National reports:

Policy and practice in India

A technical overview of programmes and plans

by N.S. Sunder Rajan

India's nuclear programme has envisaged an entirely self-sustained fuel cycle based on indigenous resources. From the start, efforts were necessary to evaluate the potential hazard of radioactive wastes at different stages of the cycle – from mining and milling and fuel fabrication, through reactor operations and, finally, the reprocessing of spent fuel. Emphasis was placed on understanding the impact of releasing radioactive wastes into the environment and on developing technologies to effectively isolate and contain them. Decades of experience have proved that present practices are safe.

Yet there is a constant endeavour to use new technologies to further restrict radiation releases. More than a decade of basic research and development in different areas of nuclear science and technology preceded the implementation of the Indian nuclear power programme, and considerable study and effort has been directed towards formulating a national policy on radioactive waste management.

Policies and objectives

The question of handling radioactive wastes apparently presents a simple option of either keeping the wastes under control or releasing them from control. But, as is well known, this seemingly simple option is a very difficult one to exercise, as any decision has far-reaching consequences – economic, societal, or other.

In principle, the Indian programme envisages two distinct modes of final disposition of radioactive wastes: extended engineered storage near the surface for low- and intermediate-level wastes (LILW), and deep geological disposal for alpha-bearing and high-level wastes (HLW). While other options – such as underground emplacement at medium depths for intermediate-level wastes – are being studied, the present strategy does not include these modes of disposal.

Much of India's future programme relates to HLW and alpha wastes. One problem area to receive attention concerns the development of improved matrices for incorporation of HLW, particularly in respect of the solidified product's long-term stability in the face of radiation and ageing. Another aspect relates to development of technically and economically viable processes to deal with alpha-bearing radionuclides present in HLW. This work will assume greatest significance in the near future when India's fast reactor programme gets under way.

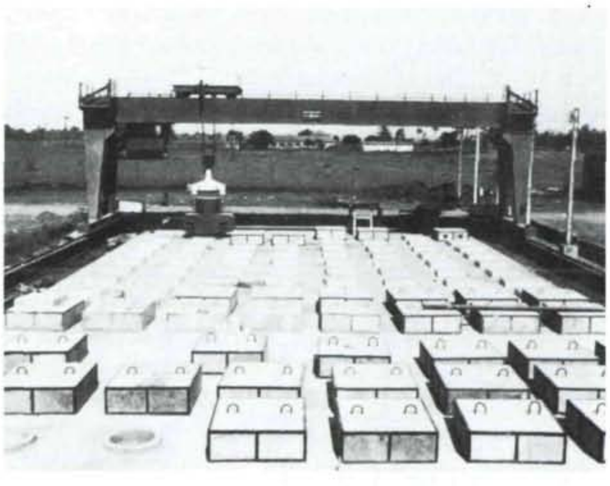
Future efforts also will be directed towards demonstrations, with field experimental data, to establish an adequate degree of confidence in deep geological disposal of vitrified HLW products. With regard to managing LILW, experience has been good and it is expected that schemes for HLW management taking effect soon also will be a step forward in fulfilling Indian objectives.

Management policy

The broad outlines of India's management policy are:

- Any environmental discharge of radioactive liquid or gaseous wastes should be as low as reasonably achievable, economic and social factors being taken into account (the ALARA principle of radiation protection).
- Conditioned primary solid wastes, and waste products resulting from conditioning of liquid wastes generated from operations of reactors and research laboratories, are to be stored in near-surface facilities specially engineered

Steel-lined, concrete "tile holes" at Tarapur's Solid Waste Management Facility. (Credit: Bhaba ARC)



Mr Rajan is Head, Waste Management Division, Bhabha Atomic Research Centre, in Trombay, India.

for the purpose. Conditioned LILW, along with trace quantities of alpha contamination from operation of fuel reprocessing units, also are permitted for storage in such facilities.

- Liquid HLW from reprocessing plants initially is stored for an interim period underground in high-integrity stainless steel tanks before conditioning. These wastes will be vitrified for interim storage in near-surface engineered facilities. This will allow for heat reduction and also facilitate quality assurance of the solidified waste products before their transportation and emplacement in a centralized repository.
- Conditioned HLW and alpha wastes will be disposed of in suitable deep geological formations in a centralized repository.

Mining and milling wastes

Indian ores, which generally contain about 0.1% of uranium oxide (U_3O_8), are mined by conventional methods. Wet mining methods and proper ventilation are used for protection against undue radiation concentration. The "barren liquor" produced from the uranium recovery process is treated with lime and barytes for precipitation of radium and other uranium daughter products. Along with the mill tailings, it is disposed into a tailing pond, which is a natural depression to ensure settling. Pond overflows are monitored to ensure that they contain less than the permissible contamination of radium and other nuclides, such as manganese.

LILW from reactors and reprocessing

In reactor operations, the major concern from the radioactive waste management point of view is the coolant getting contaminated with activation, corrosion, and fission products. Major radionuclides of interest in the coolant are caesium-137, strontium-90, and iodine-131, as fission products, and cobalt, iron, nickel, and chromium, as corrosion and activation products.

Low-level liquid wastes are treated by chemical, ion-exchange, and evaporation methods. Typically, the wastes are pre-treated to adjust them chemically to a proper pH value. After that, chemicals such as phosphates, ferrocynides, and ferric ions are added in a flash mixer. This is followed by liquid/solid separation in precipitator clarifiers and sludge blanket beds. Overall decontamination factors of up to 200 are achieved.

Alternatively, ion-exchange techniques are used for retention of specific radionuclides from the bulk of the wastes. Candidate ion-exchange materials (vermiculite, bentonite) are widely exploited in both non-regenerative columns and *in situ* operations. Synthetic ion-exchangers – in view of their regenerative nature and higher exchange capacities – also are used as a decontamination step.

Streams of intermediate-level liquid waste from fuel reprocessing plants include, for example, concentrates of evaporator handling solutions from solvent cleanup and slurries from decontaminating process waters.

Steam evaporation is used as a one-stage step of concentration for wastes having relatively higher specific activity. Evaporators of the natural circulation type, coupled with specially built remote components, have given very high volume reductions. Decontamination factors on the order of 10^6 have been achieved.

With the continuing trend to restrict environmental discharges of radioactivity to as low as possible, very high volume reduction (with practically zero release) has been attained in the non-boiling solar evaporation facility at Rajasthan Atomic Power Station. This site offers favourable climatological conditions – such as higher ambient temperatures, low humidity and high wind velocities – needed for this type of facility.

Immobilizing wastes

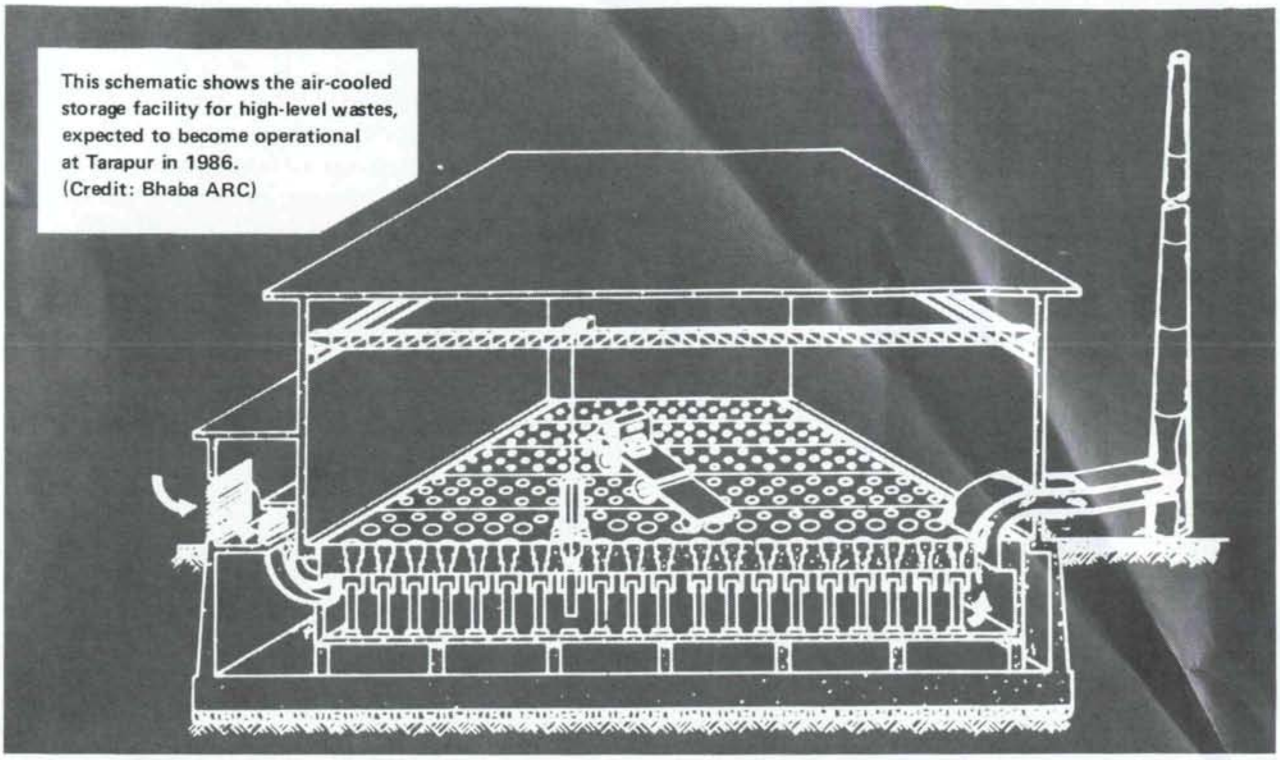
Criteria for conditioning radioactive waste concentrates normally are a function of the waste's radioactivity concentration, its compatibility to the medium in which it is to be incorporated, and the environmental conditions where extended storage/disposal of the conditioned waste is planned. Different matrices, ranging from cement, bitumen, and composite polymers, are being used for immobilization of LILW concentrates.

- *Cement.* In view of low costs and amenability to simple processing techniques, cement and cement composites have met the acceptance criteria as an immobilization matrix for relatively low-level waste concentrates. However, their high porocity has led to the use of certain additives, essentially acting as active pore fillers, to improve durability.
- *Bitumen.* Bitumen has been chosen to incorporate intermediate-level wastes because of its ability to take up aqueous streams with a high percentage of dissolved and suspended solids; its amenability to semi-continuous processing; and ease of remote handling. Considering the characteristics of the locally available bitumen, a maximum of 50% salts is permitted in the product. The product radiolysis, with this range of waste salt and activity, is expected to be negligible during extended storage.

The bituminization plant at Tarapur has a design capacity of 120 litres per hour of intermediate-level wastes. Specially designed thin agitated film evaporators, heated externally by the circulation of hot thermic fluid, have been employed for achieving the dual objective of evaporation and mixing. The resultant product is drained near the evaporator bottom into custom-built steel drums. The process is semi-continuous, producing about 1000 drums of bituminized wastes a year. These product drums are stored underground in engineered steel-lined "tile holes".

- *Polymer matrices.* Polymer matrices (barrier impregnated) are employed to immobilize wastes generating low heat and produced by reprocessing specific fuels. In this system, vermiculite fines are used

This schematic shows the air-cooled storage facility for high-level wastes, expected to become operational at Tarapur in 1986.
(Credit: Bhaba ARC)



to act as barriers for entrapping specific radionuclides. These are further immobilized in unsaturated polyester-styrene resin with catalytic curing at ambient conditions, yielding a monolithic product with good homogeneity and chemical durability. Waste content is up to 50% by volume. About 250 000 litres of such wastes, with a total radioactivity of about a million curies, have been successfully immobilized in this polymer matrix so far.

Highly radioactive waste

The highly radioactive liquid waste stream from fuel reprocessing units currently is stored in high-integrity stainless steel tanks. These are located in underground vaults lined with stainless steel to provide secondary containment as well as biological shielding. A three-stage programme has been drawn up to manage these wastes: (1) immobilization of the waste oxides in solid matrix; (2) engineered storage of solidified wastes for about 25 years; and (3) disposal of the solidified wastes.

Based on technical and economic considerations, it has been planned to provide for interim tank storage of liquid waste for about 3 to 5 years in fuel reprocessing complexes.

For incorporation of HLW oxides, vitreous and other ceramic matrices satisfy acceptability criteria. Advantages of borosilicate glass as a matrix are good leach resistance; high radiation and thermal stability; high mechanical strength; and relative ease of handling and transporting.

Tarapur's WIP

At Tarapur, the first HLW immobilization plant (WIP) is operational, on the basis of already developed melt matrices and processes. WIP uses a borosilicate matrix for incorporation of waste oxides and is based on a semi-continuous "pot glass" process involving calcination followed by melting in the processing vessel. Subsequently, the glass is cast into the storage canister. The equipment layout is designed to facilitate segregation of activities so that plant sections are amenable to easy and, where possible, less mechanized maintenance.

Recently, a project has been taken up to establish a waste immobilization plant at Trombay. Though the basic process employed is similar to the one at Tarapur, the design of equipment, such as the furnace module, has undergone major modifications. The plant is scheduled to become operational by 1990. Another plant, at Kalpakkam, is in the planning stages, with projected operation in 1993. This one is expected to have a built-in unit for handling the projected waste from reprocessing fuels of a fast breeder test reactor.

Interim storage of HLW products

The need for interim engineered storage for conditioned HLW under constant surveillance already has been well recognized. Among various alternative cooling concepts, an air-cooling system (stack-induced, natural draft) has been selected for the Solid Storage Surveillance Facility (SSSF) at Tarapur. This facility, which will become operational in 1986, caters to the storage needs of conditioned waste products from WIP and the Trombay facility over a 25-year period, with provision for continuous surveillance, cooling, and monitoring.

The basic design objectives of SSSF are to assure integrity of the product and container at all times; to provide storage under continuous cooling to remove decay heat; and to ensure retrievability of waste canisters under all conditions. The cooling system uses decay heat and a suitably designed stack to provide the driving force for air movement through the storage vault. It is self-regulating and can compensate for changes in heat load and weather conditions.

Disposal: Short-lived wastes

Underground isolation of radioactive wastes currently appears to be the most viable disposal option. Packaged and conditioned low- and short-lived radioactive wastes are received, transferred, and emplaced in repositories constructed in shallow grounds. In realizing the overall objective of environmental and operational safety, India's experience indicates the practical inevitability of accepting and adopting a total system approach in the design, siting, and operation of these shallow-ground repositories.

In general, the types of disposal modules used in Indian repositories are reinforced cement and concrete trenches, and steel-lined concrete tile holes. Due to varying conditions of geohydrology at the country's different shallow-ground repository sites, it is necessary to study specific features that would influence the repository's development and design at each site.

Over years of experience, the concept of design and development of shallow-ground repositories has undergone steady evaluation. Some major features that differentiate India's current approach from the earlier stages relate to the establishment of an adequate buffer zone between the operational areas of the respository and its external boundary; clear isolation, even at the design stage, of administrative and support facilities from the repository's operating areas; provision of facilities that may be required to segregate the waste and, when required, repack or overpack them; and provision of areas and equipment for decontamination purposes. A number of post-operational monitoring and other institutional controls are enforced for integrity and routine surveillance of these facilities.

Disposal: Long-lived wastes

Transuranic content in HLW and alpha wastes can pose a hazard for extended time periods. Although a variety of engineering concepts have been reviewed and a range of potential options are available, disposal in deep underground geological formations is the one that has received wide attention in several countries. In India, the choice is restricted to igneous rock formations and some selected sedimentary deposits. Some geological formations, particularly in the southern peninsular shield, appear to offer the scope for long-term storage and even for HLW disposal.

The Indian programme currently envisages investigation of candidate repository sites in peninsular gneiss and granite formations that are homogenous and massive. In this connection, an experimental research station has been set up in an unused portion of an underground mine located at Kolar near Bangalore. Studies being carried out are oriented towards investigations of the suitability of these formations for a final repository. *In situ* experiments have been commissioned for examining the thermal, mechanical, hydrological, and chemical behaviour of the host rock under simulated conditions.

Safety analyses

The types and quantities of wastes for repository disposal have to be defined and characterized, taking into account criteria related to acceptable radiation doses, the repository's protective barriers, and engineering factors. Because of time scales involved, performance of these disposal sites, at best, can be predicted. Evaluation and assessment include characterization of the generic host rock media, the surrounding geohydrology, and the waste-rock interaction. Safety analysis for shallow-ground repositories essentially involves predicting the temporal and spatial distribution of radionuclides consequent to an accidental release.

India's estimated waste arisings

Primary solid wastes and low-level waste concentrates constitute the bulk of the estimated waste arisings in India up to the year 2000, at a projected electric power production of 10 000 megawatts. These consist of contaminated process equipment, protective clothing, used particulate filters, concentrated precipitates, and sludges from the low-level liquid waste treatment plants. The volume of the intermediate- and high-level waste generated is small, yet it constitutes the bulk of the radioactivity.

	1985	2000
Installed capacity (megawatts-electric)	1350	10 000
Primary solid wastes* (cubic metres)	1850	107 000
Low-level waste concentrates (cubic metres)	3000	77 100
Intermediate-level wastes (cubic metres)	800	19 900
High-level wastes (cubic metres)	450	8 000

* Up to 10^4 röntgen per hour.