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DISPOSAL OF NUCLEAR WASTES BY TRANSMUTATION*

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One method for treating radioactive wastes to reduce their long-term radiotoxicity is to transmute the long-lived species to short-lived or stable products. A prerequisite for transmutation is that these species first be partitioned from the wastes and then recovered in a form suitable for bombardment with neutrons. Since the difficulties of effecting the necessary separations and recoveries are as great, or greater, than those associated with reprocessing the fuels to recover uranium and plutonium, any realistic evaluation of this approach must consider both partitioning and transmutation in a joint context. We recently completed a very comprehensive assessment of the transmutation option with a view to establishing its technical feasibility and identifying any incentives that might exist for its implementation.[1,2] Feasibility was assessed by formulating credible partitioning flowsheets based on experimental evidence, and by devising transmutation strategies that could be verified with relatively sophisticated calculations. The incentives were defined by cost-risk-benefit analysis. Only conventional chemical processes having a reasonably high assurance of success and availability were considered and LWRs were assumed to be the primary transmutation devices. Although the actinides were taken as the primary candidates for partitioning and transmutation (P-T), the long-lived fission products ^{99}Tc and ^{129}I were also considered.

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The approach used in this assessment was to perform an incremental analysis on a reference fuel cycle and a P-T fuel cycle that were based on a self-generated plutonium recycle PWR. They were identical except that the reference cycle provided for the recovery and recycle of only the economic values of uranium and plutonium, whereas the P-T cycle used additional partitioning processes to recover actinides from the fuel fabrication plant and fuel reprocessing plant wastes and recycle them back to the reactor.[3,4] Chemical flowsheets based on solvent extraction, HNO_3-HF and Ce(IV)-HNO_3 leaching, and cation exchange chromatography were generated that have the potential to reduce unrecovered actinides in the fuel fabrication and reprocessing plant wastes to <0.25%.[5,6] Waste treatment facilities utilizing these flowsheets were designed conceptually, and their costs were estimated.[7,8] A P-T fuel shipment cask was also conceptually designed, and its cost was estimated.[7,9] Finally the short-term (contemporary) risks from fuel cycle operations and the long-term (future) risks from a repository (assumed to be located at the presently proposed WIPP site) were estimated for cases with and without P-T.[10,11,12,13]

A summary of the costs, risks, and benefits of P-T is presented in Table I. The incremental cost of P-T ($9.2 million/GW(e)-yr) is equivalent to 1.28 mills/KWhr(e), an increase of 5% to the cost of nuclear-generated electricity. The increase in short-term risk to the general public was found to be 2850 man-rem/GW(e)-yr, 99.4% of which was attributable to nonradiological risks arising principally from the steam plant off-gas and from physical damage during transportation. As a basis of comparison, natural background causes about 5000 man-rem/GW(e)-yr to the

same population. The reduction in long-term risk, estimated over a 1 million-year period, which represents the benefit derivable from P-T, was found to be only 300 man-rem/GW(e)-yr. The latter is less than 0.001% of natural background. The cost/benefit ratio based only on the reduction of radiological risk is $32,400/man-rem, which is considerably in excess of the $1000/man-rem criterion that is used to determine whether additional effluent control systems on nuclear power plants are justified. There is actually a negative total benefit if nonradiological risks are included.

We concluded that, while both partitioning of the actinides from wastes and their subsequent transmutation in power reactors were feasible using currently identified and studied technology, implementation of this concept cannot be justified because of the small radiological benefits and substantially increased costs. Although greater than 99% of the long-term risk from the repository is due to ^{99}Tc and ^{129}I and while their partitioning and transmutation is probably feasible, we do not believe this would be cost-effective. If a policy decision should nevertheless be made to implement P-T, we estimate that RD&D funding of about $900 million over a 20-year period would be needed. On the other hand, it should be pointed out that some of the technology identified during this program can be effectively utilized to improve future waste management practices within conventional fuel cycle operations.

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Table I. Summary of the costs, risks, and benefits of P-T per GW(e)-yr

	Reference case	P-T case	Incremental
		Costs	
Fuel cycle costs, 10^6	181.9	191.1	9.2
		Short-Term Risk	
Radiological dose, man-rem	4	20	16
Total risk,[a] man-rem	1700	4550	2850
Natural background, man-rem (for comparison)	5000	5000	0
		Long-Term Benefit	
Radiological dose, man-rem[b]	25,800	25,500	300
Natural background, man-rem[b] (for comparison)	33.5×10^6	33.5×10^6	0

[a]Includes nonradiological risks expressed as equivalent radiological impact using a conversion factor of 5000 man-rem/health effect.

[b]Expected dose integrated over 1 million years.