

Options for the Treatment of Spent Fuel from Nuclear Power Plants - Partitioning and Transmutation

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Nuclear power's world-wide share to electrical energy production is 16%. The release of two billion tons CO₂ from fossil-fueled power plants is thus avoided annually. 10,500 tons of spent nuclear fuels are discharged annually. When compared to other hazardous wastes, this amount is rather small. However, nuclear energy's acceptance relies on both a safe operation of nuclear power plants and a safe final disposal of spent nuclear fuels.

To seclude them from the biosphere, spent nuclear fuels are to be disposed of in a deep underground final repository, for their radiotoxicity to decay. Spent nuclear fuel long-term radiotoxicity is governed mainly by the actinides (plutonium, neptunium, americium, and curium), which make for approx. 1% of the spent fuel's mass.

The idea to separate these long-lived radionuclides ("partitioning") is pursued internationally. Instead of storing them in a final repository, they could be fissioned to short-lived (and eventually non-radioactive) nuclides in suitable nuclear reactors ("transmutation"). The impact of the Partitioning & Transmutation strategy is as follows: without separation, spent fuel radiotoxicity decays to the level of natural uranium within 170,000 years. After separation of the actinides, this time span is reduced to some 300 years. Thus, the time scale to be covered by the performance assessment for a final repository could be reduced from geological to historic.

Partitioning. As of yet, there is no process which would allow to selectively separate in one step only the actinides from the more than 30 elements contained in spent nuclear fuel. Hence, the development of a multi-step separation process is pursued in Europe. In this context, the separation of americium and curium from the chemically similar lanthanides is a key issue. Highly effective separating agents are currently being developed, which need to be highly resistant to radiation. More compact and efficient process schemes are under development.

Transmutation. Transmutation can be performed using reactors with a fast neutron spectrum (such as gas-cooled or liquid metal-cooled reactors, or so-called accelerator-driven systems). The fast neutron spectrum makes for a favourable ratio of fission to neutron capture, i.e., the destruction of actinides vs. their production. However, quantitative transmutation is not feasible in a single pass. Thus the irradiated transmutation targets must be reprocessed several times, with the actinides fabricated into new targets, to eventually reach "quantitative" destruction of the actinides.

The transmutation of actinides from spent nuclear fuel could be an alternative to their final disposal. A prerequisite is their selective and almost quantitative separation. Partitioning & Transmutation appears to be a viable option, reducing the radiotoxicity time scale from the order of 10⁵ years to the order of 10² years.