Charting Nuclear Security Progress in South Asia*

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The nuclear security summits have come and gone, but the challenge of nuclear terrorism is still with us. As long as weapons-usable fissile material (highly enriched uranium, or HEU, and separated plutonium) is used in the civil sector, there is a risk that the material could fall into the wrong hands. For decades, governments have grappled with the problem of providing enough assurances that the production, use, and stockpiling of these materials in civilian economies do not increase the risks of nuclear terrorism or proliferation.

The nuclear security summits held from 2010 to 2016 helped promote support for the minimization and, where possible, elimination of HEU in civil uses. Once sent all over the world as fuel for research reactors, this material is now recognized as posing significant dangers.

There has been less progress on mitigating the risks of separated plutonium, on the other hand. Civilian plutonium has eluded restrictions for many years. One of the challenges to practitioners of nuclear security looking ahead will be to come up with viable solutions to ensure that production, use, and stockpiles of separated plutonium do not heighten the risks of nuclear terrorism.

In South Asia, there are substantial stockpiles of separated plutonium and enriched uranium that are growing rapidly. Only a fraction of the material is internationally monitored because neither country has joined the Nuclear Nonproliferation Treaty (NPT) and therefore has no comprehensive International Atomic Energy Agency (IAEA) safeguards.[1] Rising bilateral tensions and challenges from nonstate actors contribute to the risk matrix.

Luckily, experts in South Asia recognize that steps are needed to mitigate the risks. India and Pakistan have taken some steps in the last decade to improve nuclear security. For example, India chose to adhere to several export control regimes in exchange for an exemption from Nuclear Suppliers Group guidelines engineered by the United States in 2008. As a result of the U.S.-India deal, India also placed additional nuclear facilities under IAEA safeguards. Both countries participated in the four nuclear security summits and built centers of excellence to train their personnel in nuclear security. India also joined 37 other countries in June 2016 to support the Joint Statement on Strengthening Nuclear Security Implementation (INFCIRC/869).

Looking ahead, however, there are many ways in which India and Pakistan could improve their nuclear security and positively shape external perceptions of the region. This Policy Perspectives proposes that both states submit reports about their fissile material under an existing mechanism, the Guidelines for the Management of Plutonium (INFCIRC/549). The guidelines were established

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[1] See, for example, Sameer Lalwani and Travis Wheeler, "Southern Asia's Escalating Strategic Competition," in *War on the Rocks* blog, August 7, 2017; Michael Krepon, "No Peace and No War in South Asia?," *Arms Control Wonk* blog, January 29, 2017.

almost two decades ago among a small group of states to provide greater information about and predictability regarding stocks of plutonium, both separated and in spent fuel. Reporting on civilian plutonium stockpiles is a modest step in the overall context of risk reduction but an important one in the broader context.

Fissile Material Challenges: The Security Context

The only difference between atoms of uranium and plutonium in military programs and those in civilian programs is that the civilian ones are monitored. As soon as the peaceful benefits of nuclear energy began to spread half a century ago, countries realized that a system of monitoring would be necessary to ensure that fissile material was not diverted to nuclear weapons, either by states or by nonstate actors. The system began as bilateral assurances and inspections and graduated to an international inspectorate when the IAEA was created. Under the NPT signed in 1968, the monitoring extended to the production and use of fissile material, equipment, and facilities; trade in related materials and equipment began to be monitored by nuclear suppliers first under the London Club, the Zangger Committee, and ultimately, the Nuclear Suppliers Group.

In the past decade, concerns about nuclear terrorism have raised the question about whether monitoring is enough. As a result of four international nuclear security summits held between 2010 and 2016, countries agreed to minimize and, where possible, eliminate the use of HEU in the civilian sector. At the beginning of the summit process, there were more than 1500 tons of HEU in 55 countries. By 2016, more than 90 reactors fueled with HEU worldwide were shut down or converted to low-enriched uranium fuel. Thirty-three countries that had HEU no longer have any inventories of the material.

Focusing on highly enriched uranium made sense for many reasons. Its clandestine production is easier to hide than reprocessing; countries or terrorists only need to develop or gain access to the front end of a nuclear fuel cycle for HEU as opposed to the full fuel cycle to make or acquire plutonium; and crude bombs are easier to make with HEU than plutonium. Aside from naval fuel and research reactors, the uses of HEU are relatively limited, facilitating plans to minimize and eventually eliminate HEU production for civilian uses.

But this is still only one material of concern when it comes to nuclear terrorism. The summits largely left plutonium—the other route to the bomb—alone. Of the roughly 500 tons of plutonium separated from spent fuel worldwide, about half is under military control. Under the summit process, only two countries consolidated, shipped, and secured plutonium. For example, Japan agreed to return 500 kg of HEU and separated plutonium to the United States in 2014 and Italy returned 20kg of HEU and plutonium.

The Nature of the Plutonium Risk

Plutonium, by most accounts, poses a lower risk of diversion by a state or nonstate actor than HEU for several reasons. The first important distinction is whether the plutonium still resides in spent fuel or whether it has been separated. A second important distinction is whether it is reactor-grade or weapons-grade.

The IAEA considers plutonium in spent nuclear reactor fuel to be self-protecting as long as it emits a radiation dose of about 1 sievert/hour, which would be lethal to about 50 percent of all adults given exposure of three to four hours.[2] Spent fuel from

[2] Self-protecting means the radiation dose is so high that no additional protection is needed to secure it.

light water reactors remains self-protecting for about 100 years; spent fuel from heavy water reactors[3] remains self-protecting for only a few years. Obviously, the risks from plutonium rise exponentially once it is reprocessed, or separated from fission products. One irradiated fuel core from a large light water reactor (LWR) typically contains 12 kg of Pu, enough for two to three weapons.[4]

Even then, critics debate the risks of diversion for spent fuel because the bulk of spent fuel contains reactor-grade plutonium.[5] These critics suggest that countries interested in a nuclear weapon would not seek to use reactor-grade plutonium from civilian reactors but rather make fresh weapons-grade plutonium clandestinely.[6] Others doubt the ability of terrorists to separate plutonium from spent fuel or even to fashion separated plutonium into a workable nuclear device.

Finding solutions is difficult enough when the risks themselves are debated, but other factors add to the complexity. The scope is potentially enormous: plutonium is produced in both research and power reactors, whereas fresh HEU fuel is used mostly in research reactors, and even then, in only about a third of those research reactors.[7] In contrast, there are nearly 400,000 metric tons of commercial reactor spent nuclear fuel around the globe, none of which has been put in a final repository. About 250 tons of separated plutonium exist in the civil sector.

In addition, broader commercial interests are associated with plutonium because of its production and recycling for fuel in power reactors. These commercial interests may grow if nuclear energy expands in the future. Today, 31 countries (plus Taiwan) operate commercial nuclear power reactors.

Finally, reducing the risks of plutonium could require uncomfortable choices that states are not yet prepared to make. Disposing of plutonium in spent fuel would require entombing it in a geologic repository (which will be required in any case, but which countries find convenient to put off to the distant future) or shipping it overseas (costly and unattractive so far for countries to receive it) for reprocessing or disposal. Disposing of separated plutonium requires special measures to render it difficult to use for weapons (mixing with waste and disposing of it). It also requires a country willing to accept the waste. For these many reasons, programs to rollback the widespread use of HEU began 40 years ago, but there are still no programs to rein in plutonium.

Luckily, few countries have found reprocessing or plutonium fuel to be financially attractive. Uranium has been much more cost-effective and likely shall continue to be so for the foreseeable future. Supplier controls on reprocessing equipment initiated within the Nuclear Suppliers Group have also undoubtedly helped. Still, a final obstacle to widespread agreement on curbing plutonium risks is a basic disagreement on whether plutonium is a liability or

[3] There are 16 reactors in India that use natural uranium as fuel and heavy water as a moderator, based on the Canadian CANDU design.

[4] A light water reactor using low-enriched fuel with a burnup of 50 Gigawatt days/ ton of heavy metal contains about 12 kg of plutonium. The IAEA standard for the amount of plutonium needed for a crude nuclear weapon (a so-called significant quantity) is 8 kg, but experts judge the actual number is closer to 4 kg.

[5] Plutonium is a daughter product of uranium. So-called reactor-grade plutonium has been irradiated for several years and contains more of the isotope Pu-240, which acts as a poison for chain reactions. Weapons-grade plutonium is recovered after a relatively short irradiation period (only two to three months) reactor and contains less Pu-240. The U.S. Department of Energy classified such material according to the amount of Pu-240 in the material: super weapons grade (<3% Pu-240); weapons grade (<7% Pu-240); fuel grade (7–19% Pu-240); reactor grade (>19% Pu-240).

[6] While there is no doubt that weapons-grade plutonium is more desirable for a nuclear weapon, reactor-grade plutonium can be used in nuclear weapons, as proven by American weapons scientists in actual tests.

[7] Of the 60,000 irradiated spent fuel assemblies from research reactors in storage today worldwide, about a third contain HEU fuel; one-third LEU; and one-third natural uranium.

an asset. Advocates of the closed nuclear fuel cycle—wherein fuel is recycled at least once but possibly more often to use the plutonium produced through irradiation—insist that spent nuclear fuel is a much undervalued resource. This perspective is often further buttressed by advocacy of future fuel cycles (like fast breeder reactors) that may require plutonium as “starter fuel.” Opponents of closing the fuel cycle believe plutonium is a costly liability.

Existing Norms

Despite these significant obstacles, nine states—China, the United States, the United Kingdom, France, Russia, Germany, Belgium, Japan, and Switzerland—established a mechanism 20 years ago for reporting on plutonium. The Guidelines for the Management of Plutonium were published subsequently by the IAEA as an information circular (INFCIRC/549). Five nuclear weapon states and four others with separated plutonium provide information on an annual basis about their civil plutonium stocks. According to INFCIRC/549, governments agree to manage plutonium “in ways which are consistent with its national decisions on the nuclear fuel cycle and which will ensure the peaceful use or the safe and permanent disposal of plutonium.” Proliferation risks are taken into account, but the following also evidently have equal weight: “protecting the environment, workers and the public, the resource value of the material, the costs and benefits involved and budgetary requirements; and the importance of balancing supply and demand, including demand for reasonable working stocks for nuclear operations.” The Guidelines for the Management of Plutonium, which have not been altered since 1997 nor expanded to include other states, constitute an implicit recognition of the value of sharing information about separated plutonium. The nine countries, with a few exceptions, have issued annual declarations since.

The guidelines cover stored separated plutonium in unirradiated mixed/oxide (MOX) fuel elements, in other unirradiated fabricated forms and in the course of manufacturing or fabricating those items as well as plutonium declared excess to military nuclear programs. The guidelines do not apply to the management of plutonium in spent fuel or to the management of HEU, but they do recognize the sensitivity of the materials and the need to manage them with the same responsibility as separated plutonium. All, except for China, include estimated amounts of plutonium contained in spent civil reactor fuel in their declarations while only France, Germany, and the United Kingdom have made available statements on estimated amounts of HEU. Russia reported figures for weapons-origin plutonium in MOX fuel only once (in 2002), while the United States has reported figures for plutonium declared in excess to defense needs.

The guidelines assert that civil plutonium should be handled in accordance with nonproliferation treaties, international conventions on safety, physical protection, safeguards, and international transfers. They also encourage statements explaining national strategies for nuclear power and the nuclear fuel cycle, along with policies adopted for the management of plutonium.

At about the same time as the adoption of INFCIRC/549, countries established the Joint Convention on the Safety of Spent Fuel Management and Safety of Radioactive Waste Management. The Joint Convention, to which 69 countries now adhere, covers spent nuclear fuel more generally, but the national reports produced under the convention are quite detailed in terms of policies, practices, and inventories. Notably, the Joint Convention covers spent nuclear fuel and radioactive waste from the military and defense spheres “if and when such materials transfer permanently to and are managed within exclusively civilian programs.” In addition, Article 3 of the Joint Convention specifies that spent fuel at reprocessing plants is not in the scope of the convention unless a party declares reprocessing to be part of its spent fuel management plan.

The Plutonium Guidelines and the Joint Convention are two voluntary reporting mechanisms that feature information exchange as a mechanism for improving confidence and predictability about states' actions regarding spent nuclear fuel and separated plutonium. In the case of the Joint Convention, there are specific recommendations for the kind and amount of detail in reporting, as well as a well-regulated review process. That level of specificity does not exist for the plutonium guidelines, but is indicative of the kind of progress possible when states agree on the desirability of the goal. For spent nuclear fuel and radioactive waste, there is little disagreement that it should be handled safely.

Other kinds of best practices can be adopted by industry or governments unilaterally. Within industry, AREVA has adopted the equivalent of a "just-in-time" inventory policy, seeking to avoid significant stockpiles of separated plutonium. And Japan, as a matter of policy, declared as early as 1991 that it would seek to have no surplus plutonium. Japan, the only non-nuclear weapon state that has a domestic reprocessing capability, took special steps to allay international concerns about its separated plutonium stockpile. Specifically, the Japan Atomic Energy Commission (JAEC) declared that Japan would not separate plutonium for which it did not already identify a specific use.[8] However, the JAEC relies on estimates from Japanese utilities about the consumption of plutonium. The JAEC publishes information on Japan's plutonium on a regular basis and Japan adheres to INFCIRC/549. Today, however, the disarray that continues to plague Japan's nuclear industry as a result of the 2011 accident at Fukushima, new regulations and delays in completing and opening the Rokkasho reprocessing plant, and decisions to close the Monju fast breeder reactor raise questions about the credibility of Japan's plutonium consumption plan. With approximately 9.8 tons of separated plutonium at home and over 37 tons of separated plutonium at reprocessing plants in the United Kingdom and France, Japan's no-surplus plutonium policy looks hollow indeed.

South Asia Context

South Asia is one of the few regions of the world where both military and civilian plutonium stocks are growing. India and Pakistan continue to separate plutonium and enrich uranium for their nuclear weapon arsenals. They both have substantial stockpiles of fissile material, only a fraction of which is internationally monitored. Like most other possessors of nuclear weapons, the level of separation between their military and civilian nuclear activities is a sovereign issue rather than being subject to international norms. Both countries have ambitious plans for expanding nuclear power generation, which means the problem of separated plutonium is only likely to grow in the future.

India has about 400 kg of separated civilian plutonium stockpile under IAEA safeguards. An additional 5.1 ± 3.0 metric tons of reactor-grade plutonium has been separated from unsafeguarded heavy-water reactors and has been purposefully left outside of international safeguards as "strategic" material. India's weapons-grade plutonium stockpile for military use is estimated between 0.59 ± .18 metric tons.[9] Pakistan has no declared separated civilian plutonium, but reportedly has 190 kg of separated military plutonium.[10] Recent estimates put

[8] Japan Atomic Energy Commission, "Japan's Nuclear Fuel Cycle," http://www.aec.go.jp/jicst/NC/about/ugoki /geppou/V36/N08/199103V36N08.html, Accessed October 30, 2017.

[9] International Panel on Fissile Materials, "India," http://fissilematerials.org/countries/india.html, Accessed October 30, 2017.

[10] International Panel on Fissile Materials, "Pakistan," http://fissilematerials.org/countries/pakistan.html, Accessed October 30, 2017.

Pakistan's irradiated plutonium in spent nuclear fuel at 2.17 metric tons.[11] These figures could rise as a reprocessing plant near Chashma starts operations (if it has not already), giving Pakistan the capacity to reprocess the fuel from its four plutonium production reactors. An expansion of civilian nuclear energy, as Pakistan intends, could change the situation dramatically. Whether or not Pakistan joins the Nuclear Suppliers Group, China clearly will continue to supply Pakistan with civilian nuclear power reactors. Pakistan will complete a larger reprocessing plant soon, and in December 2016, Pakistan inaugurated its fourth nuclear power reactor (Chashma III), with more to come.[12] Pakistan’s early engagement through INFCIRC/549 could help dampen security concerns in India and bolster Pakistan’s nonproliferation credentials in the international community. As such, Pakistan’s implementation of plutonium stockpile guidelines would demonstrate that Pakistan is acting in good faith, mitigating its international perception as a “pariah state,” and enable it to secure its diplomatic, economic, and security interests.

Both countries have a shared interest in enhancing their international status as responsible nuclear states when it comes to fissile material management. Both participated in the Nuclear Security Summits. Pakistan has poured considerable effort and expense into its Nuclear Security Support Center since 2012, providing education and training in physical protection, material control and accounting, transport security, and cybersecurity. India’s center is currently under construction. India inaugurated its Global Center for Nuclear Energy Partnership (GCNEP) in 2014, which encompasses five schools. In addition to a School of Nuclear Security Studies, GCNEP also includes a School of Advanced Nuclear Energy System Studies (SANESS), School on Radiological Safety Studies (SRSS), School of Nuclear Material Characterization Studies (SNMCS), and School for Studies on Applications of Radioisotopes and Radiation Technologies (SARRT).

At the last summit, held in Washington, D.C., in 2016, New Delhi announced it would join around 20 other countries in a “countering nuclear smuggling” circle that aims to stop the illicit trafficking of nuclear and other radioactive materials through information exchange as well as aggressive prosecution through effective domestic legislation. It has also joined an informal structure of 53 countries, known as the Nuclear Security Contact Group, to sustain action on nuclear security and outcomes from the summit process during the “post-NSS” years. Pakistan has not joined the Group.

Looking Ahead

There is little political appetite for real restrictions on separated plutonium despite wide agreement that minimizing stockpiles will reduce risks. Meanwhile, the declarations and policy statements of INFCIRC/549 are the sole benchmarks for those monitoring stockpiles in a limited number of countries.

Even though the nuclear security summits are over, the importance of securing nuclear material against potential access by terrorists has not diminished. And while nuclear disarmament may seem far off in

[11] David Albright and Serena Kelleher-Vergantini, “Plutonium & Highly Enriched Uranium, 2015,” Institute for Science and International Security, http://isis-online.org/uploads/isis-reports/documents/2015_HEU_and_Plutonium_Presentation_FINAL.pdf.

[12] “Pakistan’s Chashma reprocessing plant may be completed,” International Panel on Fissile Materials blog, February 23, 2015, http://fissilematerials.org/blog/2015/02/pakistans_chashma_reproce.html; David Albright and Serena Kelleher-Vergantini, “Pakistan’s Chashma Plutonium Separation Plant: Possibly Operational,” Institute for Science and International Security Reports, February 20, 2015, http://isis-online.org/isis-reports/detail/pakistans-chashma-plutonium-separation-plant-possibly-operational/12; “Chashma 3, Pakistan’s Fourth Reactor, Is Connected to the Grid,” *Power*, December 1, 2016, http://www.powermag.com/chashma-3-pakistans-fourth-reactor-connected-grid/.

the future, shorter-term objectives that aid regional stability and nuclear risk reduction will require verification. Greater accountability and predictability regarding fissile material stockpiles could help all states be better prepared eventually for a fissile material treaty and/or other multilateral arms control measures.

It is possible that India and Pakistan could find value in reporting on their stocks under INFCIRC/549. Both countries could gain recognition and prestige by joining advanced nuclear states in sharing information about their fissile material. Such actions could help dampen international concerns related to internal safety and a potential arms race. INFCIRC/549 reports would enhance the important work accomplished thus far by India and Pakistan in nuclear security.

India might see this as an opportunity to advance its reputation in the global nuclear order and deflect criticism about other potential weaknesses of India's nonproliferation credentials. For example, India's separation plan between its military and civilian facilities has not been strengthened significantly since it signed its safeguards agreement with the IAEA. In addition, India's Additional Protocol is by far the weakest of any of them.

Pakistan could also see this as an opportunity to demonstrate responsible nuclear stewardship, particularly given its expressed desire to provide nuclear fuel cycle services under IAEA safeguards.[13]

In the near term, Pakistan could be encouraged to report on civilian HEU stockpiles, as France, Germany, and the United Kingdom have in past INFCIRC/549 reporting. (Pakistan has significantly more HEU than India.) Pakistan could also be encouraged to report its stockpile of weapons plutonium in excess of defense needs, as the United States and Great Britain have done.

There is ample precedent between India and Pakistan for sharing information to reduce nuclear risks. For example, the "Agreement on Reducing the Risk from Accidents Relating to Nuclear Weapons" was signed on February 21, 2007, and reaffirmed for additional five-year terms in 2012 and 2017. The well-known agreement on not attacking nuclear facilities was signed by Indian prime minister Rajiv Gandhi and Pakistani prime minister Benazir Bhutto in December 1988 and ratified by both countries in January 1992. The agreement requires an annual exchange of lists detailing the location of all nuclear-related facilities in each country and each side pledges not to attack listed facilities.[14]

Beyond benefits in the nuclear area, improved nuclear governance could help India and Pakistan reduce the transaction costs of aid, arms sales, investment, and trade and potentially make it easier to secure diplomatic, economic and security interests.

How could this be done? There do not seem to be any restrictions from additional countries adhering

[13] In its 2014 and 2016 national statements given at the Nuclear Security Summits in The Hague and Washington, Pakistan stated it was "in a position to provide nuclear fuel cycle services under IAEA safeguards."

[14] Though lists of nuclear facilities have been exchanged every year, there is some question about the definition of nuclear facilities to be declared. For example, when the lists were first exchanged in 1992, each side reportedly left off one facility. Stimson Center, "Confidence-Building and Nuclear Risk-Reduction Measures in South Asia," June 14, 2012, https://www.stimson.org/content/confidence-building-and-nuclear-risk-reduction-measures-south-asia. See also Toby Dalton, "Modernize the South Asia Nuclear Facility 'Non-Attack' Agreement," Stimson Off-Ramps Initiative, June 28, 2017, https://www.stimson.org/content/modernize-south-asia-nuclear-facility-non-attack-agreement.

to INFCIRC/549 guidelines. The procedure appears to require a letter from a country's mission in Vienna to the IAEA director general announcing its intention to adhere to the INFCIRC/549 guidelines. A declaration of the stocks would need to be included in the letter. Other approaches, of course, are possible. India and/or Pakistan could seek to coordinate actions within the regional subgroups of the Nuclear Security Support Center Network hosted by the IAEA, for example, or with other INFCIRC/549 adherents. This could be done on a bilateral basis or through relevant officials at the IAEA. India might find its hosting of the 2018 WMD Terrorism summit an opportune time to announce its own unilateral steps to promote nuclear security and Pakistan could create other opportunities to do the same.

Adhering to INFCIRC/549 guidelines may be a small step in the overall context of the nuclear arms race between India and Pakistan, but mechanisms to build trust and improve understanding of capabilities between India and Pakistan are a necessary part of the foundation for improving nuclear security in one of the world's most populous regions.

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