Radwaste

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Radioactive Waste in Nuclear Power Program

For close to half a century, nuclear technology has spread into many areas of modern society, enabling advances in energy production, defence, medicine, agriculture, and industrial applications. But along with the use of nuclear technology comes an added burden – radioactive waste or radwaste.

International Atomic Energy Agency (IAEA) defines radioactive waste as: “Any material that contains or is contaminated by radionuclides at concentrations or radioactivity levels greater than the exempted quantities established by the competent authorities and for which no use is foreseen”.

Radioactive waste has been recognised as potentially hazardous and could be damaging to human health and environment.

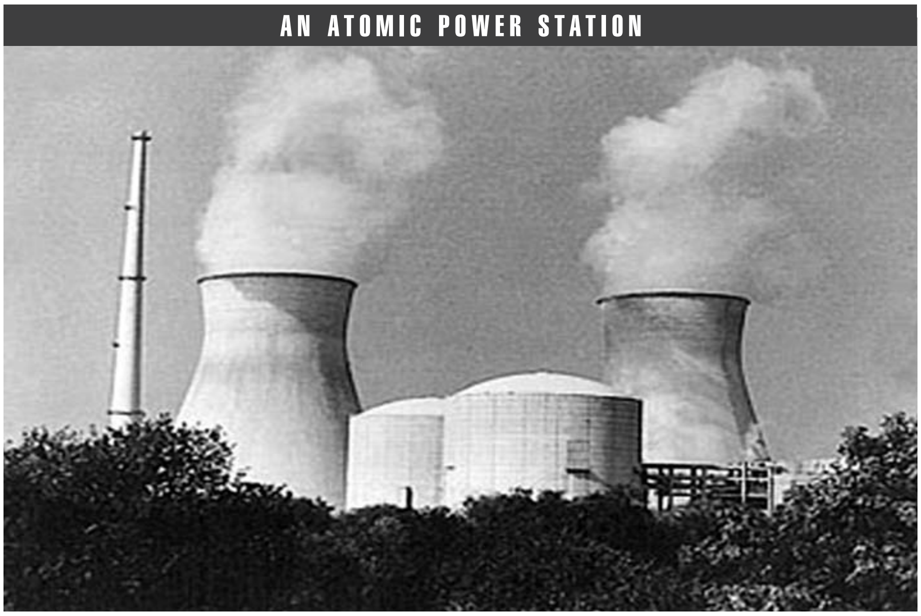
Categories of Radioactive Waste

In order to achieve the required standards of radioactive waste management, the nuclear industry has grouped radioactive wastes into a number of categories. The general considerations for classifying radioactive wastes are:

- how long the waste will remain radioactive;
- the concentration of the radio-active material in the waste;
- whether the waste is generating heat .

The persistence of the radioactivity determines its management or isolation from people and environment. The concentration and the heat generation dictate how the waste should be handled, including how much shielding may be necessary. These considerations also determine suitable disposal methods.

AN ATOMIC POWER STATION



AT A GLANCE

- **Radioactive waste results from use and production of nuclear materials.**
- **The time taken for half the radionuclides to disintegrate is called half-life.**
- **The immediate and long-term threats of radioactivity include possible cancer and genetic damage in humans and animals.**
- **Large amount of exposure leads to radiation sickness and death.**
- **Children and the unborn are especially susceptible to radiation because of their rapid cell division during physical growth.**
- **The maximum permissible dose for occupational exposure is 20 millisievert per year averaged over five years.**

Radioactivity

Some natural elements such as Uranium are unstable and disintegrate or decay, releasing energy in the form of radiation. This physical phenomenon is called **radioactivity**. The radioactive decay is expressed in units called Becquerels. One Becquerel equals one disintegration per second.

The radionuclides decay remains constant regardless of external influences and the time taken for half the radionuclides to disintegrate is called half-life. This differs for each radioelement, ranging from fractions of a second to billions of years. The half-life of Uranium 238, for example, is 4.5 billion years.

The immediate and long-term threats of radioactivity include causing cancer or genetic damage in humans and animals; large amounts lead directly to radiation sickness and death. Children and the unborn are especially susceptible to radiation because of their rapid cell division during physical growth. DNA is most vulnerable to radiation impact while cells divide.

Although we cannot see or feel the presence of radiation, it can be detected and measured in the minutest quantities with simple radiation measuring instruments. The maximum permissible dose for occupational exposure is 20 millisievert per year averaged over five years (i.e. 100 millisievert in 5 years) with a maximum of 50 millisievert in any one-year. For public exposure, 1 millisievert per year averaged over five years is the limit. These dose limits have been established based on a prudent approach by assuming that there is no threshold dose below which there would be no effect. It means that any additional dose will cause a proportional increase in the chance of a health effect.

Basic approaches to radiation protection are consistent all over the world. The ICRP recommends that any exposure above the natural background radiation should be kept 'as low as reasonably achievable' (ALARA), but below the individual dose limits.

Radioactive waste is categorised as:

Very low level waste (VLLW) or Exempt waste (EW) contains radio-active materials at a level which is not considered harmful to people or the surrounding environment. It consists mainly of demolished material (such as concrete, plaster, bricks, metal, valves, piping etc) produced during rehabilitation or dismantling operations on nuclear industrial sites. Other industries, such as food processing, chemical, steel etc also produce VLLW as a result of the concentration of natural radioactivity present in certain minerals used in their manufacturing processes. The waste is therefore disposed off with domestic refuse although countries such as France are developing facilities to store VLLW in specifically designed VLLW disposal facilities.

Low-level waste (LLW) is generated from hospitals, laboratories and industry, as well as the *nuclear fuel cycle*. It comprises paper, rags, tools, clothing, filters etc., which contain small amounts of mostly short-lived radioactivity. It is not dangerous to handle, but must be disposed off more carefully than normal garbage. Usually it is buried in shallow landfill sites. To reduce its volume, it is often compacted or incinerated (in a closed container) before disposal. This category comprises 90% of the volume but only 1% of the radioactivity of all radioactive waste.

Intermediate level waste (ILW) contains higher amounts of radioactivity and may require special shielding. It typically comprises resins, chemical sludge and reactor components, as well as contaminated materials from reactor decommissioning. Treatment and disposal of ILW varies depending on the waste form and whether it is short- or long- lived. In general, short-lived ILW can be disposed of in shallow land burial, but long-lived ILW must be disposed of in a manner similarly to that which is used for high-level waste.

High-level waste (HLW) is highly radioactive and contains long-lived radioactivity. It generates a considerable amount of heat and requires cooling for many years before disposal. It can be considered as the "ash" from "burning" uranium in a reactor. HLW accounts for over 95% of the total radioactivity produced in the process of electricity generation. There are two distinct kinds of HLW: used fuel itself in fuel rods, or separated waste from reprocessing the used fuel.

HLW has both long-lived and short-lived components, depending on the length of time it will take for the radioactivity of particular radionuclides to decrease to levels that are considered no longer hazardous for people and the surrounding environment.

India's Nuclear Energy Program

India is the first country in Asia to have initiated a nuclear program to explore the

The deposit has been discovered by the Atomic Minerals Directorate for Exploration & Research (AMD).

possibility of tapping nuclear energy for the purpose of power generation. The objective has been to use the two naturally occurring elements - uranium and thorium. The estimated natural deposits of natural uranium is under 70,000 tonnes and thorium, under 3,60,000 tonnes

India has a ***three-stage nuclear program***. The *first stage* is based on Pressurised Heavy Water Reactors (PHWR), which are fuelled by natural uranium. The *second stage* envisages utilization of plutonium produced and re-processed from the first stage. The *third stage* is based on thorium for which R&D efforts are in progress.

The current nuclear energy installed capacity is 3,900 MWe, which is 3.1% of total installed power generation capacity. Under the Eleventh Five Year Plan (2007-2012) another 3,380 MWe of capacity would be added. The nuclear contribution foreseen by 2050 is 25%.

Nature of Radioactive Waste During Nuclear Power Program

All parts of the nuclear fuel cycle produce some radioactive waste. **Nuclear fuel cycle** is the progression of nuclear fuel through a series of differing stages starting with the mining of uranium and ending with the disposal of nuclear waste.

Front end of the fuel cycle involves steps required to prepare uranium for use in a nuclear reactor and broadly include steps of mining and milling, conversion, enrichment and fuel fabrication. Once the uranium has been used in a reactor to produce electricity it is known as 'spent fuel' and undergoes a further series of steps including temporary storage, re-processing, and recycling before eventual disposal as waste. Collectively these steps are known as the *back end* of the fuel cycle.

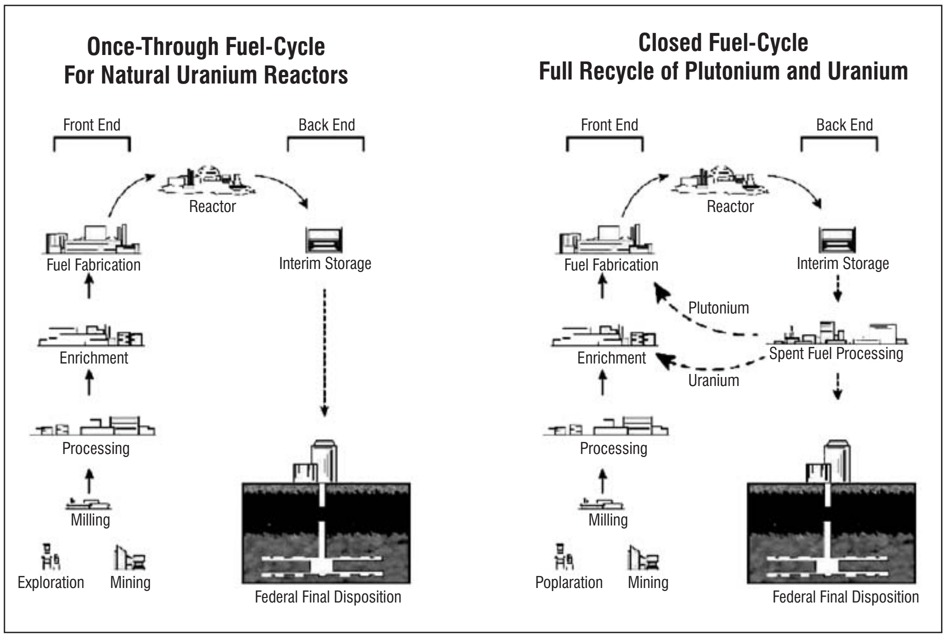
If spent fuel is not reprocessed, the fuel cycle is referred to as an *open fuel cycle* (or a once-through fuel cycle); if the spent fuel is reprocessed, it is referred to as a *closed fuel cycle*. India has adopted a *closed fuel cycle* for its nuclear program.

India's Nuclear Power Reactors

Operating : 17 (Tarapur 4, Kaiga 3, Kakrapar 2, Kalpakkam 2; Narora 2, Rawatbhata 4)

Under Construction : 6 (Kaiga 1, Rawatbhata 2, Kalpakkam 1, Kundankulam 2)

Planned/ Firmly proposed : 19 (Kakrapar 2, Rawatbhata 2, Kundakulam 2, Jaitapur 2, Others 11)



All radioactive waste has to be managed and disposed safely keeping in view the objective of protection of people and the environment. For low- and intermediate-level wastes these are mostly being implemented. For high-level wastes some countries await the accumulation of enough waste to warrant building geological repositories.

Mining and the Overburden

Mining and processing of uranium is carried out by Uranium Corporation of India Ltd, a subsidiary of the Department of Atomic Energy (DAE), at Jaduguda and Bhatin since 1967; Narwapahar since 1995; Turamdih since 2002; Banduhurang since 2007; and Bagjata in 2008 (est.) - all in Jharkhand. Work on new mines is underway at Mohuldih in Jharkhand (by 2010); at Domiasiat-Mawthabah in Meghalaya (2012 exp); at Lambapur-Peddagattu in Nalgonda Andhra Pradesh (2012 exp); and at Tummalapalle in Kadapha, Andhra Pradesh (2010)

Deposits in Jharkhand have a poor ore grade of close to 0.04%. Therefore, large amounts of ore have to be mined to get the uranium. Mining of uranium ores produce large amount of radioactive waste material in the form of:

- overburden (soil and rock that is covering a deposit of ore, such as uranium. It usually contains at least trace amounts of the ore plus radioactive decay products)
- unreclaimed, subeconomic ores (ores that have too little uranium to be profitable, called "protores")
- "barren" rock (rock containing no ore), and
- drill cuttings

Overburden contains elevated concentrations of radioisotopes compared to normal rock. This waste rock is often put in piles or "dumps". Some of it is used for backfilling the voids during mine closure. All these piles threaten people and the environment even after shut down of the mine. This is due to the release of radon gas and seepage of water containing radioactive and toxic materials.

Despite the danger, mine overburden is not classified as a radioactive waste and the need for its placement in radioactive waste disposal facilities is not felt. The Atomic Energy Act too does not specify controls over it and neither the Atomic Energy Regulatory Board (AERB) nor the Department of Atomic Energy (DAE) regulates its disposal.

Milling and the Tailings

The mined uranium ore is sent to a mill where the ore is crushed and ground to a fine slurry. It is then leached in sulphuric acid to allow the separation of uranium from the waste rock and, further, recovered from solution and precipitated as uranium oxide concentrates, also known as "yellowcake". Currently there is only one central mill operating at Jaduguda with the current capacity to process 2,100 t ore per day. The mill at Turamdih is yet to be fully commissioned.

Processing of ore generates fine sandy tailings, which contain virtually all the naturally occurring radioactive elements naturally found in uranium ore. These tailings need to be collected in engineered tailings dams and finally covered with a layer of clay and rock to inhibit the leakage of radon gas and ensure long-term stability. In the short term, the tailing material is often covered with water.

Burst Pipe

There are three tailing dams in Jaduguda, of which one is closed. A new tailings dam has been built near Turamdih mill. The poor ore grade means that almost all that is mined is left as waste. An estimate suggests over 4.1 million tones of waste from uranium mining and milling (till 2000).

Radon-222 gas emanates from tailing piles and has a half life of 3.8 days. This may seem short, but due to the continuous production of radon from the decay of radium-226, which has a half life of 1600 years, radon presents a long term hazard. Further, because the parent product of radium-226, thorium-230 (with a half life of 80,000 years) is also present, there is continuous production of radium-226. With a steady 10 km per hour wind, the Radon gas could travel nearly 1000 km before half has decayed. This gas presents a major threat to mine workers and nearby residents alike; it emits alpha radiation as it decays into radioactive bismuth, polonium and lead. Inhaling or ingesting radon, which is water soluble, poses a unique health hazard as the body becomes exposed to the chemical properties of the various decay products as well as their radioactivity.

Erosion of tailings during dry seasons, water overflow during heavy rainfall, vulnerability due to earthquakes, leachate causing groundwater contamination, structural integrity of the dam, accidents causing spillage, are among the several concerns posed by these tailings.

Waste during Conversion, Enrichment and Fuel Fabrication

The Nuclear Fuel Complex (NFC) located at Hyderabad undertakes refining and conversion of uranium. The yellowcake from the mill is not directly usable as fuel for a nuclear reactor. At the conversion facility, uranium is first refined to uranium dioxide, which can be used as the fuel for majority of the Indian reactors that do not require enriched uranium. For other reactors, this uranium dioxide is converted into uranium hexafluoride gas, ready for the enrichment plant. Only 0.7% of natural uranium is capable of undergoing fission to produce energy in a nuclear reactor. Enrichment process increases the U-235 (fissile isotope) content to about 3.5%. The main by-product at this stage is the depleted uranium (DU) in huge quantities. Some of the DU finds use in applications where its' extremely high density makes it valuable, such as the keels of yachts, anti-tank ammunition, radiation shielding and others. India does not produce waste in form of depleted uranium since majority of its reactors require natural uranium. The enriched (2.66% U-235) uranium for its two Boiling Water Reactors (BWRs) at Tarapur is imported.

Depleted uranium effects

At the fuel fabrication plant, uranium dioxide is pressed into small pellets and inserted into thin tubes to form fuel rods. The rods are then sealed and assembled in clusters to form fuel assemblies for use in the core of the nuclear reactor. The fuel for Pressurised Heavy Water Reactors (PHWR) is fabricated at Nuclear Fuel Complex with plant capacity of 400 t/yr. A small 25 t/yr fabrication plant in Karnataka makes fuel for the Tarapur BWRs. The fuel for Fast Breeder Test Reactor (FBTR) is fabricated at Bhabha Atomic Research Center (BARC), Mumbai.

Waste in the form of solid, liquid and gaseous effluents are released during these stages, which need proper management. All waste can be classified as low level waste and are disposed at the facilities itself. An estimate puts the figure of waste generated during fuel fabrication process at 2,000 m^3 (till 2000).

Nuclear Reactors and the Spent Fuel

Radioactive waste is generated in various forms like solid, liquid or gaseous.

In terms of radioactivity, High-level Waste (HLW) is the major issue arising from the use of nuclear reactors to generate electricity. Highly radioactive fission products and also transuranic elements are produced during reactor operations and are contained within the used fuel (also called spent fuel). The amount of HLW however varies with reactor technology. The newer technology is said to reduce amounts of HLW.

Low and intermediate level waste is also produced as a result of operations, such as the cleaning of reactor cooling systems and fuel storage ponds, the decontamination of equipment, filters and metal components that have become radioactive as a result of their use in or near the reactor. These waste streams are treated to reduce their activity concentration to a level at which they are allowed to be discharged according to national regulations. The processes that are employed for treatment are filtration, chemical treatment, ion-exchange, steam evaporation, solar evaporation and membrane processes.


Spent fuel

The intermediate level radioactive liquid waste is conditioned. Cementation and polymerization methods are adopted in India for management of this type of waste.

Gaseous discharge are controlled and minimised with an elaborate off-gas cleaning system consisting of condenser, scrubber, chiller, demister and absolute High-Efficiency Particulate Air (HEPA) filters is used to treat the gas before discharge through a 100m tall stack to the atmosphere.

Reprocessing and High Level Waste

India has adopted a closed cycle and utilised reprocessing to recycle material from this used fuel. The fission products and transuranic elements are separated from uranium and plutonium and treated as HLW.


Spent fuel storage

What is Spent Fuel?

With time, the concentration of fission fragments and heavy elements formed during the process in a fuel bundle increased to the point where it is no longer practical to continue to use the fuel is called 'spent fuel'. So after 12-24 months the 'spent fuel' is removed from the reactor. The amount of energy that is produced from a fuel bundle varies with the type of reactor and the policy of the reactor operator.

When removed from a reactor, a fuel bundle emits both radiation and heat. The spent fuel is unloaded into a storage pond immediately adjacent to the reactor to allow the radiation levels to decrease. In the ponds the water shields the radiation and absorbs the heat. The fuel is held in such pools for several months to several years. Ultimately it is either reprocessed or prepared for permanent disposal.

India considers 'spent' fuel as a resource and not a waste. In countries where used fuel is not reprocessed, the used fuel itself is considered a waste and therefore classified as **HLW**.

Spent fuel requires cooling for nearly 10 years before the same can be reprocessed. On an average, spent fuel ponds hold five to 10 times more long-lived radioactivity than a reactor core. Loss of pool water that cools and shields the highly radioactive spent fuel assemblies can be catastrophic. Particularly worrisome is the large amount of cesium 137. With a half-life of 30 years, cesium 137 gives off highly penetrating radiation and is absorbed in the food chain as if it were potassium. Storing this 'waste' in dry casks creates separate storage, packaging and security problems.

Spent fuel from the civil PHWRs is reprocessed by BARC at Trombay, Tarapur and Kalpakkam. HLW management facility is co-located near reprocessing plant so as to avoid any radiation hazard/exposure to public during transportation. Approximately 1.5 m^3 of high level liquid waste is generated for every tonne of spent fuel reprocessed. Upon conditioning, the waste volume is 40 L of vitrified waste.

High-level liquid waste generated during reprocessing of spent nuclear fuel is managed using a three-step strategy involving: a) Immobilization of waste oxides in stable and inert solid matrices; b) Interim retrievable storage of the conditioned waste under continuous cooling; and c) Disposal in deep geological formations.

In India, borosilicate glass matrix has been adopted for vitrification of HLW. Vitrified waste canisters are further enclosed in secondary stainless steel containers called overpacks. High-level vitrified wastes are characterized by decay heat and need to be cooled to a level where transportation and disposal in geological repository become viable and economical. These requirements necessitate interim storage of over packs spanning over 30 years and more. An interim storage facility is operational at Solid Storage and Surveillance Facility (SSSF), Tarapur with a capacity for storing nearly 1,760 overpacks

Waste from Decommissioning of Nuclear Installations

End-of-the-life decommissioning of nuclear reactors generate huge quantities of waste falling in the category of low and intermediate level waste. Some of the old reactors have undergone life extension for another 10-15 years. The AERB makes it mandatory for all nuclear installations to incorporate provisions for in situ decontamination and decommissioning provisions from design stage until end of operational phase. As part of the program for conditioning of decommissioning waste, focus is on achieving volume and size reduction.

Total nuclear waste generation in India

Step in nuclear fuel cycle	Waste estimate(2 significant digits)
Uranium mining and milling	4.1 million tonnes
Fuel fabrication	2000 m3
Reactor operations (low-level waste)	22000 m3
Reactor operations (intermediate-level waste)	280 m3
Spent fuel storage (not to be reprocessed)	400 tonnes
Reprocessing (high-level waste)	5000 m3
Reprocessing (intermediate-level waste)	35000 m3
Reprocessing (low-level waste)	210000 m3

(Estimates by MV Ramana, et. al.; 2001)

Policy Framework for Managing Radioactive Waste

The national policy for radioactive waste management is based upon universally adopted philosophy of:

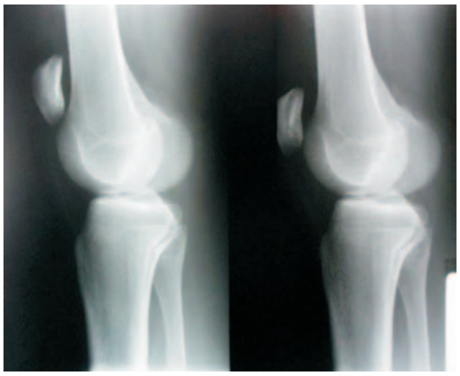
- delay and decay of short lived radionuclides;
- concentration and containment of radioactivity as much as practicable, and;
- dilution and dispersion of low-level activity to the environment well below the nationally accepted levels which are in line with international practices.

The policy for radioactive waste management is broadly as follows:

a. Discharge through gaseous, liquid and terrestrial routes are as low as reasonably achievable (ALARA).

b. Low and intermediate level solid/ solidified waste are emplaced in near surface shallow land repository, specially engineered for this purpose.

c. High-level and alpha contaminated liquid waste from spent fuel processing are immobilized in a suitable matrix and stored in an interim storage facility with appropriate cooling and surveillance for a period as necessary. Thereafter, these solidified waste products will be emplaced in a suitably engineered deep geological repository.



Nuclear medicine imaging

d. Alpha contaminated waste not qualifying for near surface disposal is provided suitable interim storage pending its disposal in a deep geological repository.

e. Spent radiation sources are either returned to the original supplier or handed over to a radioactive waste management agency identified by the regulatory body.

f. Co-location of near surface disposal facility with the nuclear installations.

g. The regulatory body determines the period for which active control of the shallow land repository (like monitoring, surveillance, remedial work) should be maintained by the waste management agency. Thereafter, the passive control (like permanent markers and land use restrictions) will be passed on to the Central Government, the agency for institutional control. Institutional control may span a period of 300 years comprising, typically, 100 years of active control and 200 years of passive control so as to allow decay of most of the radionuclides present in the waste rendering them innocuous.

Radioactive Waste: A long-term environmental problem

Radioactive waste must be properly managed to minimize risk to the environment and to the health and safety of future generations. Over the last forty years, high-level radioactive waste has accumulated in the country. The current storage methods shield any harmful radiation and are presently safe. However, modern above ground storage structures are designed for temporary storage only, and will not withstand rain, wind, and other environmental factors for the tens of thousands of years during which the waste will be hazardous. A permanent solution is yet to be found.

For decades, experts throughout the world have studied many options for permanently disposing of nuclear waste — including:

- Leaving the material at current storage sites
- Burying it in the ocean floor
- Putting it in polar ice sheets
- Sending it into outer space
- Placing it deep underground in a geologic repository

After analyzing these options, disposal in an underground repository is considered the best, long-term solution.

The idea behind deep geologic disposal is to keep the waste as dry and isolated as possible, for as long as possible, so that its radiation can diminish to levels where it does not harm people or contaminate the environment.

The most widely accepted plans for final disposal are for these to be buried in stable rock structures deep (about 500–600m) underground. Many geological formations such as granite, volcanic tuff, salt or shale are considered suitable. The first permanent disposal is expected to occur about 2010. India expects to develop the repository for its waste by 2025 or later. Major attributes to be considered for site selection include lithological formation, seismicity, rainfall, economic minerals occurrences, geohydrology, vegetation cover, population, archaeological monuments etc. The work on site selection for geological repository is underway in India.

Since there is so far no live example of final disposal, it is difficult to accurately predict the behaviour of such waste and its consequences in the long run. While it may seek to permanently isolate the waste, there is still no disposal option in sight.

Cost of Managing Radioactive Waste

The costs for waste management are integrated into the total cost of nuclear power and represents around 3% of the total cost. In absolute terms, waste management costs Rs 50 million for every MWe generated in case of the new plants. Since cost is directly proportional to the quantum of waste generated, India's focus is on waste volume reduction.

Organisational Setup

The Indian Atomic Energy Program is under the control of the Prime Minister. He/she operates through Atomic Energy Commission (AEC) and Department of Atomic Energy (DAE). The Chairman of the AEC is also Secretary of the DAE. Development of nuclear power and related nuclear fuel cycle and Research and Development activities are carried out in various units under the AEC/DAE.

The organization is broadly divided into research and development sector (e.g. BARC, IGCAR); industrial sector (e.g. Nuclear Fuel Complex, Heavy Water Board); public sector (e.g. NPCIL, UCIL, BHAVINI); services and support sector and provides for close interaction needed between the production and R&D units.

The Atomic Energy Regulatory Board (AERB) has been set up for formulating safety standards and regulations; supervision of the authorisation process at different stages like site evaluation, construction, operation, final shut down and decommissioning; and surveillance of facilities both under construction and in operation. AERB is accountable to AEC.

Lead lined radioactive material

Legislative Framework

Atomic Energy Act 1962 and rules framed there under provide the main legislative and regulatory framework pertaining to atomic energy in the country. It was enacted to provide for the development, control and use of atomic energy for the welfare of the people of India and for other peaceful purposes and for matters connected therewith. The Act provides control over radioactive substances or radiation generating plant in order to, among others: a) prevent radiation hazards; and b) ensure safe disposal of radioactive wastes. The Central Government is also empowered to fulfil the responsibilities assigned by the Act either by itself or through any corporation established by it or a Government company.

The Act further provides Central Government with the powers to frame rules or issue notifications to implement the provisions of the Act. Following rules have been framed:

Atomic Energy (Radiation Protection) Rules 2004 to establish the requirement of consent for carrying out any activities for nuclear fuel cycle facilities and use of radiations for the purpose of industry, research, medicine, etc.

Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 establishes the requirements for the disposal of radioactive waste in the country.

Atomic Energy (Control of Irradiation of Food) Rules, 1996 were framed to regulate the irradiation of foods in the country.

Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substances) Rules, 1984 that regulate the activities pertaining to mining, milling, processing and/or handling of prescribed substance.

Atomic Energy (Factories) Rules, 1996 to administer the requirement of Factories Act in the nuclear establishment of the country to ensure industrial safety.

Other Applications

Besides use in nuclear reactors (and nuclear weapons), radioisotopes have several other applications. In **medicine**, radioisotopes are widely used for diagnosis and research. Radioactive chemical tracers emit gamma radiation, which provides diagnostic information about a person's anatomy and the functioning of specific organs. Radiotherapy also employs radioisotopes in the treatment of some illnesses, such as cancer. More powerful gamma sources are used to sterilise syringes, bandages and other medical equipment.

Linear Accelerator Clinac-2100c for cancer treatment.

In the **preservation of food**, radioisotopes are used to inhibit the sprouting of root **crops** after harvesting, to kill parasites and pests, and to control the ripening of stored fruit and vegetables. Irradiated foodstuffs are commonly accepted by world and national health authorities for human consumption in an increasing number of countries. They include potatoes, onions, dried and fresh fruits, grain and grain products, poultry and some fish. Some pre packed foods are also being irradiated.

In growing crops and breeding **livestock**, radioisotopes are used. They are used to produce high yielding, disease and weather resistant varieties of crops, to study how fertilisers and insecticides work, and to improve the productivity and health of domestic animals.

Industrially, and in mining, they are used to examine welds, to detect leaks, to study the rate of wear of metals, and for on-stream analysis of a wide range of minerals and fuels. Radioactive waste is generated in the course of all these non-power applications of radioisotopes and need to be managed and disposed with care to prevent adverse impacts on health and environment.

IAEA Principles and Objective of Radioactive Waste Management

According to IAEA " the main objective of radioactive waste management is to deal with it in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generations."

The fundamental principles of radioactive waste management are:

1. Protection of Human Health
Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.

2. Protection of the environment
Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.

3. Protection beyond national borders
Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.

4. Protection of future generations
Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.

5. Burdens on future generations
Radioactive waste shall be managed in such a way that will not impose undue burden on future generations.

6. National legal framework
Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.

7. Control of radioactive waste generation
Generation of radioactive waste shall be kept to the minimum practicable.

8. Radioactive waste generation and management interdependencies
Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.

9. Safety of facilities
The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

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