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Nuclear Waste: How these are being Stored and Disposed?

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ABSTRACT

Radioactive waste is created by any nuclear fuel cycle operation that creates or utilises radioactive materials. Nuclear waste is distinct due to the handling of radiation-emitting radioactive material, which is a source of concern. In great part, public confidence in the safe handling of radioactive wastes determines whether or not nuclear energy is accepted by the public. Comparing nuclear waste to other toxic industrial pollutants, not all nuclear wastes are as dangerous or as challenging to manage.

The full spectrum of operations involved in managing these wastes includes handling, treatment, conditioning, transport, storage, and disposal. In addition to guaranteeing the greatest degree of safety in the management of radioactive waste, current technical advancements in India enable the recovery of valuable radionuclides from radioactive waste for societal purposes.

The issue of how to handle radioactive wastes gives a straightforward choice between keeping the wastes under control and unleashing them. But as is widely known, it is extremely difficult to exercise this seemingly straightforward option since every choice has far-reaching effects, whether they be social, economic, or otherwise.

Keywords: *Nuclear waste, nuclear waste storage, nuclear waste disposal, nuclear waste in India.*

I. INTRODUCTION

To begin with, we must comprehend nuclear power in order to comprehend nuclear waste. Nuclear power is essentially electricity produced by power plants that obtain their heat from nuclear fission. In a nuclear reactor, fission essentially involves the breaking of uranium atoms. Small ceramic pellets packed into long, vertical tubes make up uranium fuel. which eventually entered the reactor in packaged form. With its pumps, valves, steam generators, condenses, and other related machinery, this is essentially comparable to a sizable coal-fired power station. Simply said, it is a safe and effective method of heating water to the point where steam is produced, which turns turbines to generate energy.

Low enriched uranium fuel is used by the plant to create energy. Uranium-235 (U-235), one of

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the isotopes, is prone to easy fission. U-235 atoms receive free neutrons during the fission process, making them unstable and causing them to split into two light atoms known as fission products. Approximately the size of a pencil, uranium pellets have the same energy content as a tonne of coal, a barrel of oil, or 1,000 cubic feet of natural gas. Each individual pellet has the potential to supply energy for over five years. Additionally, due to its abundance in nature, it can supply energy to future generations.

Given that they don't burn any materials, this is the only method of creating power that produces no carbon. These are also somewhat environmentally friendly because they don't emit any form of greenhouse emissions. These energy sources are unrivalled in their ability to constantly and interruption-free create vast amounts of power. These are supplying roughly 15% of the power in the globe[2]. Additionally, the paper states that by 2050, nuclear power would produce 25% of all energy.

II. NUCLEAR WASTE

Nuclear fuel is converted into nuclear waste after being utilised in a reactor. From the outside, it resembles the fuel that was put into the reactor perfectly. Fuel is generally assembled from metal rods that surround fuel pellets. The components aren't exactly the same, though, because nuclear reactions have already place.

When a nuclear fuel nucleus splits in two, nuclear energy is released. The smaller nuclei that are left over, referred to as fission products, are the main element of nuclear waste. The fuel in which it was created still contains the majority of the radiation linked to nuclear power. Used fuel is categorised as high-level radioactive waste for this reason[3].

III. A BRIEF HISTORY ON NUCLEAR POWER

It is true that no serious scientific advancement ever begins. Instead, it builds on the discoveries of numerous others. Roentgen, one of Germany's best scientists, discovered the X-ray in 1895 while working with cathode rays in a glass tube. The first discovery in the area of medical sciences was this. Marie Curiae and her husband made the discovery of radioactivity later in 1896. Once more in the 1920s, Ernest Rutherford made the discoveries of alpha, beta, and gamma rays while researching X-rays. Chadwick Walton discovered the neutron in 1932 while studying Rutherford's findings.

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[2] *What is Nuclear Power and Energy?: Ge Hitachi Nuclear Energy* (no date) *Innovating for the Future*. Available at: https://nuclear.gepower.com/company-info/nuclear-power-basics (Accessed: December 27, 2022).

[3] *Nuclear waste* (2019) *Nuclear Energy Institute*. Available at: https://www.nei.org/fundamentals/nuclear-waste (Accessed: December 27, 2022).

Following these discoveries, a tragic episode occurred in 1945 in Japan, when cities were destroyed by an American act. People then recognised that they could harness this energy in many ways. The liquid-cooled EBR-1 reactor, which was connected to a generator, provided the first nuclear-generated power in 1951. However, these power reactors were pushed in to run submarines before the plant was put up. Later, the USSR creates an electrical reactor for the first time.

Many nuclear reactors were constructed in the 1960s and 1970s to generate power utilising designs originally developed for submarine construction. These were successful in producing inexpensive, emission-free electricity. As a result of the increased competitiveness, there was a rush among the nations to begin nuclear energy production. France used nuclear energy to generate 75% of its power[4] in 1974. The United States developed about 100 reactors and generated 20% of its energy from nuclear sources. However, later on, because to a labour scarcity and high building costs, nuclear power's expansion was sluggish. The deployment of nuclear reactors was delayed further by a number of later incidents, such as the Three Mile Island accident in 1979 and the Chernobyl disaster in 1986. Strict regulation also contributed significantly to cost increases. These factors caused widespread dread, which was a major factor in the sluggish creation of energy from nuclear power.

IV. Nature and policy of Nuclear waste in India

Extremely dangerous nuclear waste from reactors exists now and has for tens of thousands of years. Over time, the wastes that even the nuclear industry acknowledges must be tightly segregated from the environment will be discharged because the radioactive and chemical risks will outlive the containers.

The AERB is responsible for managing the waste generated by the chemical and radioactive waste plants. This does not stop there; the agency also manages the trash produced by healthcare institutions, and these facilities must adhere to the same criteria as those set out by AERB.

Nuclear waste is created through a variety of processes in business, defence, medicine, and scientific research that use radioactive materials, including mining, nuclear power generation, and the nuclear fuel cycle.

Its amount of radioactivity might differ and it can be in the form of a gas, liquid, or solid. For a few hours, many months, or even hundreds or thousands of years, the waste can continue to be radioactive. These can be categorised as exempt waste, low & intermediate level waste, and

[4] *Timeline of nuclear energy history* (no date) *What is nuclear?* Available at: https://whatisnuclear.com/nuclear-timeline.html (Accessed: December 27, 2022).

high level waste depending on the level and kind of radioactivity[5].

Nuclear or radioactive wastes differ from other types of conventional hazardous wastes due to the harmful effects they have on living things. Additionally, one of the characteristics of nuclear waste is that its breakdown requires time.

In India

When we discuss India and how these wastes are managed, we mean all forms of radioactive waste produced throughout the full nuclear fuel cycle, starting with uranium mining, fuel manufacturing, reactor operations, and then spent fuel reprocessing[6]. Contrary to other nations like the USA, Canada, etc. where spent fuel is kept as waste, in India the spent fuel is reprocessed to recover and utilise the uranium and plutonium created there. This is known as a closed fuel cycle.

Before ultimate storage or disposal, radioactive waste must be separated, handled, treated, conditioned, and monitored. Different types of radioactive waste, including solid, liquid, and gas, can develop and have a range of physical, chemical, and radiochemical properties. According to the International Atomic Energy Agency, radioactive wastes can be categorised as Exempt Waste, Low and Intermediate-Degree Waste, and High Level Waste depending on the level of radioactivity (IAEA)[7].

The general principle for radioactive waste management being followed are:

- Delay and decay of short-lived radionuclides;
- Concentrate and contain activity as practicable; and
- Dilute and disperse low-level radioactive waste within the authorized limits.

Typically, nuclear power plants dispose of their low-level solid, liquid, and gaseous waste in accordance with legal standards. The public must not be exposed to more than 1 mSv of radiation per year if they live close to nuclear power facilities, according to existing laws (i.e. 1000 micro-Sievert). These requirements follow those set forth by the International Commission on Radiological Protection (ICRP)[8]. Accordingly, in accordance with ICRP standards, AERB gives authorisation that details the quantity and kind of waste that may be

[5] *Bhabha Atomic Research Centre (BARC): Radioactive Waste Management: Indian scenario* (no date) *Bhabha Atomic Research Centre BARC* . Available at: https://www.barc.gov.in/pubaware/nw.html (Accessed: December 27, 2022).
[6] Id.
[7] *Processing* (2016) *IAEA*. IAEA. Available at: https://www.iaea.org/topics/processing (Accessed: December 27, 2022).
[8] http://www.icrp.org/page.asp?id=9

disposed of. Additionally, the authorizations that the AERB guarantees are good for three years and can be renewed based on how well nuclear power stations are operating.

The following is a list of the technologies used to handle nuclear waste:[9]

- Solid waste: After conditioning, solid waste produced by nuclear power plants is dumped at Near Surface Disposal Facilities (NSDF) situated inside the nuclear power plant's exclusion zone. The purpose of Near Surface Disposal Facilities is to confine radionuclides inside the disposal system until their activity degrades to a minimal level.
- Liquid waste: After proper treatment and ensuring that the regulation limit is met, low level liquid waste produced by nuclear power plants is released into the environment. The main components of the treatment system include chemical processing, evaporation, ion exchange, filtration, etc.
- Gaseous waste is handled right where it is produced. After filtering and dilution, the gaseous wastes are released into the environment through a 100 m-tall stack while being continuously monitored for radionuclides and in conformity with legal restrictions.India has adopted closed fuel cycle option, which involves reprocessing and recycling of the spent fuel. During reprocessing, only about two to three percent of the spent fuel becomes waste and the rest is recycled. At the end the high-[level waste are being emplaced in geological disposal facilities.

AERB must receive a "return of waste disposed of" from nuclear power stations. Consequently, AERB evaluates whether or not the wastes disposed of by nuclear power plants are within the restrictions. Additionally, Environment Study Labs, established by BARC, conduct an independent environmental survey to determine the true effects of the aforementioned waste that is discharged into the environment. According to the international framework, each nation must adhere to a complete set of norms and guidelines for managing trash[10].

V. BAARC Contribution in Nuclear Waste Management

India is one of the nations that has developed vitrification technology. BARC uses vitrification, a process for disposing of high-level waste. Operations are now conducted remotely in specialised design cubicles with 1.5-meter-thick concrete walls, known as hot cells, to cater for the strong radiation fields. These hot cells have sophisticated remote handling equipment and systems. Custom-built robots, remote welding units, remote inspection/surveillance tools, and

[9] https://aerb.gov.in/english/regulatory-facilities/radioactive-waste-management
[10] Indian Programme on Nuclear waste Management*by* PK Wattal

manipulators are a few of the main remoteization gadgets. Indigenous remote handling equipment development has been undertaken in cooperation with Indian enterprises, academic institutions, and national organisations.

These vitrification facilities are also located in India in Tarapur and Trombay. Additionally, these facilities employ a variety of additional methods to deal with these pollutants. For instance, heated metallic melters are utilised in Trombay, while heated ceramic melters are used in TarapurJoule. These methods have made it possible to dispose of trash in a safe and secure manner.

(A) Joule Heated Ceramic Melter[11]

The facility at Tarapur uses the joule Heated ceramic melter idea, whereas the unit at Trombay is based on pot glass technology. At Tarapur, material performance is satisfied in an atmosphere of molten glass and high temperatures (1000–1200 degrees Celsius). The immobilisation of High-Level Waste in a borosilicate glass matrix used in the joule metre technology is largely accomplished in a single step in a melter with a refractor liner. The joule heated ceramic melter technique is essentially a one-step procedure that takes use of the glass's high-temperature nature, in which it turns into an electrical conductor at high temperatures and undergoes favourable viscosity changes that aid in product withdrawal and shutoff. The Advance Vitrification System (AVS) of Tarapur is characterised by increasing temperatures throughout, accessibility to greater furnace temperatures, and less reliance on operator competence.

(B) Cold Crucible Melting (CCIM)[12]

It is becoming a cutting-edge method for vitrifying high-level trash. Along with being small and suitable for use in cells, they also provide versatility and the ability to process a variety of waste types while improving waste loading and melter life. The cold crucible is made of connected pieces that come together to form a cylindrical container, with a small layer of electrically insulating material between them. To reduce the power loss caused by induced currents in the crucible while providing crucible cooling, the number, shape, and insulation between the segments must be tuned. Additionally, a natural draught air conditioning system has been created for the storage vault due to safety and technological concerns.

Deep geological disposal is one of the methods being studied nowadays for the disposal of nuclear waste. This method is regarded as being among the finest at isolating waste from a human person and is also acknowledged as being safe by the worldwide regime. And for now,

[11]http://www.barc.gov.in/pubaware/nw_n5.html
[12] https://www.barc.gov.in/barc_nl/2022/2022010216.pdf

recycling and reuse are the main priorities. This tends more in the direction of a sustainable method of disposal. Major technical advancements have been made as a result of the necessity for resource utilisation with technological development, which has also reduced the load on future generations.

Nuclear Power in world today

Nuclear energy, which is how energy is created by splitting the atoms of substances like uranium and plutonium, has already been described. It was initially created in the 1940s and during the Second World War, when the primary goal was to produce explosives and destructive weaponry. Following the Second World War and the Hiroshima event, the world's focus shifted in the 1950s to the peaceful uses of nuclear energy, particularly for the production of electricity.

Today, around 450 nuclear power reactors produce roughly 10% of the world's electricity. Additionally, there are about 50 additional reactors being built, increasing the production capacity to 15% in the near future[13]. According to estimates, output increased dramatically between 2107 and 2018, going from 2503 TWh to 2563 TWh. Approximately 12 nations are thought to have produced at least one-fourth of their recent power using nuclear energy. Whereas Slovakia, Hungary, and the Ukraine receive more than 50% of their energy from nuclear sources. And nuclear energy provides a third or perhaps more of that for nations like Belgium, Sweden, Slovenia, Bulgaria, Switzerland, and Finland. One-fifth of the power used in the United States, the United Kingdom, Romania, Russia, and Spain is supplied from nuclear energy.

The information presented above demonstrates how nations have shifted away from using other conventional energy sources and toward using nuclear power. Around 10% of energy is produced by nuclear energy, with the remaining sources being coal (38%), gas (22%), hydro (16%), and other sources contributing in the same manner. The world has considerably improved its understanding of nuclear energy usage and production. And this has compelled everyone to utilise nuclear power. Many nations, like Belarus, Bangladesh, Turkey, and the United Arab Emirates, have accepted the necessity for nuclear power and are in the process of building their first nuclear power plant.

VI. How are Nuclear waste managed globally

Nuclear waste needs to be treated before it can be disposed of safely. This entails gathering the trash, storing it, lowering its volume, and modifying its chemical and physical makeup.

13 https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

Additionally, the procedure involves conditioning, which facilitates packing prior to storage and disposal.[14]

Although there are several processes in the management of nuclear waste, the IAEA highlights three crucial ones: pre-treatment, treatment, and conditioning.

Pre-treatment, which involves sorting and segregation to remove contaminated materials from non-contaminated ones, gets garbage ready for processing. To maximise its downstream processing, it may be required to minimise the size of the trash, for instance by cutting or shredding it. Decontamination methods reduce the amount of trash that has to be treated, which lowers the cost of disposal.

Once the trash has been properly prepared, the next step is to treat it, which increases its safety and lowers the costs of the storage and disposal stages of management. By isolating the radioactive component from the bulk waste, treatment techniques often lower the volume of radioactive waste while frequently altering its composition. Depending on the kind of waste and the waste acceptance standards of the preferred disposal location, a range of waste treatment processing stages are available for usage. Solid garbage is typically treated using burning, while liquid waste is typically treated using evaporation.

Conditioning, the third phase in the procedure, transforms the waste into a manageable, safe form that can be transported, stored, and disposed of. Conditioning methods are intended to reduce the rate at which radionuclides are released into the environment from discarded waste packages. The garbage is frequently packaged into specific containers or treated with cement, bitumen, or glass.

VII. Safety framework for Radioactive Waste[15]

The IAEA helps its member nations set up a security framework for the disposal of radioactive waste. Additionally, it creates Safety Standards for the appropriate implementation by its Member States of the predisposal management of radioactive waste and spent fuel. One of the five IAEA Safety Standards Committees, the Waste Safety Standards Committee, is coordinated by the agency. It intends to give the Agency comments and suggestions on its waste safety programmes.

Additionally, the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management Contracting Parties meetings' secretariat is provided by the

[14] 14https://www.iaea.org/topics/processing
[15] 15https://www.iaea.org

IAEA.

In order to harmonise methods for the safe predisposal treatment of radioactive waste, the Agency frequently conducts international initiatives and working groups. These occasions also give Member States a space for discussion.

Predisposal management subjects covered by the IAEA span a wide spectrum, including policy and strategy, inventory evaluation, costing and economic analysis, waste reduction, improvement of operating procedures at nuclear sites, and the development of waste management technology. It is also connected to international initiatives on the subject, like the CRAFT project. This project demonstrates the security of predisposal facilities.

One of the main organisations in charge of establishing rules for international regimes that aim to achieve goals in a safe and secure manner while also managing resources responsibly for a better future. However, nations have also developed the legislation and guidelines to control the nuclear industry. Countries including India, the USA, Canada, China, and others have particularly discussed managing nuclear waste.

In India, where the Atomic Energy Regulatory Board (AERB) is the supreme authority, it is discussed how to treat radioactive and chemical waste safely. The life cycle of the plants, from the planning stage through building, commissioning, operation, and decommissioning, includes an assessment of the waste management issues. Wastes are produced in solid, liquid, and gaseous forms by operating nuclear power reactors. According to the waste management concept, no garbage, regardless of its physical form, should be dumped into the environment unless it has been cleared, exempted, or exempted from rules. In choosing the procedures and technologies used in radioactive waste management plants, waste minimization and volume reduction are given top attention.[16]

similar to the USA, where the NRC (Nuclear Regulatory Commission)[17] is responsible for commissioning nuclear waste and overseeing storage and disposal. Additionally, it establishes rules and assigns duties. In "spent fuel pools," spent nuclear fuel is kept in U.S. nuclear power reactors. These swimming pools have steel liners and are composed of reinforced concrete that is several feet thick. The water, which is normally 40 feet deep, protects against radiation while also keeping the rods cold.

At privately held facilities as well as some DOE (Department of Energy) sites, the NRC also issues licences and controls the receipt and custody of high-level waste. The nation is still

[16] https://aerb.gov.in/english/regulatory-facilities/radioactive-waste-management
[17] [17]https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html

looking for a long-term solution for disposing of high-level garbage.

VIII. Conclusion

The situation that exists today and how things have radically altered and progressed for nuclear make this quite apparent. Since it is now the only type of energy that produces no carbon emissions, nuclear power has completely altered the landscape of the energy industry. There has been a significant change in the industry as a result of the disposal technology that is used today in consideration with the environment and are in such a manner that it must not have any impact on human health. While this is about the changes that nuclear has brought, the way its waste was treated has also significantly changed while taking care of the environment. Additionally, at a time when clean energy is a hot topic, nuclear energy's contribution will have a huge impact on upcoming global developments. Despite the difficulty of disposing of nuclear waste, countries with recent technological advancements have been able to do so. We are one of the nations that has attained independence in the management of all sorts of nuclear waste, therefore this is a really proud time for us. And the world, which is expanding so quickly, needs something like this to meet the demand for energy without endangering the environment. The future lies in nuclear.

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