The Disposition of Weapons-grade Plutonium as MOX Fuel in Canadian Reactors

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William J.L. Buyers
Steacie Institute for Molecular Sciences
National Research Council, Chalk River Laboratories

John Harvey
Retired Senior Health Physicist
McMaster University

and

Alan J. Slavin
Physics Department, Trent University

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Summary

In June 1999 the Canadian Association of Physicists commissioned this report. The goal was to gauge the risk, based on technical matters discussed in the literature, which might arise from the transportation, testing and use of MOX fuel in Canada. We have collected relevant data in order to clarify the issue. About 150 tonnes of weapons-grade plutonium will be removed from Russian and American missiles under current arms-reduction treaties. As long as the plutonium stays in metallic form, the possibility remains for it to be rapidly redeployed in weapons, either by these two countries or through clandestine diversion to other groups. Given the deterioration of Russian infrastructure, the latter presents a serious danger to world stability.

Two methods of "disposition" of the plutonium (rendering it largely inaccessible for weapons use) have been proposed. One is immobilization, and the other is using it as a mixed-oxide (MOX) fuel in nuclear power plants to generate electricity. Both are technically proven processes, the latter being established industrially. For immobilization, the plutonium would first be incorporated into a ceramic, which has been shown to have excellent chemical, thermal and structural stability. The current preferred method of immobilization would be to encapsulate cans of this ceramic inside a massive container of vitrified high-level nuclear waste to provide both a radioactive and weight deterrent to diversion. The Russian stance is firmly against immobilization because of the lost energy potential of the plutonium.

In the MOX option, the plutonium would be combined with uranium to form a mixed oxide fuel and then used to produce electricity in a nuclear reactor. In the spent fuel that is produced, the plutonium content is reduced to roughly 1% by weight, and is embedded in a highly radioactive matrix that would deter its diversion by criminal elements. As part of the electrical generation by civilian reactors, fresh and spent MOX fuel has been transported safely for many years in Western Europe.

Both methods satisfy what is known as the "spent-fuel standard" for inaccessibility. Under the spent fuel standard it is necessary to make the plutonium as inaccessible as the much larger quantity of plutonium residing in unprocessed civilian spent fuel. For both options, the final product would ultimately be disposed of in the same way as spent nuclear fuel, presumably by deep burial. About a third of the accumulated plutonium is unsuitable for MOX fuel and its disposition must be by immobilization.

Canada has offered to help if necessary in the disposition by extracting energy from it [1] in the form of MOX fuel in CANDU power reactors. CANDU reactors are particularly efficient for this purpose. Moreover, Canada, with a long history as a non-nuclear-weapons state, is one of the few countries to which both the Russians and the Americans might be prepared to send their weapons plutonium in the form of reactor fuel. Recently, however, the U.S. has decided to dispose of its excess plutonium in U.S. reactors, and it is not clear how this will affect Russia's position.

Contracts exist between Atomic Energy of Canada (AECL) in Canada and the Department of Energy (DOE) in the USA, and between AECL and Bochvar in Russia, in which AECL undertakes to test small quantities of MOX fuel manufactured in the USA and in Russia. This is the first time that Russia has agreed to send abroad material converted from weapons into fuel. The tests will be carried out in AECL's NRU research reactor at Chalk River, which can provide an environment similar to that of a

1. Extracting energy from fuel by fission differs from the burning of fossil fuels. The burning of any fossil fuel, which involves combustion (oxidation), releases to the environment carbon dioxide and other greenhouse gases as well as environmental pollutants. A reactor converts its fuel to energy by means of neutrons and retains the spent radioactive fuel within a metal sheath thus releasing no greenhouse gases.

CANDU power reactor. From the performance of the U.S. and Russian test samples under identical conditions (an experiment known as the Parallex Project) AECL will be able to determine the optimum parameters for the possible use of MOX as fuel in CANDU power reactors. No agreement exists for the production of electricity from MOX fuel in Canadian generating stations.

The costs and time to dispose of the plutonium would be roughly comparable under either immobilization or the use of MOX as reactor fuel. Large plants in the source countries would cost a few billion dollars. The time to construct these and to process the materials will exceed two decades.

The risks are low and comparable for each disposition option. The chemical and radiological toxicity of plutonium has been frequently overstated in the popular press and existing safety procedures for transportation appear to be entirely adequate. The biggest concern might be thought to be terrorist hijacking of the plutonium after it has been converted to ceramic or oxide in the first processing plant. For the immobilization option the plutonium would be in ceramic form en route to a plant, possibly at a different site, where it would be surrounded by vitrified, radioactive spent fuel. For the MOX option it would be in the form of oxide, en route to the fuel fabrication facility that supplies the nuclear power plant, where it would be converted to spent fuel. However, such shipments would be heavily guarded and the technical difficulty in extracting the plutonium would make it much easier for terrorists to obtain their goals in other ways; as evidence, cross-border MOX shipments have been underway in Europe for years without mishap. The transportation risk would not be significantly less for immobilization domestically within Russia, since the risk is already small and since international shipments have proven to be as safe as domestic shipments. Using the MOX fuel only in Russia, where only a few reactors are suitable, would extend the disposition process for an unreasonable time.

As for Canadian participation in the MOX option, no modifications to present power reactors are anticipated, although extra security and storage would have to be put in place. One advantage of MOX fuel is that the volume of radioactive waste requiring disposal to provide a given amount of electric power could be reduced compared with present CANDU reactors fueled with natural uranium fuel. This is because the fraction of all the plutonium and uranium in the fuel that is converted to power could be increased. This is not necessarily the economic optimum, and the fuel can be optimized for a faster rate of disposition. MOX fuel would be more expensive to fabricate than natural uranium fuel, a cost that would be born by the source countries not by Canada.

There are no clear advantages at present to either the immobilization or the MOX route for disposition of surplus weapons-grade plutonium. Both are technically feasible and there is extensive evidence of safety of the MOX route from the European experience. The likelihood of getting the plutonium out of the source countries appears to be greater if there is an agreement to accept the MOX, by Canada or by others, at least as part of a two-track approach. The immobilization option is largely a domestic activity and would not provide the incentive for export of the plutonium to other countries to increase the disposition rate. The choice of disposition route is primarily a political and social one. Both routes carry almost a negligible risk relative to the “do-nothing” option. In this option the plutonium would be left in its present form, which is readily suited to the manufacture of weapons, making it an attractive target for diversion.

Our principal conclusions are as follows.

1. The testing and use of MOX fuel in Canadian reactors presents no technical, safety, health, security or transportation risks. The safety of MOX fuel is demonstrated by its long-term use in civilian reactors in Europe. Only fabricated fresh oxide fuel, in which the plutonium is highly diluted, would be sent to Canada.

2. The residual plutonium in the spent fuel is a small part of a highly radioactive matrix. The spent fuel is difficult to handle, costly to reprocess and its radioactivity provides a strong deterrent against diversion by criminals. The spent MOX fuel is similar to spent natural-uranium fuel from Canadian reactors.

3. The CANDU reactor is well suited to the use of MOX fuel. The reactor could generate less spent fuel requiring disposal than natural-uranium fuel, since more energy could be extracted from a given weight of MOX fuel.

4. The immobilization option for the disposition of plutonium could occur on a comparable but possibly slightly shorter time-scale than the option of using MOX in reactors. It would take a long time to construct the different plants needed for both options. There is a possibility, albeit remote, of chemically extracting the fissile component from the ceramic form of the immobilized Pu if the radioactive shield surrounding the plutonium ceramic is first removed.

5. Large commitments will be needed by the partners to build the plants needed in the source countries. Immobilization requires plants for ceramic synthesis, and for vitrifying spent fuel to act as a radioactive shield. The use of MOX fuel in reactors requires a dedicated fuel fabrication line, which would not be built in Canada, and facilities for dedicated fuel storage at the utilities, which currently do not exist. The country or partnership that pays for the plants will determine if Canadian utilities will be asked to use the fuel. The final decision will lie with the Canadian government and the utilities, not the paying partners.

6. Even if Canada, the United States and Russia were to agree to dispose of some of the surplus plutonium in Canadian reactors, the process would not be able to begin for the better part of a decade. It would extend for a further twenty years or so, before disposition of the current surplus of weapons-derived plutonium is completed. Having the plants and process in place would facilitate disposition of additional weapons plutonium that could become surplus following future disarmament agreements.

7. The two options for disposition, immobilization and MOX to fuel reactors, are technically feasible and safe. The choice between the two is primarily a political and economic decision. Only the latter option would involve Canada, whose government has offered to help.

8. The greatest risk of criminal diversion of the metallic plutonium occurs when the surplus plutonium remains as it is at present, in a metallic form suitable for weapons. This risk occurs if the world chooses the "do-nothing" option, or, through indecision, delays the beginning of the disposition process. We believe this is the highest risk option and one that should be strongly rejected.