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Rajeswari Pillai Rajagopalan

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ABOUT THE AUTHOR

Rajeswari Pillai Rajagopalan is Distinguished Fellow and Head of the Nuclear and Space Policy Initiative at the Observer Research Foundation. She is also a Non-Resident Indo-Pacific Fellow at the Perth US Asia Centre for the period April-December 2020. She served as Technical Adviser to a new United Nations Group of Governmental Experts (GGE) on Prevention of Arms Race in Outer Space (PAROS) (July 2018-July 2019). As a senior Asia defence writer for *The Diplomat*, she writes a weekly column on Asian strategic issues.

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ABSTRACT

Radiological sources are used extensively in civilian sectors including for medical, industrial, agricultural and research purposes. While the positive benefits are well-recognised, concerns about terrorists using these materials to develop a "dirty bomb" are also well-known. Because of the extensive use of radiological materials in the civilian sector, these are easily accessible. The absence of an overarching regime covering radioactive sources "from cradle to grave" makes the risks more serious. This paper surveys India's radiological security policy by undertaking a review of its legislative and institutional architecture in addressing radiological security threats in the country. The central problem in this regard, although not unique to India, is the management of inventory. The problem of orphaned sources remains serious, and illustrates the challenges in the regulatory practices of India.

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INTRODUCTION

Even as nuclear and radiological security has been a global issue for several decades, it has never gained as much attention as it has following the 9/11 terrorist attacks in the United States (US). The bold and unparalleled nature of the attacks generated fear that terrorists could acquire nuclear[a] and radiological materials to cause massive destruction in the US and elsewhere. According to the International Atomic Energy Agency (IAEA) Incident and Trafficking Database (ITDB), 36 States reported a total of 189 incidents in 2019, including the trafficking and malicious use of nuclear and other radioactive material. There were 3,686 incidents and events between 1993 and 2019.[1]

While nuclear and radiological security are often discussed together, the potency and impact of the two differ significantly, and accordingly, there is a graded approach to these materials. Given the disastrous nature of nuclear materials (such as fissile material used for a nuclear weapon – Plutonium (Pu) or Highly Enriched Uranium (HEU))—i.e., they can cause immediate death and destruction, and create long-term impacts—they are considered most dangerous. On the other hand, radiological materials are more widely spread out in over 100 countries due to their large-scale use in civilian sectors including medical, industrial, agricultural and research utilities. Well-known applications include sterilisation and food irradiation, single- and multi-beam tele-therapy, industrial radiography, high- and medium-dose brachytherapy, research and blood irradiators, level and conveyor gauges, and radioisotope thermoelectric generators.[2]

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a The term 'nuclear' is used to mean fissile materials such as Plutonium (Pu) or Highly Enriched Uranium (HEU) that can potentially undergo fission and used in a fission nuclear device.

Indeed, radiological sources have been found to bring enormous positive benefits. However, if these materials fall in the wrong hands such as terrorists and criminals, they could be used for developing a Radiological Dispersal Device (RDD), or what is popularly called a "dirty bomb."[3] They are easily accessible and in the absence of a comprehensive regime that covers radioactive sources "from cradle to grave", they can pose serious risks. Unlike nuclear materials, radiological sources are not weapons of mass destruction but they have the potential to create fear and panic in an affected society in addition to resulting in major economic, social and psychological impacts.[4] Speaking about the horrific impacts of an RDD attack, Anne Harrington, the US National Nuclear Security Administration's Deputy Associate Administrator for Defense Nuclear Nonproliferation said this at a Senate Homeland Security and Governmental Affairs Committee Hearing on 12 June 2014: "An RDD detonated in a major metropolitan area could result in economic costs in the billions of dollars as a result of evacuations, relocations, cleanup, and lost wages. Radioactive sources such as Cobalt, Cesium, Americium, and Iridium are used worldwide for many legitimate purposes .... In looking at the risk, we must include not only outside terrorists attempting to steal radioactive sources as potential adversaries, but also insiders who work at these facilities who could have intimate knowledge of security procedures and vulnerabilities."[5] RDDs can also be used to make a Radiation Emission Device (RED), which when kept in a restricted place such as in a train or a crowded market place, can cause radiation exposure to a large group of people.[6]

To be sure, not all radiological sources are equally radioactive. The high-risk radiological sources include Cobalt-60, Cesium-137, Iridium-192, Strontium-90, Americium-241, Californium-258, Plutonium-238, and Radium-226. Even with these few high-risk radioisotopes, the radiation impact is not the same. The radiation impact depends on a number of factors including the amount of a particular radioisotope present in a source, the type of exposure, whether it is internal or external, the kind of radiation emitted, and whether it is alpha, beta or gamma, among other things.[7] If one were to assess these sources from a threat perspective, Cesium-137 has generated quite some interest because it has been seen as a "favourite" among terrorist groups and criminals. A number of incidents over the years reveal the smuggling and illicit trade of this particular source.[8] Cesium-137 is particularly attractive because of its large-scale use in the medical and commercial sectors. This particular feature of Cesium-137 has prompted the IAEA and the UN to identify it as a source useful for making RDDs.[9]

This paper examines the radiological security policy and practices in India.[10] It reviews the threats in the case of India, followed by an analysis of the country's legislative and institutional framework in handling radiological security threats. The third section studies the inventory management practices, which it identifies as the crux of the problem not only in India but across the globe. While the challenge of orphaned sources[b] is not unique to India, it remains a critical issue given the difficult security environment that the country is located in. The final section looks at the continuing challenges and areas for improvement for India's management of radiological materials.

MEASURING THE THREAT IN INDIA

For decades now, India has been aware of its complex and dangerous neighbourhood and has accordingly prioritised nuclear and radiological security in its threat perception well before the global community woke up to this challenge. Pakistan, for one, has remained a primary source of

b These are radiological sources that have been abandoned by industry, military and educational institutions.

India's security concerns in this regard, a view that is shared mostly by the strategic community. However, Indian security establishment has not shared this perspective entirely.[11] There are also other security concerns from various domestic insurgent groups and left-wing extremists or the Naxalites, which India has considered while developing policies against insider threats and sabotage. But there is an added issue of varying threat perception among the different actors that use radiological sources. These differences in understanding and appreciation of the problem can result in uneven preparedness and capabilities for handling a crisis, and can lead to lack of appropriate training as well.

As in other countries, India sees the large-scale use of radiological sources in the medical and commercial sectors, therefore making these materials easily available. This increases the risk of possible theft, fraudulent procurement, and even accidental discovery of orphan materials in scrap markets among other places. Given the graded-security approach, the protection of such materials is not as rigorous as it is for nuclear materials. An RDD or RED attack will not result in catastrophic disasters, but they can cause large-scale disruption and panic among the densely populated spaces in India. The concentration of economic infrastructure in cities will compound the problem, in addition to resulting in longer-term political, economic and social costs to the country.

India is yet to face a major threat in this domain except for Pakistan-sponsored terrorist attacks on key sensitive military installations such as the Pathankot airbase;[12] these incidents demonstrate certain vulnerabilities that may exist in the country's security practices. Pakistan has used innumerable means to have a better understanding of India's security layout at sensitive sites, including the Bhabha Atomic

Research Centre (BARC). This should raise India's vigilance against threats to a higher level.[13]

DOMESTIC LEGISLATIVE AND INSTITUTIONAL FRAMEWORK

India has established a fairly sophisticated legal and institutional framework to ensure the safety and security of its radiological sources, under the responsibility of the Atomic Energy Regulatory Board (AERB). The AERB has issued a number of Safety Codes, Safety Standards, and Safety Guides for the regulation of its nuclear and radiological facilities and activities in India.[14] These have detailed guidance on issues of siting, design, construction, operation, quality assurance and decommissioning of nuclear and radiological materials, along with regulatory aspects for ensuring safety and security. One of the first regulations on radiological security, called the Industrial Radiography Procedures (Radiation Surveillance), was issued in 1980 based on the Radiation Protection Rules, 1971.[15] This regulation, for instance, identifies the licensee responsible for the security of the radiological source. The most important agreement for nuclear and radiological materials is the Atomic Energy Act of 1962 which requires that a license must be procured from a competent authority (i.e., AERB) for the handling of these materials. Table 1 identifies key rules and regulations pertaining to radiological materials in India.

Table 1. Key Regulations relating to Radiological Security

Rules	Key Elements
The Atomic Energy Act, 1962	Provides the overarching rules for the conduct of all civilian nuclear-related activities in the country. Replaced the Atomic Energy Act of 1948. Supplemented by other laws and regulations on particular narrower issues.
The Industrial Radiography (Radiation Surveillance) Procedures, 1980	Emphasise on radiological security. Identifies the licensee as being responsible for the security of the source.
The Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substance) Rules, 1984	Details the rules and regulations regarding the qualification of staff, licencing, and the duties and responsibilities of safety officers.
Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987	The person authorised shall not rent, lend, sell, transfer or otherwise transport the radioactive waste without obtaining prior permission of the competent authority.
The Atomic Energy (Factories) Rules, 1996	Applicable to all factories owned by the Central Government and engaged in carrying out the purposes of the Atomic Energy Act, 1962 (33 of 1962).
The Atomic Energy (Radiation Protection) Rules, 2004 (supersedes The Radiation Protection Rules, 1971)	Cover license issues, validity, cancellation/ suspension conditions, offences and penalties, restrictions on the use of radioactive material, maintenance of records of workers, duties and responsibilities of radiological safety officer and radiation surveillance. Also focuses on the importance of radioactive material security.

Compiled by the author from various sources

In addition to these rules that detail the specific issues such as who can handle the radioactive sources, there are detailed security procedures for the transportation as well. A comprehensive security detailing has been prepared that includes real-time tracking and monitoring of materials that are considered as high-activity sources. Transport of Radioactive Material, AERB/SC/TR-1 released in 1986 was the first document prepared for this purpose although this has now been replaced by "Safe Transport of Radioactive Material" of March 2016.[16] This is an exhaustive document that specifies the design and test of different packages for transport while incorporating additional control measures that must be executed during transportation, such as restrictions on the levels of radioactivity and contamination, temperature on the external surface of the package, marking, and labelling.

The 2016 document also details design and test requirements for low dispersible radioactive material, Type C packages, fissile-excepted material and management systems in line with the relevant international measures.[17] Further, India as a founding member of the International Atomic Energy Agency (IAEA) is required to comply with the IAEA rules and guidelines pertaining to radiological safety and security. Thus, AERB's regulatory documents are developed in line with, and drawn extensively from the IAEA's Nuclear Security Series documents involving various facets of nuclear security.[18] The IAEA's "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety for Radiation Sources" published in 1996, and IAEA's "Code of Conduct on the Safety and Security of Radioactive Sources" of 2011, are key in this regard. The Code of Conduct has a bigger mandate in making pertinent recommendations to ensure safety and security "during and till their useful lives, and until their safe disposal."[19] The document places great emphasis on a safety and security culture that must be prevalent while managing radiological sources.

Further, there are a number of guidelines and manuals developed by the AERB for maintaining the inventory of the radiological sources in the country (covering both on-site and off-site safety and security of these materials). These have been developed with the objective of "protect[ing] the sources from unintentional access by inappropriately qualified personnel or attempts of theft for financial gain."[20] These guidelines provide a number of measures which are "a combination of deterrence, early detection and delay of attempts at unauthorised acquisition, mitigation of consequences and response to a loss of authorised control including recovery."[21] These documents apply to the entire life cycle of a source including manufacture, supply, receipt, storage, use, transfer, import, export, transport, operation, maintenance or disposal of radioactive sources. There are also detailed operating procedures in the case of theft or loss of sources including ways to recover lost material along with alarms to indicate possible radiation. For instance, the AERB Safety Guide, "Radiation Therapy Sources, Equipment and Installations" identifies specific procedures for end-to-end management of the source used at the radiation facilities. For example, there are automated systems for the return of the sources to the source storage; in case of failure of return, warning signals will alert authorities of the situation so that manual retraction of the source to the storage container can be carried out.[22] Depending on the potency and severity of the radioactive source, facilities also do weekly accounting of their inventory.

There are also strict guidelines for ensuring security during the transportation of radioactive sources. Key considerations while developing these guidelines include access control; administrative control (e.g. personnel verification); information control (need-to-know basis); specific training of carrier's personnel (familiarisation for better response capabilities); tracking of shipment (use of GPS for highly radioactive materials[23]); transport schedules and shipment routes; and informing state authorities prior to and during shipment.[24]

As in other areas of security, the efficacy of these regulations will depend on their strict implementation and the parties' compliance to them. Non-implementation of these rules could mean serious harm in the health, social and environmental domains. Mindful of these consequences, the AERB has put in place varied penalties for non-compliance under the Atomic Energy (Radiation Protection) Rules, 2004.[25] AERB ensures compliance by hospitals, universities and other radiation facilities through a number of activities including "surprise inspections, review of the periodic safety status reports submitted by the facilities, safety performance appraisals of the facility while renewing its license."[26] Table 2 shows the inspections carried out by the AERB in 2009 in universities, medical and other institutions that have radiation facilities.[c] In addition, some of these aspects were corroborated during interviews with radiology department officials in hospitals in Delhi.[27]

Table 2. Regulatory Inspections of Radiation Facilities (January to December 2009)

Facilities	Number of Inspections
Diagnostic X-ray	46
Radiotherapy	11
Nuclear Medicine	41
Industrial Radiography	57
Gamma Irradiators	15
Nucleonic Gauges	7

Source: Lok Sabha, "Radioactive Materials," Starred Question No. 404, 25 August 2010, http://dae.nic.in/writereaddata/lssq404_250810.pdf

c This kind of information is not easy to access. In August 2010, the Minister of State for Science & Technology and earth Sciences, Prithviraj Chavan provided the information in Parliament.

Further, in March 2016, in response to a question in the Lok Sabha, the Minister of State in the Prime Minister's Office, Dr. Jitendra Singh provided details of states and union territories that use radioactive materials.

Table 3. States with Diagnostic and Research Facilities using Radioactive Materials (only facilities registered with the AERB)

Sl. No.	State	Diagnostic facilities using radioactive materials	Research facilities using radioactive materials
1	Andhra Pradesh	11	1
2	Arunachal Pradesh	0	0
3	Assam	1	2
4	Bihar	2	0
5	Chhattisgarh	2	0
6	Goa	1	1
7	Gujarat	10	5
8	Haryana	6	3
9	Himachal Pradesh	1	2
10	Jammu and Kashmir	2	1
11	Jharkhand	2	0
12	Karnataka	20	21
13	Kerala	15	7
14	Madhya Pradesh	7	2
15	Maharashtra	35	14
16	Manipur	0	0
17	Meghalaya	0	2
18	Mizoram	0	0
19	Nagaland	0	0
20	Odisha (Orissa)	3	2

21	Punjab	11	2
22	Rajasthan	5	0
23	Sikkim	0	0
24	Tel angana	13	16
25	Tamil Nadu	22	14
26	Tripura	5	0
27	Uttar Pradesh	13	5
28	Uttarakhand	2	1
29	West Bengal	15	8

Source: Lok Sabha, "Inspection of Diagnostic Centres," Starred Question No. 274, 16 March 2016, http://www.dae.gov.in/writereaddata/parl/budget2016/lssq274.pdf

Table 4. Union Territories with Diagnostic and Research Facilities using Radioactive Materials (only facilities registered with the AERB)

Sl. No.	Union Territory	Diagnostic facilities using radioactive materials	Research facilities using radioactive materials
1	Delhi	27	10
2	Puducherry (old Pondicherry)	1	1
3	Andaman and Nicobar Islands	0	0
4	Chandigarh	2	2
5	Dadra and Nagar Haveli	0	0
6	Daman and Diu	0	0

Source: Lok Sabha, "Inspection of Diagnostic Centres," Starred Question No. 274, 16 March 2016, http://www.dae.gov.in/writereaddata/parl/budget2016/lssq274.pdf

The fact that this list comprises only of those facilities that are registered with the AERB is a glaring gap. In 2012, a report from the Comptroller and Auditor General (CAG) revealed that a large majority of the facilities are not registered. (This will be discussed in a latter section of this paper.) The AERB has to bring these facilities under its control if India is to effectively address the issues of possible theft, sabotage and orphaned sources. With a vast majority of the facilities falling outside the ambit of the AERB, India's regulatory practices with regard to radiological security cannot be described as efficient.

It is noteworthy that the AERB lays fair amount of focus in the security culture that must prevail to make security practices more effective.[28] The AERB guidelines note that "security culture" has several layers, including identifying the personnel and their roles in maintaining radiological security, having a detailed operational security plan, imparting training to security managers, providing security awareness briefings to staff contractor, periodic performance testing, and preventive maintenance. The AERB identifies the employer, licensee, general security personnel and the radiological safety officer (RSO) with a particularly important role in promoting the security culture in a facility.

Given the complex nature of nuclear security, India attaches enormous importance to the role of international cooperation. This comes from a recognition that no one country has all the capability to undertake stringent nuclear security measures. India is signatory to various international instruments dealing with nuclear security, such as the Convention on the Physical Protection of Nuclear Material (CPPNM) including the 2005 amendment to the convention, which remains one of the few legal instruments being supported by all the major powers. India is also an adherent to the 5th revision of the recommendations contained in IAEA's INFCIRC/225, in addition to backing the 2003 IAEA Code of Conduct on the Safety and Security of Radioactive Sources; India has implemented the provisions of the latter. Indeed, even as India is not a member of the Nuclear Suppliers Group (NSG), it endorses and implements its guidelines on a voluntary basis.

INVENTORY MANAGEMENT

The AERB is responsible for maintaining a complete inventory of all radiation sources used within the country.[29] Commonly used sources within the country include Cesium-137, Cobalt-60,[30] Tritium (H-3), Sodium-24, Bromine-82, Anthanum-140, Iodine-131, Molybdenum-99, Scandium-46, and Krypton-79. These are being used predominantly by the medicine, agriculture and industry sectors. Keeping with the global trend to replace High Enriched Uranium (HEU) with Low Enriched Uranium (LEU) to minimise the threat of HEU misuse,[31] India is setting up a production facility to produce "medical grade Mo-99 by the uranium fission route using LEU targets. The LEU targets will be made in India and irradiated in an indigenous research reactor."[32] Cesium-137 has found large-scale use in both the medical and well logging purposes in the oil and gas sector[33] and this is "being recovered from the high level waste arising from reprocessing spent fuel from thermal reactors."[34]

The key principles that guide the Indian approach in securing these materials include the following: access control to location of the source and timely detection in case of unauthorised access; delay mechanism to suspend unauthorised access to radiological sources through physical and technological barriers; timely alert of intrusion through an alarm; timely response to an alarm; and lodging of FIR to the relevant police authorities of the theft/ loss.[35]

The AERB also has the responsibility for security during transportation of the radioactive sources.[d,36] There are specific guidelines and codes issued by the AERB for the safe handling and security of these sources. There are a couple of formats for developing these guidelines for transportation globally. In India, the guidelines are developed by the operators based on the category and security levels of the materials being transported.[37] The AERB specifies the type of packaging for each category of materials as well as the container for transportation.[38]

The Board of Radiation and Isotope Technology (BRIT), an independent institution under the Department of Atomic Energy (DAE) has played a significant role in maintaining radiological security in India. It has developed a number of products including Radiopharmaceuticals, Labelled Compounds and Nucleotides, Sealed Radiation Sources, Gamma Chambers, Blood Irradiator and Radiography Exposure Devices and radiation processing services at ISOMED,[e] and a Radiation Processing Plant at Vashi. It also provides consultancy services for establishing radiation processing plants in the private sector, Isotope application services, and Radioanalytical services to its customers.[39] Additionally, it conducts quality control analysis and quality assurance of radiopharmaceuticals.[40]

Even as these regulations and quality control measures are in place, the large-scale use of these sources in civilian sectors continues to pose

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d Some of the commonly transported sources include Irradiated nuclear fuel, Special nuclear material in different types of packages, Unirradiated enriched nuclear fuel, Wastes arising from the nuclear fuel cycle, Uranium hexafluoride (enriched), Decayed sealed sources for disposal, Gamma irradiator sources, Teletherapy sources, Remotely handled brachytherapy sources, Manually handled brachytherapy sources, Industrial radiography sources, Neutron sources used in oil-well logging, and Nucleonic gauges.

e A radiation sterilisation facility for medical products at Trombay in Mumbai.

complex challenges for India. While responding to a question in Parliament in March 2017, Minister of State in the Prime Minister's Office, Dr. Jitendra Singh, said that the number of "radiation oncology facilities for cancer care in India and the number of treatment units (Liner Accelerators and Telecobalts) have increased from less than 250 in the year 1995 to approximately 552 units in 2015."[41] A 2012 CAG report stated that as of February that year, there were 57,443 medical X-ray facilities in the country.[42] The report also does not provide a comforting picture on the AERB, noting that about 91 percent of the 57,443 facilities (or some 52,173 units) are not registered with the Board.[43] This is a significant lapse and loss of materials from such facilities is a real possibility, and thus adding to the challenge of orphaned sources.

While it is commendable that the AERB has issued specific norms for diagnostic and research facilities using radioactive materials, it applies only to those that are registered with the Board. The specific norms laid out by the AERB for these facilities include features such as layout, shielding requirements, availability of qualified personnel, and responsibilities of the key stakeholders.[44] AERB inspections are conducted for diagnostic facilities once every three years, and for research facilities, on a sample basis.[45] While the frequency of inspections done at diagnostic centres is an issue, the bigger challenge is that a large number of facilities are not registered with the AERB.[46] This is an obvious gap in India's radiological security practices, which needs focused attention from the atomic energy managers including the AERB. This also relates to the urgent need for the government to debate and pass the Nuclear Safety Regulatory Authority (NSRA) Bill.[47] In fact, a report of the Public Accounts Committee 2013-2014 on the activities of the AERB submitted to the Parliament in December 2013 argued that the NSRA "still lacks somewhat on the count of independence."[48] The report also emphasised on the need for the AERB to have appropriate legal status that will make the agency autonomous and independent in its functioning. This lack of appropriate status and authority has impacted the AERB's ability to develop rules for nuclear and radiation safety "as the rule-making power under Section 30 of the AE Act, 1962 vests with the Central Government, that is, with the DAE and the AERB is involved in the consultative process." These problems, unless addressed in a fixed timeframe, could unleash bigger issues in India's nuclear and radiation security practices. The first step in this regard is to debate the NSRA Bill in Parliament. The current government, with a comfortable majority in Parliament, should make it a priority to do this at the earliest.

Given the daunting regulatory challenges, AERB has taken the initiative of establishing a Directorate of Radiation Safety (DRS) under the Health and Family Welfare Department at the state level to do periodic regulatory inspections and audits of these facilities.[49] The first of such facilities was set up in Kerala in 1998 and today, DRS exists in Arunachal Pradesh, Chhattisgarh, Meghalaya, Punjab and Tripura. To strengthen the registration of diagnostic facilities, the DRS in Kerala was initially given the power to register all the radiation units in the state. This authority, however, was later taken away and "the duties of the DRS were restricted to carrying out inspections of medical diagnostic x-ray installations in the State."[50] To strengthen the regulatory functions, Regional Regulatory Centres (RRCs) have been established in Chennai, Kolkata and Delhi for southern, eastern and northern regions, respectively.[51] However, there are gaps even in these inspection practices. The Public Accounts Committee report of December 2013 raised serious questions on the inspection practices by the AERB in the period from 2005-06 to 2011-12. The Committee expressed "dismay" that the AERB "has not conducted 85 per cent of regulating inspections during the seven-year period 2005-06 to 2011-12 for both industrial radiography and radiotherapy units identified as having high radiation hazard potential. Alarmingly, there was shortfall of over 97 per cent regulatory inspection in case of diagnostic radiological facilities every year."[52] The AERB has to fill this gap before it gets confronted with a major catastrophe.

KEY CHALLENGES AND AREAS FOR IMPROVEMENT

One of the key challenges in India's radiological security is keeping a watch on the "orphan" materials.[53] This is not a challenge unique to India, and there have been many major incidents globally. In India, there has been one major incident involving Cobalt-60 (an orphan case) in 2010.[54] This incident showed serious lapses including improper accounting of radiological sources and also non-adherence to guidelines for the safe and secure disposal of used materials at the end of its life-cycle.[55] Although the casualty from the incident was limited, it reflects deficiencies in the country's radiological security system. Since the Mayapuri incident of 2010, the AERB and the University Grants Commission have tried to address the issue, further tightening the rules for educational and research institutions that use radiological materials. In May 2010, the AERB organised an awareness camp for the Mayapuri scrap dealers broadly on the safety, legal and regulatory aspects while handling and disposal of radioactive materials.[56] Also, the MEA in its brief publication, *Nuclear Security in India* noted that the "AERB guidelines for use of radioisotope-based scientific devices have been strengthened" after the incident in 2010.[57]

These "awareness camps" and workshops, however, do not appear to be taking place on a regular basis. Their coverage also needs to be expanded, in terms of the number of both the states and stakeholders. It is not clear if the awareness among the first responders including the medical community has improved significantly since the Mayapuri incident. Indeed, one of the problems during the Mayapuri incident was the lack of awareness even among the medical community as to the nature and dangers of what they were dealing with. Medical doctors have gone on record to say that they have read about the symptoms of a radiological incident but they had not dealt with them, prior to the Mayapuri incident; therefore they were not able to ascertain if the person had been exposed to radiation.[58] Apart from the awareness camps, the atomic energy agencies are reported to have installed radiation detectors in Mayapuri but they were removed in 2013, according to scrap dealers in the area who have expressed disappointment over the government's lack of attention to the issue.[59] While the atomic energy agencies reiterate and highlight the strengthened radiological security policies and practices, a lot depends on the implementation and compliance level of updated regulations. The AERB claims that it has updated the inventory of radiological sources and enhanced its regulatory inspections of radiation facilities.[60]

Another key challenge is in finding alternate sources to more potent radioactive sources like Cobalt-60 and Cesium-137. Given the high-risk nature of these two sources in the hands of terrorists and criminals, many countries have been exploring alternate technologies. Globally, alternate options are being explored, including: x-rays, cesium in alternate forms (non-powder), cobalt sources, and linear accelerators (LINACS).[61] There are also specific alternative steps being suggested that include radiosurgery, internal radiation in the medical domain, downhole applications, and radiography in the oil and gas industry, which may gradually become possible.[62]

Table 5. High-Risk Radionuclides and Potential Replacements

Industry	Use	Device and Radionuclide(s)	Possible Alternative	Feasibility of Substitution
Medicine	Cancer treatment-teletherapy	Teletherapy machines using Cs137 or Co-60	Linear Accelerator (LINAC) using proton beam for treatment	Availability of substitution limited by increased cost, training and maintenance costs, and demands for stable power source
Medicine	Radiosurgery for cancer and nonoperable tumors	Gamma knife using Co-60	LINAC for some application	Gamma knife is still preferred method
Medicine	Instrument Sterilization	Cs-137 or Co-60 sterilizer	X-ray machines or return to prior methods such as steam/ heat sterilization methods	Cost and reliability are major factors for x-ray. Efficiency and quality control are major issues for older less effective measures
Medicine	Blood irradiation	Blood irradiators which are primarily Cs-137 with some Co-60	X-ray blood irradiation units. LINACs can perform blood irradiation, but such use is inefficient. UV light method shows promise	Cost and reliability major factors. Current Cs-137 machines have a long life and do not typically need replacement for quite some time

Construction	Radiographic cameras	Field use for x-ray-like nondestructive testing. These devices use an assortment of radionuclides including Co-60, Cs-137, Ir-192, Se-75	Portable x-ray machines with increasingly portable power supplies are now available but due to size issues can't replace radiographic cameras in all applications	Cost is a problem. The nondestructive testing industry has shown flexibility on reducing dose and threat by, for example, shifting away from loner lived radionuclides to the use of relatively shortlived Ir-192
Food Processing	Food sterilization	Large underground facilities using tens of thousands of curies of primarily Cs-137 but also some Co-60	At present, there are no x-ray alternatives available that can handle the required throughput	Cost of x-ray units (which would be large units) and maintenance and reliability problems would probably preclude x-ray alternative, even if one were available
Oil and Gas	Well logging	Density measuring devices primarily with Cs-137. AmBe neutron sources for detection and well mapping and Am-241 for	Both current devices can be replaced. Small D-T accelerators can provide neutron sources and small x-ray units can	The oil and gas industry is reluctant to replace the current use devices primarily because of cost and reliability and

		minerology	replace Cs-137 for density measurements. A new alpha particle accelerator with a Be target is under development	the fear that new devices' output can't be correlated with historic data that has been obtained at significant cost
Oil and Gas	Pipeline inspection	See discussion above on radiographic cameras	See discussion above on radiographic cameras	See discussion above on radiographic cameras
Nondestructive Testing	Radiography	See discussion above on radiographic cameras	See discussion above on radiographic cameras	See discussion above on radiographic cameras

Source: George M Moore and Miles A. Pomper, "Permanent Risk Reduction: A Roadmap for Replacing High-Risk Radioactive Sources and Materials," CNS Occasional Paper #23, Middlebury Institute of International Studies at Monterrey, James Martin Center for Nonproliferation Studies, July 2015, https://www.files.ethz.ch/isn/192898/permanent_risk_reduction.pdf

In India, the atomic energy establishment has paid attention to this issue and the country's effort has been on finding an alternative to Cobalt-60. India has found it economically viable to use Cesium-137 in place of Cobalt-60. BARC scientists determined in 2015 that Cesium-137, a high-yield radionuclide, can be harvested from the nuclear waste that is discarded by the nuclear power plants, and can be used for medical and industrial applications. Following the discovery, Dr. Sekhar Basu, the chairman of the Atomic Energy Commission said, "This technology is being used for the first time in the world in commercial domain."[63] CP Kaushik, an engineer at the BARC added, "The new Caesium based irradiator is more economical and requires lesser handling so it is safer."[64] Cesium-137 is considered an appropriate substitute also because of its longer half life (30 years) compared to the short half life of 5.27 years of Cobalt-60, which meant "multiple handling, transportation and loading-unloading operations."[65] However, the AERB, still recognising the dangers of Cesium, has plans to use it not in the traditional powder form, which is "highly soluble in water and the powder can get easily dispersed resulting in release of activity during accidental conditions." Therefore, India has established a separate facility to produce vitrified Cesium-137 pencils that can then be used for blood irradiation.[66] As the global community moves from Cesium-137 to safer options, India is exploring Cesium-137 in place of Cobalt-60. This means that there will continually be questions about India's rationale considering the dangers associated with Cesium-137.

A third key challenge for India relates to the inventory management. The fact that there are orphan materials found available shows the weakness of the current inventory system. Given the extensive use of radioactive materials in the medical and commercial sectors, it is almost unreasonable to assume that the state has complete control over all the radioactive sources. The task of achieving 24/7 surveillance on these sources is unmanageable, yet the authorities continue to laud its "foolproof system" that has been put in place.

This is not to suggest that India should give up on this task. In light of the Mayapuri incident, India should contemplate on an electronic database system that will maintain a 24/7 tracking process. An electronic national-level source monitoring system could help avoid a replay of the Mayapuri incident. The report of the Public Accounts Committee 2013-2014 on the activities of the AERB submitted to Parliament in December 2013 chronicled several of these problems. When much of the diagnostic facilities are not registered with the AERB, the efficiency of the regulatory system becomes questionable. For instance, to a specific query on the registration and thereafter inspection of these facilities, the Chairman of AERB admitted to the Public Accounts Committee of the AERB failure. He said, "central agency with 300 engineers and scientists cannot control 50 odd thousand x-ray machines."[67] He went on to add, "the real safety in xray machines is design. Operation does not make that much difference and the design-related control is already quite well established through the regulation of manufacturing facilities in the country."

On the regulation of x-ray units, the DAE Secretary too responded to the Public Accounts Committee by saying that "what we have been doing with the resources available is to focus on the design of these facilities. It is because the number of manufacturers is limited and we can access them more easily. Major hazards from x-ray, whatever hazard is there, can be controlled from the design, that is, if it is well-shielded and it has all the interlocks and so on. That we control by doing type approval or design approval. Only type approval machines are allowed to come into the market."[68] While this adds a layer of protection, a more decentralised system with institutional mechanisms such as the Directorate of Radiation Safety can strengthen regulatory practices around inventory management. One cannot say with any certainty that the DAE has by now instituted the required level of vigilance in inventory management.

A related issue is the absence of a separate, centralised database with updated information on incidents, intelligence or reports of radiological incidents, including sabotage, material thefts, intentional misuse or illegal trading. Criminal investigations and enquiries are part of the current approach, but the review mechanism with regard to India's regulatory practices could be strengthened further. In addition, the differences in threat perception continues to be an issue. Given the number of different stakeholders involved in the handling of radioactive materials, India's nuclear and radiological security managers could invest in better training and awareness missions on a fairly frequent basis involving Radiological Security Officers (RSOs) and others who handle these materials.

CONCLUSION

While India presents an overall success story regarding its nuclear and radiological security policies and practices, this is an issue on which it cannot afford to make any mistakes. India has maintained a strong emphasis on nuclear and radiological safety and security practices even before these had become global issues after the 9/11 terrorist attacks in the United States. India's troubled neighbourhood, especially the threat of terrorism from Pakistan, has been a constant reminder of the security challenges that India should be prepared for. Decades of cross-border terrorism and internal security challenges of varying degrees have been important considerations in maintaining vigilance on these issues. India has continued to use a mix of technology and policy prescriptions to drive its security around nuclear and radiological materials.

Even as India has maintained a stringent approach, global rankings such as that of the NTI Nuclear Security Index have given India a poor assessment.[69] While this author has differing opinions on such quantitative assessments, nevertheless, India could make efforts to streamline and synchronise the process in line with global policies and practices.[70] This will be relatively easier for India since New Delhi follows almost all of the global measures even if they do not use the same nomenclature.

One area where India could make possible progress is its engagement with the global nuclear community, especially since it has a strong case in this regard. Proactive engagement and publicising India's successes can go a long way in alleviating some of the concerns about nuclear and radiological security policies. This is possibly one area that India has lagged and may be strengthened to register its voice in the global nuclear security community. India's reluctance to engage has done more harm because the general assumption is that New Delhi does not have effective measures in place; this is far from true.

Lastly, even as India maintains fairly strong security measures, it could undertake better review and regulatory practices given the varied nature and number of different stakeholders who handle radiological materials. Global practices, for instance, with regard to finding less risky alternatives to some of the high-risk sources could be explored by the atomic energy managers as an effective step at reducing the security vulnerabilities. India's shift from Cobalt-60 to Cesium-137 is a case in point. While India has made a strong case for Cesium-137, it could be useful for India to explore other replacements that might not present the same dangers as Cesium-137. Given India's overall efforts to integrate with the global non-proliferation architecture, such steps could be given additional weightage as the country's atomic energy managers engage in these efforts. ORF

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69. The NTI's Nuclear Security Index provoked some responses in the Indian context. See, R Rajaraman, "India and the Nuclear Security Index," *Global Asia*, Vol.11 No.1, March 2016, https://www.globalasia.org/v11no1/focus/india-and-the-nuclear-security-index_r-rajaraman; Kaveri Ashok and Rajeswari Pillai Rajagopalan, "Nuclear Security: India and the NTI Ranking," *ORF Issue Brief # 76*, September 2014, https://www.orfonline.org/wp-content/uploads/2014/09/IssueBrief_76.pdf; Ramesh Thakur, The 2016 Nuclear Security Index: An Introduction," *Global Asia*, Vol.11 No.1, March 2016, https://www.globalasia.org/v11no1/focus/the-2016-nuclear-security-index-an-introduction_ramesh-thakur

70. Quantitative assessments are never the best means to assess a country's nuclear security policies and practices. By assigning numbers against a country, for instance, if it has a particular policy measure or not, does not give the full picture. It is more important to monitor how a policy is being implemented, which gives a more accurate picture.

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20, Rouse Avenue Institutional Area, New Delhi - 110 002, INDIA
Ph. : +91-11-35332000 Fax : +91-11-35332005
E-mail: contactus@orfonline.org
Website: www.orfonline.org