High Costs, Questionable Benefits of Reprocessing

The department of atomic energy's claim that "economic considerations dictated the need for spent fuel reprocessing in India" is questionable since reprocessing is far more expensive as a waste management strategy than the common alternative of direct disposal in geological repositories. This is unlikely to change even under the assumption that the plutonium extracted has some economic value when used to fuel breeder reactors to generate electricity.

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In a recent newspaper interview, Anil Kakodkar, chairman of the Atomic Energy Commission, stated that "We have been adopting the principle or philosophy of closed nuclear fuel cycle, which means that the spent fuel, after its use in the reactor, must be reprocessed, and uranium and plutonium recycled" [Subramanian 2006]. Based on this logic, Kakodkar has argued that allowing for reprocessing is a necessary precondition for the Indo-US nuclear deal and that the conditions imposed by the US Congress on reprocessing and enrichment would not be acceptable. This presupposes that reprocessing of spent nuclear fuel is desirable in the first place.

In this note, we examine some of the arguments offered by Kakodkar and others in favour of reprocessing and find them wanting. We also look at the economic rationale of reprocessing – an aspect completely neglected by the department of atomic energy (DAE) and other policy-makers. We show that reprocessing is far more expensive as a waste management strategy than the most common alternative, direct disposal in geological repositories. This is unlikely to change even if one assumes that the plutonium extracted has some economic value when used to fuel breeder reactors to generate electricity.

Background

The DAE's interest in reprocessing goes back to its inception in 1954 and the adoption of a nuclear power programme comprising of three stages [Bhabha and Prasad 1958]. The first stage was to involve the use of uranium in heavy water reactors, the second stage was to involve breeder reactors (which produce more fissile material than they consume) fuelled by plutonium, and the third stage was to involve breeder reactors fuelled by uranium-233 derived from thorium. Both plutonium and uranium-233 are obtained by reprocessing spent fuel. Reprocessing, therefore, is a necessary step for the breeders and the three-stage programme.

More than 50 years after the announcement of this programme, the DAE is yet to build even one industrial scale breeder reactor that would be part of the second stage. The first, the prototype fast breeder reactor (PFBR), is just being constructed in Kalpakkam. Despite this gaping mismatch between its widely proclaimed interest in breeders and actual construction, the DAE projects that by 2052 there will be 2,75,000 MW of installed nuclear capacity, of which over 2,60,000 MW will be from breeders.

The alternative to reprocessing, direct disposal, involves long-term storage of the spent fuel followed by its encapsulation and permanent storage in a geological repository. In this alternative the plutonium is left in the spent fuel itself where the fission products provide a radioactive barrier to its removal.

Table: Cost Components and Other Assumptions
(in 2004 Rs, unless otherwise mentioned)

Construction cost (mixed year Rs crore)	558.2
Overnight construction cost (Rs crore)	1285.5
Annual O&M expenses (PREFRE) (Rs crore)	9.4
Construction of waste immobilisation plant (Rs crore)	164.25
Annual O&M expenses of WIP (Rs crore)	6.2
Capital cost of S3F (Rs crore)	135.46
Transportation of vitrified waste (Rs lakh/tSF)	1.35
Geological disposal of vitrified waste (Rs lakh/tSF)	2
Decommissioning of KARP (Rs crore)	412
Efficiency of reprocessing plant (per cent)	80
Amount of plutonium per tonne of spent fuel (kg/tSF)	3.75
Interim storage of spent fuel before direct disposal (Rs lakh/tSF)	3.7
Transportation of spent fuel (Rs lakh/tSF)	3
Geological disposal of spent fuel (Rs lakh/tSF)	4.5

Reprocessing also produces three waste streams classified on the basis of their radioactive content as high level, intermediate level and low level wastes. We emphasise that reprocessing does not neutralise any of the radioactivity present in the spent fuel. The volumes of radioactive waste produced actually increase, and some of this is released to the environment. Radioactive discharges from the Sellafield reprocessing plant in England have been detected as far away as Ireland and Norway [NRPA 2002]. Further, all of the radioactive wastes not immediately released to the environment still have to be disposed of at geological repositories. Thus, reprocessing is by no means environmentally benign and results in greater ecological impact than direct disposal.

Though the DAE did not advertise the fact when it first started reprocessing spent fuel in the mid-1960s, plutonium can also be used to make nuclear weapons. The DAE's own priorities for plutonium can be gauged by when its first breeder reactor became operational and when it conducted its first nuclear weapons test: 1985 and 1974 respectively.

Although many reasons are provided by the DAE to refuse safeguards on its reprocessing facilities and the breeder programme, DAE officials hesitate to openly admit to the possibility that plutonium generated at the PFBR and other breeders might be used to make weapons. Every year the PFBR could produce on the order of 135 kg of weapons grade plutonium, sufficient for about 25-30 weapons, a four to fivefold increase over the current weapon plutonium production capacity [Mian et al 2006]. The DAE does not want to let go of this option because its institutional clout is hinged upon its ability to make large quantities of fissile material for weapons.

Reprocessing Costs

The general conclusion in western studies is that reprocessing is uneconomical [NEA 1994; National Research Council 1996; Deutch et al 2003; Bunn et al 2005]. Nevertheless, and without any rigorous study to support its assertions, the DAE maintains that "*economic considerations dictated the need for spent fuel reprocessing in India*" [Prasad 1996:13] (our emphasis). This assertion can be questioned in two ways. First, as a mere waste management option is it cheaper to reprocess spent fuel or directly dispose it? Second, if the economic consideration is the use of plutonium in breeder reactors, then would the electricity produced therein be cheaper than other alternatives when the costs involved in obtaining plutonium through reprocessing are internalised?

We have undertaken an independent analysis to estimate the reprocessing costs using publicly available data [Ramana and Suchitra, forthcoming]. Since the Nuclear Power Corporation (NPC), which operates the heavy water reactors producing spent fuel, does not pay anything for reprocessing [Thakur and Chaurasia 2005], the cost of plutonium derived would equal what it costs to extract it from the spent fuel, i e, the cost of reprocessing. This cost should determine the rate at which the DAE either "sells" or "leases" plutonium to BHAVINI, the organisation set up to operate breeder reactors.

In India, currently there are three major reprocessing plants – at Trombay, Tarapur (PREFRE) and Kalpakkam (KARP). The DAE envisions augmenting its reprocessing capacity several fold to cater to the needs of additional breeder reactors. The reference point in our examination of the economics of reprocessing is the costs associated with the most recently commissioned reprocessing plant, KARP, which is also to serve as the standard design for future plants [Dey 2003].

The cost of reprocessing is derived from the total lifecycle cost, calculated using the discounted cash flow methodology with a real discount rate of 5 per cent, of the plant, assumed to function at a particular capacity factor. Since there is no information available on the actual capacity at which the plant has been operating, we estimate the costs assuming a capacity factor of 80 per cent.[1] This assumption is optimistic (and favourable to the economics of reprocessing) since the past performance of reprocessing plants in India has been mediocre at best. PREFRE, at Tarapur, operated at an average throughput of less than 25 tHM/y for over a decade, while its nominal design capacity was 100 tHM/y [Hibbs 1995].

The total cost of reprocessing consists of three components. These are the capital cost of constructing the facility, the annual operations and maintenance (O&M) costs, and the waste management expenses from the running of the facility in an environmentally acceptable manner. There is also the cost of decommissioning the facility and disposing the radioactive and other materials after the plant has finished its operating life.

The data sources used for the estimation of these costs are the Performance Budgets and Annual Reports of the DAE, the Expenditure Budgets of the government of India, and reports of the comptroller and auditor general (CAG) and the ministry of statistics and programme implementation. Unfortunately, none of these sources is comprehensive in reporting the expenditure on the reprocessing plant and associated facilities. There are also various inconsistencies between different reports (and sometimes different pages on the same report) that we have tried our best to resolve.

In the case of direct disposal, the main cost components are those associated with the storage of spent fuel prior to its emplacement in a geological repository, transportation, and the actual geological repository. The first is estimated from the projected costs of the Away From Reactor storage facility in Rajasthan [Kulkarni et al 2003; Srinivasan 1995]. Neither data nor any projections are available for geological repository costs and we use Canadian estimates as a proxy. These costs and other assumptions are listed in the table.

Based on these figures, our estimate for the total cost of reprocessing is Rs 25,983 per kg of spent fuel. Assuming that 100 per cent of the plutonium is recovered, the cost of producing each gram of plutonium is Rs 6,745. The cost of reprocessing depends sensitively on the efficiency with which the plant operates. If the capacity factor were 70 per cent, the reprocessing cost goes up to Rs 29,569 per kg of SF. On the other hand, direct disposal costs only Rs 1,120 per kg of spent fuel. Clearly, as a waste management option, reprocessing is several times more expensive than direct disposal.

What could make reprocessing economically viable would be if the plutonium were to be used in nuclear reactors to produce electricity, and that turns out to be cheaper than the corresponding costs of producing electricity using uranium fuel. It has been established that this is not the case with western reactors and associated facilities till uranium prices are much higher than current values [Bunn et al 2005]. Our preliminary calculations using cost estimates of the PFBR indicate the same.

All of this nullifies the DAE's claims that reprocessing is dictated by economic considerations.

Plutonium Mining Argument

In his interview, Kakodkar offers another justification for reprocessing: "spent fuel, if deposited in repositories for long-term disposal, would over a period of time become a virtual plutonium mine once most of the radioactive components decay out. This can thus become a serious security issue over a long term". Since this is a new consideration within the Indian debate, we discuss it at some length.

While spent fuel emplaced in geological repositories could eventually become a source of plutonium, it would be attractive only if acquiring it is easier than alternative means; this is almost never the case [Lyman 1994,1998]. Two possible scenarios may be considered. One is that the nation that has a geological repository also has an active nuclear fuel chain, with operating reactors and other nuclear facilities. Then, there will be a ready supply of spent fuel available at reactors. Further, if as in the case of India, there are reprocessing plants as well, there would also be stockpiles of separated plutonium. Spent fuel in a sealed geologic repository well below the surface, then, would be a relatively unattractive source of plutonium, assuming that repositories were safeguarded at a level consistent with other stages of the fuel cycle.

The second possibility is that nuclear power had been phased out and neither operable reactors nor retrievable spent fuel storage facilities exist. In this case, the only means of acquiring spent fuel other than mining the repository would be the construction and operation of production reactors and associated front-end facilities (e g, uranium mining and fuel fabrication) from scratch. While this would at face value seem more difficult, the catch is that both mining plutonium from geological repositories and the alternative, i e, producing plutonium from scratch, would have to be done in a clandestine fashion without being detected. Monitoring and detection is far easier at a limited number of known repositories while clandestine nuclear production could go on virtually anywhere. Only when the scale of the clandestine production becomes very large, roughly at a rate comparable to the highest rate of production achieved by the superpowers during the cold war, would its detection achieve a level of certainty that is comparable with plutonium mining [Lyman 1994].

To this technical argument, we may add three more. First, there are far more serious security concerns because of plutonium being extracted at reprocessing plants. It is not only more easily accessible since it is above the ground, but it is in theory possible to access it today. This is much more dangerous than the situation foreseen – that at some undefined time in the future, the spent fuel which has been buried deep in the earth would become an attractive source of plutonium. Second, the hypocrisy of the DAE is abundantly evident in this statement – it is currently sitting on plenty of plutonium resulting from reprocessing and making nuclear weapons using the same while pontificating about unspecified people accessing plutonium. Finally, considering the DAE's history of secrecy and lack of transparency, it will be nearly impossible for outsiders to get adequate information on the geological repository, especially details such as location and depth that are needed to proceed with mining spent fuel.[2]

If indeed one is serious about future security concerns, the obvious thing to do is to stop producing any more plutonium, which would mean the shut down of all nuclear reactors. Preaching about the insecurity caused by nuclear weapons while producing more and more of them is hypocritical, to say the least.

Conclusion

For too long now the DAE has been touting the necessity of reprocessing, while neglecting to analyse its economics. Our estimates show that reprocessing spent fuel is much more expensive than directly dispose it. These figures also suggest that breeder reactors will be more uneconomical than the DAE's heavy water reactors, even at much higher uranium prices, calling to question the idea of reliance on breeders for energy security.

The DAE and others have also advanced a number of other specious arguments in favour of reprocessing. An old one is that reprocessing is environmentally-friendly is untenable. When spent fuel is reprocessed, the radioactive elements therein are separated into multiple waste streams and gases; some of these are released to the environment and disperse over wide areas. A new argument within the Indian debate (but has been punctured elsewhere) is that direct disposal of spent fuel would lead to the creation of virtual plutonium mines. The slight risk that spent fuel could be mined from a geological repository and plutonium extracted to make nuclear weapons pales in comparison with the extant risks of having large stockpiles of separated plutonium and continuing to make more and more of it.

Reprocessing, therefore, is costly, and its benefits, questionable. It may be time for the DAE to give up its 50-year old attachment to this bad idea. EPW

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Notes

1 Studies based on reprocessing plants in the west also assume capacity factors in the range of 70 to 80 per cent. In the OECD/NEA study, for example, the reprocessing plant is assumed to operate at a capacity factor of 75 per cent [NEA 1994]. Actual performance figures may be even lower; for example, the British THORP reprocessing plant has been running at 50 per cent of capacity for the last several years [Brown 2003]. Similarly, the Tokai reprocessing plant in Japan operated at less than 45 per cent capacity between 1977 and 2005 [Walker 2006].

2 The DAE's efforts at identifying a site for geological waste disposal are also shrouded in secrecy. In March 1997 the inhabitants of Sanawada village near Pokhran were told that the Minerals Exploration Corporation (MECL) was digging for precious stones [Special Correspondent 2000]. Only by accident was it discovered that it was the BARC that was drilling and that Sanawada was being considered as a potential nuclear waste storage location. Apparently even the chief minister of Rajasthan did not know of these plans. Thanks to a campaign by anti-nuclear activists, the BARC stopped drilling.

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