn could not buy any nitric acid, he decided to make some. He heated potassium nitrate with sodium bisulfate, and then cooled the gas to collect the nitric acid.[91] Potassium nitrate is a fertilizer and food preservative found at garden and home improvement stores.[92] Sodium bisulfate, known as sodium hydrogen sulfate, is in foods as a preservative and in the treatment of water for pools and spas[93] found at home improvement stores. He hand ground the pitchblende with a hammer and applied the nitric acid. Hahn was unsure of what to do with the sludge of pitchblende and nitric acid. The correct action would have been to heat the mixture[94] to create an endothermic reaction,[95] but Hahn thought he could strain the nitric acid and pitchblende mixture to separate the uranium. The uranium was not as soluble as Hahn thought and it was caught in the filter.[96] When his homemade process to extract uranium failed, he decided to try thorium.

Thorium-232, an alpha emitter,[97] when bombarded with fast neutrons, transmutes to uranium-233.[98] Like uranium-235, uranium-233 is a fissile material, able to capture slow moving neutrons.[99] For a teen that enjoyed experiments, Hahn was likely looking for a good target for his neutron gun. Thorium and its product, uranium-233 would have been appealing. To find thorium, Hahn referred to his Boy Scout merit badge pamphlet, which informed him that thorium-232 coats the mantles of gas lanterns. Hahn bought thousands of them. He pulled out the mantles and burned them to ash using a blowtorch, producing thorium dioxide. He needed to find a substance to bind with the oxygen to create a decomposition reaction to remove two oxygen atoms from the molecule to leave thorium metal.[100] Hahn referenced one of his dad's chemistry books and researched that lithium binds to oxygen. He subsequently bought $1,000 worth of lithium batteries, dissected them of their lithium, placed the lithium and thorium dioxide together inside of aluminum foil, and heated it. The result was a purified form of thorium metal.[101]

When his neutron gun could not produce enough neutrons to change the thorium into uranium, Hahn pursued acquisition of radium-226 to replace the americium in his neutron gun.[102] It is unclear why Hahn chose to use radium over americium. Americium is a better alpha emitter than radium, and emits three times the amount of alpha particles.[103] Additionally, the decay energy of the americium is higher than that of radium; they are 5.4 MeV and 4.87 MeV respectively.[104] It is likely that Hahn was lacking either sufficient quantity or concentrations of americium.

Hahn knew that radium was a component of luminescent paint on pre-1960 clock faces and dashboard panels. Radium paint would make surfaces glow, but could cause cancer. He began looking for radium by scouring junkyards and visiting antique shops. The little bits he found, he would scrape off and save in pill vials. His luck changed when he drove past an antique shop on his way to his girlfriend's house. He noticed the Geiger counter that he kept in his car registered a high level of emissions. He stopped and bought an antique luminescent clock for $10. The clock contained a vial of radium paint on the inside, presumably for touch ups.[105]

In order to concentrate the radium for use in his neutron gun, Hahn needed barium sulfate. Hospitals use barium sulfate as an x-ray contrast medium for x-rays,[106] so Hahn used the rapport that he had built at the hospital where he had conducted an atomic merit badge visit. They remembered him and when he asked, they gave him a sample of barium sulfate. Hahn heated the barium sulfate to a liquid and used the same method he had attempted with the uranium. He then dried the solution, forming into a crystalline solid of radium that he packed inside the lead housing within his new gun. Hahn learned from his information from the NRC, that beryllium was a "richer source" of neutrons when bombarded with alpha particles than aluminum foil.[107] In order to obtain beryllium, he enlisted a friend, enrolled at the Macomb Community College, to steal beryllium from the chemistry department. The friend did and Hahn placed it on his gun. The result was a much stronger neutron gun. He pointed it at the thorium and measured the results with his Geiger counter. The thorium was apparently becoming more reactive, but was not transmuting into uranium. If Thorium-232 captured neutrons and became thorium-233, it would decay by beta decay to protactinium-233.[108] Pa-233 subsequently experiences a beta decay to become U-233, a fissionable material. The only way Hahn would have known the difference is if his Geiger counter distinguished between alpha, beta, and gamma radiation, and to perform an accurate assay on the material.

Frustrated, Hahn posed again as the professor intent on conducting radiation experiments with students, and drafted another letter to the NRC. The NRC responded and advised him that his beam was “too fast.” He needed to slow the neutrons down with a filter. [109] Fissionable materials have a range of neutron speeds that they can capture. For example, fissile materials are able to capture slow neutrons, but non-fissile materials cannot. Fissionable thorium, though unable to capture slow moving neutrons is a more fertile emitter than uranium.[110] To slow the neutron, which means reducing its kinetic energy, the NRC recommended using water, tritium, or deuterium. Water would seem the most likely and conveniently available candidate, but Hahn chose to acquire tritium.

Tritium is a radioactive form of hydrogen that is naturally occurring and can be a byproduct of nuclear reactions.[111] To obtain tritium, Hahn contacted the same source list among industry that he had written to before. Hahn discovered that tritium is a glow in the dark substance found in the sights for guns and bows. He went to various sporting goods stores and purchased sights containing it. He brought the sights home, extracted the tritium, and returned the sight, citing return for an operational flaw for repair. Every time the repaired sight returned from the manufacturer, he would extract more tritium. He coated the beryllium metal, bombarded by the radium, with the tritium flakes. The tritium flakes were intended to act as a filter to slow the emitted neutrons prior to bombardment of the thorium, but tritium flakes would not have provided an optimal and uniform filter around the beryllium.

Because a Geiger counter does not typically detect neutrons, Hahn would not have been able to measure the effectiveness of his filter. The way to know that his neutron gun was working was by bombarding a fissionable substance with neutrons and detecting the emissions of that reaction. The filter must have been at least partially effective. He monitored the emissions with his Geiger counter for weeks, and concluded that it was becoming more reactive every day.[112] When he pointed his neutron gun at the thorium, he was likely detecting beta particles emitted from the thorium decay, transmuted to uranium. Measurement probably also included alpha particles emitted from the radium and the emissions from all of the other unused sources within his lab.

Hahn's apparent success with thorium gave him the idea to construct a "breeder reactor," but he knew that he did not transmute thorium to enough uranium, nor could he obtain enough to establish a sustainable reactor, so he set his goal on making radioactive isotopes "interact with one another."[113] He took the blueprint out of one of his father's college textbooks and used the items he already had. He ground and mixed the americium, radium, beryllium, and aluminum and placed it inside an aluminum foil shell. He heated the package to create a core for the reaction. He then duct taped the thorium ash, uranium powder and some carbon cubes to the outside of the core and monitored the radioactivity. Over the next couple of weeks, the emissions became "far greater"[114] as was measured by his Geiger counter. It was from the growth in emissions that Hahn concluded he had been successful in transforming at least some of the radioactive material. However, the increased emissions began to make Hahn nervous. When emissions were detectable five houses away, Hahn decided to disassemble his breeder reactor and disperse the materials. He kept the radioactive thorium, radium, and americium at his mother's residence and within the shed, but placed the rest of his radioactive items in his car to disperse the materials.

It was then in a moment of circumstance, that police stopped Hahn, who were responding to the report of a teenager stealing tires in the area. The police decided to search his vehicle. When they opened his trunk, they saw all of the mercury switches, round disks and various items, but what drew their interest was a padlocked and duct taped metal box. Hahn warned them that the metal box was radioactive. His experiments came to an abrupt halt at this point.

Hahn's mom, in an effort to save her house from government possession, went through and collected up anything that looked suspicious and threw it in the garbage. She threw away his neutron guns, the thorium, and the radium. By the time the officials from the Department of Public Health were able to survey the property, most of the radioactive material was gone. Even so, a vegetable can registered 1,000 times background radiation. Hahn joked that "they only got the garbage, and the garbage got all the good stuff."[115] His experiment resulted in more than $60,000 of cleanup effort to disassemble, containerize, transport, and bury the shed with other low-level radioactive materials.[116]

Literature research revealed no reports of radiation sickness from his family or from the 40,000 neighbors living in the area despite reports of radiation levels at 1,000 times the normal levels of background radiation. There was no clear data on lot size or distances from the shed to his mother's house or the neighbor's houses. What was clear was that David Hahn was regularly working in the shed on the weekends when he was at his mother's house, but never sought treatment for radiation sickness. Neighbors did express concern. One neighbor claimed to have seen the shed emit an eerie glow. The next-door neighbor reported having watched the clean-up operation from her house.[117]

In his lab, he had small amounts of americium-241, potentially a category 2 isotope. What he had a lot of was thorium, an alpha emitter. Alpha emissions would not have posed an immediate threat to anyone who was not in the shed breathing in the particulate alpha materials and the emitted alpha particles.

Hahn understood the dangers of radiological materials, had very limited protective equipment, but regardless, continued to amass quantities of isotopes. He used items like coffee filters to isolate dangerous materials to keep from spreading radioactive contamination.[118] He also changed his shoes after leaving the shed and sometimes wore a thin lead vest, like those worn for taking x-rays.[119] However, the risks in dissecting lithium batteries and burning alpha emitters to a fine ash were not without significant risk.

Hahn's passion was in science experiments, not terrorist acts. He told PBS News reporters that the idea to build an RDD had never even occurred to him.[120] Hahn amassed enough radiological source material to produce radiological emissions more than 1,000 times the normal background radiation.

Some of the routes that Hahn took to obtain materials and information are now closed. However, individuals now have the use of the internet to gather information. Regardless of increased security, individuals continued to obtain radioactive materials.

United Kingdom officials arrested Al Qaeda operative, Dhiren Barot in 2004, for plotting to building an RDD from the americium in fire alarms. Officials discovered his plot through the interrogation of a fellow operative at Guantanamo Bay.[121] In 2009, after alleged US Nazi James Cummings' wife shot him to death, investigators found a very small amount of radioactive materials in their home, along with instructions on how to build an RDD.[122] There have been incidents of thieves obtaining radiological material that investigators are unable to find and recover. Thieves stole an industrial camera containing iridium-192, a category 2 gamma, and beta radiological source, out of a truck in a hotel parking lot. In 2013, a vehicle in Mexico was stolen that contained iridium-192. Iridium-192 has a short half-life of 73 days,[123] so the stolen material would not be much of a risk in 2016. However, for a time, the potential for abuse existed. Individuals with persistence and an ability to think beyond norms, have consistently found ways to exploit vulnerabilities and create opportunities to obtain radioactive sources.

Table 5. Case Study 3 analysis: David Hahn "Radioactive Boy Scout"

Case	Motivations	Effects	Accessibility	Obstacles
Case 3: David Hahn's Breeder Reactor	1. No terrorist related motivations	1. No reported incidents of radiation sickness	1. Americium salvaged from commercial sources	1. Few institutional obstacles prior to the September 11, attacks
	2. Build a Breeder Reactor	2. Created an environment with more than 1,000 times the normal background radiation level	2. Uraninite from the shores of Lake Michigan, attempted smelting (unsuccessful)	2. Detected incidental to unrelated law enforcement stop
	3. Gain respect	3. $60,000 clean-up costs	3. Thorium from lanterns	
		4. Created public concern, but not panic	4. Radium paint from an antique shop	
			5. Tritium from weapons sights	
			6. Knowledge was readily accessible through literature, industries and governmental agencies	

Source: Created by author.

Motivations

There were no terrorist motivations. Hahn pursued his passion for chemistry experiments in an attempt to gain respect from his peers. His ultimate goal was to build a breeder reactor to create energy solutions.

Effects

Hahn created an environment that had 1,000 times more radiation than the normal background levels. Regardless, there were no reports of radiation sickness. Neighbors expressed concern over the presence of cleanup crews and reporting an eerie glow emanating from the shed, but not public panic. The cost of cleanup was $60,000 in 1995.

Accessibility

Hahn acquired radioactive materials sufficient to produce a radioactive source that was 1,000 time the normal background levels. He was able to obtain americium-241 salvaged from smoke detectors, uraninite from the shores of Lake Michigan, thorium-232 from lantern mantels, radium-226 from iridescent paint, and tritium from weapon sights.

Hahn had an easier time obtaining radiological information from industry and governmental organizations in 1994 than one would find in 2016. Even then, he had to write many letters and pose as an instructor to gain much of his information. However, one thing Hahn did not have in the mid-90s that is abundant today, is information from the internet.

Obstacles

There were few obstacles preventing Hahn's obtainment of radioactive materials. He was able to overcome reluctance from government and industry to provide material by building rapport and posing as a professor. Police discovered Hahn’s experiments through an unrelated investigation.

Summary

Hahn lacked the terrorist motivations to build an RDD, and there were no long term or serious effects. However, this case study highlights the accessibility of material to a motivated individual who was willing to think outside of norms to overcome obstacles. David’s determination and ingenuity puts a spotlight on a future potential threat.

Case Study 4: Samut Prakarn, Thailand Cobalt-60 Accident

Description and Context

In 2000, four thieves with the intent to sell scrap metal partially disassembled a teletherapy machine. They successfully stole a teletherapy head containing a cobalt-60 source from an unsecure storage facility in Thailand. The unit was in the control of a company not licensed by the Office of the Atomic Energy for Peace (OAEP) to possess multiple teletherapy machines.[124] When the teletherapy heads moved from a secure site to a non-secure site without the approval of the OAEP, accountability was lost and the material was outside the control of Thai regulators.[125]

The Atomic Energy Commission (AEC) of Thailand, a subordinate organization of the OAEP had policies in place, but lack of enforcement ultimately encouraged companies to store radioactive sources illegally. The AEC produced the policies that govern radiological use, storage, security, and transfer. The regulations required yearly licenses, yearly inspections for license renewal, and notification prior to the transfer, exportation or importation of radiological sources. The AEC was responsible for executing those policies, and overseeing licensing for the possession and use of radioactive materials within Thailand.[126]

At the time of the accident, the AEC was managing more than 650 licenses with eight inspectors. The requirement for yearly inspections was more than was possible. Therefore, the AEC prioritized inspections based upon an unofficial classification of potential risk.[127]

The OAEP did not penalize companies or individuals who possessed a radioactive source after a license had expired. If a company lost its license, the OAEP authorized three options. In the first option, the former licensee could store the radioactive item in an approved licensee's storage area. Second, the former licensee could transfer the item to a current licensee. Finally, the licensee could pay the OAEP to take possession of the item.[128] The safest option as related to security, which was the transfer of items to the OAEP, was the most costly for the consumer. Therefore, the system encouraged illegal storage and failed to enforce compliance.

This was precisely what happened to the teletherapy unit involved in the accident. It was an aged, 1969 unit, whose contracted maintainer went bankrupt. Contracted maintenance personnel must replace teletherapy sources periodically, to alleviate long treatment times. Therefore, without contracted maintenance, in 1994, the Bangkok Hospital discontinued use of the teletherapy unit. The new Canadian company contracted by the Bangkok Hospital, Nordian, would not take the radioactive source because they were not the original manufacturer. The Bangkok Hospital was facing a storage dilemma with the non-functioning unit.

Under OAEP regulations, Bangkok Hospital could have paid the OAEP to take possession of the item or find a licensed user to store the unit. Presumably, not wanting to pay the OAEP to take responsibility of the item, Bangkok Hospital found a sub-company of Nordian, named Kamol Sukosol Electric (KSE), to store it. KSE was already a licensed user, possessing and storing a teletherapy machine for a physician. To the Bangkok Hospital, this appeared to be an authorized transfer to a qualified OAEP licensee. However, neither the Bangkok Hospital nor KSE notified the OAEP of the transfer.

Kamol Sukosol Electric requested approval of additional storage for disused units, but the AEC disapproved the location due to security concerns. In a 1996 inspection, the AEC discovered that KSE was in possession of four teletherapy units. However, the AEC only licensed KSE to store one unit.[129] Presumably, due to their overwhelming caseloads and the lack of policy on enforcement regarding possession of sources, there was no penalty by the OAEP against KSE. Therefore, four years later, in 1999, KSE was still in possession of four teletherapy units.

In 1999, when KSE lost their lease for a warehouse that had been storing the sources, they returned the one licensed teletherapy unit to its owner. Without sufficient storage for the other three teletheraphy units, KSE moved them into a roofed building inside the Nordian parking lot. The parking lot had a sheet metal fence around it, but it was unsecure and neighborhood children would often play in the parking lot. It was from this lot that thieves gained access to the teletherapy unit. Therefore, the source was under minimal security with no observation and in a location not disclosed to authorities.[130] Consequently, the cobalt-60 was easily accessible to unauthorized persons.

Cobalt-60, a category 1 source, has the potential to be 1,000 times or greater activity than a source that the IAEA determines as dangerous. The IAEA threshold for an isotope to be dangerous has an activity level that produces 2.5 Gy per hour within two centimeters. This level would produce localized burns and moderate level radiation sickness in a case of close proximity exposure for an hour.[131] 1,000 times this level is 2,500 Gy per hour within two centimeters; it is strong enough to produce very severe radiation exposure within 15 seconds. In 2000, officials estimated the Samut Prakarn source to have decayed from its original strength of 196 TBq in 1981 to 15.7 TBq (425 Ci).[132] It was at 8 percent of its original strength. This means that even after decay, depending upon its original strength, the source remained with at least 80 times the activity level the IAEA determines as dangerous. Exposure within two centimeters of the Samat Prakarn source would result in approximately 200 Gy exposure in an hour or 10 Gy in three minutes. This would be a category 2 source. Exposure to such a source for more than a few minutes could cause permanent injury. Exposure of several hours to days could cause death.[133]

On February 1, two of the thieves brought the partially disassembled source to a junkyard for further disassembly and separate sale of the parts. The thieves claimed to have bought the head on January 24, 2000 and stored it at a thief's home until the end of January. The four thieves tried to disassemble the head to separate the parts for sale with a chisel and hammer. Two of the thieves were successful in breaking the weld, and when they did, a liquid ran out. After seeing the liquid, the owner of the house told the others to stop. The homeowner and a thief responsible for separating the weld transported the teletherapy head it to the Samut Prakarn junkyard. The latter thief rested his leg on the partially disassembled head during the 30-minute travel time.[134]

At the junkyard, a young worker successfully opened the housing with an acetylene torch, but did not separate the steel and the lead. Upon opening the housing, the junkyard worker saw yellow smoke and a couple of metal pieces fall out of the two cylindrical objects onto the ground. The metal pieces were the cobalt-60 source. The junkyard worker picked up the source in order to weigh it in his hand,[135] presumably for assessing value.

Figure 2. Drawer of the teletherapy unit

Source: International Atomic Energy Agency, *The Radiological Accident in Samut Prakun* (Vienna, Austria: International Atomic Energy Agency, February 2002), 9, accessed October 12, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1124_scr.pdf.

Figure 3. Housing unit. The left portion is hollow and housed the Cobalt-60 source.

Source: International Atomic Energy Agency, *The Radiological Accident in Samut Prakun* (Vienna, Austria: International Atomic Energy Agency, February 2002), 10, accessed October 12, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1124_scr.pdf.

The junkyard worker stated that the metal pieces had made his hands tingle. He and an additional junkyard worker who worked in the same proximity began feeling ill with nausea and vomiting almost immediately. Both workers returned to work at the junkyard. Both the junkyard workers died, 47 days and 38 days later. The actual deaths were due to septic shock as a complication from the exposure.[136] They received more than 6 Gy of full body radiation, a dose consistent with severe radiation sickness. Before dying, they exhibited skin burns, thinning hair, nausea, vomiting, headaches, and weight loss.[137]

Figure 4. Junkyard employee that was working in proximity to the exposed source

Source: International Atomic Energy Agency, *The Radiological Accident in Samut Prakun* (Vienna, Austria: International Atomic Energy Agency, February 2002), accessed October 12, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1124_scr.pdf. *Note*: Hair loss and ulcers were apparent 21 days after exposure. Died 38 days after exposure.

Other members of the group suffered lesser effects from their exposure. The two thieves that transported the housing with integral source to the junkyard had nausea, vomiting, headaches and localized burns. Both thieves were believed to have received 2 Gys of radiation absorption which is consistent with mild to moderate exposure.[138] The thief who helped open the weld and laid his leg over the partially disassembled head, received burns on his leg and hand. Medical professionals conducted two debridements and at least one skin graft on his leg, due to infection.[139] The thief who used his house to partially disassemble the telepathy head and transported the device had to have a portion of one of his hands amputated.[140] The two thieves that were not in near proximity to the partially disassembled source during transportation received 1 and 2 Gys of radiation resulting in nausea, vomiting, and localized burns that healed.[141]

Figure 5. Homeowner's radiation exposure burns

Source: International Atomic Energy Agency, *The Radiological Accident in Samut Prakun* (Vienna, Austria: International Atomic Energy Agency, February 2002), accessed October 12, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1124_scr.pdf. *Note*: First picture, 23 days after exposure. Second picture, 8 weeks after exposure.

Figure 6. Radiation burns on leg of thief who aided in disassembly and draped leg over source

Source: International Atomic Energy Agency, *The Radiological Accident in Samut Prakun* (Vienna, Austria: International Atomic Energy Agency, February 2002), accessed October 12, 2015, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1124_scr.pdf. *Note*: First picture, 23 days after exposure. Second picture, five weeks after exposure.

Beyond the group with immediate access to the source, others received radiation exposure and subsequent sickness. The junkyard owner and her husband who lived across the street, within 15 meters of the source and who spent time in and around the junkyard absorbed more than 6 Gy of radiation. Both exhibited nausea, vomiting, hair loss, and weakness. The owner's husband died 52 days after exposure.[142] The 75 year-old mother of the owner lived in the house with the couple. The house was across the street from the junkyard, within 15 meters of the source. She only experienced nausea and vomiting.[143]

Thailand authorities consciously made decisions to reduce the risk of public panic. OAEP and public health officials considered civilian evacuation from the area, but due to the risk of public panic, response personnel restricted access to the road outside the junkyard and to the junkyard itself. They moved as rapidly as possible to recover the source.[144] Not until months after the event did news outlets, such as the Asian Times, complain of the secrecy surrounding the event and expressed concerns over the potentially unaware but effected civilians, and the Thai government's lack of preparation.[145] By this time, the deaths had already occurred and those affected had already sought treatment. There was public frustration, but not panic. Thai officials recovered the cobalt-60 source. Nine individuals developed radiation sickness varying from nausea to death. Meanwhile Thai officials took steps to reduce public panic.

Doctors at Bangkok Hospital alerted the OAEP when multiple patients sought treatment for symptoms consistent with radiation sickness. Thai authorities recovered the cobalt-60 source and requested assistance from the IAEA. Three people ultimately died from exposure.[146]

Table 6. Case Study 4 analysis: Samut Prakarn, Thailand Cobalt-60 accident

Case	Motivations	Effects	Accessibility	Obstacles
Case 4: Samut Prakarn, Thailand Cobalt-60 Accident	Terrorist motivation absent: 1. Opportunistic thieves-scrapping metal for cash 2. No training on use or handling of sources	1. Three died and six received treatment for radiation sickness 2. Thai government Prevented public panic	1. Policy flaw that encouraged violations by failing to detect 2. Security lapses made theft easy 3. Lack of material accountability	1. Overtasked AEC employees unable to conduct yearly inspections 2. No prosecution for policy violations 3. Policies did not encourage control and security of sources

Source: Created by author.

Motivations

Radiological terrorism was not a motivation for the four thieves responsible for stealing the teletherapy head. They were not lone wolves, autonomous cells, or a part of a hierarchical organization. They were intent upon making money from selling or scrapping the parts. When the thieves could not disassemble the unit into individual parts for sale, they brought the partially disassembled teletherapy head to the Samut Prakan junkyard for disassembly.[147]

Effects

It took more than two weeks for the two employees that received moderate to severe exposure to radiation to seek medical aid. Three out of four people that received more than 6Gy of radiation died from complications of radiation sickness, but not until over a month after exposure. The mother of the owner who lived within 15 meters of the source was relatively unaffected.

The progression of radiation sickness documented through pictures and spread throughout media and social media have the possibility to incite public panic. This was not the case in Thailand, because officials made a conscious effort limit release of information in order to reduce panic. Their method of reducing panic by hiding an incident would not be acceptable in the US, but there are other more acceptable methods that can be employed, like public education.

Accessibility

The OAEP policies that intended to control, track, and secure radiological sources actually encouraged poor practices. It resulted in the accessibility of radiological sources. High costs to properly dispose of material deterred licensees in Thailand from properly storing radiological sources. It was the lack of policy enforcement that caused licensees to disregard security standards and licensee obligations to comply with OAEP regulations.

Obstacles

Because of the heavy caseload on the AEC, policy that was intended to be an obstacle to radioactive source obtainment contributed to its accessibility. There were insufficient personnel to conduct the annual inspections of licensees. This resulted in the loss of licensing standards and the ability to make recommendations. The lack of enforcement bred a culture of licensees that did not comply with security regulations.

Interesting in this case study is the presence of the shielding encasing the source. It was not until they cracked the seal that the thieves began to exhibit illness. We know this because the source sat at the thieves' house for a week with no incidents of illness until they cracked it open with a hammer and chisel. It is feasible that a terrorist, if properly equipped to open the cylinder, could expose the shielded source, emplace it in an RDD, and emplace the RDD. They would be anticipated to experience radiation sickness and burns from a category 1 gamma source. That would be helpful to law enforcement officials to identify terrorists responsible, but potentially not until weeks after the exposure.

Summary

There was no terrorist motivation, but only opportunistic aspirations. The result of the thieves' ignorance was the death of three victims. At the time of the incident, the OAEP was more of a tracking system than a regulatory institution. While regulations might have required effective security measures for radioactive sources, the OAEP and Thai government were not effectively enforcing those standards. Therefore, OAEP policies were not an effective obstacle to obtaining radioactive sources. However, the Thai government was successful in its effort to prevent public panic. The manufactured shielding around medical and industrial sources allowed safe transportation of the source. Educated terrorists could safely utilize this shieling to transport and store a strong gamma source.

Case Study 5: Chernobyl

Description and Context

On April 26, 1986, the Chernobyl staff prepared the reactor to test a new rapid voltage regulator design and its effects on turbines under a loss of the main electrical power supply. The test required staff to disable automatic safety shutdown mechanisms, which placed the reactor in an "unstable condition."[148]

The reactor had several policy and mechanical safeguards. However, Chernobyl technicians made critical errors. They manually disabled all safeguards in preparation for the test, to include the emergency core cooling system. When pressed for time, technicians powered down the system too quickly, which caused an unsafe buildup of byproducts in the reactor core. When they recognized the buildup of byproducts, they attempted to increase the power again by raising most of the control rods. Even with the control rods removed, technicians were unable to raise the energy of the core, resulting in an extremely unstable condition. According to Russian engineer Grigory Medvedev, technicians should have waited 24 hours for the system to stabilize. However, the Chernobyl technicians did not want to stop, so they attempted to raise the power of the reactor, by removing more control rods. The minimum number of control rods authorized for operation within the reactor was 30. The engineers brought the system down to six control rods.[149]

Regardless of the unstable condition, technicians decided to conduct the test, which meant turning off the generators that circulated the cooling water. The cooling water began to boil. The change from liquid to gas left less water to absorb neutrons from the core's reaction. Free neutrons reacted with other atoms in the core instead of being absorbed by the water or the control rods. The result was a power surge and out of control reactions. When technicians noticed the power surge, they attempted to reinsert all 205 control rods and the emergency rods.[150] However, the reactor contained a design flaw. The control rods had graphite on the tips.[151] Graphite is a neutron moderator. It reduces the kinetic energy of a neutron, slowing it to equivalent speed of the surrounding particles. The slowed neutrons do not have sufficient energy to dislodge a subsequent neutron from a bombarded atom.[152]

In this reactor, there was a one-meter section of the control rods that was hollow between the graphite tip and the rest of the control rods. In this hollow section, there is no moderator. When the operators inserted all of the control rods at once into the water, the graphite moderator, followed by the hollow space, displaced the neutron moderating water. This raised reactivity, which increased the temperature and the amount of steam. Liquid water moderates neutrons more effectively than steam. The bubbles in the boiling water created “voids” where the neutron moderation was much lower. The combination of less moderation due to water displaced with hollow space and the creation of voids, resulted in a rapid creation of steam within the reactor. The rapid buildup of steam caused the first explosion.[153] A second explosion occurred, for unverified reasons.[154] There was no terrorist motivation for the accident. It was the result of a design flaw and the operators placing the reactor into an unsafe state.[155]

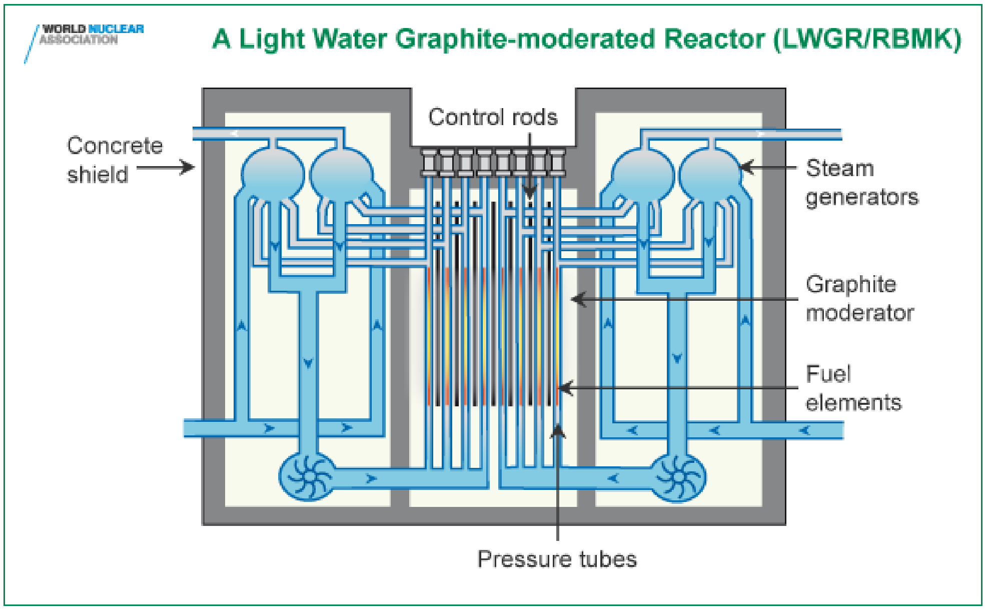

Figure 7. Chernobyl RBMK reactor design

Source: World Nuclear Association, "RBMK Reactors," accessed May 31, 2016, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/appendices/rbmk-reactors.aspx.

According to Russian nuclear engineer Grigori Medvedev, the amount of radiation released into the atmosphere was equal to "ten Hiroshimas."[156] Two workers died from the initial explosions. Around 1,200 tons of graphite and an unspecified amount of radioactive fuel ejected from the reactor. The graphite and fuel started various fires, dispersing radioactivity. About 85 PBqs of cesium-137 released into the atmosphere. This is 216,000 times more radiation than was present at the Samut Prakarn accident. In total, the accident released roughly 5 percent of the reactor core, or 5,200 PBq into the atmosphere.[157] The World Nuclear Association confirmed acute radiation sickness in 134 on site workers and response personnel. Most of the high doses of radiation occurred among the 1,000 personnel there on the day of the accident. More than

200,000 people were involved in the cleanup and recovery. Radiation deaths totaled 28 people within the first few weeks; six of those were firefighters. Only those personnel who were onsite received acute radiation sickness.[158]

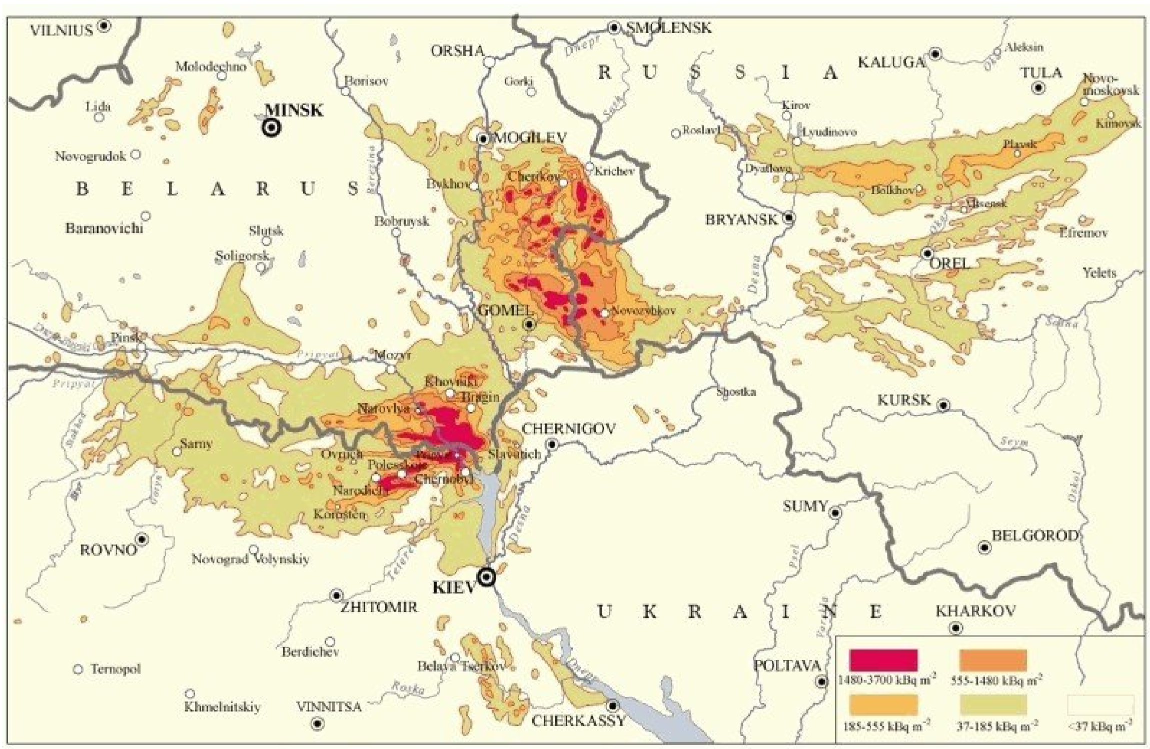

Figure VI. Surface ground deposition of caesium-137 released in the Chernobyl accident [I1, I3].

Figure 8. Surface ground deposition of Cesium-137 released in the Chernobyl accident

Source: United Nations Scientific Committee on the Effects of Atomic Radiation, “Maps of Radionuclide Deposition,” 2000, accessed March 14, 2016, http://www.unscear.org/unscear/en/chernobylmaps.html.

At the time of the accident, 49,000 people were living within 3 km of the reactor.[159] The accident displaced 116,000 people within 30 km of the reactor,[160] and an additional 220,000 from contaminated areas in subsequent years.[161] Many returned at their own risk to live within the contaminated area. In 30 years since the accident, the only attributable illness is an increase in thyroid cancer among children. However, some cases may have been due to the screening process.[162] In a thyroid scan, a patient ingests a radioactive iodine capsule. The scanner then detects the radioactive material collected within the thyroid gland. Some medical professionals questioned whether the children developed thyroid cancer from the iodine and cesium released from Chernobyl or the iodine they ingested for the tests.[163]

The media and authorities understood the potential for public panic from over analyzing excessive and unnecessary information. Therefore, both media and authorities decided to withhold some information to prevent panic.[164] Although transportation systems, such as trains and planes were overwhelmed, there was not an indication of widespread panic.[165] The impact of misinformation was apparent when some physicians within Europe advised mothers to abort babies due to the mother's potential exposure to radiation and the subsequent potential effects on the fetus. It was estimated that the overall fetal death due to abortion was "likely much greater than directly from the accident."[166]

People near the site experienced psychological impacts. Many exposed to the radiation adopted a fatalistic view from their perceived exposure and "took on the role of invalids."[167] Others turned to self-destructive behaviors, such as smoking and alcohol abuse, similar to the behaviors that arise in people after other major disasters.[168]

The cost of the containment shelter for the damaged reactor, and its implementation plan was close to $4 billion. In 2011 to 2015, a new plan costing $2.2 billion was implemented to refurbish the abandoned areas and return them to habitable living areas. The initiative focused on the re-establishment and refurbishment of essential services, roadways, and demolition of condemned houses.[169]

Analysis

Table 7. Case Study 5 analysis: Chernobyl

Case	Motivations	Effects	Accessibility	Obstacles
Case 5: Chernobyl	NA-No terrorist motivation.	1. Two people died from explosions 2. 28 died due to radiation sickness 3. 134 confirmed cases of radiation sickness 4. Increased amount of thyroid cancers 5. Over $6 Billion in costs for containment and rehabilitation 6. Authorities prevented public panic by withholding information	NA–release did not create collection opportunity	NA–RDD assembly and transportation were not issues

Source: Created by author.

Motivations

There were no terrorist motivations. The accident occurred due to a combination of Chernobyl nuclear plant worker incompetence and reactor design flaws. The workers overrode all safety mechanisms and ignored policies pertaining to control rods. Reactor design flaws caused a rapid buildup in reactivity and steam that caused an initial explosion.

Effects

Although this incident occurred in a very well prepared structure separated 3 km from inhabitants, it shows the effects of radiation dispersal over a large area. Two people died immediately from the explosion and 28 personnel that were onsite died within the first few weeks. An additional 134 people that worked onsite or responded received acute radiation sickness. Most of these illnesses were from the 1,000 personnel that were present on the first day and not the 200,000 workers that continued cleanup and containment. No one that was off site received acute radiation sickness. However, there was an increased amount of thyroid cancers, especially among children. The cost of containment and rehabilitation was more than $6 billion.

Accessibility

There was no accessibility of sources. The cases of radiation sickness were from the contamination onsite and within the reactor.

Obstacles

This was not a case of radiological terrorism, so there were no obstacles to the employment of an RDD.

Summary

There were no terrorist motivations, terrorist accessibility to radioactive isotopes, or obstacles from the employment of an RDD. This case highlighted the effects similar to that of a large RDD where the effects are due to radiation and not the explosive event. The result was not mass deaths. From more than 2,000 tons of graphite and radioactive material released into the atmosphere, only those onsite received acute radiation sickness or death. Children offsite had a raised incidence of thyroid cancer.

Overall Chapter 4 Interpretations: Cross-case Analysis

First, the terror motivations toward the employment of an RDD are immediate death and injury, public panic, recruitment, asset denial, economic disruption, and long-term illness[170] in order to advance their political and ideological goals. In the case studies, Al Qaeda's goals were parity for the deaths of four million Muslims and the employment of spectacular attacks to cause economic disruption and fear to further their ideological and political goals. Similarly, Chechen rebels used mass casualty, spectacular attacks to create fear and force Russian forces from Chechnya. They used radiological terrorism to show a capability to hurt the Russian people in order to force Russian officials to withdraw troops from Chechnya. In both cases, terrorists were motivated to use attacks threatening physical and political effects to generate public panic or fear in order to advance their political goals. Although David Hahn did not have a motivation to construct an RDD, he demonstrated what can be achieved by a persistent individual in search of isotopes. The Thai thieves, as well as other more recent thefts, indicated that a motivation for profit inadvertently exposed individuals to radioactive material and provided a radioactive source for other groups. Finally, the Chernobyl case demonstrated how individuals with benign motivations concerning radioactive material can nonetheless create conditions conducive to widespread contamination. It showed the effects of radiation dispersed over a large area with significant populations.

Second, the effects of an RDD presented in the case studies are death and injury from the conventional explosive event, possible radiation sickness or death from exposure to a radioactive source, public fear of a radiation exposure, and high cleanup costs. Al Qaeda and Chechen rebels have used explosive events for years to cause immediate death and injury. The explosion at Chernobyl was not from a terrorist induced conventional explosive event. Regardless, two people died from the explosion. Neither David Hahn nor the thieves at Samut Prakarn were interested in terrorist attacks, so there was not a terror induced explosive event.

Third, Al Qaeda did not employ an RDD or any radiological terrorism, so there were no effects due to radiation. At Izmailovsky Park, Moscow, there were no effects from radiation because the source was not active enough to cause radiation sickness. David Hahn's experiments generated a source 1,000 times the background radiation, but still lacked the effects of radiation sickness on Hahn, his Family or his neighbors. The effects of radiation sickness from the Samut Prakarn accident progressed over weeks, resulting in the death of three people and radiation sickness in at least six others. At Chernobyl, more than 2,000 tons of graphite and radioactive material ejected into the atmosphere. Yet, the only people that received acute radiation sickness were those on site. Of the 134 confirmed cases of acute radiation sickness, 28 people would ultimately die within a few weeks from exposure. The only documented effect to people in the towns and areas surrounding the nuclear plant, were increased cases of thyroid cancer within children.

Both Al Qaeda and Chechen rebels intended to use fear to advance their political goals. However, none of the case studies involving radiation terror or accidents resulted in public panic. Al Qaeda did not use radiological terrorism, so there was no panic from its employment. In the case of the radiological source emplaced in Izmailovsky Park, Russian civilians familiar with radiation sickness did not panic or pressure Russian officials to withdraw forces from Chechnya. In the case of David Hahn and his "breeder reactor," his neighbors showed concern, but not panic. The Thai government prevented public panic by moving fast to recover the source and not evacuating the area. By the time news media found out about the incident, it was beyond the timeframe when individuals would have observed symptoms. At Chernobyl, both media and authorities chose to withhold certain information that could cause panic or misinformation. Effects of the latter caused some European physicians to recommend abortions to expectant mothers.

The relatively low cost to eliminate the contamination accumulated by Hahn was \$60,000. By contrast, the cost to contain and rehabilitate, but not remove the contamination at Chernobyl was \$6 billion. The literature did not include the costs for cleanup of the Samut Prakarn accident or the source emplaced in Izmailovsky Park. There was no cost of cleanup associated with the Al Qaeda because there was not a radiological incident.

The only effect that met motivations to generate fear through mass deaths was the explosive event. The radiological incidents failed to create fear and panic. The varied cleanup costs, other than at Chernobyl, were not great enough to create economic disruption.

Third, the case studies showed that radioactive sources are available. Hierarchical terrorist organizations like Al Qaeda and Chechen rebels have had access to radiological sources through the sale of stolen or found materials. Thieves, like at Samut Prakarn, are able to access radioactive material by taking advantage of vulnerabilities in security. Similarly, radioactive material was available to individuals like Hahn, who are self-educated and motivated individuals. The case studies did not present examples of autonomous cells; no incidents of autonomous cells pursuing RDDs were within the literature. Both individual terrorists and hierarchical terrorist organizations have the ability to identify and exploit weaknesses in security of sources to obtain radiological material. This is not applicable to Chernobyl, since that was not about obtainment of radioactive sources, but emission of material through the explosive event and subsequent fires.

Finally, the obstacles preventing employment of an RDD are intelligence and investigations; government policies on the security, storage and possession of radiological sources; the GNDA; deterrence; and a lack of public or political reaction. Intelligence and investigations were the most effective counters in these case studies. They prevented RDDs by arresting terrorists and recovering material. These were factors in the case studies preventing attacks from Al Qaeda and Chechen rebels. Police investigating reports of stolen tires and coincidentally identifying suspicious material ended Hahn’s experiments and resulted in the recovery and cleanup of radioactive sources. In Thailand where OAEP policies related to the storage of radiological sources were ineffective, sources were vulnerable to poor security and theft. The principal obstacles to the Samut Prakarn thieves were technology, equipment, and knowledge in the safe handling of radioactive isotopes to prevent injury to the handlers of the material. Although the GNDA was not yet established, detection may have contributed to deterrence. The capture of an Al Qaeda operative crossing into Israel created a deterrence that made Khalid Sheikh Muhammed hesitant to support Jose Padilla’s RDD plot. The GNDA and radiation material security upgrades did not exist when Russian rebels emplaced cesium-137 source within Izmailovsky Park or when thieves stole a cobalt-60 source in Thailand. Fear of Russian retaliation and the lack of panic after the emplacement of the radioactive source within Izmailovsky Park apparently made Chechen rebels change tactics. At Samut Prakarn, poor policies designed to prevent the theft of radiological sources, actually encouraged improper storage. The lack of enforcement of policy and the over tasked AEC personnel, created an absence of material accountability. Obstacles related to the Chernobyl accident are not applicable, because the explosions were due to a reactor flaw and technician incompetence, not a result of a terrorist act. With all of these obstacles, intelligence and investigations were the only obstacles that appeared in multiple case studies.

Table 8. Cross case analysis of the five cases

Case	Motivations	Effects	Accessibility	Obstacles
Case 1: Al Qaeda's pursuit of RDDs or Nuclear Devices	1. Parity for 4 million dead	RDD has not been employed by AQ. Consequently: 1. Only case of injury due to radioactivity was an operative guarding material	1. Obtained radiological materials from Chechen rebels	1. Intelligence and Investigations
	2. Spectacular attack to advance political and ideological goals through fear	2. No public panic generated.	2. "Nuclear suitcases" that could be used as RDDs	2. Deterrence created from effective interdiction
	3. Economic disruption to advance political and ideological goals			
Case 2: Chechen Rebel Radiological Source in Izmailovsky Park	1. Coercion through mass casualties; cause Russian force withdrawal from Chechnya	1. Source more than 100 times the normal background radiation level, but no measurable effect on people	1. Obtained radioactive sources	1. Few impediments to acquisition or transportation
	2. Create public panic; demonstrate Chechen radiological capability that will cause Russian withdrawal	2. Failed to incite fear and panic	2. Poor radiological security after the 1991 fall of the Soviet Union	2. Fear of Russian retaliation may have created deterrence

		3. Death and injury due to explosive device (in other attacks	3. Radiological waste dumped throughout Moscow	
Case 3: David Hahn's Breeder Reactor	1. No terrorist related motivations 2. Build a Breeder Reactor 3. Gain respect	1. No reported incidents of radiation sickness 2. Created an environment with more than 1,000 times the normal background radiation level 3. $60,000 clean-up costs 4. Created public concern, but not panic	1. Americium salvaged from commercial sources 2. Uraninite from the shores of Lake Michigan, attempted smelting (unsuccessful) 3. Thorium from lanterns 4. Radium paint from an antique shop 5. Tritium from weapons sights 6. Knowledge was readily accessible through literature, industries and governmental agencies, but no internet	1. Few institutional obstacles prior to the September 11, attacks 2. Detected incidental to unrelated law enforcement stop
Case 4: Samut Prakarn, Thailand Cobalt-60 Accident	Terrorist motivation absent: 1. Opportunistic thieves - scrapping metal for cash	1. Three died and six received treatment for radiation sickness	1. Policy flaw that encouraged violations by failing to detect	1. Overtasked AEC employees unable to conduct yearly inspections

	2. No training on use or handling of sources	2. Thai government Prevented public panic	2. Security lapses made theft easy 3. Lack of material accountability	2. No prosecution for policy violations 3. Policies did not encourage control and security of sources
Case 5: Chernobyl	NA - No terrorist motivation.	1. Two people died from explosions 2. 28 died due to radiation sickness 3. 134 confirmed cases of radiation sickness 4. Over $6 Billion in costs for containment and rehabilitation 5. Authorities prevented public panic by withholding information	NA – release did not create collection opportunity	NA – RDD assembly and transportation were not issues

Source: Created by author.

Answers to the Secondary Research Questions

The cross-case analysis answered the following secondary research questions:

1. What are terrorist motivations?

2. What are the effects of an RDD?

3. How accessible are hazardous radioactive isotopes?

4. What are the obstacles preventing the creation and employment of an RDD?

The first secondary research question was, “What are the terrorist motivations?” In the Al Qaeda and Chechen rebel case studies, both organizations were interested in producing mass casualties and fear in order to advance their ideological and political goals. Also, they were interested in using an RDD to produce fear through radiation sickness to advance their political goals.

The second research question, “What are the effects of an RDD?” The effects were death and injury due to the explosive event, radiation sickness due to radiation exposure, a lack of public panic, and varying cleanup costs. Both Al Qaeda and Chechen rebels used explosive devices to inflict death and injury. They have shown interest in the effects of radiation sickness from an RDD, but have not been successful employing them. In David Hahn’s experimentations generating 1,000 times more than the background radiation, no one reported incidents of radiation sickness. In Samut Prakarn, the cobalt-60 source, which was well beyond its half-life, resulted in the death of three people and the radiation sickness of six others. Chernobyl resulted in the death due to acute radiation sickness of 28 people and radiation sickness in 134 others from onsite. Public panic was prevented or did not present itself in any of the five case studies. The cost of cleanup varied greatly from $60,000 to $6 billion.

The third research question was, “How accessible are hazardous radioactive isotopes?” Throughout all of the case studies and within the literature, radioactive material was available through poor security, policies, and theft. The exception was Chenobyl, which was not a case of radiological material obtainment.

The fourth research question was, “What are the obstacles preventing the creation and employment of an RDD?” Intelligence and investigation were the only obstacles present repeatedly throughout multiple case studies. Intelligence and investigations through subsequent arrests stopped terrorist attacks and RDD plots. Police investigations were responsible for the recovery of material. With the exception of Al Qaeda, the GNDA did not yet exist over the timeframe the cases occurred, so was not a factor.

Summary

In this chapter, five case studies involving the improper or malicious intent to use or actual use of radioactive isotopes analyzed against the four factors of motivation, effects, accessibility, and obstacles. The results of the cross-case analysis answered the secondary research questions. The final chapter of this paper will identify the trends, RDD employment opportunities, and challenges to terrorists, answer the primary research question, identify areas for further study, and present recommendations.

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CHAPTER 5

CONCLUSION

The primary research question was: How credible is the threat of an RDD employed by terrorists within the United States?

The secondary research questions were:

1. What are terrorist motivations?

2. What are the effects of an RDD?

3. How accessible are hazardous radioactive isotopes?

4. What are the obstacles preventing the creation and employment of an RDD?

The cross-case analysis facilitated the results of the secondary research questions. The case studies identified that the most prevalent terrorist motivations for the employment of an RDD are to cause death and injury from the explosive event, and fear and panic from radiation sickness. The actual or reasonably expected effects from an RDD were: death and injury directly attributable due to the conventional explosives alone and some radiation sickness due to radiation exposure; although severe injury and death was possible, these effects were extremely localized and were limited to a very few number of victims; a lack of public panic; and cleanup costs that varied from negligible to enormous. Radiological material was accessible to individual terrorists and hierarchical terrorist organizations. Investigations and intelligence were the consistent obstacles to the employment of an RDD.

Trends

This study has identified five notable trends. The first trend is the availability of radioactive sources both within the US and abroad. A second trend is the absence of RDD employment. The third trend is continued terrorist interest in the employment of an RDD. The fourth trend is a reduced hierarchical terrorist organization interest in RDDs as they increased knowledge of risks to detection and limited effects. The fifth trend is the varying cost of cleanup.

Radioactive sources were readily available globally with more than 2,400 known sources outside of regulatory control as of 2013.[1] Al Qaeda and Chechen Rebels had access to radioactive sources and the means to construct RDDs. There have been several incidents of radioactive sources stolen and sources found outside of regulatory control within the US. Security of radioactive sources has been a priority and received funding, but a risk remains through insider threat.

Chechen Rebels and Al Qaeda have had the means and motivation to employ an RDD, but have lacked the opportunity. An Al Qaeda operative attempted to transport an RDD into Israel. Officials intercepted the device at the border.[2] US officials arrested Al Qaeda operative, Jose Padilla at the Chicago airport re-entering the US, soon after receiving approval and funding to construct and implement an RDD within the US.[3] Chechen Security Services recovered RDDs near a railroad in Chechnya, where ongoing conflicts between Chechen Rebels and Russian forces have occurred.[4]

Terrorists continue to show interest in RDDs. Revealed from the case studies in this paper, hierarchical terrorist organizations such as Chechen Guerillas and Al Qaeda have shown a consistent interest in RDDs. More recently, the Islamic State has shown an interest in radioactive isotopes when they established patterns of life on a research scientist and his family in November 2015.[5] In addition to hierarchical organizations, individual terrorists have shown the desire to obtain and employ an RDD. In the December 2009 investigation of the shooting of Nazi enthusiast, James Cummings, investigators found both instructions on how to build an RDD and an insufficient amount of radioactive material.[6] This study did not identify any autonomous cells that attempted or showed interest in employing an RDD.

Even though there has been a consistent interest in RDDs from hierarchical terror organizations, their desire to obtain and employ an RDD has declined as their knowledge of the risk of detection and limited effects have increased. Both Al Qaeda and Chechen Rebels initially showed interest in RDDs, but as operatives were caught or their knowledge of the limited effects due to the addition of dispersed radioactive sources, they changed tactics. Interest in mass casualty producing explosive events replaced interest in RDDs. Already, officials intercepted the Islamic State attempting to plot radiological terrorism by establishing patterns of life on a researcher and his family. This capture continued the pattern of deterrence that Al Qaeda apparently recognized.

The overall cost of cleanup of an incident varied. It cost $60,000 in 1994 to clean up and dispose of the shed in which David Hahn was conducting his experiments. It cost an estimated $135 million in Moscow for two years of funding to clean up dumped radioactive waste. It cost more than $6 billion to contain and rehabilitate the area after the Chernobyl accident. What is potentially more costly, would be the economic impacts if an attack were to shut down the government or suspend the New York Stock Exchange.

Al Qaeda attacked the World Trade Center twice, in an attempt to produce an economic disruption.

Opportunities for Terrorists

With more than 2,400 known sources outside of regulatory control, there are and there have been sources available.[7] With the relatively long half-lives of several particular isotopes, like cobalt and cesium, radioactive sources outside of regulatory control remain a security risk for many years. [8] Once a terrorist has a radioactive source, if they exercise Osama Bin Laden's mantra on patience,[9] they have the ability to wait for the optimal opportunity to construct and employ a device. Clausewitz said that "If the military leader is filled with high ambition and if he pursues his aims with audacity and strength of will, he will reach them in spite of all obstacles."[10] Hahn displayed this level of determination obtaining and compiling radioactive sources that produced more than 1,000 times the normal background radiation in order to build his "breeder reactor."[11]

In the case study of Chernobyl, dispersed radiation was not as effective as concentrated radiation at producing casualties. Two tons of graphite and radiological material that spread across the Ukraine, Russia, and Europe only caused acute radiation sickness where it was concentrated, at the Chernobyl site. At Samut Prakarn, the concentrated source did cause radiation sickness and death, but only to very few people. A terrorist is more likely to produce mass casualties from a concentrated source in a highly populated area, than a source widely disbursed from a large, mass casualty producing explosive event.

A risk remains from an insider threat. An insider with access to radioisotopes and knowledge of handling could steal a source. With knowledge of radiation risks and mitigations, they could successfully overcome shielding challenges by utilizing manufactured cases inherent to the systems in which they are housed. Within the US, subjectivity in regulations governing licensee control of access, training, and background checks has left vulnerabilities within US medical centers and within industry.[12] Outside the US, insider threats and blackmail still exist. A Belgian nuclear power plant worker died fighting for the Islamic State. The power plant worker had intimate knowledge of reactors and could have helped devise a plan to attack a plant within the US. Additionally, Belgian police discovered an Islamic State video tracking the movements of a Belgian nuclear researcher and his family for the purposes of kidnapping a family member and holding them for exchange of radioisotopes.[13]

Challenges for Terrorists

The most effective challenge identified throughout this study to the obtainment of material and employment of devices, has been investigations and intelligence. Investigations and intelligence were responsible for interrupting Jose Padilla's plan to construct and employ an RDD. They stopped Zacarias Moussaoui from conducting attacks or participating within the 9/11 attacks.[14] Intelligence and investigations resulted in the recovery of 18 out of the 20 total weapons grade material outside of regulatory control from 1992 to 2001. It is often hierarchical organizations' reliance on networks and communication that leave them vulnerable to exploitation through surveillance.

Intelligence and investigations have created deterrence for Al Qaeda's use of an RDD. Khalid Sheikh Muhammed was hesitant to support Jose Padilla's RDD plot. He thought he would get caught. His fears were confirmed when Padilla was arrested stepping off the aircraft in Chicago.

It was the capture of operatives and their plots which created deterrence, and not how the interdiction occurred. Therefore, any other means that create an opportunity for interdiction would add to the effect of deterrence. Increased security of radiological sources would result in more failed attempts; if the GNDA creates additional obstacles through more detection opportunities, that would also add to deterrence.

Even though vulnerabilities still exist, increased security efforts globally through Congressional funding, make it more difficult for terrorists to obtain and transport radioactive materials. The NNSA's efforts through the GTRI have contributed to the increased security of radiological sources within the US.[15] This is of great importance because sources stolen or lost within the US have fewer detection opportunities than sources transported across national borders. Increased security worldwide helps to prevent the obtainment of sources before they can reach our borders.

The establishment of the GNDA assists in preventing the transport of radiological materials globally through detection opportunities before they reach our borders, at our borders, and within US borders. According to the IAEA incident and tracking database 2015, the number of radiological and nuclear sources lost or stolen has remained relatively the same since 2003. However, the amount of sources found, detected, or recovered has continued to increase since 2003.[16] It is unclear whether the increase is due to the GNDA or other factors, like scrap yard worker awareness.

A motivational challenge to Chechen Rebel RDD employment was the ineffective results from radiological terrorism compared to the consistently high death toll from conventional explosive devices. The source hidden in Izmailovsky Park did not generate sufficient fear to create public panic or force Russian forces out of Chechnya. Explosive devices became a reliable and preferred method of attack for the rebels resulting in large numbers of casualties.

The Primary Research Question

Based on the results of the secondary research questions, an answer to the primary research question emerges. How credible is the threat of an RDD employed by terrorists within the United States? It is a weapon of opportunity, but not a priority. The cross-case analysis and the results that emerge from the consideration of secondary questions indicate a lack of alignment between motivations and the actual effects of an RDD. Simply stated, large explosive devices generate more casualties, and although radiological incidents have generated public concern, they have not generated public panic. Because of this misalignment, it is apparently not the weapon of choice; its employment is therefore not likely. Although individual terrorists and terror organizations continue to show interest in RDDs, the effectiveness of intelligence and investigations, and a lack of panic or fear from radiological incidents created deterrence to employment. If the opportunity presented itself, terrorists might use an RDD. However, with mass casualty effects and fear originating from an explosive event alone, the lack of public panic from radiological terrorism, and increased security and detection makes the addition of radioactive material an unnecessary risk from the terrorist perspective. Attacks that kill and injure mass amounts of people, like the attacks on September 11, the World Trade Center bombing, or the planned gas apartment building attacks are more likely.

Areas for Further Study

Smuggling opportunities for nuclear and radioactive sources across the Northern and Southern US borders needs further research, particularly in areas not monitored with GNDA detection technologies. In addition, the effectiveness of the GNDA should be a consideration.

According to the IAEA fact sheet, there has been a slight, linear increased trend in the amount of loss, theft, sales, transportation, or possession of radiological and nuclear materials since 2010.[17] The effectiveness of programs related to the increased global security of radiological sources needs more research. The assessment needs to analyze the intent behind theft and sale. For example, are the thefts in response to a demand for cheaper radiological sources for medical and industrial applications or for RDDs? This will give a realistic perspective of the threat due to sources outside of regulatory control. It will also identify which sources are at a higher risk, due to a higher demand.

An area that needs more research is the combined cost of the recovery after an RDD and the economic risks from an RDD compared to the cost associated with preventing an RDD. That analysis will help to prioritize RDD prevention and mitigation related to specific targets. The particular case studies chosen did not address economic disruption. However, the cost of the US government shut down in 2013 cost $130 million per day and $1.6 billion in a week.[18] In 2016, the New York Stock Exchange controlled 20 percent of trading and had a stock value of more than $19 trillion. Of the average $279 billion traded by US investors per day, 20 percent was $55 billion. That is not to say that a one day halt in the New York Stock Exchange would directly result in a $55 billion per day loss. There is resiliency built into the system where traders can trade within the other

11 trading platforms. However, an interruption in trading could affect investor confidence and affect the value of those trades and the overall strength of the economy.[19] Similar economic impacts could occur with the shutting down of any major port or commerce. The GNDA spent $2.2 billion dollars for 72 programs at its inception.[20] The cost of intelligence operations and investigations is unknown. It is an area that needs further analysis.

Another area requiring exploration is the evaluation of EPA standards. The CRS suggested in 2003 that the EPA standards might not accurately reflect the risks to human life and likelihood of cancers.[21] Evaluating recent incidents and understanding the actual increases in cancers and birth defects can help to create a standard based on historical data. Those findings could help educate the public, prevent public panic, and use the results for planning.

Recommendations

Even though the trend has been no employment of an RDD, there remains the motivation to employ an RDD. With the availability of sources and vulnerabilities in obstacles, individuals with the persistence, proper training, and the right equipment could employ an RDD. This study has shown that radiological terrorism has been a consistent subject of interest within hierarchical terrorist organizations and individuals. The case study of David Hahn has displayed the accessibility of sources within the US. There remains a risk of employment when there is an availability of radioactive sources, the motivation to create spectacular attacks, and opportunities for employment. In order to prevent a future attack within the US, a defensive strategy should reduce terrorist access to radioactive materials.

As shown in trends, economic impacts remain a terrorist motivation for the employment of an RDD due to the cost of cleanup and potential effects of asset denial. The way to reduce the prevalence of this motivation is by reevaluating EPA standards to ensure that a contaminated area is not restricted for an unreasonable amount of time, or incurring excessive clean-up costs. The increased incidence of cancers need to be compared to the incidence of cancers from all other causes. Comparing and contrasting relative incidents of cancers will help educate the public on the true effects of radioactive isotopes and will help to reduce the potential for public panic of an RDD.

Public panic was a motivation for the employment of a radioactive device identified within this study. Basayev attempted to generate fear through radiological terrorism among Russian residents and officials by directing news reporters to a buried cesium source within Izmailovski Park, Moscow. His attempt did not result in generating panic, possibly from the abundance of radioactive waste already resident within the city of Moscow since 1949. Moscow residents know the effects of radiation, because they live with it. Because the desired effects of public panic and Russian force withdrawal from Chechnya were not met through radiological terrorism, Basayev changed tactics. We can learn from this experience by reducing or eliminating public fear.

In the US where the risks of exposure to radiation outside of regulatory control are far less likely, panic can generate from media reporting, especially displays of graphic pictures. Publication of pictures of radiological burns that increase for weeks and result in skin grafts, infections, and potential amputation like those taken after the Samut Prakarn accident can exacerbate public fears. The way to reduce the effects of public panic is through education. The American public needs to be educated on the relatively low incidence of radiation sickness and even lower incidence of death, compared to an explosive event. As shown in the Samut Prakarn incident, close contact to a radiological device for several days resulted in the death of only three people; those three people had extremely close contact with the radioactive source, and for an extended period of time. More than 300 people were killed in the four Chechen rebel apartment building bombings[22] versus the 28 killed from the tons of contamination released from Chernobyl. It follows that the deaths due to the conventional explosive component of an attack would be greater than from the radiological effects. The intent is not to breed complacency or a reduction in effort to prevent an RDD attack, but to limit fear and to further reduce the likelihood of public panic. Charles Ferguson assessed that an RDD would remain a terrorist motivation unless the public can be educated on the relatively few people that an RDD would affect.[23]

There are two ways to reduce terrorist ability to employ an RDD. The first is by preventing the obtainment of controlled radiological sources worldwide through increased security of the sources. The second is to improve the ability to detect sources already outside of governmental control before terrorists can employ them.

To continue to protect against a future RDD attack, funding should continue to be applied to the heightened security of radiological sources, the continuation of intelligence and investigations, and the maintenance and advancement of technologies within the GNDA to catch sources outside of regulatory control. As outlined in this study, intelligence and investigations globally have prevented RDD plots and recovered several sources outside of official control. Additionally, funding the GNDA not only protects against RDDs but nuclear explosive devices as well. Funding must include radiological detectors that identify alpha, beta, and gamma radiation, and detectors that identify the heat generated from plutonium and x-rays from other isotopes to identify shielded sources.

Sources traveling from outside the US to within the US through ports and checkpoints have the most likelihood of detection by the GNDA at locations where detection instruments are already in place. Those radioactive sources are not a threat to the homeland if they remain outside of the US. Therefore, foreign security and detection must remain a priority. The current level of detection has been sufficient. However, the current detectors continue to have limitations and any upgrades aid not only in the detection of RDD material, but fissile nuclear material too.

However, sources that fall outside of regulatory control within the US are the largest risk because they have the least likelihood of GNDA detection and are closest to target areas within the US. Incidents of loss and theft have occurred where sources are available. For example, officials never recovered 19 cesium tubes stolen from a hospital in North Carolina.[24] Opportunities remain for theft from opportunists or insider threats at hospitals and industrial sites or from smuggling across the border at sites not monitored by the GNDA. Additionally, subjective NRC policies that allow licensee discretion when determining employee access and criminal record screening is a risk.[25] Priority and funding must remain with the DNDO to maintain and enhance detection opportunities around target areas within the US that have the greatest opportunity for loss of life, injury, and economic impacts.

Khalid Sheikh Muhammed displayed hesitation to support an RDD plot, potentially from a failed attempt to transport an RDD into Israel. His reluctance was based on his fears that authorities would catch Jose Padilla. Whatever the reason for his hesitation, the effect was deterrence. In order for him to think Padilla may be arrested, Muhammed must have thought that intelligence, investigations or detection were effective. Padilla's arrest stepping off the plane in Chicago may have reinforced his concerns, and consequently may have deterred subsequent employment of an RDD in the US. Continuing support to intelligence, investigations, and the GNDA allows the US to continue to capitalize on the presence of deterrence.

Summary

Because of a lot of interest within the media generated around 2004 and due to residual conflicts of opinion by experts on the likelihood of an RDD attack, this study set out to objectively evaluate the credibility of an RDD attack by terrorists with the US. Analyzing the factors of motivation, effects, accessibility, and obstacles provided the foundation for answering secondary research questions. Prior to this study, there was no comprehensive, open source study, which compared radiological incidents to identify trends, terrorist opportunities, and terrorist challenges to the employment of an RDD in order to create recommendations on strategy, priority of effort for defense or mitigation, or funding. A modified methodology, combining both Creswell's case study methodology and Wolcott's methodology established the framework for the analysis. The study analyzed five radiological case studies individually and then comprehensively, to answer the secondary research questions, then identify trends, terrorist opportunities, and terrorist challenges to the employment of an RDD, and finally to create recommendations.

This study concluded that the employment of an RDD within the US or its territories is unlikely; it is a weapon of opportunity and not a priority for terrorists. Despite a low likelihood due to poor alignment of motivations and reasonably anticipated effects, an interest among individual terrorists and hierarchical organizations to employ an RDD remains. However, deterrence from intelligence and investigations has so far prevented an RDD attack and has apparently shifted preferred terrorist tactics to conventional explosive attacks.

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[3] Ripley.

[4] Krock and Deusser.

[5] Malone and Smith.

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GLOSSARY

Activity Ratio. The ratio of the radioactive activity within a specific quantity of a specific isotope divided by the value, which the IAEA defines as the dangerous level of activity.[1]

Becquerel. The SI unit to measure the activity of the source, by measuring the quantity of material required to produce one nuclear decay per second.[2]

Curie. The old common unit for the activity of the source. 1 curie = 3.7×10^{10} nuclear decays per second.[3]

Decomposition Reaction. The process of separating a compound into two or more compounds or elements.[4]

Endothermic Reaction. Heat absorbed to create sufficient energy for a chemical reaction.[5]

Fissile Material. A nuclear material that can undergo fission and can capture slow moving neutrons.[6]

Fissionable Material. A nuclear material that is capable of capturing either fast or slow moving neutrons and dividing into smaller elements through fission.[7]

Gray (Gy). The SI unit for the absorbed dose. One Gy is 1 J/kg.[8]

Half-Life. The amount of time it takes for half of the atoms within an isotope to decay.[9]

Insider Threat. A person with legitimate access that steals information, products or property.[10]

International System of Units (SI). A standardized, international system of measure based of the metric system.[11]

Ionizing Radiation. Radiation that has enough energy to significantly damage living cells[12] The threshold for ionizing radiation is about 10 electron volts (eV). The radiation associated with nuclear radiation is in the realm of MeV, which is 10^6eV. That is 100,000 times higher than the threshold.[13]

Nuclear Fission. An atom with a nucleus of more than 200 atomic mass units, splits into a smaller nucleus of less mass and releases at least, but possibly more neutrons.[14]

Rad. The old standard term for measuring absorbed dose. It's International System of Units (SI) counterpart is the Gray. One rad is .01 Joules/kg. One Gray (Gy) is 1 J/kg. Therefore, 1 Gy=100 Rad.[15]

Radioactive Waste. Byproduct of spent Uranium fuel.[16]

Radiological Dispersal Device (RDD). Also known as a “dirty bomb,” is an explosive device intended to disperse a radioactive source.[17]

Radionuclides. Forms of elements that are radioactive.[18]

REM. The old standard unit for the biologically effective dose. It is an acronym that stands for Roentgen Equivalent Man (REM). It expresses the effect of ionization radiation on human tissue.[19] The unit of measure is the relative biological effectiveness (RBE). It is measuring the effective of a particular type radiation on tissue. For gamma and beta radiation, 1 Rad is equivalent to 1 REM. For alpha radiation, 1 Rad is equivalent to about 20 REMs.[20]

Roentgen. Measures radiation intensity in the air only. It only applies to gamma rays and x rays. It is not an accurate measure of effects on human tissue . . . especially at high energies.

Sievert (Sv). The SI unit for biological effective dose. One Sv is equal to 100 REMs.[21] The Sievert for gamma particles is 1Sv equals 1 Gy. For alpha particles, 1Sv equals 20 Gy.[22]

Terrorist. A terrorist is an individual or organization that uses fear to meet political motivations.

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