

THE FUTURE: INNOVATIVE TECHNOLOGIES FOR RADIOACTIVE WASTE PROCESSING AND DISPOSAL

Safe, proliferation resistant and economically efficient nuclear fuel cycles that minimize waste generation and environmental impacts are key to sustainable nuclear energy. Innovative approaches and technologies could significantly reduce the radiotoxicity, or the hazard posed by radioactive substances to humans, as well as the waste generated. Decreasing the waste volume, the heat load and the duration that the waste needs to be isolated from the biosphere will greatly simplify waste disposal concepts.

Recycling and reusing minimizes the waste volume. This concept, together with the optimal use of natural resources, forms the basis of the 'closed fuel cycle', where the reusable parts of the spent fuel are recycled and not considered as waste.

Spent nuclear fuel could be processed to separate and/or convert the long lived radioactive elements into shorter lived, less hazardous forms. Known as 'partitioning and transmutation', or P&T, this process results in a smaller volume of waste with considerably less radiotoxicity.

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Partitioning and Transmutation

Spent nuclear fuel discharged from a nuclear reactor is highly radiotoxic due to three groups of elements it contains: major actinides, which are uranium and plutonium; minor actinides including neptunium, americium and curium; and fission products. Due to the long lived actinides and heat generating fission products, the spent fuel is considered high level waste and must be contained and isolated from

the biosphere in a deep geological facility for hundreds of thousands of years.

Long lived actinide elements are the highest contributor to long term radiotoxicity. Fission products, although they generate heat, are short lived and contribute to radiotoxicity only during the first 100 years.

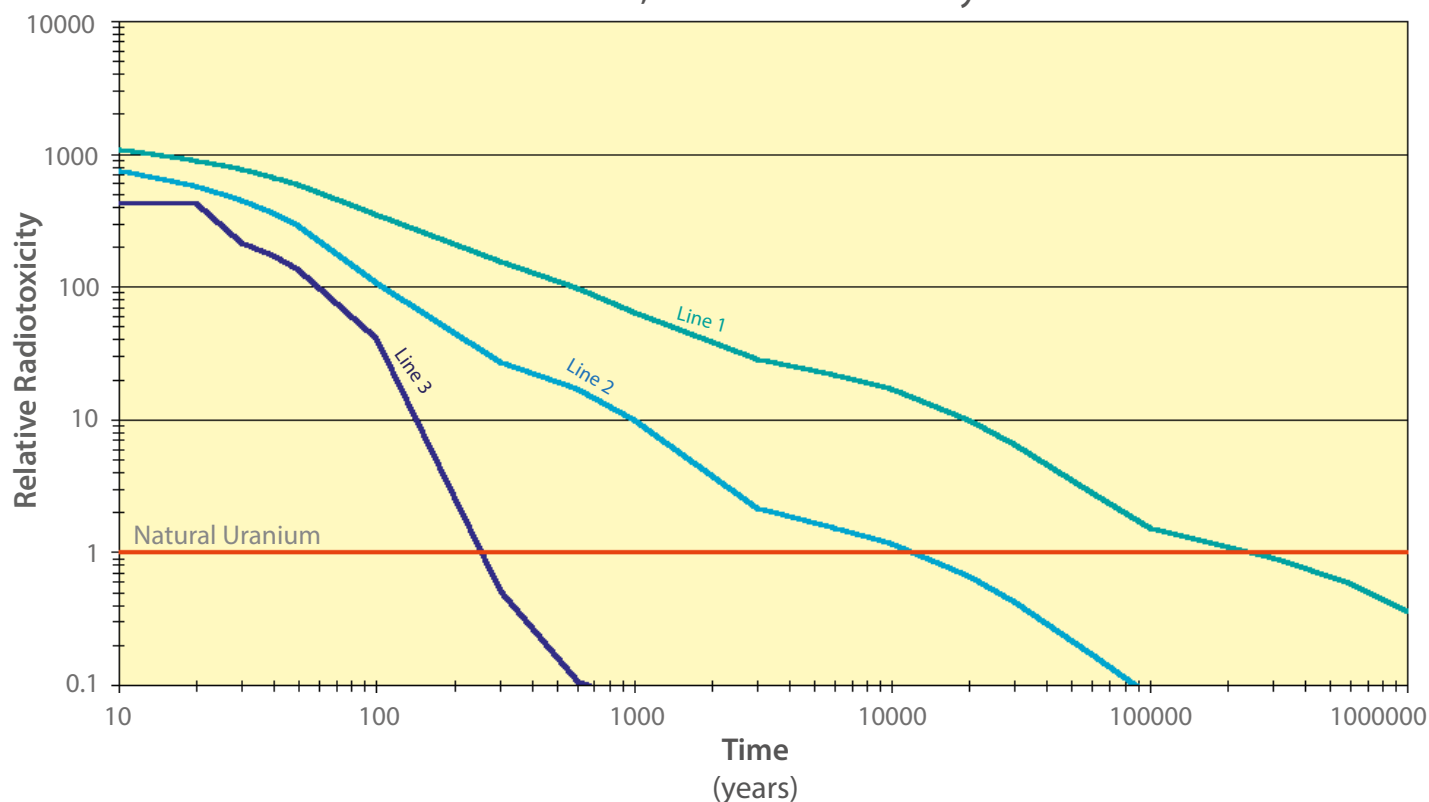
In P&T, the plutonium and minor actinides are extracted from spent fuel by chemical separation. This is followed by transmutation where the transuranic elements (neptunium, plutonium, americium and curium) are destroyed by fission in a specially designed nuclear reactor. Utilizing a P&T approach can improve the efficiency of radioactive waste management because of the reduction in the volume of waste which results in more cost effective management schemes.

Today, fast neutron systems are the most studied transmutation technology to destroy the long lived actinide elements. Transmutation is possible in other reactors such as pressurized water reactors but fission is less efficient in them.

A distinct advantage is that when fast reactors are used in combination with new fuel cycle technologies, it is possible to recycle major and minor actinides without the need for high purification schemes, as in the case with existing reprocessing plants in France, India, Japan and the Russian Federation. This system is highly proliferation resistant, as there is no need to separate the plutonium from the other actinides. The combination of fast reactors (or utilization of the fast spectrum) with advanced pyroprocessing of the spent fuel is currently under development and being demonstrated in India, the Russian Federation and the European Union.

Recycling the actinides in fast reactors provides a significant reduction in waste volume, heat load and time required for radiotoxicity levels to decrease to that of the natural uranium ore used for the light water reactor fuel. Current research and development (R&D) demonstrates that the concept of 'natural equivalent disposal'

Nuclear Waste Radiotoxicity over time, for different fuel cycles



Line 1: Spent Fuel Direct Disposal
Waste includes Pu + MA + FP

Line 2: Plutonium Recycling
Waste includes MA + FP

Line 3: Pu + MA Recycling
Waste includes FP

FP = Fission products MA = Minor actinides Pu = Plutonium

Fast neutron technology can reduce the radiotoxicity of the waste to the level of natural uranium in about 400 years instead of hundreds of thousands of years.

is viable. In other words, it is technically possible to generate radioactive waste that would decay to such natural levels over the course of 300 to 400 years, instead of the 250 000 years needed if you would directly dispose of spent fuel. Or simply, the development of a modern nuclear power plant would drastically reduce the waste burden on future generations.

Nevertheless, this is a complex task and it is necessary to enhance reprocessing and recycling technologies: to improve the efficiency of actinide separations, to reduce the volume of secondary wastes, and to avoid proliferation problems. IAEA studies in the area of fast reactor development and innovative fuel cycles demonstrate that these issues could be solved and the nuclear industry could advance to a more sustainable new fuel cycle.

There are also serious R&D efforts focusing on using thorium instead of uranium, and on the increased use of reactor systems with higher fuel burnup, such as high temperature gas-cooled and molten salt reactors. The goal of these efforts is to reduce the amounts of transuranic elements while producing the same amount of electricity.

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