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Nuclear Waste Management in India Vis-A-Vis Sustainable Development: Policies and Practices

***Dr. Balwinder Singh and **Navin Pal Singh**
*Associate Professor, School of Law, UPES, Dehradun
** Assistant Professor (SG), School of Law, UPES, Dehradun

ABSTRACT

ALL LIVING LIFE IS BUILT OUT OF ENERGY! Energy is everything that comes from the sun to the air we breathe, to water and wind. Now the population is increasing and so is technology level, we are using Energy from every resource that is available on the earth. We now know that there are all forms of energy known to this planet upon which we base our civilization, some renewable, some non-renewable or in the language jargon of today: conventional or non-conventional that have a great deal to do with said improvement in quality of life. Energy is utilized by all sectors such as industry, commerce, agriculture, household, transport and also for telecommunication etc. Thus, in simplest terms Energy is Work done. We can go to the moon or expedition Antarctica just because of harnessing energy fuels. We are moving ahead in the era of modernism and among them, the dependency on energy is rising. Rapidly depleting all other forms of resources, the technology has now turned to nuclear capabilities. Nuclear is not just the largest source of energy, it is also a very clean option for producing power. The management of nuclear wastes in India is a crucial area that at the intersection of larger goals for sustainable development. With India in process of expanding its nuclear power programme by the year 2050 to meet energy needs and to cut down its carbon emissions, responsible management of nuclear waste will become even more vital, for environmental sustainability as well as public safety. Some even confirmed to the query Are we headed towards a nuclear future? & Is nuclear energy indeed be the answer to India's increasing power needs?

Keywords: *Nuclear energy, Sustainable Development, Clean energy, Technology*

I. INTRODUCTION

Nuclear is the fifth-largest source of energy production in India. India has around 22 nuclear reactor in operation of 6780 MW capacity producing 30,292.91 GWh contributing to less than 3% of total electricity generation.[1] India is racing towards advancing thorium-based fuels with the aim to increase the electricity generation from 2.8% to 9% within 25 years as thorium is found in abundance in India. This is in line with major goal of India as set by A.P.J Abdul Kalam that ‘energy independence is India's first and highest priority.’ At present, Indian’s nuclear power capacity is expected to increase from 7480 MW to 22,480 MW by 2031. Generally, it is believed that nuclear power is a clean, reliable and base load source of energy that can help ensure India’s long term energy security. India had also committed to cut on its global carbon emission and Nuclear is one of the best alternative India has. Though it is not completely viable since the involvement of two major issues, firstly, because of its drastic effect on human and environment on being exposed, and secondly due to the fact that it is not as clean as it is often made out to be. There has been issues in *Kundankulam case* whereby the people complained about the hot water discharge from the plant and its harmful effect on the marine life and the surrounding places.[2] The nuclear accidents at Three Mile Island in Pennsylvania in 1979, and Chernobyl, Ukraine in 1986 showed the world the high risk nuclear power possess and the proper method that has to be adapted whether it is its usage or disposal.

Disposal is also one among the many issues that nuclear fuel brings in itself. Proper and safe disposal of nuclear waste is as important as power generation. It is a scary thought to consider that if not disposed of properly it can actually have serious implication on the environment and the people. The major problem regarding radioactive waste is that it has been noticed that the generated radioactive waste remains radioactive for a longer period, so the accumulation of this type of waste becomes a serious problem. Efforts to deal with the radioactive waste have been timely put in place by a host of

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[1]M. Ramesh, *Why nuclear when India has an ‘ocean’ of ener*gy, THE HINDU (June 30, 2019), https://www.thehindu.com/business/Industry/why-nuclear-when-india-has-an-ocean-of-energy/article28230036.ece *As on August 2024 there are total 23 operational, 7 under construction and 12 planned nuclear reactors.*

[2]Shankar Sharma, *Is Nuclear Energy the Answer to India’s Growing Energy Needs?,* EPW (July 3, 2019), https://www.epw.in/engage/article/nuclear-energy-answer-indias-growing-energy-needs

organizations such as nuclear industries, international organizations, civil society, NGOs etc. It should be noted that the IAEA and the OECD Nuclear Energy Agency have also worked related to prevention of accidents on spent fuel by developing safety recommendations that the various standards, national criteria, regulation and management radioactive waste are based.

II. WHAT IS NUCLEAR WASTE AND WHY IT MATTERS?

Nuclear waste is hazardous in nature which adversely affects human life as well as environment. It contains radioactive materials emerging out from various sources primarily nuclear power plants and usage of nuclear energy in medicinal research activities. The very nature of radioactive material is such that it diminishes with the time provided it is disposed of in proper manner. Therefore, proper disposal of radioactive material is the biggest challenge before the stakeholders such as regulators, industries, public authorities working in the field of nuclear energy. These stakeholders have to come up with viable solutions for disposal of radioactive materials in order to protect all humans and environment from the harmful effects.

According to the definition given by International Atomic Energy Agency (IAEA), radioactive waste is any material that contains a concentration of radionuclides greater than those deemed safe by national authorities, and for which no use is foreseen.[3] A different definition has been brought up by Article 2(h) of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 1997 which defines radioactive waste to include ""*radioactive waste" means radioactive material in gaseous, liquid or solid form for which no further use is foreseen by the Contracting Party or by a natural or legal person whose decision is accepted by the Contracting Party, and which is controlled as radioactive waste by a regulatory body under the legislative and regulatory framework of the Contracting Party*;"[4]. Also, Article L 542.1-1 of the French Environment Code, states that final radioactive waste means radioactive waste for which no further treatment is possible under existing technological and economic conditions. Here treatment pertains to any possibility of extracting any material that can be recycled or reducing other pollutants and hazardous waste it contains. Therefore, in all ways radioactive waste is those radioactive left out of which no future use or treatment is possible.

The classification of radioactivity is based on the classification which circumcise the radioactive waste on two basis firstly, on the intensity of their radiation emission and secondly on the length of the time in which they remain radioactive, which remains from decades to millions of years. The waste according to their span of life and level of radioactivity is divided into low-level waste (LLW), intermediate-level waste (ILW) and high-level waste (HLW). The higher the radioactivity the higher the threat is to the environment and human health, so the HLW waste needs utmost shielding from the environment whereas the ILW mainly consist of metal fuel containing uranium and other metal components which have a life span of few decades and the LLW includes gloves and other minor equipment which are also of such nature that are required to shield and protect the workers and the public form exposure.[5] The main radioactive components in radioactive waste occurred through man-made activity such as usage in nuclear industry is caesium-137 and naturally occurring radioactive material is radium-226. Radioactive waste is classified according to activity level and the half-life of radionuclide it contains. This becomes the major factor to evaluate the degree of protection required to be taken in case of radioactive waste disposal. The higher the activity level and the time of half-life the more the precaution standards for the treatment and disposal.[6]

Radionuclide	**Half-life[7]**
Cobalt-60	5.2 years
Tritium	12.2 years
Radium-226	1600 years
Carbon-14	5730 years

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[3]IAEA, *The Principles of Radioactive Waste Management*, 111- F, SAFETY SERIES(1995); Lutz Strack, *The Safety Regime Concerning Transboundary Movement of Radioactive Waste and its compatibility with the Trade Regime of the WTO,* OECD(2003), https://www.oecd-nea.org/law/nlb/nlb-73/025_049.pdf

[4]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art.2 cl. h, Sep. 5, 1997.

[5]*Organization for Economic Cooperation and Development, Radioactive Waste Management in Perspective*, 19 NUCLEAR ENERGY AGENCY (OECD, 1996).

[6]*Radioactive Waste Management*, IRSN (2009) https://www.irsn.fr/EN/publications/thematic/Documents/irsn_booklet_radioactive_waste.pdf

[7]The time it takes for a radioactive sample to lose half of its activity.

Plutonium-239	24,110 years
Iodine-129	15,700,000 years
Uranium-238	4,470,000,000 years

Characterization of Waste- The classification is mainly very short-lived waste (VSLW), very low-level waste (VLLW), Low-and intermediate-level short-lived waste (LILW-SL), Low-level long-lived waste (LLW-LL), intermediate-level long-lived waste (ILW-LL), high-level and long-lived waste (HLW-LL).

1. Very short-lived waste (VSLW)- this mainly includes medically applied nuclear energy, for diagnosis and therapy having half-life of less than 100 days.
2. Very low-level waste (VLLW)- this mainly comes up in decommissioning operations, consisting of dismantled equipment. It is generally not considered harmful for the people or the environment. It contains materials such as plaster, bricks, metals etc. generated during rehabilitation and dismantling operations.
3. Low-and intermediate-level short-lived waste (LILW-SL)- this originates from research laboratories.
4. Low-level long-lived waste (LLW-LL)- includes waste contaminated by radium from the radioactive raw material or graphite waste. The radioactive content in these waste does not exceed 12 GBq/t beta-gamma activity. It does not require shielding during handling or transportation. It comprises some 90% of the volume but only 1% of the radioactivity of all radioactive waste.[8]
5. Intermediate-level long-lived waste (ILW-LL)- this mainly originates from spent fuel reprocessing and nuclear facility maintenance work. It requires shielding during transportation and handling. It comprises of resins, metal fuel cladding, chemical sludges, and other contaminated material from nuclear reactor decommissioning.
6. High-level and long-lived waste (HLW-LL)- this is mainly the fuel that cannot be recycled and is mainly spent fuel. This requires both cooling and shielding. It arises from the burning of uranium fuel from the nuclear reactor. It contains the fission products and transuranic elements generated in the core of the nuclear reactor. It Contains 99% of radioactivity.

III. INTERNATIONAL LEGAL REGIME IN NUCLEAR WASTE

Nuclear disposal safety management got into purview after the mishap of 1986 at the Chernobyl disaster, which pointed out the deficiencies in the international regulatory regime as well as the safety aspects of handling active nuclear. The accident of Chernobyl on April 26,1986 became an eye-opening event, as prior to this incident there were fewer international legally binding commitments governing the aspect of nuclear safety. It was thought of as a domestic affairs of state, as the power plants were within the territory of a country and therefore international regulation was not necessary. But after the 1986 incident the trans-boundary effect of the nuclear disaster was witnessed in many areas. In addition, this incident of 1979 at Three Miles Island, in United States (Pennsylvania) also caused a rethinking in developing a nuclear law and regulation after which numerous international treaty and non-binding commitments were enacted within International Organization. The deficiency was also highlighted in the year 2001, in a terrorist attack in USA, whereby the terrorist used various radioactive or nuclear weapons and USA had no proper strategy to combat the loss. Therefore, the major step to strengthen the international legal framework on nuclear security was taken after 2001. But it is imperative to note that the international regime on nuclear had never been emptied as we had important convention like the Agenda 21 by the United Nations Conference on Environment and Development in Rio de Janeiro; International Atomic Energy Agency (IAEA) Safety Fundamentals entitled "The Principles of Radioactive Waste Management" (1995); the Convention on Early Notification of a Nuclear Accident (1986); the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1994); The Convention on Nuclear Safety (1994); Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (1986); the Convention on the Physical Protection of Nuclear Material (1980) etc. that dealt in the nuclear safety.

Despite the development brought forth in the laws of nuclear safety, with the recent advancement and development, the dependency on nuclear energy has tremendously weakened the regulatory framework. Growing numbers of nuclear power reactors and associated facilities, increased production and transport of nuclear materials, higher levels of nuclear waste and spent nuclear fuel, and the possible re-emergence of spent fuel reprocessing geared towards sustaining a so-called “plutonium economy” make it vital that the global governance regime for nuclear safety and security be as

[8]*Radioactive Waste Management*, WORLD NUCLEAR ORGANIZATION (Apr., 2018), https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx

effective as possible.[9] The regulatory framework in Nuclear power mainly deals with the binding and non-binding legal instruments, IAEA guidelines, and nuclear safety standards, domestic and other regulatory mechanisms.

The Convention on Nuclear Safety 1994- It was adopted on 17 June 1994 and had 61 state parties. The main purpose of this convention is to govern safety of nuclear power plants, which was later changed to include the new safety regime with respect to the trans-boundary effect of unsafe nuclear usage. The convention does not provide for a detail set of safety standards rather makes it an obligation on the state to take necessary legislative, regulatory and administrative steps to ensure nuclear safety.[10] Article 5 of the convention makes it mandatory for the countries to make detailed report on its fulfillment of obligations set under the convention. The Preamble of the Convention itself includes safety provision with respect to the disposal of nuclear waste, it states-

> "*Affirming the need to begin promptly the development of an international convention on the* ***safety of radioactive waste management*** *as soon as the ongoing process to develop waste management safety fundamentals has resulted in broad international agreement*;"[11]

Besides this Article 15 of the Convention provides for the steps to be taken to ensure that the workers and the public are not exposed to the nuclear radiation which is affirmed with respect to waste management in Article 19 clause (viii) relating to the operation which states that-

> "*Each Contracting Party shall take the appropriate steps to ensure that: the* ***generation of radioactive waste resulting*** *from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary* ***treatment and storage of spent fuel and waste directly related to the operation*** *and on the same site as that of the nuclear installation take into consideration conditioning and disposal."*[12]

The domestic country operating nuclear power plant has to ensure that the public is not exposed and no risk is caused to humans or the environment. The convention being the first in its operation does not specifically talk about waste management but binds the contracting parties to ensure safety in usage of nuclear energy. The Indian Government ratified the Convention of Nuclear Safety, 1994 on 31st March 2005. The obligation as under the Convention of Nuclear safety is based on the principles of IAEA safety fundamental documents "Fundamental Safety Principles (SF-1)" and cover for instance, siting, design, construction, operation, the availability of adequate financial and human resources, the assessment and verification of safety, quality assurance and emergency preparedness.[13] "India submitted its first national report for the Convention for the 4th Review Meeting in 2008. Subsequently national reports were submitted for the 5th Review meeting in 2011, 6th Review Meeting in 2014 and 7th Review Meeting in 2017. Apart from these India also submitted a national report for the 2nd Extra-ordinary meeting held in August 2012."[14]

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 1997- The Joint convention was adopted on 5th September 1997, becoming the first ever convention to deal with the matter of safety of spent fuel and radioactive waste management. It was adopted by a diplomatic conference convened by the International Atomic Energy Agency. It brought the purview of radioactive waste management on a global scale, by establishing fundamentals of safety principles to be followed for radioactive waste management. The scope of the joint convention includes waste from nuclear reactors, waste from military and defense purposes, nuclear facilities etc. The Joint Convention mainly consists of safety of radioactive waste management, safety requirements, regulatory body, quality assurance, emergency preparedness, radiation protection, trans-boundary movement etc. The preamble of the Joint Convention clearly mentioned about sound implementation on waste management, informing public on issues of radioactive waste management, recognizing State's responsibility in radioactive waste management and banning import of such radioactive waste any other concerning issues. The objective of the convention was to prevent any accident and to maintain high level safety standards in every nation. The Joint Convention, Chapter III dealt with the radioactive material general safety requirement which the contracting parties must follow. The main issues that the contracting

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[9] Aaron Shull, *The Global Nuclear Safety and Security Regimes*, 2 NUCLEAR ENERGY FUTURE, THE CENTRE FOR INTERNATIONAL GOVERNANCE INNOVATION 3 (Nov. 2008).
[10] The Convention on Nuclear Safety, art. 4, June 17, 1994.
[11] The Convention on Nuclear Safety, pmbl, June 17, 1994.
[12] The Convention on Nuclear Safety, art.19 cl. viii, June 17, 1994.
[13] Convention on Nuclear Safety, AERB- GOVERNMENT OF INDIA (1983), https://www.aerb.gov.in/english/convention-on-nuclear-safety
[14] *Id.*

parties has to ensure the minimization and reduction of the residual heat generated, to ensure that the waste generated is minimal, to provide for effective protection and to adopt protective methods approved by the regulatory body for such protection, to take into account all the effects of the hazards that can be imposed on the future generation.[15] Other Articles of the joint convention include development of facilities, standards for design and construction[16], assessment of safety of these facilities[17], institutional measures[18], quality assurance[19], emergency preparedness[20], legislative and regulatory framework[21], trans-boundary movement.[22] India has not ratified the Joint Convention as of now, but follows the IAEA guidelines.

The International Atomic Energy Agency (IAEA)- It promotes the adherence and implementation of various nuclear treaty drafted, which includes the Convention on Nuclear Safety, Joint Convention of Radioactive Waste Management, Convention on Early Notification of a Nuclear Accident, Convention on Assistance in the case of a Nuclear Accident or Radiological Emergency. The IAEA also gives guidelines which the member countries have to follow for the dumping and treatment purpose. The limits and procedure prescribed are with respect to marine dumping, emergency handling and other standards of treatment before disposal. Under Article III of the statute, IAEA is authorized to adopt measures for setting standards for the safety of the environment and human health from any kind of radioactive material. The main objective of the Agency's statute is to *"accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".[23]* The safety standards issued by the IAEA has to be followed by every member state, in addition to their domestic laws. The IAEA safety fundamentals is divided in six chapter consisting of matters in relation to[24]-

1. **General Introduction-** consisting of basic meaning and importance of disposal, its harmful effect on environment etc.
2. **Protection of people and environment-** This chapter talks about the importance of protecting the biosphere, marine life, and other natural resources from such types of waste. The life of the people shall not be endangered by any activity of the operators is the key goal of IAEA standards. It aims to work in periods when the Nuclear Power Plant is operational, in which proper monitoring is done to check the safety standards, and also to minimize the waste generated by these activities. It also issues guidelines for post-closure period radiation protection.
3. **Safety requirement for planning for the disposal of radioactive waste-** These sets the responsibility of the operator to properly dispose of the radioactive waste discharged from the use of nuclear energy. It issues government responsibilities, responsibilities of the regulatory body, and the responsibility of the operators in ensuring safety of waste disposal. While setting the responsibility is works in stipulation with the Joint Convention. Also, there are a total of 26 requirements that a member state has to follow in order to ensure safe disposal of nuclear waste, of which safety requirement disposal of radioactive waste has 10 requirements which are-
   i. ***Government Responsibility***: It is the responsibility of the member state government to ensure that the legal framework for the safety is allocated for the disposal facilities with respect of site, design, operation and closure. Every specification, financial responsibility and working of the regulators have to be set. A well-

[15]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art. 11, Sep. 5, 1997.
[16]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art. 14, Sep. 5, 1997.
[17]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art.15, Sep. 5, 1997.
[18]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art. 17, Sep. 5, 1997.
[19]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art. 23, Sep. 5, 1997.
[20]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art. 25, Sep. 5, 1997.
[21]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art. 19, Sep. 5, 1997.
[22]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art. 27, Sep. 5, 1997.
[23]The Statute of IAEA, art. 2, Oct. 23, 1956.
[24]*IAEA Safety standards for protection people and Environment- Disposal of Radioactive waste,* IAEA-SSR-5 (2011), https://www-pub.iaea.org/MTCD/publications/PDF/Pub1449_web.pdf

versed radioactive waste management system should be made, in which the government has to define proper national policy, defined legal, technical and financial responsibilities etc.

ii. ***Regulatory body Responsibility***: The regulators have to work in consonance with the government. It has to provide guidance in the interpretation of national policy and to carry out such activities as are necessary to ensure that the conditions are met. It also provides for the procedure to be followed during authorization and licensing.

iii. ***Operators Responsibility***: The operators are also to work for the safety. They have to carry out safety assessments and to carry out evaluations of design, construction, operation and closure. It shall also be the responsibility of the operator to give information to the organization on the updates of the nuclear power plants.

iv. ***Importance of safety in the process of development and operation of a disposal facility-***_The fourth requirement is to make the operator rely on the importance of safety in the process of making and developing of the disposal facilities. This has to be followed in all steps starting from the inception of the closure or decommissioning.

v. ***Passive means for the safety of the disposal facility***- the operator must evaluate all the sites, design, by passive means and take appropriate steps.

vi. ***Understanding of a disposal facility and confidence in safety***

vii. ***Multiple safety functions***

viii. ***Containment of radioactive waste***

ix. ***Isolation of radioactive waste-*** The disposal facilities have to be made such that the sites provide for isolation of radioactive waste from the people and from the accessible biosphere. This isolations can be for a period depending on the type of waste.

x. ***Surveillance and control of passive safety features***

4. **Requirements for the development, operation and closure of a disposal facility-** These requirements include the step-by-step development and evaluation of disposal facilities, detailed safety assessment, documentation of safety case and safety assessment for records, site characterization, design specification, and procedure and guideline for construction, operation and closure of disposal facilities.
5. **Assurance of safety-** The waste acceptance at the disposal facility for packed or unpacked waste should be in accordance with the safety standards and the specification of that disposal unit. The modeling and testing on the waste should also be done with proper precautions and any anticipated operational occurrence and accidents should be meted up properly. Other requirements include monitoring programs at the disposal facility and having nuclear security measures.
6. **Existing disposal facilities-** All the existing disposal facilities shall be accessed periodically until a termination of license is given. All changes made in the safety guidelines have to be adopted by the facility. If the facility does not meet any of the requirements proper measures should be taken for the up gradation of safety.

IV. NUCLEAR WASTE MANAGEMENT

Radioactive waste management is a step initiated after radioactive waste is generated. It includes treatment, handling, conditioning, storage, discharge and lastly comes the disposal. As per the definition provided in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 1997:

"*radioactive waste management" means all activities, including decommissioning activities, that relate to the handling, pretreatment, treatment, conditioning, storage, or disposal of radioactive waste, excluding off-site transportation. It may also involve discharge.*[25]

Therefore, before disposal there are various other steps that have to be taken care of. The first ever radioactive disposal site was constructed in Oak Ridge, Tennessee, USA, in 1944 were more the 100 LILW disposal facilities have been put into effect and presently around 45 repositories are under construction in the IAEA member states.[26] There are various views when it comes to dealing with the radioactive waste, in practical sense some opinion lies that radioactive material can be disposed of and managed by proper mechanism while other believe that since the time for its dissolving and loosing radioactivity is very high so this could cause some level of problems for the environment. Therefore, the

[25]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art.2 cl. i, Sep. 5, 1997.
[26]Kong Won Han et. al., *Radioactive Waste Disposal: Global Experience and Challenges*, 39 IAEA BULLETIN(March 1997), online at http://www.iaea.org/Publications/ Magazines / Bulletin / Bull391 / bonne.html.

suggestion made in this regards the discontinuation of such waste production.[27] The rising concerns of radioactive waste has not only raised issues relating to environment but also political issues. This increase has evolved the concept of "Not in my Backyard (NIMBY)." This has gained the attention of the policy makers to make laws in order to ensure the dumping criteria in the countries. This particularly means that the country has gotten aware on the fact that the dumping cannot be made in other territory if the other country denies. The management of radioactive waste involves the process of treatment, conditioning, disposal which is done in a lined-up process which starts with the characterization of waste followed by sampling, monitoring, testing, heat treatment, clearance, discharge, storage etc. The waste treatment is done in three different zones, firstly the aqueous waste, then organic waste and thirdly the solid waste.

Aqueous waste	Radioactive organic liquid	Solid waste
• *Chemical precipitation* • *Ion exchange/sorption* • *Evaporation*	• *Incineration* • *Wet oxidation* • *Acid digestion* • *Distillation*	• *Decontamination* • *Compaction* • *Cutting* • *Crushing* • *Incineration* • *Shredding*

Before disposal, radioactive material goes through various phases to extract all that is usable. The first step is treatment and conditioning in which changes are made in waste streams, so that it is not harmful. The process involves filtration, compacting, reducing in volume, incineration, ion exchange and precipitation to induce changes in composition.[28] Incineration is a process used to combust the waste to reduce the volume. The gases and fumes produced during this process are treated and filtered prior to out letting in the atmosphere. These emissions are as per the international standards and national regulation as specified by the IAEA safety guidelines. After this process the resultant ash is further conditioned through methods such as cementation or bituminization prior to disposal.[29] Conditioning is another waste volume reducing technique by immobilization of waste in containers for easy transportation and handling of waste. Compacting also is a process for mainly solid industrial LLW and transuranic waste. Cementation through the use of specially formulated grouts provides a means to immobilize radioactive in sludges or fragmented solids. These solid waste are then placed in a container and grouts are added and then these are allowed to set. Germany, USA and UK use this technology for reduction of volume of radioactive waste. Vitrification is a process currently in operation in France, Japan, Russia, USA and UK and is seen as a suitable and adequate process for management of separated HLW arising from reprocessing. In this method the HLW is kept separately in a borosilicate glass used as a matrix material. The capacity of one vitrification plant is about 1000 tons a year and remains in operation for about three decades.[30] Synroc and composite waste forms are also method in which the radioactive material is pressed at over 1200 C and 150 MPa. It gives a free-flowing powder granules which are then placed in steeled cans. They are then converted into dense solid waste ready for disposal.

Electrochemical treatment of radioactive waste- The ET or electro remediation or electrokinetic remediation process in which a physicochemical technology is used by the by the electrochemical transformation through which the organic or inorganic waste are remediated. This process offers many advantages such as removal of pollutants by direct application of electricity to the soil.[31] It works by applying electrodes into the waste and then direct application of low voltage gradient through them. This process mineralizes the organics into carbon dioxide and water, without discharge of any toxic. Some of the common examples of use of this technology is when combustible waste contaminated with 137Cs and 134Cs, was generated at Fukushima, due to the Tsunami, on being incinerated produced a large amount of radioactive ash.

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[27]JaBae, *Environmental security in East Asia- The Case of Radioactive Waste Management*, 29ASIAN PERCEPTION, 73-97 (2005).
[28]*Radioactive Waste Management*, WORLD NUCLEAR ORGANIZATION (Apr., 2018), https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx
[29]*Treatment and Conditioning*, WORLD NUCLEAR ORGANIZATION (June, 2017), https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/treatment-and-conditioning-of-nuclear-wastes.aspx
[30]*Supra* note 29.
[31]V. Valdovinos , *Treatment Methods for Radioactive Wastes and Its Electrochemical Applications,* INTECHOPEN (Mar. 26, 2014), https://www.intechopen.com/books/environmental-risk-assessment-of-soil-contamination/treatment-methods-for-radioactive-wastes-and-its-electrochemical-applications

Storage is done at various level of waste management process. It keeps it isolated from the external environment, which also allows the radioactivity to decay. These facilities are mainly on the site of the power plant and are stored after treatment. Disposal of radioactive waste is the final step in the management of radioactive waste. It involves the confinement of the radioactive waste in repositories so it is not present in the open. It is basically an isolation of waste from the biosphere. Article 2 (d) of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 1997 defines disposal as- ""*disposal" means the emplacement of spent fuel or radioactive waste in an appropriate facility without the intention of retrieval;"*[32]

The disposal of each type of waste is done differently depending on what kind of waste is generated. In dealing with LLW waste is disposed of immediately after packaging. This waste is very well treated all over the world, which amounts to 90% of all the waste. The HLW waste is stored and allowed to decay for a long time. Separate facilities are meant from their disposal on site of the reactor while the ILW waste that contains long-lived radioisotopes are firstly stored geological repository. Some of the commonly accepted disposal option are-

OPTION	**SUITABLE WASTE TYPE**	**EXAMPLES**
Near-surface disposal (10m)	LLW and ILW (short-lived)	Used in Finland, UK, USA, Japan
Deep geological disposal (250m-1000m for mined repositories) and 2000m-5000m for boreholes.	ILW (long-lived) and HLW	USA, other preferred sites includes, France, Sweden, Finland. Geological repository sites in UK and Canada.
Specific landfill disposal	VLLW	USA, Canada, France
Borehole Disposal	Small amount of waste of VLLW.	East-Asia.

Near-Surface disposal- This type of disposal is done in two types of facilities, one at ground level and the other below ground level. The IAEA gives the guidelines which countries have to follow while developing these disposal facilities. The term near-surface has replaced shallow land and ground disposal as used earlier. These types of disposal facilities are considered safe but can be affected by long-term climate changes such as glaciation. These includes step of Stone-lined earth trenches, Reinforced concrete trenches, Tile holes, Surveillance, Performance assessment, Safety assessment, interim storage of vitrified waste. These types of facilities are used for LLW and short-lived ILW of half-lives up to 30 years.

i. **Near-surface disposal at ground level-** These facilities may be above or below ground level with the level above would be of few meters thick. In these facilities waste is placed in constructed vaults and they are backfilled. The vaults are then covered and caped with an impermeable membrane and topsoil. This facilities include drainage system and gas-venting system in the facilities.
ii. **Near-surface disposal below ground level-** These are shallow disposal requiring unground excavation of caverns. These are at least 10M below the ground surface and are accessed through drifts. Countries like Sweden and Finland use this type of repository for short-lived radioactive waste. Sweden near-surface disposal facility is operated by the Swedish Nuclear Fuel and Waste Management Company, wherein the depth is around 50m. In Finland, they use repository at Olkiluoto for LLW and ILW waste. This has been in operation in Finland since 1992. The depth of these repositories are about 100 meters.

Deep Geological Disposal- These includes depositing in stable geological formations. The waste material is isolated by a combination of both engineered techniques and natural barriers like rock, salt and clay. There is no obligation of maintaining of these depositors by the future generation. These are considered to be the best way to prevent the radionuclides from reaching humans and the environment by waste packaging, engineered repository and geology. The technique has proved efficient due to the fact that the waste so deep are devoid of oxygen therefore, minimizing the possibility of chemical mobilization of waste. Countries like Australia, Argentina, France, Japan, UK, USA, Switzerland, Sweden, Canada prefer deep geological disposal over other nuclear waste management. The only purpose-built deep geological repository that is currently licensed for disposal operations is the Waste Isolation Pilot Plant (WIPP) in the USA.[33]

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[32]Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, art.2 cl. d, Sep. 5, 1997.
[33]*Storage and Disposal of Nuclear Waste*, WORLD NUCLEAR ORGANIZATION (Oct., 2018), https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx

Sea-disposal and Sub-seabed disposal- In Sea disposal the radioactive waste is dropped in the sea in a way that it either sinks to the seabed intact or disperses and direct release into sea or implodes at depth of the sea. Over time the radionuclides present are dispersed and diluted into the sea mainly by natural decay or by the process of sorption. This type of method is highly condemned and is banned by various international agreement. The Basel Convention, IAEA fundamental guidelines and the London Convention 1972, prohibit sea or ocean disposal due to its harmful effect on the marine life and the carry away of radioactive substance to other territories. This method has been earlier used by UK, Japan, Italy, Netherlands, Sweden. In Sub-seabed disposal option, the waste is kept in the repository below the seabed or the burial in deep ocean sediment which is accessible from the uninhabited islands or offshore structure. Countries like Sweden and UK have considered these type of repositories. This has been proved sufficient as compared to other forms of sea disposal due to the fact that monitoring is easy. Two different techniques are used in these deep ocean sediments, one is penetrators and other is drilling placements. Other methods of disposal are-

OPTION	COUNTRIES	OPERATION	USED FOR
Long-term above ground storage	France, UK, USA, Switzerland	Not implemented anywhere.	
Disposal in outer space	USA	Abandoned due to cost and risk	Proposed for wastes that are highly concentrated
Rock-melting	UK, USA, Russia	Not implemented anywhere.	Proposed for wastes that are heat-generating.
Disposal at subduction zones	USA	Not implemented anywhere and even not permitted by International agreements.	
Disposal in ice sheets	USA	Rejected by countries that have signed the Antarctic Treaty or committed to providing solutions within national boundaries.	Proposed for wastes that are heat-generating)
Deep well injection	Russia	Adopted by Russia for LLW and ILW, Abandoned in USA	For liquid wastes)

V. THE STATUS OF NUCLEAR WASTE MANAGEMENT IN INDIA AND USA

Different countries have adopted different radioactive waste management technique as per their capabilities and technology. Indian government has been working very efficiently in the disposal of nuclear waste and has enacted Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 under the Atomic Energy Act, 1962. The Atomic Energy Regulatory Board (AERB) has been entrusted with the duty to prescribe rules and regulation and to set standards for radioactive waste management which are environmentally and economically sustainable. These standards are basically not national and international standards relating to quality assurance, decommissioning, siting, design, construction etc. The current regulations which is in consonance with the limits prescribed by the International Commission on Radiological Protection (ICRP) and in order to promote the sustainable development of the society, it has various provisions, one such being that it states that the radiation dose that is to be exposed to the public living near the nuclear power plant shall not exceed annual limit of 1 mSv (i.e 1000 micro-Sievert).[34] The waste generated in India comes from mainly three regions-

1. **Waste from Nuclear power plants**
2. **Waste from fuel cycle facilities other than NPPs, and**
3. **Waste from Medical, Industrial and Research Facilities.**

In order to make the nuclear waste disposal environment friendly and sustainable, AERB maintains a close relation with all these sectors, whereby India has adopted fuel cycle option, including reprocessing and recycling, while the HLW is emplaced in geological disposal facilities. NPPs are also supposed to submit return of waste disposed to the AERB. Also, the Environment Survey labs under BARC are instituted which work independently to check on the impact of release into the environment. The Indian radioactive waste disposal policy is based on the ***waste volume minimization, recycle and reuse techniques*** for which international standards set by IAEA are followed. No waste is released or disposed without

[34]*Radioactive Waste Management*, Government of India, AERB, https://aerb.gov.in/english/regulatory-facilities/radioactive-waste-management

following these regulations.[35] The management of waste in India is very comprehensive and in consonance with IAEA, which separately deals with Gaseous waste, solid waste, liquid waste and HLW waste. The gaseous waste is dealt at the very source of inception, by methods such as absorption or filtration. Liquid wastes are treated in suitable inert matrices, by method of filtration, absorption, evaporation, ion exchange, reverse osmosis etc. The Solid wastes are then disposed off by using techniques like the compaction and incineration, while HLW is mainly vitrified by storing it in Solid Storage Surveillance Facility for an interim period. With the advancement of technology India has planned to convert the long-lived radio isotope in short-lived species by planned burning in the fast reactors or the Accelerator Driven Sub critical systems. ***It is imperative to note that India is the first country to use the by-product from the waste***. The fission products like Cs-137 and Sr-90 present in the waste are recovered and are later employed in medicinal purpose or external irradiators.[36]

The facilities such as mining areas are regulated under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987. It follows the safety codes on Management of Radioactive Waste (2007), AERB Safety Guide on Classification of Radioactive Waste (2011) and Management of Radioactive Waste from Mining and Milling of Uranium and Thorium (2007).[37] And for the management of radioactive sources coming out of medical and other research facilities like agriculture, research or industry of paper, plastics, glassware the AERB safety guidelines for management of spent radioactive sources and radioactive waste Arising from the Use of Radionuclides in Medicine, Industry And Research, including Decommissioning of Such Facilities, is followed which provides for principles like-

1. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987-

This rule has been made under Section 30 (1), (2) (i) and Section 17 (1), of the Atomic Energy Act, 1962, whereby the Central government has power to make rules in the radioactive disposal activities. The rues restrict any person to dispose the radioactive waste without proper license and authorization and such authorization has to be attained after giving due concern to the adequacy in the disposal facility and regards to human health and environment.[38] This rule makes the duty of the authorized person under the rule, to comply with the provision of the Radiation Protection Rules, 1971. This also works as a guide for the radiological safety office to work in the regards as to ensure and maintain records for the proper disposal of nuclear waste.[39] The RSO, is empowered to test, investigate and initiate prompt and remedial measure for the proper protection of radiation hazards. The rule basically empowers the Central government to issue authorization to person, hospitals and other operators for disposing nuclear waste. This has to be in consonance with the AERB safety code, and DAE's regulations. Together with these rules India follows Factories Act, 1948 and Atomic Energy (Factories) Rules, 1996.

2. Atomic Energy Regulatory Board (AERB) Safety Code-

- ***Management of Radioactive Waste (Aerb Code No. Aerb/Nrf/Sc/Rw)***- This safety code is for the NPPs. They have to work in the area of protection of environment, responsibilities associated with RWM and predisposal management for both near surface and geological disposal. The AERB also sets safety code for quality assurance to be made for siting, construction, decommission etc. The safety code provides for the method of treatment, conditioning to be done for the various forms of waste. It provides for a simple framework to be followed which includes-
- ***Management Of Radioactive Waste from mining And Milling of Uranium and Thorium (AERB Safety Guide No. AERB/Nf/Sg/Rw-5)*** - this deals with the safety procedure for non-NPPs. This also provides the same guideline as the above.
- ***Management of Spent Radioactive Sources and Radioactive Waste arising From the Use Of radio nuclides In Medicine, Industry And Research, Including Decommissioning Of such Facilities. (AERB Safety Guide No. AERB/Rf/Sg/Rw-***6) –These are basically safety codes for LLW or short-lived ILW waste generated from areas such as medicine, industry and research laboratories. This provides provision for safety during decommissioning, transportation, disposal of all forms of waste together with quality assurance, documentation and radiological surveillance.

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[35]*Disposal of Nuclear Waste*, Department of Atomic Energy, GOI, PRESS INFORMATION BUREAU (July 19, 2018), https://pib.gov.in/newsite/PrintRelease.aspx?relid=180732
[36]R. Lakshmanan, *Disposal of Radioactive waste, Unstarred question, Rajya Sabha,* DOE (Aug. 3, 2017), http://dae.nic.in/writereaddata/parl/monsoon2017/rsus2086.pdf
[37]*supra* note at 35.
[38]Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, § 3 (1987).
[39]Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, § 12 (1987).

USA has an installed nuclear capacity of around 99, 221 MW. It is one of the major players in generating power from nuclear energy contributing to 20% of the power source in USA.[40]The waste is mainly generated from three areas, one is commercial, defense and nuclear weapons. The Department of Energy, U.S. Environmental Protection Agency and US Nuclear Regulatory Commission works in consonance with the Nuclear Waste Policy Act, 1982 for the disposal of nuclear waste in USA. USA was among the first countries to ratify the IAEA guidelines in the year 1957. In the USA, Waste Isolation Pilot Plant (WIPP) at New Mexico has been one of the most renowned disposal facility, used for defense-related transuranic (TRU) waste mainly consisting of ILW or LLW. This plant was closed down for three years after the 2014 radiological release incident from a single waste drum happened. USA is not among one of the country in which nuclear waste has been efficiently dealt. As per the Waste Isolation Pilot Plant Land Withdrawal Act of 1992, the official capacity of WIPP is 175, 570 cubic metre, but as per 2018 a total of 93,500 cubic metre has already been disposed with around 78,000 cubic metre of waste officially slated for disposal.[41]

The Nuclear Waste Policy Act, 1982 works for the safety disposal of HLW. The major aim provided for proper responsibility assign to DOE for site, construction, operation and closure of NPPS. In order to implement this Act, the DOE also established an office of Civilian Radioactive Waste Management for the proper management of radioactive waste and to look into the follow up with the International Standards. The preamble of the Act itself states that the objective is to build repositories for the proper disposal of HLW. The Act provides for ways of disposal, applicability, interim storage measure, authorizations Sire characterization, termination etc. The Act is also useful for research and development for disposal of HLW and to find alternative for the permanent disposal of HLW.

Yucca Mountain Case- The Yucca mountain case in Nevada a desert 100 miles from Las Vegas is a site proposed for deep geological repository for nuclear waste, but this project has not meted its end due to political reasons. The project began in the year 1980's and till now the US government has spent over $15 billion on this project.[42]It has dense volcanic rock with small pores, preventing any waste leaking effectively shielding the waste. The DOE approved the Yucca Mountains in the year 1987 for the opening of possible repository sites but was openly criticized by the residents and the politician due to safety reasons. Also, the mountains were held to be of some traditional significance, which became a major reason for the in-operation. The current status is that the repositories are not operational hanging between the political and legal issues as of May, 2018[43].

VI. CONCLUSION

After conducting safe and successful operation in nuclear fuel facilities, and efficiently managing the nuclear waste, India has achieved self-reliance in the radioactive waste management. The Indian waste management has been in consonance with the international standards set by various international organizations. India has proved its efficiency by becoming the first country to come up with the uses of by-products of the wastes generated, which clearly show the country's endeavors towards sustainable development while production of energy and its waste management. The fact that India's advancement in both technology and the natural human resource has made India to sustain in each aspect of getting the nuclear facility to function efficiently. The governments work to minimize waste, and initiatives to start up recycle and reusing of the nuclear waste (nuclear fuel cycle) has brought greater perspective to deal with the issue of the waste management and thereby striving towards sustainable development. The only lacuna in the nuclear waste management of India is that the inadequacy of proper legislation that is specifically related to the aspect of the nuclear waste management. But the reports of Department of Atomic Energy as of 19th July 2018, the AERB specified that no incident of leakage or discharge of radioactivity through unauthorized route or beyond the limits have from came up from any nuclear power plant for the past three years. This shows that India has been very well in dealing with the nuclear waste disposal. The waste as divided into LLW, ILW and HLW are treated in consonance with the national norms and International Standards. The major priorities in deciding these norms are set in accordance with the environment and radiation protection goals. In order to bring their functions in line with the sustainable development, the primary goal of Indian government has been to recover actinides, to recycle and reuse and on the fission products. The development of newer methods for the ILW and LLW has been also on prerogative of Indian government. In the case of HLW vitrification in borosilicate matrix is used using induction heated metallic melters in the plants at Tarapura and Trombay.

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[40]Madeleine Jennewein, *Looking for a Trash Can: Nuclear waste management in the United States*,SITN BLOG HARVARD EDUCATIOn (May, 2018), http://sitn.hms.harvard.edu/flash/2018/looking-trash-can-nuclear-waste-management-united-states/

[41]Luisa Kenausis&Scoville Fellow, *Nuclear Waste Issues in the United States*, *Centre for Arms Control and Non-Proliferation (*Aug. 22, 2018), https://armscontrolcenter.org/nuclear-waste-issues-in-the-united-states/

[42]Kenausis, *supra* note at 42.

[43]Jennewein, *supra* note at 41.

Currently, in India there are seven near surface disposal facilities located in various parts of the country as a part of the NPPs used for the ILW and LLW. National wide screening and monitoring is conducted for these near-surface depositories to check its performance assessment. For the HLW waste an interim storage facility is operation which keeps in HLW waste for over thirty years or more. The Department of Atomic Energy also has been working very efficiently in this area and has recently developed all essential remote-handling gadgets which will prove efficient for the operation and maintenance of waste management systems and during assembling and decommissioning.[44] Overall India's endeavors in the nuclear waste management have to be regarded as a self-sufficient and self-reliable management and are in consonance with the concept of sustainable development. The various rules enacted under the Atomic Energy Act, 1962 and the regulators such as DAE and AERB have shown commendable work in making provision for the safety of human as well as the environment. India has also been following the IAEA guideline and has ratified the Convention of Nuclear Safety. This has led India to achieve robust disposal frameworks which also promotes the sustainable development.

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