An introduction to radiological terrorism

Colella, Logan, McIntosh and Thomson discuss the issues involved in a radiological terrorist attack and consider some of the likely consequences

Abstract

Unthinkable as terrorist events may seem, the unprecedented attacks of September 11 2001 have underlined that attacks by well-organised terrorist networks are difficult to predict and can have devastating consequences. Moreover, the recent images of the Australian embassy bombing in Jakarta (2004) and the Sari club explosion in Bali, Indonesia (2002) have confirmed that Australia cannot consider itself immune from terrorism. While most terrorist organisations continue to use conventional weaponry, there are significant concerns that some groups are attempting to acquire radioactive materials for malevolent purposes.

Disturbingly, organisations have attempted to acquire nuclear materials, which are radioactive materials that can be used to fabricate a nuclear weapon, in the recent past. In the early 1990s Aum Shinrikyo, the cult responsible for the Sarin gas attacks in Tokyo 1995, met with ex-Soviet nuclear specialists and expressed an interest in acquiring a nuclear device (Mutalik et al., 1996). Al Qaeda has also sought to acquire such materials, with their efforts dating back as far as 1993 (Bunn, 2002). Although there have been no recorded terrorist incidents involving nuclear materials, there is significant information indicating that nuclear materials are being trafficked for potential sale on the black market. In 1994 alone, 6.2g of weapons-grade plutonium–239 was seized in Tengen, Germany; 363g of plutonium–239 was intercepted at Munich Airport, Germany; 2.7kg of highly enriched uranium was seized in Prague; and 2.9kg of highly enriched uranium was seized in St. Petersburg, Russia (IAEA NewsCenter article, 2003). While these individual quantities are not considered sufficient to create a basic 'critical mass' nuclear weapon, the fact that such items are being intercepted is of great concern to the international community.

Non-nuclear radioactive materials are not capable of being used to create a nuclear explosion. However, these materials do have the potential to be used as weapons either in the form of a radiological dispersal device (RDD) or a radiation emission device (RED). The use of an RDD or an RED is considered by many to be the most likely terrorist scenario because many radioisotopes are used widely in medicine, industry and science, and therefore accessible to the criminal element (Ferguson et. al., 2003).

An RDD is a device that disperses radioactive material into the environment, resulting in radioactive contamination. This contamination would present a significant health hazard to the general public. An RED utilises a radioactive source to expose potential victims to radiation. The source is placed or concealed in a location where it can deliver a radiation dose to a target, and may go undetected for a long period of time. While the use of either an RDD or an RED is considered the most plausible terrorist act, the general consensus is that such actions would result in a small number of immediate deaths (IAEA Press Release 2002). The benefit to terrorists using such a device lies in the disruption such a device is likely to cause, for example, hysteria from the general public and significant anxiety from people who think they may have been exposed to radiation (Granot, 2000). In the case of an RDD, the contamination resulting from such a device is likely to take a considerable period of time to clean up, resulting in long-term evacuation of the area, which is likely to have significant economic impact.

While no recorded terrorist incidents involving nuclear materials have ever been reported, there have been incidents involving non-nuclear radioactive materials. In 1995, Chechen rebels alerted the international media to a canister of radioactive material strategically placed in Ismailovski Park in Moscow, which they threatened to detonate (González, 2001). The canister was found to have contained radioactive cesium-137. A second incident in 1998 involved a container of undisclosed radioactive materials attached to a mine found next to a railway line near Argun in Chechnya (Edwards, 2004). In both cases the devices were not detonated and were safely recovered. Closer to home, a quantity of cesium-137 was recovered in Thailand in 2003 (Andreoni et al., 2003). While the amount of material was small and not linked to any potential terrorist activity, the fact that it was recovered in the South-East Asian region is a reminder that Australia's geographical isolation is no reason for complacency.

Table 1. Commercial radioactive sources: Those of greatest concern (Ferguson et al., 2003).

Isotope	Common Use	Form	Half-life	Primary Emissions
Cesium-137 (Cs-137)	Teletherapy, blood irradiations, and sterilisation facilities	Solid, chloride powder	30.1 yrs	beta and gamma radiation
Cobalt-60 (Co-60)	Teletherapy, industrial radiography, and sterilisation facilities	Solid, metal	5.3 yrs	beta and gamma radiation
Iridium-192 (Ir-192)	Industrial radiography and low dose bracytherapy	Solid, metal	74 days	beta and gamma radiation
Radium-226 (Ra-226)	Low dose bracytherapy	Solid, metal	1600 yrs	alpha and gamma radiation
Strontium-90 (Sr-90)	Thermo-electric generators	Solid, oxide powder	28.8 yrs	beta radiation
Amercium-241 (Am-241)	Well logging, thickness, moisture and conveyor gauges	Solid, oxide powder	433 yrs	alpha radiation
Plutonium-238 (Pu-238)	Heat sources for pacemakers and research sources	Solid, oxide powder	88 yrs	alpha radiation

These examples highlight the threat posed by illegally trafficked radiological materials to both international and national security. This paper endeavours to address some of the issues involved in a radiological terrorist attack, in particular the use of non-nuclear radioactive materials, and will touch on some of the likely consequences and hazards involved.

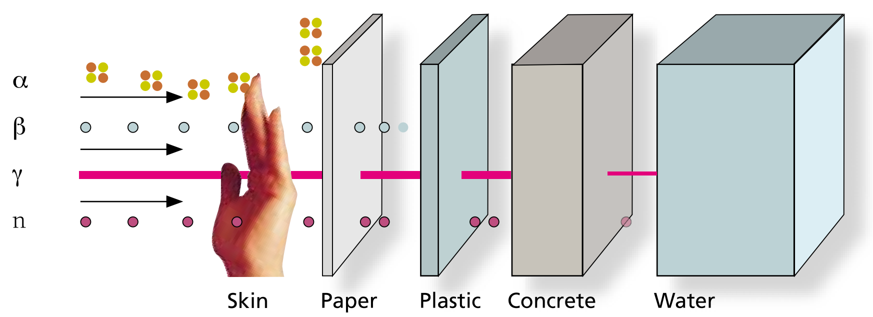
Radioactive materials

What are radioactive materials? Radioactive materials contain unstable atoms that undergo spontaneous disintegration. This process of radioactive decay is accompanied by the emission of radiation, which is measured by a unit called the Becquerel (Bq). Radiation can be classified into four groups alpha (α), beta (β), neutrons, and gamma (γ) radiation, each of which has different physical properties. The type of radiation emitted by a material will depend on the type of atoms (isotopes) present (see Table 1).

Alpha radiation consists of positively charged particles whose energy can easily be deposited within the surrounding environment. Therefore, α radiation is absorbed by materials such as paper or human skin. This means that α radiation external to the body poses a limited radiation hazard. However, α emitting materials are much more hazardous if ingested (e.g. inhaled or eaten) because all the energy from the radiation will be absorbed in a localised area of tissue (Martin & Harbison, 1996).

Neutrons, β, and γ radiation are more penetrating than α radiation, allowing the radiation to penetrate the body and interact with biological cells. Therefore, they present a greater external radiation hazard. Within occupational environments, this hazard is reduced by the use of appropriate shielding materials. Shielding materials that absorb radiation are placed between the radioactive materials and workers. The shielding of β radiation can be achieved by the use of perspex or aluminium. The use of dense shielding materials such as lead for β radiation should be avoided, because their use can result in the production of X-ray (Bremsstrahlung) radiation. The shielding material most suitable for neutrons is water or concrete, while γ radiation is typically shielded by the use of lead, water or concrete (see Figure 1).

Figure 1. Diagrammatic representation showing the penetrating properties of the alpha, beta, neutron, and gamma radiation.



Care must be taken when considering appropriate shielding materials, as many radioactive materials can emit more than one type of radiation.

The penetrating properties of β, neutrons, and γ radiation enable them to be detected relatively easily using commercially available equipment. The ability to detect and measure α radiation is hampered by the fact that α radiation is readily absorbed by air (NHMRC, 1995). This means that α radiation can only be detected at very short distances from the material, making direct detection in the field more difficult. Fortunately, many α emitting materials also produce γ radiation which can be used to detect and identify the radioactive material.

Radiation and its effect on the human body

The prime reason for measuring radiation is to monitor an individual's actual or potential radiation exposure. The effect on humans due to exposure to radiation is primarily dependent on the effective dose a person receives. The unit most commonly used to measure the normalised effect of radiation in biological materials is the Sievert (Sv) (for more details see Martin & Harbison, 1996; IAEA Publication, 2004).

Radiation is not only produced from man-made processes, it is present (albeit at low levels) in the environment and in many of the materials we use and consume. On average, each Australian will receive a yearly dose from background radiation of approximately 2 milliSieverts (mSv), depending on the local surrounding environment and daily living patterns (Uranium Information Centre, 2004).

Exposure to radiation ultimately results in some of the radiation being absorbed by the body. The absorbed radiation results in the formation of charged particles. These charged particles can cause, at a cellular level, a number of chemical reactions to occur, which ultimately may result in the attack of biological material. The end result is that some of these interactions will result in the death or permanent modification of individual cells.

Ultimately, as a human is exposed to higher doses of radiation more cells are likely to die. Eventually a threshold is reached which results in reduced organ function. Effects observed above this threshold are ***deterministic*** and result in acute radiation syndrome (ARS), more commonly known as radiation sickness (CDC, 2003).

The first symptoms of ARS are nausea, vomiting, and diarrhoea. A list of likely deterministic effects is shown in Table 2 (Martin & Harbison, 1996; NOHSC, 1995). The chance of survival for people with ARS decreases with increasing radiation doses. The cause of death in the most severe cases is due to severe gastrointestinal and haematological (bone marrow) damage, which results in infections and internal bleeding (CDC, 2003).

Table 2. Deterministic effects of radiation exposure compared with some typical occupational exposures (Martin & Harbison, 199; NOHS: Report 1013, 2002).

Dose (millSieverts*)	Deterministic effects
>15,000	Short term death
4,500	50% chance of lethal dose (LD50)
1,000	Possible radiation sickness
500	Earliest detectable blood changes
	Occupational exposures
20	Annual occupation limit (radiation workers)
7	Typical dose from CAT scan
2	Annual normal background radiation
1	Exposure limit placed on general public (including emergency services personnel)

**Sievert (1000 milliSieverts) is the unit for equivalent dose, and represents the ability of a particular type of radiation to cause damage*

When a human is exposed to low doses of radiation, latent health effects such as tumours, may result from permanent modification to cells. These effects are ***stochastic*** in nature. The study of radiation health effects has been conducted over many years and the information collected has been used to shape the current guidelines used by organisations such as the International Commission on Radiological Protection (ICRP) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) (example ICRP, 2004). From this information, limits for exposure have been derived. The annual limits for public and occupational exposures to ionising radiation (above background) set by the Australian National Occupational Health & Safety Commission are 1 mSv and 20 mSv, respectively (NOHSC: Report 1013, 2002).

The use of radiological material for malevolent purposes

Responsibility for securing nuclear assets (e.g. power reactors, reprocessing plants and repositories) ultimately rests with the individual countries that own such facilities. However, the international efforts of the United Nations through the International Atomic Energy Agency (IAEA) have resulted in the development of co-ordinated programs to assist members to properly account for their radioactive materials, while also providing support for programs aimed at countering the systemic problem of the illicit trafficking of nuclear material and equipment (IAEA Annual Reports).

While a terrorist attack using a nuclear device is unlikely, it obviously has the most severe potential to cause extensive damage. The aftermath of such a detonation would result in mass destruction and a large number of casualties. Furthermore, such an attack would render the area uninhabitable for a long period of time (Bunn, 2002; Levi & Kelly, 2002). The economic and sociological impacts would be devastating, while leaving survivors with a lasting psychological and emotional legacy.

Non-nuclear radiological terrorism is undoubtedly the more credible threat, given the large number of radioactive sources accessible in the public domain. Radioactive materials are used in the community for a variety of purposes including blood irradiators, tumour treatment, industrial radiography, diagnostic imaging, and moisture gauges. The wide use of these materials creates opportunities for radioactive sources to be 'orphaned'. An orphaned source is one that has been lost or stolen. Although only a few of those orphaned sources would be suitable for malevolent use, it may only take one to create an effective RDD or RED.

Prior to September 11, the emphasis of regulation on the security of radioactive sources was primarily based on limiting the use of such sources by unqualified staff or the general public and securing sources from being pilfered by persons seeking scrap metal for resale or similar (IAEA TECDOC Series No. 1355, 2003 and IAEA, CODEOC, 2004). In response to the heightened security fears, many States have acted to review current procedures and protocols in order to account for the new threat that comes from terrorists seeking to cause radiation exposure or to disperse radioactive materials (IAEA TECDOC Series No. 1355, 2003).

The IAEA has also taken a number of steps to improve international standards relating to control over radioactive sources. Sources have been categorised in order to ensure that those who pose the greatest risk are given priority by national regulators (IAEA TECDOC 1344, 2003). The Code of Conduct on the Safety and Security of Radioactive Sources, first drafted in 2000, was comprehensively revised to incorporate considerations relating to the new security threats (IAEA, CODEOC, 2004). Guidance on the international trade in radioactive sources, which allows the transfer of highly active sources only to countries with adequate regulatory systems, has also been adopted (IAEA 2004 General Conference document GC(48)/13). Meanwhile, many developing countries have had their regulatory infrastructures upgraded through a global technical assistance project.

Radioactive sources have the potential to be used malevolently in a variety of ways. For example, a RED may be hidden and used to expose the public to radiation. Another means of exposing the public to radiation would be to disperse the material using a RDD. Passive dispersion would involve simply leaving the radioactive substance exposed to the elements and allowing it to silently disperse over time. The radiation exposure to an individual would be difficult to assess and would depend on factors such as the time spent near the contamination, the amount of material ingested, the chemical and physical nature of the material and the activity of the source.

Other RDDs may incorporate mechanical or chemical methods, such as explosives, to volatilise and distribute radioactive dust. This is likely to result in widespread external and possibly, internal contamination through ingestion of the material. Where an explosive device has been used, immediate death is likely to be caused primarily by the explosion. For those individuals in the direct vicinity of the release, the effective dose a person receives will again be difficult to assess. The general consensus of experts is that the detonation of such a device is unlikely to cause a great number of short-term deaths from radiological causes (IAEA Press Release, 2002).

Unless radioactive materials have been ingested, once an area is evacuated and the affected individuals are decontaminated, there is no risk of further exposure. However, the ingestion of radioactive materials would create a much more complicated scenario, where the dose received will be dependent on the success of medical intervention and the period of time the material remains in the body. The chemical effects of the materials must also be considered, as many radioactive materials are also chemically harmful.

While it is generally considered that the number of immediate deaths from RDD devices is likely to be small, a well-executed radiological attack on an unprotected population would necessitate costly environmental cleanup, societal disruptions, potentially significant economic costs, and tremendous psychological trauma to those affected (Mutalik et al., 1996). For these reasons, the use of radioactive material for terrorist purposes could be considered as a 'weapon of mass disruption'.

Incident response: what to expect?

It is fortunate that no large scale terrorist act has been perpetrated using radioactive materials. However, this means that our understanding of such events is purely limited to hypothetical scenarios. From the large body of work published, it is clear that many consider the most probable terrorist assault would involve an RDD or 'dirty bomb' scenario.

While this may indeed be the case, it should not be viewed as the only possible route of attack. Clearly, there appears to be an assumption that terrorists will choose the easiest route in conducting an attack. Events such as September 11 highlight that this is not necessarily the case. Organisations such as Al Qaeda are willing to recruit specialists, train individuals, and invest time and money to achieve their goals. Therefore, it is imperative that government agencies and the research community consider all scenarios when planning and preparing for a radiological incident.

Our best understanding of the possible consequences of a radiological dispersion device incident comes from the results of accident situations. One of the most referenced cases is the incident that occurred in Gioánia, Brazil in September of 1987. Although this incident was not malevolent in nature, it highlights the difficulties involved with the release of highly radioactive material into the environment (IAEA, 1988).

In this incident, scrap yard workers released cesium-137 from an abandoned teletherapy (radiotherapy) machine that had at one time belonged to a cancer treatment clinic. The workers had no knowledge of its dangerous contents. The teletherapy head consisted of 93 grams of highly soluble cesium-137 chloride salt, sealed inside two stainless steel capsules, in turn sealed with an international standard capsule, which had standardised dimensions common to most teletherapy units. The workers removed the assembly containing the two stainless steel capsules and took it home to dismantle. The rupture of these capsules and the ensuing dispersal of radioactive material triggered the second largest radioactive accident after Chernobyl (Drielak, 2004).

The cesium-137 chloride powder appeared as an attractive luminous blue powder, thought to be fluorescence due to moisture absorbed by the source (IAEA, 1988). Both adults and children, believing the powder to be harmless, rubbed the substance into their skin, and at least one child ingested the powder. Over the next few days, some of these people starting displaying symptoms of ARS. Seven days later, the child was diagnosed with ARS.

The cesium-137 released into the general population produced a large amount of radioactive contamination. The magnitude of this incident was overwhelming for the national authority, and emergency assistance from the international community though the International Atomic Energy Agency (IAEA) was requested. The relief effort was massive. A stadium was designated where people who were thought to be contaminated could be diagnosed and receive medical attention. Twenty people were diagnosed as having deterministic effects and were admitted to hospital. The most serious cases were treated with *Prussian Blue*, a chemical which assists in the removal of cesium from internally contaminated patients. Full body radiation monitoring was set up to provide ongoing information to medics about the levels of internal contamination in patients. Blood, urine and faecal samples were taken daily and used to monitor patients. In total, 112,000 people were monitored and 249 people were found to have been contaminated (IAEA, 1988). Of the 249 contaminated, 129 people exhibited both internal and external contamination. Forty nine of these patients were admitted to hospital, 20 of these needing intensive medical care. Among these patients, ten were deemed to be in a critical condition. Within a period of one month, four people died from the incident and one patient had an arm amputated. The surviving patients were discharged after treatment and are under continued medical supervision.

A major environmental survey of Gioánia and the surrounding area was also conducted. Forty two houses were demolished, and contaminated dust and soil were removed from the area. The clean-up took six months to complete, and waste from the incident totalled 3500 m^3. There were significant psychological effects from the incident. For example, 74 per cent of residents had presented for full body monitoring, even though many could not have been contaminated. These people – the "worried well" – had a significant impact on the ability of medical staff to identify contaminated patients. There were also considerable economic effects, a 25 per cent downturn in the sale of Gioánia's produce resulted, and 10 per cent of the town's residents were affected economically by the tragedy (IAEA, 1988).

A team of experts reviewing the facts of this case made several key recommendations. The first, and undoubtedly one of the most important, related to ensuring that there were strict regulations regarding the discharging of responsibility for radioactive sources. The team also saw the need for better communication between the relevant agencies to ensure the objectives of regulatory control were being achieved. Furthermore, when regulating the use of these materials there should be due consideration of the physical and chemical properties of the source, not just the activity of the material.

Medically, the incident highlighted the need for specialist staff, such as health physicists and medical staff, to be available to respond to such an incident. The complexity in dealing with persons exposed to radiation requires medical staff with experience in a variety of areas such as haematological, immuno-suppression, and chemotherapeutic procedures and therapies.

The environmental issues relating to a radiological incident are as relevant today as they were in 1987. There are significant costs associated with cleaning up a contaminated site. These costs manifest in both the actual cost of the clean up and the cost associated with the closure of a city (or even part of a city). Prior to any incident, intervention levels need to be established to determine the level to which a site must be decontaminated to ensure it is safe. The question "how clean is clean?" needs to be addressed so that effective strategies can be developed.

Dirty bomb scenario

Figure 2 shows the effects of a simulated radiological dispersal device detonated outside of Central Station in Sydney. This scenario was modelled using the Hotspot™ modelling code (HOTSPOT, version 2.05, 2003). The code was applied to model the ground contamination resulting from the detonation of an americium-241 industrial gauge source (40 GBq activity) with 1kg of TNT and a wind speed and direction of 1 meter per second in a northerly direction. Figure 2 details the predicted 50-Year Committed Effective Dose Equivalent (CEDE) in sieverts received by an individual remaining at a specific location during the radioactive material release. The red represents a CEDE greater than 10 mSv, the green represents a CEDE of greater than 5 mSv, and the blue represents CEDE of greater than 1 mSv. These figures represent the sum of the committed dose equivalents to various organs within the body.

The resultant ground contamination that results from the dispersion of radioactive material is detailed in Figure 3. Here the Ground Contamination Levels (GCL) are detailed in three zones. The red zone represents GCL of greater than 100 kBq per m^2, the green represents GCL of greater than 10kBq per m^2, and the blue represents GCL of greater than 1 kBq per m^2. Areas up to 1.7 kilometres downwind from the explosion would contain contamination levels of at least 1 kBq/m^2. These values can be employed to estimate the effective dose people coming into the incident scene (after the plume has dissipated) will receive from ground contamination (IAEA TECDOC 1162; ARPANSA, 2002). Therefore, contamination levels of 1 kBq/m^2 would result in a maximum lifetime dose (over 50 years) of approximately 7 mSv (ARPANSA, 2002). Preventative measures taken immediately after an incident would likely result in even lower values.

Figure 2.

Figure 2: *The dispersion of a radioactive plume resulting from a hypothetical detonation of a dirty bomb (40 GBq americium-241 source; 1kg TNT) over Sydney. The scenario was modelled using Hotspot™ software code. The defined regions represent the predicted 50-Year Committed Effective Dose Equivalent (CEDE) in Sieverts from the plume, received by an individual remaining at a specific location during the radioactive material release. The red represents a CEDE greater than 10 mSv, the green represents a CEDE of greater than 5 mSv, and the blue represents CEDE of greater than 1 mSv. Photograph © Department of Lands (2004).*

The long-term effects this type of RDD event would have on the population of Sydney is difficult to assess. While the health risks associated with the dispersal of the material are likely to be small, there would probably be significant disruption due to public fear and anxiety (Granot, 2000). Following this, there would be a need to evacuate areas of the city to allow surveying and decontamination. It is likely that the cleanup would take several months. This would result in significant impacts, both financially and socially, on Sydney residents. The same issues faced by the Brazilian government during the Gioánia incident would undoubtedly be encountered in this scenario, but on a much larger scale.

Figure 3.

Figure 3: The defined regions represent various ground contamination levels (GCL) from the same scenario used in figure 1. The red represents GCL of greater than 100 kBq per m2, the green represents GCL of greater than 10kBq per m2, and the blue represents GCL of greater than 1 kBq per m2. Photograph © Department of Lands (2004).

Sources of greatest concern

Australia classifies radioactive sources based on the risk they pose to health in accordance with an International Atomic Energy Agency (IAEA) technical document (IAEA TECDOC 1344, 2003). This document primarily categorises sources in terms of the A/D ratio, that is the activity of the source (A) and the level at which a source is deemed to be dangerous (D). The resulting ratio is used to group the source into five categories; category 1 being the most dangerous. At present there is no separate international classification system to categorise materials according to the potential for malevolent use. However, parameters to consider for such a system would include those spelt out in IAEA TECDOC 1344 plus issues related to source dispersability, portability, and the potential for theft (e.g. accessibility and quantity required).

Table 1 details the results of a recent report commissioned by the Monterey Institute of International Studies to determine the radioactive materials that pose the greatest risk to public health and safety, focusing on the potential consequences of their malevolent use (Ferguson et al., 2003).

The number of sources in use worldwide is unknown. Estimates from a recent US Government Accounting Office (GAO) survey of 49 countries reported a total of approximately 7.8 million sealed sources in use within their countries (US GAO, 2003). While most of these sources would be low risk, it is unclear as to the number of Catergory 1 to Category 3 (i.e. more dangerous) sources that are incorporated in these figures. Domestically, Australia has approximately 550 Category 1 (significantly dangerous) sources and approximately 10,000 Category 2 and 3 registered sources (Loy, 2003), which would make an effective RDD.

In spite of comprehensive global government regulatory control of radioactive sources, many are still reported abandoned, lost or stolen worldwide annually. Industrial sources may be at particular risk of loss or theft, given the need to transport these materials to and from construction sites (O'Neil, 1997). According to the IAEA, orphan sources are a widespread phenomenon. Of the 49 countries surveyed by the GAO, 39 countries indicated that orphan sources were a concern in their country (US GAO, 2003). Survey respondents reported that 612 sources had been lost or stolen since 1995. Of the 612 reported orphan sources, 254 had not yet been recovered. From a regional perspective, Asian respondents reported that 93 sources had been reported lost/stolen, of which 11 had been recovered. In the South Pacific, 44 sources had been reported lost/stolen, with 21 recovered. Unfortunately, information on category type was not reported.

Since 1993, there have been 540 confirmed cases (as detailed in Table 3) of illicit trafficking of nuclear and radioactive materials registered on the IAEA's illicit trafficking database (IAEA NewsCenter article, 2003). The IAEA believe that this figure represents a conservative estimate of the true figure, with growing concerns that more sophisticated and organised trafficking in nuclear material may be occurring undetected (Cameron, 2002).

Table 3. Confirmed incidents involving illicit trafficking of nuclear materials and radioactive sources by participating Member States (IAEA NewsCenter, 2003)

Illicitly trafficked material	Confirmed incidents (1993–2003)
Nuclear material	182
Other radioactive material	300
Both nuclear and other radioactive material	23
Radioactively contaminated material	30
Other	5

These figures illustrate the need for comprehensive programs worldwide to both secure existing sources and to recover lost, discarded or stolen sources. Furthermore, these figures illustrate the potential threat of orphaned sources falling into the wrong hands.

It must be noted that Australian regulatory controls of radioactive and nuclear materials are wide-ranging. Each State and Territory's responsible agency manages radioactive source licensing. Where sources fall under federal jurisdiction, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is responsible. The Australian Safeguards and Non-Proliferation Office (ASNO) regulate and account for all nuclear materials and items subject to IAEA safeguards within Australia. ASNO is also responsible for the physical protection of nuclear materials within Australia (ASNO Annual Report, 2003).

Conclusion—preparing for the unthinkable

The public hysteria associated with radioactive materials and the potential disruption that may accompany the malevolent use of a radioactive source (Granot, 2000), makes the acquisition of radioactive material very attractive to terrorists. It is widely accepted that effective strategies such as providing radiological training to customs, emergency services, and medical personnel, and educating the community about the real hazards and appropriate protective measures required, will minimise the consequences of a radiological attack. Furthermore, increased research and development in areas such as new radiation detectors, radiological modelling computer software, effective decontamination techniques, forensic science techniques for radiological materials, and bio-dosimetry technologies that would lead to more effective response capabilities and casualty management, should be encouraged. Ultimately, the best line of defence is to limit opportunities for terrorists to obtain or import dangerous radioactive materials. Measures such as improving the world-wide security of radioactive materials through education, international co-operation, treaties and legislative means, and ensuring adequate regulatory regimes for radioactive sources are adopted, will clearly go a long way to achieving this goal.

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