International Commission on Nuclear Non-Proliferation & Disarmament

« *A possible international regime to cover radiological materials* »

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Executive Summary

Even if a "dirty bomb" has never been used to date, the perception of the existence of a threat is shared by many.

Four main types of radiological and nuclear terrorist attacks can be outlined:

- acquisition and use of a nuclear weapon,
- attacks and acts of sabotage against a nuclear reactor or another nuclear facility,
- acquisition of fissile material for the elaboration of an Improvised Nuclear Device,
- terrorist use of radiological materials for the elaboration of a Radiological Dispersal Device (RDD).

This paper seeks to evaluate the probability for a terrorist group to acquire and make use of radiological materials in the objective of detonating a RDD, and the current international framework put into place to address such a threat. Is an international regime to cover radiological materials already in place? How comprehensive / integrated is it? Does a new and/or separate system need to be set up?

Before 9/11, two events in particular served to illustrate the threat of a radiological or nuclear terrorist attack: Moscow in 1996, Argun in 1998. Since the 9/11 attacks, a few other radiological events have occurred, which could suggest that the threat is becoming more pressing.

It must be noted that the use of a dirty bomb by a terrorist group would most probably be aimed at the contamination of a given geographical area, rather than mass destruction and killing. Indeed, the lethal impact of such weapons remains limited. For this reason, dirty

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bombs are considered by analysts as weapons of mass disruption rather than weapons of mass destruction. Impacts would be more important in the psychological or economic realms:

- targeting highly populated environments, such as cities, would most probably not result in a high death toll;
- compared with impacts on health, psychological impacts of such an attack would be much more serious, both within and outside the targeted population;
- economic damage is probably the greatest threat posed by such attacks, particularly as radioactivity cannot be eliminated but only transferred from one place to another. Although it is difficult to give any precise figure, costs could in this case soar to trillions of dollars.

The international community has begun concerning itself with nuclear and radiological terrorism officially since 9/11. In a rather unusual way in the field of international security, implementation of instruments to combat radiological terrorism anticipated the materialization of the risk. It is legitimate to ask oneself today if we have at our disposal an in-depth defence strategy, in which the many existing layers of action are integrated effectively. In the negative, it could be that a sense of false security proves more worrying and damageable than the threat itself.

It is important to keep in mind that the international struggle against radiological terrorism necessitates long term efforts. IAEA, as an institution, appears to be, at least officially, the cornerstone of radiological safety and security. Although the initiatives of the Agency are based on the good will of Member States (action plans, code of conduct, recommendations, guides, partnerships, etc.), the inklings of an international regime on the issue have emerged, through iterated cooperation within the Agency.

In this context, the risk of the emergence of a two-tier system, in which the bottom tier would be composed of comprehensive but ineffective mechanisms (multilateral awareness and non binding or unverifiable tools), and the upper tier of fragmented and unbalanced ones ("*coalition of like-minded*" approach), is real. The project to move towards a more integrated regime to cover radiological materials thus seems a timely one.

On a political level, five main issues at least must be addressed in order to establish a more comprehensive and effective international architecture for radiological and nuclear security:

- integration and increased coherence necessitates financing and institutional authority (who?);

- effectiveness implies an effective monitoring capacity, whatever the form (binding tools, assessment processes, registers and updated lists, means of verification, etc.);

- because radioactive sources are an integral part of the global market, the security of sources must be ensured in a cost-effective manner;

- high-level political leadership is needed (involvement of big powers? Security Council Resolution under Chapter 7 of the Chart?);

- common security standards must be agreed on by the 150 IAEA Member States.

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Introduction

One year ago, on October 27, 2008, in his address to the United Nations General Assembly, IAEA Director General Dr. Mohamed ElBaradei declared that nuclear and radiological terrorism remained real causes for concern. According to him: "*The possibility of terrorists obtaining nuclear or other radioactive material remains a grave threat.* (…) *Equally troubling is the fact that much of this material is not subsequently recovered.*"

Even if a "dirty bomb" has never been used to date, a fact that needs to be kept in mind, from now on, the perception of the threat is shared by many. What's more, the distinction between a dirty bomb and a nuclear device is not always clearly made. In his speech delivered in Prague April 5, 2009, president Obama recalled: "*we must ensure that terrorists never acquire a nuclear weapon. This is the most immediate and extreme threat to global security. One terrorist with one nuclear weapon could unleash massive destruction. Al Qaeda has said it seeks a bomb and that it would have no problem with using it. And we know that there is unsecured nuclear material across the globe.*"[2] Other speeches and communications seem to suggest that the American government takes seriously the possibility of a large scale terrorist nuclear attack, including one involving the use of a dirty bomb. President Obama also announced that a Global Summit on Nuclear Security would be hold in the beginning of 2010.[3]

Precisely, four main types of radiological and nuclear terrorist attacks can be outlined:

1. acquisition and use of a nuclear weapon,
2. attacks and acts of sabotage against a nuclear reactor or other nuclear facility,
3. acquisition of fissile material for the elaboration of an Improvised Nuclear Device (IND),[4]
4. terrorist use of radiological materials for the elaboration of a Radiological Dispersal Device (RDD)[5], or "dirty bomb".

This paper seeks to evaluate the probability for a terrorist group to acquire and make use of radiological materials in the objective of detonating a RDD, and the current international framework put into place to address such a threat. Is an international regime to cover radiological materials already in place? How comprehensive / integrated is it? Does a new and/or separate system need to be set up?

1. Context

1.1. A brief history of the threat

In theoretical terms, the possibility for nuclear science to be used for terrorist purposes was envisaged even before the successful explosion of the very first nuclear bomb. The Secretary

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[2] http://www.whitehouse.gov/the_press_office/Remarks-By-President-Barack-Obama-In-Prague-As-Delivered/

[3] April 2010 as it seems.

[4] Definition in Annex 3

[5] Definition in Annex 3

of War of the first Truman Administration, Henry Stimson, declared in April 1945 : "*The future may see a time when such a nuclear weapon may be constructed in secret and used suddenly and effectively with devastating power by a wilful nation or a group against an unsuspected nation or group of much greater size and material power.*"[6]

In practical terms, the strategic analysis of non state nuclear and radiological threats began in the 1970's in the United States, with the increase in the intensity of the violence projected by terrorist attacks.

That said, international mass destruction terrorism was not taken up in earnest by analysts before the 1990's, and the emergence of new forms of transnational violence of a religious or millenarist type. The Aum Shynrikio sect provides one of the first examples of such a development through its chemical (but non nuclear) attacks in Japan. Nuclear and radiological terrorism remained perceived as risks – as opposed to full-blown threats – until the events of 9/11.

Two events in particular served to illustrate this risk:

In 1996, Chechen insurgents placed a dynamite/radiocesium device in Moscow's Izmailovo Park, subsequently informing a Russian television station of their action. The bomb was not set off, the intention of the insurgents being predominantly dissuasive, but such an initiative showed that the possibility of such an attack was not only theoretical.

In 1998, suspected Chechen rebels deployed an explosive mine with unidentified radioactive material in Argun, 10 miles east of the Chechen capital of Grozny. Russian-backed Chechen Security Service announced that a Security Service team had found a container filled with radioactive materials and attached to an explosive mine hidden near a railway line. The bomb was defused but the radioactive substances involved could not be identified.

Apart from the aforementioned events, several radiological accidents have occurred in the past, without any criminal or political intention proven: Windscale (UK) in 1957, Palomares (Spain) in 1966, Three Mile island (USA) in 1979, Chernobyl (USSR) in 1986 are the most well known.

The best example of radiological event may be that of the Goiânia Radiation Incident (GRI), which happened in Brazil between September 1987 and March 1988, as the case helped the IAEA evaluate the potential damages of a modest attack on an urban environment: two scrap dealers got into an abandoned radiotherapy clinic, where they pickep up a capsule containing a 50 bq Cesium-137 source (1 Terabecquerel = 1000 billions Becquerel, 1 Becquerel corresponding to one disintegration per second. One 70 kg individual has in the average an activity of about 8000 bq). They brought the capsule back to one of the men's house to dismantle it and sell the parts for scrap. Later that same day, the two men started showing signs of acute radiation poisoning: vomiting, diarrhoea, one of the men even suffering from a swelling of one of his hands. A few days later, one of the two men bursted the thick window of the capsule, thus dispersing the powder trapped within it. Upon discovering the blue shimmer of the powder at night, he decided to take it with him and show it to his family and friends. After a couple of weeks of dispersion, radiation exposure provoked increasing dizziness and unease amongst the exposed group and was eventually diagnosed and treated as

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[6] Excerpt from *Terrorism and Weapons of Mass Destruction, Descriptions*, ODCCP, 2001

acute radiation poisoning syndrome. To this day, 249 people have been contaminated. Among them, 151 showed internal as well as external signs of contamination, 20 became seriously ill and 5 died. A specialised clinic was set up by the authorities to detect further exposure in 100 000 people. 46 private residences and 50 public places were contaminated in total. Thousands of tons of waste were disposed in temporary waste disposal areas, to be transferred to permanent installations only ten years later, in 1997.

Prior to 9/11, two thesis conflicted on the issue of radiological terrorism:

- The terrorist agent seeks publicity and visibility of his cause rather than a massive death toll.

- It is the growing availability and accessibility of non conventional weapons that determines the increasing likelihood of their use for terrorist purposes. Within pre 9/11 American analyses, the issue of radiological terrorism is still envisaged in such dichotomous terms, as pointed out by Jessica STERN in an article published in September 2001: "*Will terrorists use unconventional weapons? Debate about this question tends to be conducted in extremes.*"[7]

After the 9/11 attacks, nuclear and radiological terrorism becomes considered as a full-blown and undeniable threat. The overarching perception after the attacks, in the United States and elsewhere in the West, was that the question was no longer to know if hyper terrorism was going to materialise, but where and when? Pandora's box had been opened. Since the publication of the *U.S. National Strategy for Combating Terrorism* in 2003, official American analyses present nuclear terrorism as one of the most serious threats weighing on the country's national security. This was true during the Bush administration, and remains so under the new one, and in the minds of the American population. Polls showed, in 2002 and in 2008, that a majority of Americans consider nuclear terrorism as one of the gravest threats to their security.[8] In Europe, the threat of the use of a dirty bomb is more widely debated.

Since the 9/11 attacks, a few other radiological events have occurred, which could suggest that the threat is becoming more pressing:

In June 2002, Jose Padilla, American citizen and former member of a Chicago gang with known ties to Al Qaeda, was arrested in Chicago's O'Hare airport on suspicion of planning to build and detonate a dirty bomb in an American city. F.B.I agents suspected Padilla had recently undergone training in Lahore, Pakistan, where he was thought to have studied the mechanics of dirty-bomb construction, including the wiring of explosive devices and to the optimisation of radiological dispersion in bombs. Officials believed Padilla, who arrived in the U.S. carrying a suitcase packed with $10,000 in cash, was on a reconnaissance mission for a future dirty-bomb attack.

In January 2003, based on evidence uncovered in Herat, Afghanistan, British intelligence officers and weapons researchers concluded that Al Qaeda had succeeded in constructing a

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[7] Jessica Eve Stern, « Between Prudence and Paranoia, The Middle Ground in the Weapons-of-Mass-Destruction Terror Debate », in *Controlling Weapons of Mass Destruction*, ed. Deepa M. Ollapally, United States Institute of Peace, Washington D.C., September 2001, p. 60, http://www.docstoc.com/docs/868658/Controlling-Weapons-of-Mass-Destruction-Findings-from-USIP-Sponsored-Projects

[8] http://www.sagafoundation.org/

small dirty bomb, though the device was never found. Officials did not know how much radiation the dirty bomb could spread, but they suspected that Afghanistan's Taliban regime helped Al Qaeda build the device by providing radioactive sources from medical devices. Furthermore, Abu Zubaydah, the captured Al Qaeda lieutenant now in American custody, told interrogators that such a device did indeed exist. According to the Porton Down defence research centre in Wiltshire, "*al-Qaeda had a small dirty bomb but probably not a full blown nuclear device.*"[9] In addition, in Kabul, in April 2002, IAEA experts secured several powerful unguarded radiation sources, mainly cobalt, once used in medical and research applications.

Is radiological terrorism a threat? Threat is defined as a materialised risk. In a stricter sense, a threat has to combine the will and necessary capacity for the acquisition, development and use of nuclear material. To this day, and though the will to do so exists, no terrorist group has yet managed to acquire that effective non-conventional capacity. Such nuances in the qualification of the threat have however been bypassed in the post 9/11 context. The dominant viewpoint, in the United States if not in the West more generally, is that nuclear and radiological terrorism has upgraded from a risk to a full blown threat.

1.2. The characters of the threat

The fear of terrorism and the realisation of its threat has meant that a number of new nuclear materials, beyond Highly Enriched Uranium (HEU) and Plutonium, have been recognised as potentially dangerous if put in the wrong hands. The radionuclides posing potential security risks, if used in huge quantities, are nuclear reactor-produced: Americium-241, Californium-252, Cesium-137, Cobalt-60, Iridium-192, Plutonium-238, Strontium-90, mostly[10]. IAEA lists sixteen radionuclides usable in order to built a dirty bomb, "*providing a categorization by activity levels for radionuclides that are commonly used.*"[11]

A dirty bomb is one of the easiest weapon of mass destruction to make for a non state actor. According to the American Government Accountability Office (GAO), "*the risk of terrorists using an RDD is, in large part, determined by their ability to gain access to the materials needed to construct these devices.*"[12] Much of the radioactive materials needed can be bought on the market, and building a dirty bomb is relatively easy. However, one could argue that the transport of important quantities of materials is a problematic endeavour, as some sources are heavy and can be detected. Moreover, combining the material with a conventional explosive is a very hazardous operation.

It must be noted that the use of a dirty bomb by a terrorist group would most probably be aimed at the contamination of a given geographical area, rather than mass destruction and killing. For this reason, dirty bombs are considered by analysts as weapons of mass disruption rather weapons of mass destruction. Three societal effects can be summoned:

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[9] « Al-Qaeda 'was making dirty bomb' », *BBC News Online*, January 31, 2003, http://news.bbc.co.uk/2/hi/uk_news/2711645.stm

[10] Charles D. Ferguson, Tahseen Kazi, Judith Perera, *Commercial Radioactive Sources : Surveying the Security Risks*, CNS, Monterey Institute of International Studies, January 2003, Table 5, p. 16

[11] See Annex 1

[12] *Combating Nuclear Terrorism*, United States Government Accountability Office, September 14, 2009, http://www.gao.gov/new.items/d09996t.pdf

- Targeting highly populated environments, such as cities, would most probably not result in a high death toll. Only a limited amount of people would die from direct exposure to the ionizing radiation,[13] and in the long term increased risks of cancer will depend largely on the material used, its amount and its dispersibility. For instance, if Cesium-137 is potentially dangerous because it is in the form of powder, other radioisotopes, such as Cobalt-60 are in a solid metal form, and thus not easy though not impossible, to disperse. Finally, experts in the field usually consider that contaminating water supplies would require too much radioactive material to be effective.[14]

- Compared with impacts on health, psychological impacts of such an attack would be much more serious, both within and outside the targeted population (initial public panic, collective trauma, increased sense of vulnerability, etc.). In this regard, a dirty bomb seems to be an effective weapon of terror. The Goiânia Radiation Incident also revealed that an RDD attack could even be silent, as an explosion is not necessary to disperse the radioactive material. Terrorist acts do usually seek a broad media attention, but one could argue that responsibility for the attack could be claimed a few hours or a few days after the dispersion in the absence of a blast.

- Economic damage is probably the greatest threat posed by such attacks, particularly as radioactivity cannot be eliminated but only transferred from one place to another. Depending on the power of the device and the size of the area, the costs would involve clean-up, demolition[15] and reconstruction, and then potential large-scale relocation. Although it is difficult to give any precise figure, costs could soar to trillions of dollars.

Emergency Response for a Dirty Bomb Blast

"Three principles to minimize excess radiation exposure. These principles are time, distance, and shielding. Minimize the time of exposure. Maximize the distance between you and the radiation source. Maximize the amount of shielding between you and the source."

Dr. Charles Ferguson, *Center for Nonproliferation Studies*, Washington D.C., http://www.pbs.org/wgbh/nova/dirtybomb/ferg-030303.html

1.3. Illicit trafficking

At this stage, the question of illicit trafficking must be addressed. Several databases on nuclear and radiological traffics exist, the more authoritative being the one of the IAEA. This instrument was launched in 1995, based on State-confirmed reports (a hundred States are currently participating on a voluntary basis) and open media sources. Three categories of incidents occurring each year are listed:

1. unauthorized possession and related criminal activity,
2. thefts and losses,
3. other unauthorized activities.

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[13] But radioactive materials could be mixed to maximize health hazards, combining gamma-emitting and alpha-emitting sources of radiation.

[14] Charles D. Ferguson, Tahseen Kazi, Judith Perera, *Commercial Radioactive Sources: Surveying the Security Risks*, CNS, Monterey Institute of International Studies, January 2003, 66 p.

[15] Indeed, in many cases, demolition is the only effective way to decontaminate buildings exposed at important levels of radiation.

As of the 31st of December 2007, the latest IAEA Illicit Trafficking Database (ITDB) contained 1340 confirmed incidents since 1995. 303 involved incidents of the first category, 390 of the second, 570 of the third, 77 incidents not being detailed enough to be precisely qualified. Criminal activity, thefts and losses have decreased between 2006 and 2007 but also more generally since the beginning of the century, although un-recovered materials (66% of the cases) include category 2 and 3 « high risk 'dangerous' radioactive sources ». The general increase in confirmed incidents coincides with the increase in the number of States participating to the ITDB (4 new States since 2006), as well as with the extension of the scope of monitoring activities. 18 incidents have involved HEU and Plutonium since 1993 but, according to the document, « *a few of these incidents involved seizures of kilogram quantities of weapons-usable nuclear material, but the most involved very small quantities.* » The major part of the trafficking seems to involve radioactive sources used in many industrial and medical applications, like Cesium-137, Cobalt-60, or Strontium-90.

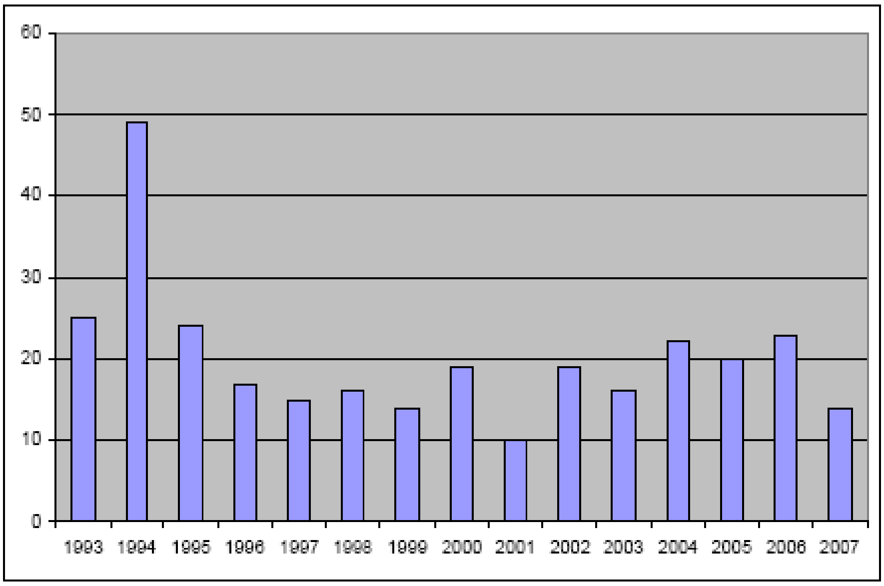

Figure 1. Incidents reported to the ITDB involving unauthorized possession and related criminal activities, 1993-2007

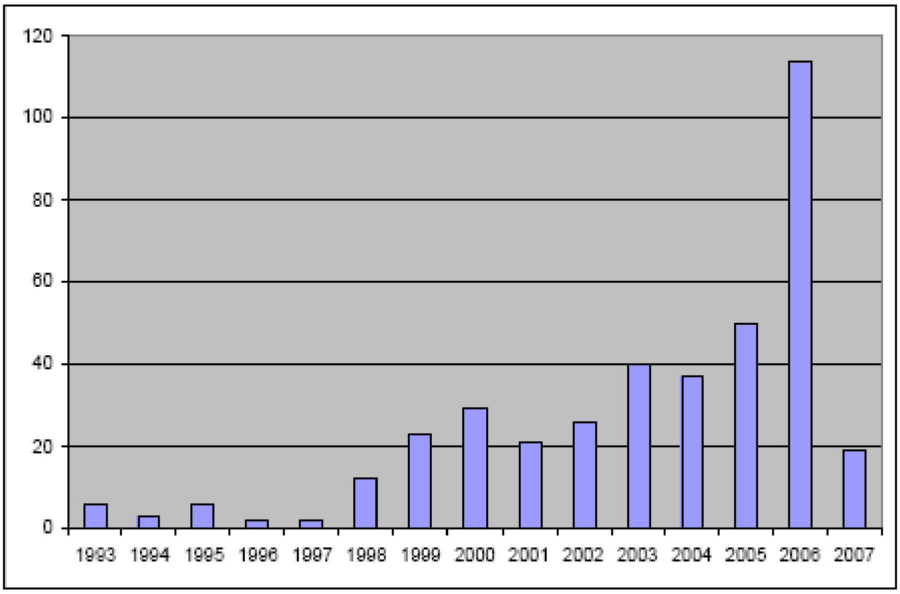

Figure 2. Incidents reported to the ITDB involving theft or loss, 1993-2007[2] [16]

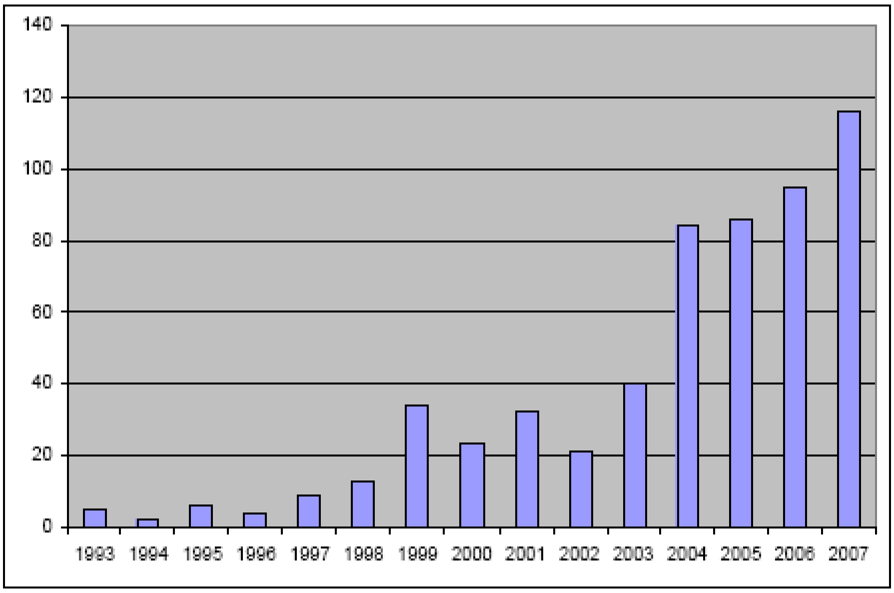

Figure 3. Other unauthorized activities, 1993-2007

Source: *IAEA IDTB Fact Sheet*, 1993 - 2007
http://www.iaea.org/NewsCenter/Features/RadSources/PDF/fact_figures2007.pdf

[16] *"The significant increase of the number of reported case involving theft or loss in 2006 is due almost entirely to a change in the reporting practice of one state that greatly increased their number of reports."* (IDTB Fact Sheet)

A number of trends can be extracted from the study of incidents. At the beginning of the 1990's, many incidents involved underpaid employees in Russian facilities. Trafficking was mostly directed to European countries, before being redistributed to Central Europe and the Caucasus. Few criminal or terrorist organizations have been involved to date, which does not necessarily signify a lack of interest: well organized criminal activities will tend to be less detectable.

Most of the materials involved in trafficking come from the former USSR. However, it must be remembered that over a hundred countries are concerned by illicit trafficking, and 20% of this trade comes from the United States, which may explain the acute perception of a threat there. Africa and South East Asia have also started to be affected by this issue since 2001.

Most of the reported incidents cover losses of industrial sources from commercial companies. Individuals tend to operate on their own, outside any organised market. Their motivations and intentions have been categorised into four groups by a number of recent American studies:

1. Absence of intention: "innocent" incidents occur due to an obvious lack of safety (incident of Ciudad Juarez, Mexico, 1983 – 1984, for instance).

2. Economic and financial motivations: underpaid employees or unscrupulous companies abandon their waste (nuclear waste dumping by a foreign company in the port of Koko, Nigeria, 1987).

3. Criminal intention: several reports mention such a motivation. One of the most recent cases saw former KGB agent Alexander Litvinenko get poisoned by radioactive Polonium-210 in London, in November 2006.

4. Political intention and terrorism: no case to date.

2. Successes and failures of the international response

Formally, the whole international community has been concerned with nuclear and radiological terrorism since 9/11. A few days after the attacks, Dr. Mohamed ElBaradei claimed: "*The tragic terrorist attacks on the United States were a wake-up call to us all. We cannot be complacent. We have to and will increase our efforts on all fronts—from combating illicit trafficking to ensuring the protection of nuclear materials—from nuclear installation design to withstand attacks to improving how we respond to nuclear emergencies.*"

It seems that the call of Dr. ElBaradei has been heeded if one refers to the range of measures instigated since then. In a rather unusual way in the field of international security, implementation of instruments to combat radiological terrorism anticipated the materialization of the risk.

A convenient classification of the tool box is difficult to give because the whole architecture is based on a multilayered approach partly redundant.

2.1. Evolution of the institutional response at international level

It has already been said that the IDTB was launched under the aegis of the IAEA in 1995, as the very first international tool against illicit trafficking of nuclear and radiological materials. The International Conference on the Safety of Radiation Sources and Security of Radioactive Materials held in Dijon, France, in September 1998, can be seen as the second step specifically taken to address the issue of radiological terrorism on a multilateral level, notwithstanding other national or bilateral initiatives taken after the collapse of the USSR in 1991 (Cooperative Threat Reduction Program of the United States for instance). Based on the findings of the conference, the IAEA's Board of Governors requested the IAEA Secretariat to put forward an action plan. This action plan called for the development of a Code of Conduct on the Safety and Security of Radioactive Sources, a first version of which was published in March 2001. Since the Dijon conference, international conferences under the auspices of IAEA have punctuated the work of the Agency, in relation with others international bodies (G8, the European Union, Interpol, World Customs Organization, etc.).

This historical background can explain why the international reaction after 9/11 was so fast, varied and multilayered, and remains so to this day. That said, it is now legitimate to ask oneself if we have at our disposal an in-depth defence strategy, in which the many existing layers of action are integrated effectively? In the negative, it could be that there exists a worrying and damageable sense of – false – security.

The issue of "radiological weapons" and nuclear security in a wider sense emerged on the international agenda many decades ago. As reminded by Jozef Goldblat, "*the 1948 UN definition of weapons of mass destruction (…) included 'radioactive material weapons'. Referring to this, in 1979 the United States and the Soviet Union proposed the conclusion of a convention prohibiting radiological weapons.*"[17] It is well known that these initiatives stumbled over the definition of a radiological weapon, and subsequently over the scope of the prohibition, at the Conference on Disarmament in Geneva. According to several states, banning radiological weapons but excluding nuclear explosives, which was the core of the proposal, would have been a way to legitimize the use of nuclear weapons. No consensus could be reached either on the prohibition of damage to nuclear reactors and facilities, notably because this would have been a way to prohibit counter-proliferation options, if need be (the destruction of Osiraq by the Israeli aircraft in 1981 gives an illustration).

Radiological terrorism is at the crossroads of two major agendas in the field of international security: non-proliferation and anti-terrorism. The failure of the negotiations on radiological weapons at the Conference on Disarmament could be an indicator that the issue is best tackled outside the traditional multilateral non-proliferation and disarmament arenas, and even more so today, as the nuclear non-proliferation regime is under pressure.

As far as nuclear security is concerned, which is not exactly our point, four main tools are worth considering:

- The Convention on the Physical Protection of Nuclear Material (CPPNM) was elaborated under the aegis of the IAEA. It was opened for signature in March 1980, and entered into force in February 1987 (137 parties). Originally, the text applied to

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[17] Jozef GOLBLAT, *Arms Control. The New Guide to Negotiations and Agreements*, Prio / SIPRI, 2002, p. 162

the transportation of nuclear material used for peaceful t. It was amended in July 2005 to cover national transport and stockpiling of materials on national territory. Unfortunately, States parties to the IAEA could not reach consensus on international verification measures for the physical protection of nuclear facilities and materials, which is troublesome because of the huge disparity between states on the issue.[18]

- IAEA regularly publishes recommendations for the physical protection of nuclear materials and equipments (INFCIRC/225/rev.4). Recommendations are not legally binding but it seems, according to Anita Nilsson[19] for instance, that they are widely endorsed at the international level.

- Based on an instrument proposed by the Russian Federation in 1998, and after years of negotiations on the scope of the treaty, The International Convention for the Suppression of Acts of Nuclear Terrorism was adopted by the United Nations General Assembly in April 2005, entered into force in July 2007. (49 ratifications and 115 signatures as of July 2009). The text provides a definition of acts of nuclear terrorism, and criminalizes offences. States are encouraged to cooperate in the prevention of terrorist attacks through information sharing.[20]

- Resolution 1540 (April 2004) of the United Nations Security Council (UNSCR) is focused on the non-proliferation of weapons of mass destruction to non state actors. Although Resolution 1540 is binding, its legitimacy was questioned for a long time within the General Assembly of the United Nations. Even today, the 1540 Committee responsible for its implementation is not a verification Committee. The international community in charge of the whole mechanism is based on a partnership, pursuant to the letter and the spirit of UNSCR 1540, UNSCR 1673 (April 2006), and UNSCR 1810 (April 2008): awareness raising, experience and information sharing, networking for assistance programmes, etc. Could the role of the Committee be strengthened?

- Another instrument deserves to be mentioned: in October 2005, two protocols were concluded by the International Maritime Organization (IMO) to amend the 1988 *Convention for the Suppression of Unlawful Acts against the Safety of Maritime navigation* (the SUA Convention). The texts were opened for signature in February 2006. In particular, the amendments outlaw the transport aboard ships of: « *any radioactive material, knowing that it is intended to be used to cause death or serious damage for the purpose of intimidating a population or to compel a government or an international organization to do or abstain from doing any act;*”. The amendments will come into effect once 12 member countries have ratified them. To date however, the protocols have still not come into force.

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[18] Text of the Convention: http://www.iaea.org/Publications/Documents/Infcircs/Others/inf274r1.shtml

[19] “*As head of the IAEA Office of Nuclear Security, Ms. Nilsson is responsible for coordinating and implementing the IAEA´s* Nuclear Security Plan *to prevent, detect and respond to acts of nuclear terrorism and threats thereof.*” http://www.iaea.org/Resources/Women/firstladies.html

[20] Text of the Convention: http://www.iaea.org/Publications/Documents/Treaties/unga040405_csant.pdf

Those multilateral instruments do not specifically deal with dirty bombs, but radiological materials have entered the scope of nuclear security, which could suggest that the international approach to nuclear security has become increasingly “holistic”.

Regardless of the type of threat posed, one issue remains open, with regards to a possible international regime to cover radiological materials: how can we be sure that ambitious instruments are effectively implemented? Tools for the monitoring of the implementation of international initiatives may be key for the establishment of a successful international regime.

2.2. The IAEA instruments against radiological risks and threats: main issues

IAEA is the cornerstone of international activity on radiological security. In brief, the Agency’s approach is mostly preventive, focusing on security of sources[21]. Its main instrument is the *Code of Conduct on the Safety of Radioactive Sources* (henceforth “the Code”)[22].

Following the International Conference on Security of Radioactive Sources that took place in Vienna in March 2003[23], a revised Code was approved, taking into account the concerns borne out of the 9/11 attacks. The Code was published in January 2004. The Conference also recommended launching international efforts to facilitate the location, recovery, and securing of orphaned sources, under the aegis of the IAEA's Department of Nuclear Safety and Security. Other documents have been released since then, providing practical guidance for governments on compliance with the Code (*Guidance on the Import and Export of Radioactive Sources*[24], approved by the Board in September 2004, and *Security of Radioactive Sources, implementing Guide*[25], July 2009, mainly). The Code points out the components of an effective national regulatory system, in order to strengthen the security of those sources that pose the greatest risks (health and environmental hazards). Action plan and measures were also taken to implement the findings of the Dijon and Vienna conferences (regulatory infrastructures, disused radioactive sources, emergency response, etc.).

The increasing amount of literature is a proof of the increasing interest taken by Sates in this issue.[26] It also reveals the complexity of it, and the necessity for further research and action. According to Anita Nilsson, speaking in April 2009, two problems must be taken into account:

- First, “*there are no tools that can guarantee nuclear security, because the bottom line and the overarching approach is that the responsibility rests with the State*” (even if “*security gains from a recognized international dimension*”.).

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[21] In detail, the IAEA approach intends to be “holistic”, based on three pillars: prevention, detection and response, information coordination and analysis.

[22] http://www-pub.iaea.org/MTCD/publications/PDF/Code-2004_web.pdf

[23] Representatives of 120 countries participated in the event. Findings of the Conference: http://www-ns.iaea.org/downloads/rw/meetings/rdd_findings.pdf

[24] http://www-pub.iaea.org/MTCD/publications/PDF/Imp-Exp_web.pdf

[25] http://www-pub.iaea.org/MTCD/publications/PDF/Pub1387_web.pdf

[26] See Annex 2 for the international support of the Code

- Second, "*recently it has been recognized that much more needs to be done. The materials and facilities that are subject for security considerations are much broader than initially thought.*" [27]

A third problem must be added, which is that about 50 States still do not qualify for IAEA assistance.

Finally, the issue of financing must be raised. Nuclear and radiological security activities are affected by the structural budgetary issues the IAEA is facing since the early 1980's, as indicated in the table below:

Years	**Ordinary Budget (millions euros)**
1993	191
2003	249
2004	268
2005	281
2006	274
2007	284
2008	295
2009	296
2010 (proposal of the director general)	336
2011 (proposal of the director general)	341

Even if the year 2003 marked the beginning of moderate increase of the ordinary budget of the Agency, its functioning has been negatively affected, since 1985, by a zero-growth budget policy. Today, the IAEA's financial resources (450 millions euros for 2008 – 2009) come for one third from voluntary contributions (150 million euros), which could raise problems for the long term investment capacity of the Agency.

Example of a partnership: IAEA removes dangerous radioactive sources from Lebanon

"*An IAEA mission to get powerful radioactive sources out of Lebanon was completed 30 August 2009, after a plane carrying the high-activity cargo safely touched down in Russia, where the sources are now securely and safely stored.*
They comprised 36 Cobalt-60 sources, with a combined activity of 3.500 curies. A single source is powerful enough to kill a person within minutes, if directly exposed.
Mr. Robin Heard, an IAEA radioactive source specialist, oversaw the mission.
"Given the political situation in the Middle East and particularly in Lebanon we saw this source as vulnerable to malicious acts. If it was stolen it could cause a lot of damage to people," Mr. Heard said.
The Cobalt-60 sources were from an irradiator that was once used for an agricultural project. But that was 10 years ago. The project ceased, and the staff that had the knowledge to properly look after the irradiator had left the organization.

[27] "The evolving landscape of nuclear security", by Ritu Kenne & Giovanni Verlini, Interview with Anita Nilsson, Reprinted from *the IAEA Bulletin* 50.2, April 2009, http://www.iaea.org/NewsCenter/Focus/NuclearSecurity/pdf/Interview_AN.pdf

In support of the IAEA activities in nuclear security, in 2005, the Council of the European Union decided to provide funds of € 3.914 million to the IAEA´s Nuclear Security Fund. This paves the way to securing high radioactive sources like those in Lebanon.
"The challenges to this project were all security related," Mr. Heard said. "Just after we went on our first fact finding mission to Lebanon in 2006, the Israelis bombed the airport, so there was no way we could fly the sources out at that time. So there was a long delay while we waited for things to normalise in Lebanon," he said.
But their perseverance paid off, working closely with the Lebanese Atomic Energy Commission. "Having some Cobalt-60 sources for the research irradiator in the agriculture centre not secure and not used, posed some threat, actually a lot of threat on the public, on Lebanon. So the IAEA experts, with the acceptance of the Lebanese authorities agreed that they be removed... It was a very good thing for Lebanon and for nuclear security in the world," Ms. Muzna Assi, Section Head, Radioactive Waste Management and Safe Transport of Radioactive Sources at the Commission said.
The job involved extracting the sources from the irradiator and moving them to special transport containers. They were then flown to Russia on an aeroplane hired specifically for the job."

Staff Report, 10/09/2009. See Story Resources for more information. -- *Kirstie Hansen, IAEA Division of Public Information*
http://www.iaea.org/NewsCenter/News/2009/lebanon.html

2.3. Bilateral, regional and global partnerships: an overview

The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction (Kananaskis Summit, 2002) acknowledged the threat of RDDs in 2003. An Action Plan for Radioactive Source Security was passed[28], which calls for guidance on export and import controls for high-risk radioactive sources, assistance for "the most vulnerable states", and support for the IAEA's efforts in the field. In a preventive way, a document was produced, providing States with seven recommendations on the security of radioactive sources:

"*These recommendations will take into account the findings of the 2003 International Conference on Security of Radioactive Sources and could consider addressing, in particular, the following:*

- *Establishing a national register to track sources throughout their life-cycle,*
- *Setting up an outline for creating a national mechanism for the recovery and securing of "orphan" or poorly-controlled sources within their national territory,*
- *Establishing a series of guidelines with respect to the control of exports of sources, conditions attaching to them, and mechanisms (e.g. notifications) for monitoring these exports,*
- *Developing national measures as necessary to combat malevolent acts involving radioactive sources,*
- *Identifying possible measures to be taken by the State in order to safeguard and restrict access to sources,*
- *Identifying measures that the State could take regarding the conditioning and/or encouraging the recycling of sources at the end of their life,*
- *Putting in place a system which aims to detect the passage of radioactive sources at strategic points such as border crossings.*"

On a bilateral basis, many American initiatives were taken under the Bush administration in order to strengthen the security of the global transport chain. Approximately 95% of the world's traded goods are transported in containers, which comprises the device itself, trucks, seaports, vessels, points of transfer and transhipment hubs. Those initiatives aimed at

[28] http://www.g8.fr/evian/english/navigation/2003_g8_summit/summit_documents/non_proliferation_of_weapons_of_mass_destruction_securing_radioactive_sources_-_a_g8_action_plan.html

implementing a culture of security in like-minded countries. Four main mechanisms can be highlighted:

1. *Proliferation Security Initiative* (PSI) launched in May 2003, intends to create agreements and partnerships between countries which endorsed the Statement of Interdiction Principles of the mechanism,[29] in order to board and inspect planes and ships carrying suspicious loads and seize illegal weapons and materials. 90 States are on record for having officially supported the PSI to date.

2. *Container Security Initiative* (CSI)[30] launched by the Department of Homeland Security (DHS), is a program intended to help increase security for containerized loads shipped worldwide to the United States. The purpose is to identify and inspect all containers destined to the United States that represent a potential terrorist risk. The technology involves large-scale X ray and gamma ray machines and radiation detection devices. 35 seaports around the world are operational to date.

3. *Megaports Initiative* (launched by the US National Nuclear Security Administration, 2003), intends to equip seaports with radiation detection equipment, in collaboration with foreign partners (100 ports targeted by 2015). Installation to date has been completed in 27 ports around the world.

4. *Secure Freight Initiative* (SFI), jointly managed by DHS (US Border and Customs Protection) and DOE, was built on CSI and *Megaports* as an evaluation system for both initiatives in 7 seaports (capabilities for large-scale radiation scanning, methods to integrate new data into screening and targeting systems).

The American Department of Energy also contributes to the recovery of radioactive sources, *via* two programs. The US Radiological Threat Reduction Program was launched in 2003. More than 11,000 "*excess, unwanted, abandoned and orphan radioactive sealed sources and other radioactive material from the environment*" have been recovered. The International Radiological Threat Reduction (IRTR) program works to secure radioactive sources around the globe. IRTR has secured over 200 sites, and has removed over 1,000 sources from Iraq. Similar more modest efforts have been undertaken by France in Africa to secure nuclear materials in medical or research facilities.

Global Initiative to Combat Nuclear Terrorism (GICNT), a bilateral project launched by the United States and the Federation of Russia on the eve of the G8 Summit of Petersburg on July 2006, was presented as a partnership open to every nation fully committed to comply with the 8 points of the Statement of Principles adopted in Rabat in October 2006. Amongst them, radioactive materials are mentioned, in a spirit of prevention, detection and response:

- "*Develop, if necessary, and improve accounting, control and physical protection systems for nuclear and other radioactive materials and substances;*
- *Enhance security of civilian nuclear facilities;*
- *Improve capabilities of participants to search for, confiscate, and establish safe control over unlawfully held nuclear or other radioactive materials and substances or devices using them*

[29] Adopted in Paris, 4 September 2003, http://www.land.polemb.net/index.php?document=105

[30] CSI In brief: http://www.cbp.gov/xp/cgov/trade/cargo_security/csi/csi_in_brief.xml

- *Improve capabilities of participants for response, mitigation, and investigation, in cases of terrorist attacks involving the use of nuclear and other radioactive materials and substances, including the development of technical means to identify nuclear and other radioactive materials and substances that are, or may be, involved in the incident.*" [31]

Three years after its adoption, GICNT has garnered support from 76 States, along with the IAEA, the European Union, and INTERPOL as official observers.

One of the most recent American initiative to date is the launch of the *World Institute for Nuclear Security* (WINS)[32], in September 2008, premised on the idea that "*there is no threat more potentially devastating than a terrorist nuclear attack*".[33] Its mission consists in preventing varied forms of nuclear terrorism (thefts, sabotage, armed attacks, etc.), by collecting, sharing and putting into place best practices from around the world. Presented as a "forum" bringing together on a voluntary basis practitioners from the field of nuclear security, the WINS intends to promote new professional standards through the organization of workshops.

All of those initiatives are based on a mixed approach, at the crossroads of prevention, detection, and counter-proliferation. They have in common their informality and flexibility as mechanisms working from outside of the multilateral system. Very ambitious, their purpose is to fill the gaps within the global security structure and mechanisms by bypassing political obstacles inherent to multilateral solutions. Presented by the United States as "innovative and proactive", the approach has never received unanimous backing among the international community. Can it serve as a basis to create international norms, common practices, and a common culture and understanding of radiological security issues?

The question now is therefore: how can "mechanisms" be institutionalized? In his speech delivered in Prague last April, president Obama proposed to institutionalize PSI and GICNT, an idea that has been supported a majority of the Democrats in Congress for a few years: "*we should come together to turn efforts (…) into durable international institutions*". This point will no doubt be much debated during the Global Summit on Nuclear Security next April.

Conclusions and recommendations

It is important to keep in mind that the international struggle against radiological terrorism needs long term efforts. IAEA recognizes that "*even states with relatively strong security measures in place face significant challenges in preventing the diversion of radioactive materials; these materials, either through malevolence or human error, do get stolen or lost. Over 100 states have been found to have inadequate controls over these dangerous*

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[31] For a detailed presentation, see *NTI Issue Brief*: http://www.nti.org/e_research/e3_global_initiatives.html

Statement of principles adopted in Rabat: http://www.state.gov/t/isn/rls/other/126995.htm

[32] "*OUR VISION – To help secure all nuclear and radioactive materials so that they cannot be utilised for terrorist purposes*

OUR MISSION – To provide an international forum for those accountable for nuclear security to share and promote the implementation of best security practices" http://www.wins.org/

[33] Sam Nunn, inaugural speech, Vienna, September 29, 2008

materials.”[34] Work on this issue has begun roughly a decade ago; it is thus too early for a comprehensive assessment.

IAEA, as an institution, appears to be, at least officially, the cornerstone of radiological safety and security. Although the initiatives of the Agency are based on the good will of Member States (action plans, code of conduct, recommendations, guides, partnerships, etc.), the inklings of an international regime on the issue have emerged, through iterated cooperation within the Agency. Moreover, in the past few years a number of initiatives have been set up with a view of strengthening the regime. To date, several are binding but unverifiable, while the others are non-binding. Depending on one’s perception, it can be said of this regime that it is flexible and economical, or incoherent, unbalanced and too discrete.

In this context, the risk of the emergence of a two-tier system, in which the bottom tier would be composed of comprehensive but ineffective mechanisms (multilateral awareness and non binding or unverifiable tools), and the upper tier of fragmented and unbalanced ones (“*coalition of like-minded*” approach), is real. The project to move towards a more integrated regime to cover radiological materials thus seems a timely one.

On a political level, five main issues at least must be addressed in order to establish a more comprehensive and effective international architecture for radiological and nuclear security:

1. Integration needs financing and institutional authority (who?)
2. Effectiveness implies an effective monitoring capacity, whatever the form (binding tools, assessment processes, registers and updated lists, means of verification, etc.)
3. Because radioactive sources are an integral part of the global market, the security of sources must be ensured in a cost-effective manner;
4. High-level political leadership is needed (involvement of big powers? Security Council Resolution under Chapter 7 of the Chart?)
5. Common security standards must be agreed upon by the 150 IAEA Member States

[34] International Atomic Energy Agency, "Q & A: Safety and Security of Radioactive Sources," *Features: Radioactive Sources*, accessed at: http://www.iaea.org/NewsCenter/Features/RadSources/radsrc_faq.html

On the operational level, international and national efforts should focus on:

- the adoption of a gradual approach. A "*one-size-fits all* security" regime will not be feasible;
- high-risk radioactive sources;
- orphan sources around the world;
- technological innovations and solutions (improvement of the cleanup of contaminated areas, acceleration of emergency health responses, elaboration of less dispersible sources and technological substitute, etc.);
- national disaster recovery strategies (exchange of best practices);
- regular recovery exercises for first responders (coordination between agencies);
- training for personnel operating response equipments;
- public information campaigns (mitigation of panic effects, social resilience in open societies);
- the improvement of export licence systems;
- the improvement of nuclear reactors security (high risk radioisotopes are produced by nuclear reactors).

"*'DIRTY BOMB' BREAKTHROUGH*"

"British scientists have developed a revolutionary method of treating victims of radiation contamination. Trials of a new device, no bigger than a small suitcase, which can rapidly detect the extent of cellular damage caused by exposure to a nuclear "dirty bomb" or a radiation leak, will be announced this week. It could mean doctors being able to scan hundreds of potential victims at an incident within hours.
Current methods involve scientists taking blood samples which then undergo a complex battery of tests. Experts estimate that existing UK labs could handle only 100 samples a week.
Dr Kai Rothkamm, of the UK Health Protection Agency, said: "If there was a major radiological or nuclear event the hospitals in this country could be overwhelmed."
The new equipment will assess the total body dose of radiation by detecting the damage to proteins in the nucleus of cells. Each machine will be capable of processing 30 samples per hour."

By Nina Lakhani, *The Independent*, 13/09/2009

http://www.independent.co.uk/news/science/dirty-bomb-breakthrough-1786616.html

Annex 1 : Annex 1 of the Code of Conduct on the Safety and Security of Radioactive Sources, IAEA, January 2004

ANNEX I: LIST OF SOURCES COVERED BY THE CODE

Category 1 sources, if not safely managed or securely protected would be likely to cause permanent injury to a person who handled them, or were otherwise in contact with them, for more than a few minutes. It would probably be fatal to be close to this amount of unshielded material for a period of a few minutes to an hour. These sources are typically used in practices such as radiothermal generators, irradiators and radiation teletherapy.

Category 2 sources, if not safely managed or securely protected, could cause permanent injury to a person who handled them, or were otherwise in contact with them, for a short time (minutes to hours). It could possibly be fatal to be close to this amount of unshielded radioactive material for a period of hours to days. These sources are typically used in practices such as industrial gamma radiography, high dose rate brachytherapy and medium dose rate brachytherapy.

Category 3 sources, if not safely managed or securely protected, could cause permanent injury to a person who handled them, or were otherwise in contact with them, for some hours. It could possibly — although it is unlikely — be fatal to be close to this amount of unshielded radioactive material for a period of days to weeks. These sources are typically used in practices such as fixed industrial gauges involving high activity sources (for example, level gauges, dredger gauges, conveyor gauges and spinning pipe gauges) and well logging.

Table I provides a categorization by activity levels for radionuclides that are commonly used. These are based on D-values which define a dangerous source i.e.: a source that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects. A more complete listing of radionuclides and associated activity levels corresponding to each category, and a fuller explanation of the derivation of the D-values, may be found in TECDOC-1344, which also provides the underlying methodology that could be applied to radionuclides not listed. Typical source uses are noted above for illustrative purposes only.

In addition to these categories, States should give appropriate attention to radioactive sources considered by them to have the potential to cause unacceptable consequences if employed for malicious purposes, and to aggregations of lower activity sources (as defined by TECDOC 1344) which require management under the principles of this Code.

TABLE I. ACTIVITIES CORRESPONDING TO THRESHOLDS OF CATEGORIES

Radionuclide	Category 1		Category 2		Category 3	
	1000 x D		10 x D		D	
	(TBq)	(Ci)[a]	(TBq)	(Ci)[a]	(TBq)	(Ci)[a]
Am-241	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00
Am-241/Be	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00
Cf-252	2.E+01	5.E+02	2.E-01	5.E-00	2.E-02	5.E-01
Cm-244	5.E+01	1.E+03	5.E-01	1.E+01	5.E-02	1.E+00
Co-60	3.E+01	8.E+02	3.E-01	8.E+00	3.E-02	8.E-01
Cs-137	1.E+02	3.E+03	1.E+00	3.E+01	1.E-01	3.E+00
Gd-153	1.E+03	3.E+04	1.E+01	3.E+02	1.E+00	3.E+01
Ir-192	8.E+01	2.E+03	8.E-01	2.E+01	8.E-02	2.E+00
Pm-147	4.E+04	1.E+06	4.E+02	1.E+04	4.E+01	1.E+03
Pu-238	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00
Pu-239[b]/Be	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00
Ra-226	4.E+01	1.E+03	4.E-01	1.E+01	4.E-02	1.E+00
Se-75	2.E+02	5.E+03	2.E+00	5.E+01	2.E-01	5.E+00
Sr-90 (Y-90)	1.E+03	3.E+04	1.E+01	3.E+02	1.E+00	3.E+01
Tm-170	2.E+04	5.E+05	2.E+02	5.E+03	2.E+01	5.E+02
Yb-169	3.E+02	8.E+03	3.E+00	8.E+01	3.E-01	8.E+00
Au-198*	2.E+02	5.E+03	2.E+00	5.E+01	2.E-01	5.E+00
Cd-109*	2.E+04	5.E+05	2.E+02	5.E+03	2.E+01	5.E+02
Co-57*	7.E+02	2.E+04	7.E+00	2.E+02	7.E-01	2.E+01
Fe-55*	8.E+05	2.E+07	8.E+03	2.E+05	8.E+02	2.E+04
Ge-68*	7.E+02	2.E+04	7.E+00	2.E+02	7.E-01	2.E+01
Ni-63*	6.E+04	2.E+06	6.E+02	2.E+04	6.E+01	2.E+03
Pd-103*	9.E+04	2.E+06	9.E+02	2.E+04	9.E+01	2.E+03
Po-210*	6.E+01	2.E+03	6.E-01	2.E+01	6.E-02	2.E+00
Ru-106 (Rh-106)*	3.E+02	8.E+03	3.E+00	8.E+01	3.E-01	8.E+00
Tl-204*	2.E+04	5.E+05	2.E+02	5.E+03	2.E+01	5.E+02

* These radionuclides are very unlikely to be used in individual radioactive sources with activity levels that would place them within Categories 1, 2 or 3 and would therefore not be subject to the paragraph relating to national registries (11) or the paragraphs relating to import and export control (23 to 26).

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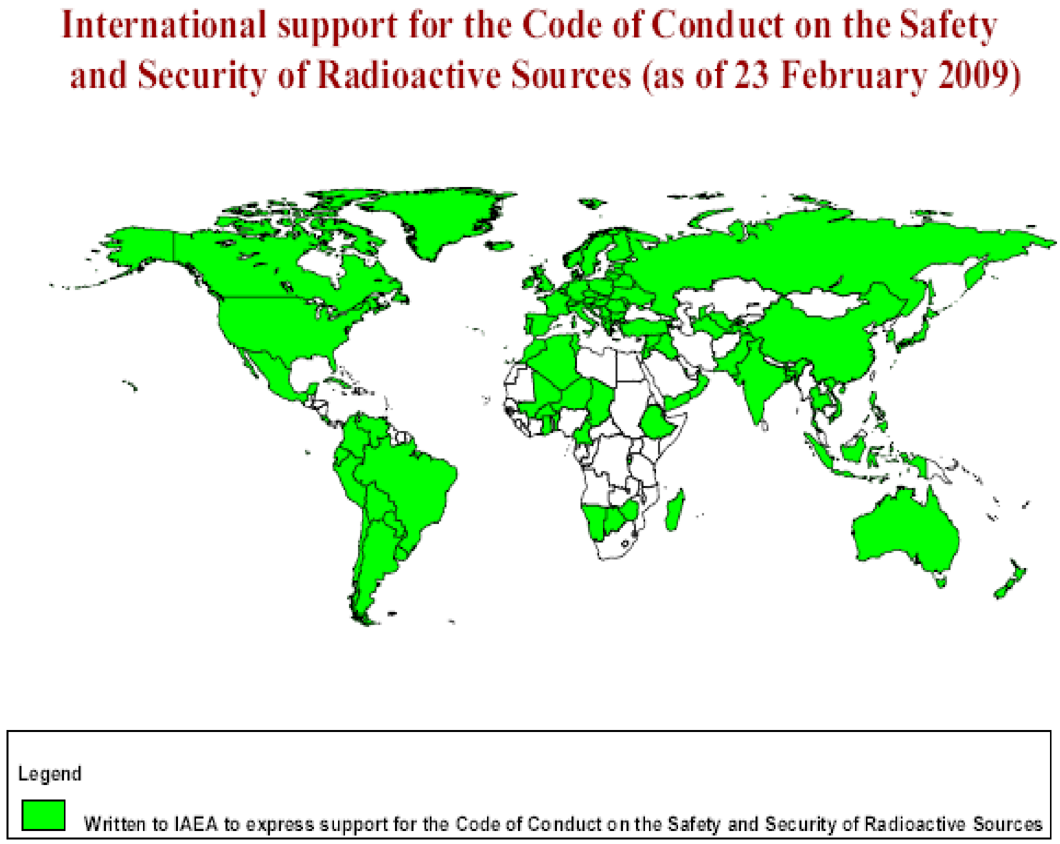
[a] The primary values to be used are given in TBq. Curie values are provided for practical usefulness and are rounded after conversion.

[b] Criticality and safeguard issues will need to be considered for multiples of D.

Source: http://www-pub.iaea.org/MTCD/publications/PDF/Code-2004_web.pdf

Annex 2 : International support for the Code of Conduct (IAEA)



Source: *Code of Conduct on the Safety and Security of Radioactive Sources*, IAEA, http://www-ns.iaea.org/downloads/rw/meetings/code-conduct-map.pdf

Annex 3 : Definitions

Improvised Nuclear Device: *"A device incorporating radioactive materials designed to result in the dispersal of radioactive material or in the formation of nuclear-yield reaction. Such devices may be fabricated in a completely improvised manner or may be an improvised modification to a US or foreign nuclear weapon."* (US Department Of Defense)

Orphan source: *"A radioactive source which is not under regulatory control, either because it has never been under regulatory control, or because it has been abandoned, lost, misplaced, stolen or transferred without proper authorization."* (IAEA)

Radioactive material: *"Any material whose radioactive activity exceeds 2 nCi/g (n designates 10^-9) or 70 Bq/g."* (AIEA)

"Material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity." (IAEA)

Radioactive source: *"Radioactive material that is permanently sealed in a capsule or closely bonded, in a solid form and which is not exempt from regulatory control. It also means any radioactive material released if the radioactive source is leaking or broken, but does not mean material encapsulated for disposal, or nuclear material within the nuclear fuel cycles of research and power reactors."* (IAEA)

Radiological Dispersal Device: *"Any device, including any weapon or equipment, other than a nuclear explosive device, specifically designed to employ radioactive material by disseminating it to cause destruction, damage, or injury by means of the radiation produced by the decay of such material."* (US Department of Defense)

Radionuclide: *"An isotope that undergoes radioactive decay. Any element with an excess of either neutrons or protons in the nucleus is unstable and tends toward radioactive decay, with the emission of energy that may be measurable with a detector. The processes of radioactive decay include beta particle emission, electron capture, isomeric transition, and positron emission."* (Mosby's Medical Dictionary, 8th edition, 2009, Elsevier)

Safety: *"Measures intended to minimize the likelihood of accidents involving radioactive sources and, should such an accident occur, to mitigate its consequences."* (IAEA)

Security: *"Measures to prevent unauthorized access or damage to, and loss, theft or unauthorized transfer of, radioactive sources."* (IAEA)