Possible Options for International Management of Plutonium Stockpile

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The growing stockpile of plutonium is one of the most important security risks we face today. A total of 518.6 tons of separated plutonium, which is equivalent to 86,440 Nagasaki bombs (6kg/bomb), exist now (as of the end of 2016), and is still increasing primarily due to civilian reprocessing programs. Roughly 60% of it (roughly 290 tons) is civilian plutonium and about 97% of it are owned by only four countries (UK [110], France [65], Russia [57] and Japan [47]), all of which have on-going civilian reprocessing programs. At the 2014 Nuclear Security Summit, the Hague Communique stated that “we encourage States to keep their stockpile of separated plutonium to the minimum level, both as consistent with national requirements.” There are also “excess” military plutonium stockpile, which is roughly 78 tons (US and Russia) which are not yet under international safeguards. Then more than 70% of plutonium stockpile are “non-military purposes” and thus should be kept safety and securely. It is an urgent task for the international community to manage such large stockpile of plutonium and to reduce to minimum level as soon as possible.

This paper addresses possible international management options to deal with such a large stockpile of separated plutonium, especially those of civilian and “excess” military plutonium. There are four possible options: 1) enhanced transparency by strengthening International Plutonium Management Guidelines (INFCIRC/549), 2) International Plutonium Storage (under the custody of IAEA) of “excess” plutonium, 3) International Cooperation on Plutonium Disposition, and 4) Moratorium on commissioning of new reprocessing facilities.
**Introduction**

Plutonium was once considered a valuable energy resource as it can be recycled from spent nuclear fuel into Fast Breeder Reactor (FBR) fuel, making nuclear energy virtually an unlimited energy resource. However, plutonium was first used as a raw material for the nuclear bomb dropped over Nagasaki City on August 9, 1945. Since then, plutonium is defined by the International Atomic Energy Agency (IAEA) as “special nuclear material” which can be directly used to manufacture nuclear bombs. Another special nuclear material that can be used to make nuclear bomb is Highly Enriched Uranium (HEU) that was used in the bomb dropped over Hiroshima on August 6, 1945. HEU and plutonium are called “weapons-usable materials (WUM)”, and now the increasing stockpile of WUM is one of the most important security risks we face today.

The HEU stockpile is declining overall since the end of Cold War as it can be “diluted” to Low Enriched Uranium (LEU) which can be used as nuclear fuel for civilian nuclear power plants. While plutonium can also be mixed with uranium to be used for nuclear fuel (called MOX fuel), its high costs are barriers to using MOX fuel on a large scale. Therefore, disposition of plutonium is more difficult than that of HEU. Meanwhile, civilian reprocessing programs continue in a small number of countries. As a result, the plutonium stockpile, unlike HEU, is increasing steadily. It is a critical moment for international community to consider policy options to deal with increasing plutonium stockpile.

**Global Plutonium Stockpile**

A total of 518.6 tons of separated plutonium, which is equivalent to 86,440 Nagasaki-type bombs (6kg/bomb), exist now (as of the end of 2016) globally, and is still increasing primarily due to civilian reprocessing programs. For HEU, the total global stockpile is now estimated to be 1,342.5 tons, which is equivalent to 20,977 Hiroshima type bombs (64kg/bomb). Compared with the data published in 2015 (as of the end of 2013), the HEU stockpile was slightly reduced (-7.0 tons) from 1,349.5 tons, while plutonium stockpile is increasing steadily (+18.2 tons) from 500.4 tons in 2015. The increase in the plutonium stockpile has come primarily from non-military use. The military stockpile has declined from 160.3 tons to 152.3 tons (-8.0 tons), while the non-military stockpile has increased from 340.1 tons to 366.3 tons (+26.2 tons). Roughly 60% of current stockpile (roughly 290 tons) is civilian plutonium and about 97% of it is owned by only four countries (UK [110],

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France [65], Russia [57] and Japan [47]), all of which have on-going civilian reprocessing programs. Almost all of the increase in the stockpile actually came from an increase in the civilian plutonium stockpile. For military plutonium, its stockpile increase comes from only three countries -- Israel, India and Pakistan -- although its total amount is about 8.2 tons (India [7.0ton] Israel [0.9ton] and Pakistan [0.3ton]).

**Global reprocessing programs**

Civilian reprocessing programs are facing critical moments, whether they will continue to expand or they may gradually phase out. So far, ten countries built civilian reprocessing plants (Belgium, China, France, Germany, India, Italy, Japan, Russia, UK, and the US) and another eleven countries (Armenia, Bulgaria, Czechoslovakia, East Germany, Finland, Hungary, Netherland, Spain, Sweden, Switzerland and Ukraine) shipped their spent fuel to France, UK and Russia for reprocessing. As of now, only six countries have significant reprocessing programs and all others have small amounts of plutonium left from past reprocessing activities. There are three categories of these six countries with continuous civilian reprocessing activities.

First is France and Japan. Both have nuclear energy programs with a closed nuclear fuel cycle; France has two operating reprocessing plants while Japan has closed one small reprocessing plant and is completing the safety licensing process for one large reprocessing plant (Rokkasho). Both countries have research and development programs on fast breeder reactors but no large breeder reactor is under construction, and they both plan to consume plutonium in existing light water reactor (LWRs) as MOX fuel. But both countries are facing uncertainties in the future of reprocessing programs. In France, the newest reprocessing plant (UP-3) is now almost 30 years old (operating since 1989) and its new nuclear energy policy is to decrease its share in total electricity production from current 70% to 50%, resulting in fewer reactors to consume MOX fuel. In Japan, the new Rokkasho reprocessing plant has been delayed 24 times and now its planned operation date is March 2021, but the number of reactors to burn MOX fuel is only four as of July 2018, much smaller than the planned number of 16-18.

The UK example is different. The UK has decided to end its reprocessing program when its current contracts are fulfilled in 2020. The UK has the largest civilian plutonium stockpile due to past reprocessing activities and is now facing a decision on how to dispose of more than 100 tons of plutonium. In 2011, UK government released its basic program to dispose

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plutonium, which included MOX fuel as its first choice, but also investigation of a disposal option. The UK government has been willing to take title of foreign owned plutonium stored in the UK as long as it does not have extra financial burden on UK tax payers. The decision on plutonium disposition has been delayed.3

The third category includes Russia, India and China. Russia and India have been operating relatively small civilian reprocessing programs and both have on-going breeder R&D programs. Russia and India have already significant plutonium stockpiles, while India’s facilities can be dual-purpose. China has also a policy of pursuing the closed fuel cycle and yet has only a small reprocessing plant with an experimental fast reactor. China is now considering building a large reprocessing facility and has signed a memorandum of commercial agreement with French AREVA to build an 800 ton/year reprocessing plant in China4 despite strong local public opposition at a potential site.5

Additionally, the Republic of Korea (ROK) is also interested in reprocessing although such a step would require consent by the United States, which has thus far been denied under the US-ROK bilateral nuclear cooperation agreement6. ROK insists that they want similar right which Japan is granted under the 1988 US-Japan bilateral agreement, i.e. “programmatic prior consent” which allows Japan to reprocess without US approval for 30 years since 1988. Now that the US-Japan bilateral agreement has been extended into the future indefinitely, Japan can still continue reprocessing without US approval. Both parties have the right to terminate the agreement with six months’ advance notice, leading some observers to suggest that the agreement may become more unstable.7

In short, all reprocessing programs are facing critical decision making points regarding whether to continue to expand or to stop and shrink their reprocessing programs. If they

continue to reprocess, the global civilian plutonium stockpile will likely to grow, which poses greater security risks to the world.

**Civilian Plutonium Management: Need for a new norm**

Given the background above, it may be wise to consider a new international norm on management of civilian (and possibly “excess” military) plutonium. At the 2014 Nuclear Security Summit, the Hague Communique stated that “we encourage States to keep their stockpile of separated plutonium to the minimum level, both as consistent with national requirements.”\(^8\) This is a positive step in right direction, but it is not clear whether this will eventually reduce plutonium stockpiles as it still allows a minimum level of stockpile for national requirements. There is no clear definition of “minimum” level.

In order to mitigate the risks of increasing stockpile of separated plutonium, John Carlson presented specific proposals for establishing a new norm for civilian plutonium stockpile management\(^9\). They are:

- Committing to keep separation (reprocessing) in balance with consumption. Ensuring the rate of reprocessing output is consistent with the capacity to consume such output
- Considering mechanism and incentives to encourage states to declare surplus or “excess plutonium” (ex. If there is no plan to use plutonium within a defined period)
- Such “excess plutonium” could be placed under IAEA control or could be made available for consumption elsewhere
- Consider development of regional or multinational plutonium storage schemes
- Take appropriate actions for management and disposition of excess civilian and military plutonium

Carlson also recommended to establish a Forum for addressing separated plutonium issues and to develop a Code of Conduct for separated plutonium, too.

Based on these recommendations, I propose four specific options as near and mid-term steps to reduce and eventually eliminate risks of plutonium stockpile.

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Option 1: Enhancement of International Plutonium Management Guidelines (INFCIRC/549)

The first option is to enhance the International Plutonium Management Guidelines (INFCIRC/549) which are voluntary guidelines established in 1997 by nine countries (Belgium, China, France, Germany, Japan, the Russian Federation, Switzerland, the UK, and the US). The guideline is only applicable to civilian plutonium which is under the IAEA safeguards. The guidelines outline general principles of plutonium management strategy including to: 1) ensure the peaceful use of the safe and permanent disposal of plutonium, 2) avoid contributing to the risks of nuclear proliferation, 3) protect the environment, workers and public, 4) take into account the resource value, costs and benefits involved and budgetary requirements, and most importantly, 5) balance supply and demand, including demand for reasonable working stocks for nuclear operations.

In order to reduce the plutonium stockpile, the principle of 5) is crucially important, although the definition of “working stocks” is not clear. To enhance the plutonium guidelines, the following can be included. Some of them can just follow Japan’s “Status Report of Plutonium Management in Japan” which has higher transparency than the Guideline. The national statement by the government should:

- Specify “Demand” (consumption/disposition) for the next 3 years
- Restrain “Supply” (reprocessing) up to the amount specified by the demand, including current stockpile
- Define “excess” stockpile (beyond the quantity defined above)
- Numbers should be in kg rather than tons (following Japan’s example)
- Specify sites where separated plutonium is stored (following Japan’s example)
- Include HEU stockpile, if any
- Review of national nuclear fuel cycle policy (cost, rationale, environmental impacts, safety etc.)

It is reported that a similar policy may be introduced by the Japan Atomic Energy Commission (JAEC) soon. The report says that JAEC will “cap” the stockpile and restrains

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10 International Plutonium Management Guideline, INFCIRC/549.  
https://www.iaea.org/sites/default/files/infcirc549.pdf

http://www.aec.go.jp/jiest/NC/about/kettei/170801_e.pdf  
Japan’s status report show the quantities in kg rather than ton, and specifies specific sites of plutonium storage.
the pace of reprocessing in order to match specific plutonium demand specified in a certain time period.\textsuperscript{12}

**Option 2: International Plutonium Storage (IPS) revisited**

Linked to the Option 1, an international plutonium storage concept can and should be considered as a reasonable option to enhance the transparency of a growing plutonium stockpile. Article XII of the IAEA Statute provides that the IAEA has the right to “require deposit with Agency of any excess of any fissionable materials recovered or produced as a by-product over what is needed for...in order to prevent stockpiling of these materials...at the request of the member of members concerned special fissionable materials so deposited with the Agency shall be returned promptly to the member or members concerned.”\textsuperscript{13} This is the basis of IPS concept, which was once considered in 1980s and again in 1990s.

More recently, Fred McGoldrick proposed that Japan should consider an agreement with the IAEA for a custodial regime for its excess plutonium. He suggested that the following broad characteristics should be included, although the details of such an agreement must be negotiated between IAEA and Japan.\textsuperscript{14}

- Japan would determine the amount of plutonium to be placed under IAEA custody, but there would be a presumption that material not being used or not designated for use within a specified period of time would be excess and be deposited with the agency.
- Japan and the IAEA would agree on the location of storage sites, presumably co-located with Japanese reprocessing and MOX fuel fabrication facilities.
- The agency would retain custody of the excess plutonium until the Japanese government requests its release for a specified peaceful use, for example, in a MOX fuel fabrication plant, a nuclear power plant, a vitrification facility, or a direct disposal site.
- Japan could not remove the materials from IAEA custody until it submitted to the IAEA a request for release of a specified quantity accompanied by an end-use certificate. The certificate of use would contain the following assurances and information:

\begin{itemize}
  \item assurance that no excess plutonium was diverted to another use,
  \item assurance that no excess plutonium was diverted to any use prohibited under the NPT,
  \item assurance that no excess plutonium was diverted to any use prohibited by Japan’s nuclear law,
  \item assurance that no excess plutonium was diverted to any use prohibited by Japan’s nuclear law for national security reasons.
\end{itemize}


\textsuperscript{13} The Statute of International Atomic Energy Agency (IAEA). Article XII. https://www.iaea.org/about/statute#a1-12

- an assurance that the material would be used for exclusively peaceful, nonexplosive purposes;
- an assurance that the plutonium would be subject to continuing IAEA safeguards in accordance with the provisions of the IAEA-Japanese safeguards agreement or, if the material were to be exported to another country, that it would be subject to the safeguards agreement between the IAEA and that country;
- an assurance that the material would remain under effective physical protection in accordance with accepted international standards;

This could be a good example to be followed by other countries who own plutonium stocks and can be adopted as a part of International Plutonium Management Guidelines if all members agreed. But voluntary efforts by any plutonium stockholder would enhance transparency and international confidence.

**Option 3: International Cooperation on Plutonium Disposition**

The above two options are good measures to improve transparency and international confidence, and may help “capping” the plutonium stockpile but may not contribute to significant “reduction” of plutonium stockpile. In order to reduce plutonium stocks effectively, international cooperation could and should be considered more seriously.

One option is “swapping” the ownership of plutonium to consume plutonium more quickly and effectively. International commercial transactions have already helped to reduce plutonium stocks. For example, in March 2013, the Tokyo Electric Power reported that it “swapped” its 434 kg of plutonium kept in France for the same amount in Britain owned by a German utility, following a proposal by a British and French nuclear authority. The swap was a “win-win” deal for all parties in Japan/Germany/UK/France. The German utility wanted to manufacture MOX fuel kept in UK but UK did not have MOX fabrication plant. So the Germans swapped the plutonium owned by TEPCO in France so that the German utility was able to quickly convert its plutonium in the French MOX fabrication plant. MOX fuel fabricated in France can be shipped to Germany LWR to consume, which cuts the need for plutonium shipments from UK to Germany which would have been necessary if the swap did not take place.

A second option is the one proposed by the UK government which is willing to take “title” of foreign-owned plutonium stored in the UK, subject to commercial terms that are

acceptable to the UK Government. The UK government would treat such plutonium as UK-owned plutonium. There are already several cases under this proposal. The UK Nuclear Decommissioning Authority (NDA) has agreed:

- Taking ownership of about 800 kg of material owned by Swedish utility
- Taking ownership of about 140 kg of material owned by a German research organization

These transactions, which were agreed by the EURATOM Supply Agency, would not result in any new plutonium brought into the UK and would not increase the overall amount of plutonium in the UK, but could eliminate plutonium shipments from the UK to original owner countries. So these transactions have also entailed win-win cooperation among participating parties.

Japan has the largest foreign-owned stockpile in the UK and naturally it would be great if UK and Japan agreed to eliminate the need for plutonium shipments from the UK to Japan. Japan also can reduce its plutonium stockpile quickly, although the global plutonium stockpile would not change until the UK eventually disposes of such plutonium. Japan previously agreed to give up ownership of 331kg of weapon-grade plutonium stored as fuel in Fast Critical Assembly (FCA) in 2014 and plutonium will be eventually disposed of instead of being used as nuclear fuel. Such international transactions between plutonium owners or countries who are willing to take foreign owned plutonium for their disposition programs. It would be ideal the nuclear weapon states will take titles of plutonium owned by non-nuclear weapon states.

A third option is called “virtual reprocessing.” Under this option, customer utilities ship spent nuclear fuel for a “reprocessing contract” but the plutonium can be drawn from the existing stockpile rather than from new reprocessing. Although this may reduce the plutonium stockpile, it may encourage utility companies to ship spent fuel and plutonium back to the original customer. It then may be useful to consider this option with combination of IPS concept so that plutonium can be stored until the customer proves its specific demand for plutonium.

Finally, international cooperation on R&D of plutonium disposition can be encouraged. For example, the US and UK are conducting an R&D program on plutonium disposition

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See also “Plutonium from Japan to be disposed of underground in New Mexico”, The Japan Times, April 2, 2016.
https://www.japantimes.co.jp/news/2016/04/02/national/politics-diplomacy/plutonium-japan-disposed-underground-new-mexico/#.W0GhUtL7Rdg
technologies as an alternative to the MOX program. Given the failure to proceed with MOX fuel in the US, the Department of Energy (DOE) is now conducting a direct disposal of excess plutonium from dismantlement of nuclear weapons. DOE’s plutonium disposition working group is now focused on the simplest possible direct-disposal strategy -- down-blending the plutonium and packaging it in drums to be deposited in an already operating underground waste-plutonium depository, called the Waste Isolation Pilot Plant.

There are other options, such as can-in-canister disposal and packaging for disposal in a geological disposal, or deep borehole disposal. The UK government is also searching for alternatives to a MOX program. The UK National Nuclear Laboratory is setting up a plutonium “immobilization” process at the Sellafield reprocessing site where contaminated plutonium oxide is to be immobilized. The process creates a solid composite using “hot isostatic pressing”. The UK may have to use an “immobilization” strategy for about 14-21 tons of its 140 tons of plutonium, which may be too impure to be fabricated into MOX.

International R&D on such plutonium disposition programs can be quite useful to share technology and possibly share the financial burden. Japan, France or Russia may join such international R&D efforts to explore alternatives to MOX programs.

**Option 4: Moratorium and phasing out reprocessing for all purposes**

Lastly, but not least, in order to eliminate plutonium stocks, reprocessing activities must be phased out eventually. The Pugwash Council made a statement in 2015 on this issues, saying; “Reprocessing to separate plutonium should end in all countries, including all nuclear weapon countries, whether for energy or weapon purposes...In view of the international security consequences of fuel cycle decisions, countries need to mutually agree to restrictions on their national sovereignty in making nuclear fuel cycle decisions.”

In Japan, about 20 experts and policy makers made a series of recommendations on plutonium management after the conference on this subject in 2017, in particular to the government of Japan, saying; “Commit to a reprocessing moratorium in order to prevent the further accumulation of separated plutonium in the Northeast Asian region. Japan’s government should lead the way by indefinitely postponing the startup of the Rokkasho reprocessing plant since Japan has already accumulated 48 tons of separated plutonium.

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18 Frank von Hippel and Gordon McKerron, ibid.

Other governments in the region should follow this example by committing to suspend all activities and future plans to separate plutonium through reprocessing.” 20

Based on these recommendations, I would propose that four countries (UK, France, Japan and Russia) could agree not to commit to further reprocessing while transferring ownership of plutonium among four countries if necessary. There is enough plutonium for energy use for decades to come and no further separation of plutonium is needed for a foreseeable future. In order to realize such a plan, it is essential that spent fuel storage capacity should be secured. Besides, it may be a good time to establish a new norm for reprocessing -- commitment to no new reprocessing facilities and placing existing ones under multinational control. This may take more time, but we have enough time to discuss these proposals until existing plutonium stocks will be substantially reduced.

**Conclusion**

Increasing plutonium stocks is a global security issue and needs to be addressed under an international framework. Japan is unique as a non-nuclear weapon state with a large plutonium stockpile. But the issue of plutonium management and disposition is common to all plutonium owner countries. They need to collaborate further to solve this complex issues. It is time to establish a new international norm on plutonium management and disposition.

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