

Forum: Environmental Commission (EC)
Issue: Ensuring the Safe Handling of Radioactive Waste
Student Officer: Stella Athanassoglou
Position: President

PERSONAL INTRODUCTION

Dear delegates,

My name is Stella Athanassoglou and I am currently attending the 11th grade in the German School of Athens. This year I have the honor to serve as the President of the Environmental Commission in this year's PSMUN conference. Seeing as how this is our first introduction, I would like to welcome you all to our committee and cannot wait to see and hear all your different ideas and points. I am sure you will give your best efforts and do good preparation. Together, we will explore the various facets of radioactive waste management, examining its environmental, social, and economic dimensions.

We find ourselves at the forefront of addressing critical global issues. The Environmental Commission tackles pressing matters, such as climate change, biodiversity loss, and, of course, our current focus: "Ensuring the Safe Handling of Radioactive Waste." This topic is of paramount importance in today's world, impacting both the environment and global security. To kickstart our discussions, this guide will introduce you to the agenda's first topic, offering insights into major countries' positions, past initiatives, and potential solutions. But keep in mind that this manual is only the beginning; I encourage you all to carry out your own research and contribute your distinct viewpoints.

While the challenges we face are significant, I am confident that with your collective wisdom, determination, and passion for positive change, we can shape actionable resolutions that promote a safer, sustainable, and brighter future for all and work hand in hand towards a world where the safe handling of radioactive waste is no longer an aspiration but a reality. Our goal is to hear opinions from all parts of the globe while evaluating and debating so I would appreciate seeing your interest and actively participating during the conference.

Please do not hesitate to contact me at: stellaathanassoglou@gmail.com . I wish you the best of luck and cannot wait to meet you all in March!

Best regards,

Stella Athanassoglou

INTRODUCTION

Nuclear power, a pivotal component of the evolving world of science and technology, offers substantial benefits such as reduced carbon emissions, increased energy output, and enhanced energy security. However, these advantages come with a profound responsibility: the safe handling of radioactive waste. In order to mitigate possible threats and safeguard the well-being of future generations, strong management techniques are required to address the enormous environmental and public health concerns posed by radioactive waste.

Radioactive waste, originating from a multitude of sources including nuclear power plants, hospitals, research institutes, and industrial activities, presents a perilous and intricate challenge. How people can effectively handle, transport, and ultimately dispose of this hazardous material while minimising harm to both humanity and the environment is a paramount concern that requires careful consideration.¹ The fundamental issue at hand is the long-term storage of radioactive waste, as some of its isotopes can remain dangerous for centuries or even millennia.² This means that even after many decades or even centuries, it is dangerous to approach such elements as they can still pose a threat to humans. A complex undertaking that necessitates not only scientific and technological prowess but also international cooperation and unshakable dedication is finding a careful balance between our urgent need for sustainable energy solutions and the preservation of the health of our planet.

To address these complex challenges, we must consider critical issues such as knowledge transfer to developing countries, equitable duty allocation, and the legal obligations of participants within the commercial nuclear sector. In order to ensure the safety of present and future generations, it is imperative that comprehensive policies be crafted to cover the entire lifecycle of radioactive waste, from its initial production to its ultimate disposal. This comprehensive approach ensures a holistic understanding and management of the issue. Crafting a unified strategy for the safe and responsible treatment of radioactive waste, amidst differing national interests and agendas, mandates diplomacy, teamwork, and pragmatic problem-solving.

The conference's theme, "Paradox of Progress," closely aligns with the topic of "Ensuring the Safe Handling of Radioactive Waste." This alignment underscores how technical advancements introduce new challenges to our ever-evolving world. Safely managing radioactive waste is a critical imperative as we strive for sustainable energy

¹ "IAEA Safety Standards Disposal of Radioactive Waste." www.pub.iaea.org/mtcd/publications/pdf/pub1449_web.pdf.

² "Storage and Disposal Options for Radioactive Waste - World Nuclear Association." *World Nuclear Association - World Nuclear Association*, world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx.

solutions through nuclear power. This highlights the delicate balance between progress and its inherent contradictions, prompting us to delve deeper into the complexities of our choices in pursuit of a safe and sustainable future for all delegates to explore.

In conclusion, ensuring the safe management of radioactive waste is a significant problem for the whole world community. All nations must cooperate and put policies into place that not only assure the appropriate treatment of radioactive waste but also encourage openness and collaboration in this effort. Failure to do so might have disastrous effects on the environment and general welfare, thus, the handling of this issue being imperative.

DEFINITION OF KEY TERMS

Natural Rock Formations

“A rock formation is an isolated, scenic, or spectacular surface rock outcrop.” Geological structures like underground salt or granite formations that can be used as repositories for storing radioactive waste safely. They provide a barrier against the release of radiation.³

Waste Canisters

“Also known as waste containers or storage casks, play a pivotal role in the safe handling and storage of radioactive waste.” These specialized containers are designed and engineered to securely contain radioactive materials, preventing their release into the environment and safeguarding human health.⁴

Bentonite Clay Buffers

“A layer of bentonite clay placed around waste canisters to create a physical and chemical barrier.” It helps isolate and shield the waste, ensuring safe storage by limiting the movement of radioactive materials.⁵

³“Rock Formations.” *Natural Atlas*, 19 July 2021, [naturalatlas.com/rock-formations](https://www.naturalatlas.com/rock-formations).

⁴ “Waste Container Definition.” *Law Insider*, www.lawinsider.com/dictionary/waste-container

⁵ “J.M. Huggett, in *Encyclopedia of Geology*, 2005 Illitization in Bentonites.” www.sciencedirect.com/topics/earth-and-planetary-sciences/bentonite.

Radioactive Contamination

“The presence of radioactive substances in an area where they are not desired, posing risks to human health and the environment.” Proper containment and disposal of radioactive waste are essential to prevent radioactive contamination. If waste leaks or is not stored securely, it can contaminate soil, water, and air, leading to health risks and environmental damage.⁶

Nuclear Fuel

“Material used in nuclear reactors to produce energy through controlled nuclear reactions.” After nuclear fuel has been used in reactors, it becomes "spent fuel" or "high-level radioactive waste." Proper handling and disposal of spent nuclear fuel is crucial for safety.⁷

Radiation Sickness

“Radiation sickness is a set of symptoms, such as fatigue, vomiting, unconsciousness and even death that can occur when a person is exposed to high doses of ionizing radiation over a short period.” Ensuring safe handling of radioactive waste involves preventing exposure to radiation to avoid radiation sickness.⁸

Ionizing Radiation

“High-energy radiation that can ionize atoms and molecules, potentially damaging living cells.” Radioactive waste emits ionizing radiation, necessitating safe containment and disposal methods to protect people and the environment.⁹

Decay Rates

Decay rates, in the context of radioactivity, refer to the speed at which radioactive isotopes transform into more stable non-radioactive elements through the process of radioactive decay, typically measured as the time it takes for half of a given quantity of a radioactive substance to decay. “The rate of decay, or activity, of a sample of a radioactive substance is the decrease in the number of radioactive nuclei per unit time.”¹⁰

⁶ "Radioactive Contamination and Radiation Exposure | CDC." *Centers for Disease Control and Prevention*, 7 Apr. 2022, www.cdc.gov/nceh/radiation/emergencies/contamination.htm.

⁷ "Nuclear Fuel." *Energy Education*, energyeducation.ca/encyclopedia/Nuclear_fuel.

⁸ "Radiation and Health." *World Health Organization (WHO)*, www.who.int/news-room/questions-and-answers/item/radiation-and-health?gclid=CjwKCAjwgZCoBhBnEiwAz35RwrCyZHIZ3N8uxbgykL0lcPRo8LOZHv4eh-GZiPsvAcwTCJvw4L9BKhoCzA8QAvD_BwE.

⁹ "What is Ionising Radiation?" www.arpansa.gov.au/understanding-radiation/what-is-radiation/ionising-radiation.

¹⁰ "21.4: Rates of Radioactive Decay." *Chemistry LibreTexts*, 19 June 2021, chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_Chemistry_-

BACKGROUND INFORMATION

Nature and Sources of Radioactive Waste

Radioactive waste, encompassing any material containing radioactive elements or contaminated with radioactive substances that have outlived their utility, arises from a diverse array of processes. These processes include nuclear power generation, nuclear medicine, research activities, industrial applications, and the decommissioning of nuclear facilities, each contributing to the accumulation of radioactive waste. The nature and sources of radioactive waste can be categorized into various forms, each distinguished by its characteristics, origin, and potential hazards.

Causes of radioactive pollution

Through a complicated web of interactions, many human activities can lead to a rise in radioactivity in the environment. Due to equipment malfunctions and natural disasters, significant amounts of radioactive elements have been discharged into the environment in catastrophic nuclear mishaps, such as the Fukushima and Chernobyl tragedies. This load has been increased by past nuclear weapons testing, which contaminated the atmosphere with radioactive fallout. Environmental radioactivity may also be made worse by the incorrect management and disposal of radioactive waste from nuclear power plants, as well as the usage of radioactive materials in some industrial and medicinal applications. Radioactive dust and tailings can unintentionally enter the environment through mining and mineral extraction processes, particularly when dealing with naturally radioactive materials such as uranium and thorium. Radon gas is a naturally occurring gas that may seep into structures and cause hazards if left unchecked. Theft and smuggling of radioactive materials are examples of illegal behaviors that might contaminate the environment. Lastly, certain areas are long-shadowed by historical residual pollution resulting from the creation of nuclear weapons. Tackling this complex issue requires stricter laws, enhanced safety procedures, appropriate disposal of waste, and close observation of nuclear power plants. To prevent pollution and protect the environment, public education and knowledge of the risks posed by radioactive materials are essential.

The spectrum of radioactive waste

Low-Level Radioactive Waste (LLW)

Within the spectrum of radioactive waste, we find Low-Level Radioactive Waste (LLW), which comprises materials with relatively low levels of radioactivity and short half-lives, which means that radioactive materials in LLW will become less radioactive over a relatively short period of time. These

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materials often result from activities such as nuclear power plant maintenance, medical treatments involving radioisotopes, which are isotopes of chemical elements that are unstable and undergo radioactive decay, emitting radiation in the process and research experiments.¹¹ Examples of LLW include contaminated gloves, protective clothing, and laboratory tools. Compared to other types of radioactive waste, LLW is thought to be less dangerous because of its comparatively low radioactivity and faster decay rates. To guarantee safe storage and disposal, however, adequate management is necessary. This is usually done in facilities that are specifically constructed to retain and isolate LLW from the environment while it remains radioactive.

Intermediate-Level Radioactive Waste (ILW)

Moving to a higher level of radioactivity, people encounter Intermediate-Level Radioactive Waste (ILW). This category includes materials with increased radioactivity, often arising from the nuclear industry's applications. ILW may include contaminated reactor components, machinery, and items used in various nuclear processes. It includes refurbishment waste, ion-exchange resins and some radioactive sources used in radiation therapy. Some examples of nuclear industry applications include the disposal of used or damaged sealed radioactive sources used in industrial, medical, and research applications and waste generated during the decontamination and cleanup of nuclear facilities, such as contaminated equipment, tools, and protective gear. More stringent handling and containment procedures are required because of the ILW materials' greater radioactivity and longer half-lives. Storage in specially designed repositories that offer shielding and isolation is normally required for the proper disposal of ILW. To avoid possible groundwater and environmental contamination, long-term management of ILW is essential.

High-Level Radioactive Waste (HLW)

At the pinnacle of radioactive hazards lies High-Level Radioactive Waste (HLW). This waste is characterised by extreme radioactivity and the presence of long-lived transuranic elements, elements that are beyond uranium, and they are all radioactive, and highly radioactive fission products, the fragments created when an atom splits and releases energy. It primarily results from the reprocessing of spent nuclear fuel and poses substantial challenges for safe management and disposal. HLW poses significant challenges in terms of safe storage and disposal. Typically, HLW is vitrified, which involves encapsulating

¹¹ "Radioactive Waste Management | Nuclear Waste Disposal - World Nuclear Association." *World Nuclear Association - World Nuclear Association*, www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx.

it in a glass matrix to immobilise the radioactive materials. The vitrified HLW is, then, stored in deep geological repositories, often hundreds of metres below the Earth's surface, to prevent its release into the environment. The management of HLW is of utmost concern due to its potential to cause severe harm to human health and the ecosystem if not handled with extreme care.

Overall, understanding the nature and sources of radioactive waste is crucial for implementing effective waste management strategies. These strategies aim to protect public health and the environment by isolating radioactive materials from the biosphere while ensuring the long-term integrity of storage and disposal facilities. Proper handling and containment procedures, as well as adherence to international safety standards, are essential for managing the diverse and hazardous radioactive waste generated by various nuclear-related activities.

Hazards and Risks Associated with Radioactive Waste

Radioactive waste presents a range of hazards and risks that stem from the emission of ionizing radiation, radioactive contamination, and potential ecological impacts. Understanding these risks is crucial for developing effective strategies to ensure the safe handling of radioactive waste.

To ensure the safe processing and disposal of radioactive waste, a thorough awareness of all the risks and dangers is necessary. DNA, a vital component of all living things, is susceptible to harm from ionizing radiation released by radioactive materials. Humans who are exposed to ionizing radiation for an extended period of time or significantly can suffer from serious health effects, such as an increased risk of cancer, genetic changes that could have an impact on future generations, and the onset of radiation sickness. Ionizing radiation can damage live cells and tissues, perhaps resulting in long-term health problems, at the cellular level. Ionizing radiation poses a risk, which emphasizes the significance of taking strict safety precautions when handling and storing radioactive waste to reduce human exposure.

Additionally, a serious issue with radioactive waste is radioactive contamination. It happens when radioactive substances or particles encounter surfaces, which could expose people who come into contact with contaminated settings or materials to radiation on the inside or outside of their bodies. Contact with contaminated surfaces may result in external exposure and tissue or skin radiation. When radioactive particles are swallowed, eaten, or enter the body through open wounds, contamination can happen internally. Internal contamination increases the danger of persistent radiation exposure and radiation-related health problems. To protect both the public and the employees involved in managing radioactive waste, contamination must be prevented.

Radioactive material contamination has the potential to harm local flora and animals by contaminating the soil, water, and air. When radioactive materials enter the environment, they have the potential to upset the ecological balance and have an

impact on a species' capacity for reproduction and survival. Furthermore, radioactive materials may enter the food chain as they migrate through ecosystems, which could result in bioaccumulation and biomagnification, where the concentration of radioactive materials rises at higher trophic levels. Biomagnification is the increase in concentration of a chemical as it goes up the food chain, whereas bioaccumulation is the slow accumulation of a substance over time within an organism's tissues. This process poses serious health hazards to wildlife, and it might even have an effect on human populations that depend on contaminated environments for food. As a result, thorough risk analyses and environmental monitoring are crucial parts of managing radioactive waste to reduce negative ecological effects and save biodiversity.

Not only does radioactive waste harm the local wildlife, but it also puts the nearby plants at serious risk. It can be difficult for plants to flourish when radioactive elements are discharged into the environment because they can pollute the soil and water. Excessive radiation levels have the potential to stunt plant development, interfere with photosynthesis, and harm plant DNA, which can result in mutations and worse reproductive outcomes. Since many species rely on these plants for food and refuge, this might have significant effects on ecosystems. Furthermore, long-term ecological disturbance brought on by soil pollution may make it impossible for native plant species to recolonize regions that have been impacted.

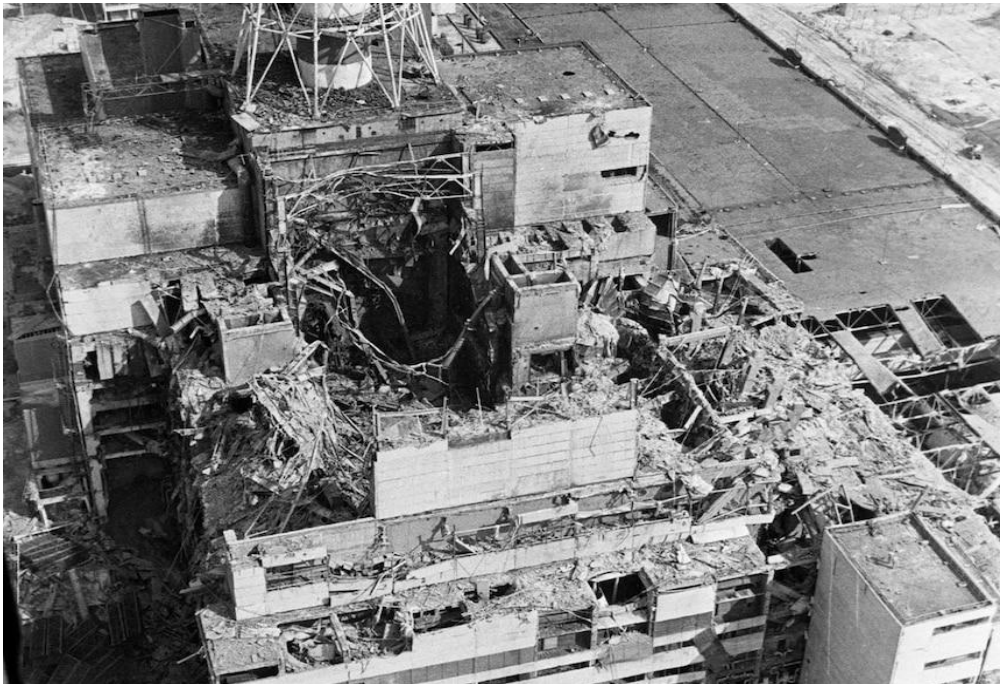


Figure 2: An aerial view of the ruined reactor four of the Chernobyl nuclear power plant in Ukraine, 1986.¹²

The ecosystem is seriously threatened by radioactive waste, especially when it comes to how it affects the quality of the air and water. Unmanaged radioactive materials have the potential to pollute surface and groundwater, escape into the atmosphere through evaporation or wildfires, and leak into groundwater. In addition to posing a threat to aquatic ecosystems, this pollution may cause radioactive particles to disperse throughout the atmosphere, which might have an impact on human and animal populations. Additionally, radioactive elements can cause mutations and growth inhibition in plants, upsetting the delicate equilibrium of the local flora.

In examining the risks associated with radioactive waste, it is essential to recognize the profound impact of past nuclear disasters, such as the Chernobyl nuclear catastrophe in Ukraine, which unfolded in 1986. It resulted in widespread radioactive contamination, affecting not only Ukraine but also neighboring countries and leaving a lasting legacy of environmental and health consequences. A year later, in 1987, the United States took a significant step in addressing radioactive waste with the passage of the Low-Level Radioactive Waste Policy Amendments Act. This legislation aimed to enhance the safe management of radioactive waste through the establishment of regional disposal compacts, fostering collaboration among states to handle and store low-level radioactive waste more effectively. Furthermore, the Fukushima Daiichi nuclear disaster in Japan, occurring in 2011, served as a stark reminder of the critical importance of nuclear safety and waste management.

The hazards and risks associated with radioactive waste encompass a broad spectrum of potential consequences, ranging from immediate health impacts on humans to ecological disturbances and threats to wildlife. Mitigating these risks requires a multifaceted approach that includes stringent safety protocols, thorough contamination control measures, and robust environmental monitoring.

Regulatory Framework Currently in Place

Ensuring the safe handling of radioactive waste relies on a robust regulatory framework and a suite of safety measures implemented at every stage of waste management. These measures are crucial to preventing environmental contamination, protecting human health, and adhering to global norms and regulations.

At the global level, international organizations like the International Atomic Energy Agency (IAEA) play a pivotal role in establishing norms, regulations, and safety principles for the safe treatment of radioactive waste. These international guidelines

¹² "The Day the Sky Glowed Red: The Chernobyl Disaster Explained." *ABC (Australian Broadcasting Corporation)*, 26 Apr. 2016, www.abc.net.au/news/2016-04-26/chernobyl:-how-a-routine-test-became-a-deadly-nuclear-disaster/7347402.

provide a foundation upon which individual nations can base their own regulatory frameworks.



During handling and transportation, the safe containment and shielding of radioactive waste are ensured through the use of specialized containers and packaging designed to withstand various environmental conditions and prevent the escape of radiation. These containers undergo rigorous testing to verify their structural integrity under extreme circumstances. Additionally, waste management facilities, such as storage sites and repositories, are constructed with multiple layers of safety features, including engineered barriers, monitoring systems, and access controls. These safeguards collectively contribute to preventing releases and safeguarding public health and the environment.

Figure 2: The Onkalo disposal facility for spent fuel being constructed in Olkiluoto, Finland, consists of an engineered system of tunnels.¹³

Long-Term Isolation of HLW

High-Level Radioactive Waste (HLW) presents a particularly challenging aspect of radioactive waste management due to the presence of long-lived radioactive isotopes. To prevent potential emissions over extended periods, it is imperative to isolate and contain these isotopes effectively. This typically involves geological disposal in deep repositories, where multiple barriers, including natural rock formations and engineered barriers like waste canisters and bentonite clay buffers are used to safeguard against releases of radioactive materials. The isolation period can extend for thousands of years, necessitating meticulous planning and monitoring to ensure long-term safety.

¹³ "Developing the First Ever Facility for the Safe Disposal of Spent Fuel." *International Atomic Energy Agency | Atoms for Peace and Development*, www.iaea.org/newscenter/news/developing-the-first-ever-facility-for-the-safe-disposal-of-spent-fuel.

Routine Monitoring and Safety Assessments

Routine monitoring, inspections, and safety assessments are conducted throughout the whole radioactive waste management process to verify the effectiveness of safety measures and to ensure strict conformity to laws and specifications. Radiation levels are continuously measured in and around storage and disposal sites as part of monitoring.¹⁴ Inspections guarantee that equipment and facilities adhere to safety requirements, and safety assessments are carried out on a regular basis to review and improve safety precautions as needed. These continuing initiatives are crucial to preserving the reliability of systems for managing radioactive waste and adjusting to changing scientific and technological developments.

In summary, the regulatory framework and safety measures surrounding radioactive waste management are integral components of ensuring the safety of both humans and the environment. By adhering to international standards, establishing comprehensive regulatory structures, implementing long-term isolation strategies for HLW, utilizing specialized containers, and conducting routine monitoring and safety assessments, nations can effectively manage and mitigate the risks associated with radioactive waste. This concerted effort not only upholds safety but also contributes to responsible and sustainable waste management practices on a global scale.

MAJOR COUNTRIES AND ORGANISATIONS INVOLVED

Japan

Japan's involvement in the Fukushima Daiichi nuclear disaster in 2011 has given it a strong voice in concerns about radioactive waste. This incident sharpened Japan's attention to nuclear security and the disposal of radioactive waste. For the safe storage, handling, and disposal of radioactive waste, Japan has been actively developing and putting into practice cutting-edge technologies. Japan is at the forefront of developing solutions for the safe, long-term storage and responsible management of radioactive waste, representing a significant advancement in nuclear safety and environmental protection. Japan is recognized for its groundbreaking research into deep geological repositories and innovative decontamination techniques. This country can serve as an example for other countries facing comparable difficulties.

¹⁴ "IAEA safety Standards for protecting people. and the environment." www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf.

France

France is a global leader in the generation of nuclear energy and, as a result, in the management of radioactive waste. The nation has a comprehensive strategy for waste management, which includes nuclear material reprocessing and recycling. On the topic of safe waste treatment, France's knowledge in these areas is essential. Additionally, it actively contributes to global initiatives to establish best practices for the long-term disposal of high-level nuclear waste. One well-known example is the Bure Underground study Laboratory in northern France, where a significant amount of study is done to determine whether it is feasible to store radioactive waste underground in stable geological formations.

Ukraine

The Chernobyl nuclear accident in 1986 has an impact on Ukraine's participation in discussions on the management of radioactive waste. The nation has first-hand knowledge of how to handle the aftereffects of a nuclear disaster and manage the radioactive waste that results from it.¹⁵ International talks on nuclear safety and waste management continue to be informed by Ukraine's experiences and efforts to lessen the effects of Chernobyl.

United States (USA)

Due to its enormous nuclear infrastructure, the United States has a significant influence on issues regarding radioactive waste. The Yucca Mountain Nuclear Waste Repository is a long-term repository being developed by the United States to safely store high-level radioactive waste. However, disagreements regarding the repository's location and security have made the subject divisive. The US experience is instructive for other nations grappling with the challenges of siting and developing repositories for radioactive waste.

Brazil

One nation that is actively working to ensure the safe treatment of radioactive waste is Brazil. With many nuclear power plants and research institutes, the nation's nuclear sector is expanding, making effective waste management crucial. A thorough regulatory structure, headed by the National Nuclear Energy Commission (CNEN), has been constructed in Brazil. Their primary focus lies in the creation and use of cutting-edge technology for the secure handling, transit, and elimination of radioactive waste. As part of this dedication to safety, a deep geological repository is being built in the state of Ceará, Brazil, to safely store high-level waste for an extended period of time.

¹⁵ "NUCLEAR SAFETY, SECURITY AND SAFEGUARDS IN UKRAINE." *International Atomic Energy Agency / Atoms for Peace and Development*, www.iaea.org/sites/default/files/22/09/ukraine-2ndsummaryreport_sept2022.pdf.

International Atomic Energy Agency (IAEA)

When it comes to guaranteeing the safe treatment of radioactive waste, the IAEA is a crucial international agency. It is crucial in creating international norms and regulations for the secure handling and disposal of radioactive materials. To make sure that these criteria are being followed, the IAEA conducts inspections and offers technical support in member nations.¹⁶ Additionally, it encourages international collaboration in the advancement of safe nuclear technologies and makes it easier for member governments to share knowledge and best practices.

World Nuclear Association (WNA)

The WNA is an important industrial group that concentrates on nuclear energy and related issues, such as the secure management of radioactive waste. It stands for a vast network of businesses and organizations involved in nuclear energy. The WNA is dedicated to advancing nuclear technology while maintaining the greatest levels of safety.¹⁷ The association is crucial in spreading awareness among the general public and decision-makers about the industry's dedication to ethical waste management and disposal procedures.

Nuclear Energy Agency (NEA)

The Nuclear Energy organization (NEA), an OECD organization, deals with a variety of nuclear energy-related issues, including the management of radioactive waste.¹⁸ It carries out research and analysis to create efficient waste management plans and disseminates this information across member nations. The NEA also promotes worldwide collaboration on programs involving research and development pertaining to the secure handling and disposal of radioactive waste.

¹⁶ "Handling and Processing of Radioactive Waste from Nuclear Applications." www-pub.iaea.org/MTCD/Publications/PDF/TRS402_scr.pdf.

¹⁷ "Radioactive Waste Management | Nuclear Waste Disposal - World Nuclear Association." *World Nuclear Association - World Nuclear Association*, world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx.

¹⁸ "Radioactive Waste Management." *Nuclear Energy Agency (NEA)*, www.oecd-nea.org/jcms/c_12892/radioactive-waste-management.

TIMELINE OF EVENTS

DATE	DESCRIPTION OF EVENT
1 March 1896	Henri Becquerel discovers radioactivity.
2 December 1942	The first controlled nuclear chain reaction occurs at the Chicago Pile-1.
1 December 1959	The Antarctic Treaty is signed, designating the continent as a nuclear-free zone.
1982	The Nuclear Waste Policy Act (NWPA) enacted in the US, establishing a national policy for radioactive waste management.
26 April 1986	The Chernobyl nuclear disaster occurs in Ukraine, leading to widespread radioactive contamination.
1987	The Low-Level Radioactive Waste Policy Amendments Act passes in the US, addressing regional disposal compacts.
5 September 1997	The Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management is adopted, establishing international safety standards.
11 March 2011	The Fukushima Daiichi nuclear disaster occurs in Japan, prompting increased focus on nuclear safety and waste management.
19 October 2015	The United Nations General Assembly adopts the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management."
18 November 2021	The US Nuclear Regulatory Commission (NRC) approves the license for Interim Storage Partners to construct a storage facility for spent nuclear fuel in Texas.

PREVIOUS ATTEMPTS TO SOLVE THE ISSUE

Joint Convention on the Safety of Spent Fuel Management and on the safety of Radioactive Waste

This convention, which was adopted in 1997 and has been in effect since 2001, aims to ensure the safe handling of radioactive waste and spent nuclear fuel. To achieve compliance, it creates safety standards and global peer review processes. In order to protect human health and the environment, this convention focuses on establishing strict safety standards, guidelines, and international peer review processes. By means of information sharing and periodic evaluations, participating nations work together to maintain safety protocols, accountability, and openness globally, therefore, strengthening the safe management of radioactive materials. While this Convention is a critical international agreement, it faces challenges related to enforcement and adherence by member states. Not all countries fully implement the safety standards, leading to disparities in safety measures worldwide. Additionally, the convention relies on peer review processes, which can be limited by political considerations and the willingness of countries to open their facilities to international scrutiny.

Sweden's KBS-3 Method

The KBS-3 disposal method was created by Sweden for the disposal of high-level radioactive waste. Noteworthy for its meticulous planning and assessment, this method utilizes copper canisters to encapsulate the waste, providing an extra layer of containment and corrosion resistance. The waste is buried in a stable bedrock geological repository, ensuring its isolation from the environment. Rigorous evaluation and public engagement were integral parts of the KBS-3 project, fostering public trust through transparent decision-making processes and robust safety analysis. The long-term durability of the copper canisters and the nearby geological repository is one of the main worries. Thousands of years of study and analysis have been done to address this problem, yet the method's success is still unknown. Furthermore, the approach is site-specific due to its dependence on deep geological repositories; as a result, it could not be appropriate or relevant in all nations with various geological circumstances.

Yucca Mountain Repository (Past Attempt by the United States)

The US made a bold effort to create a high-level nuclear waste storage with the Yucca Mountain storage project. It did, however, confront several difficulties, including technical difficulties pertaining to water intrusion and corrosion issues. Strong public opposition combined with political resistance at the state and federal levels was perhaps the most severe impediment. Political leaders in Nevada, local towns, and environmental organizations fiercely opposed the repository, resulting in financial uncertainty and legislative deadlocks. The project eventually fell victim to these

difficulties and was shelved in the early 2010s; it is now used as a case study for understanding the complex terrain associated with developing nuclear waste repositories. Technical issues including corrosion and water intrusion raise questions about the site's safety, which makes it a less desirable option for long-term nuclear waste storage. The project's inability to materialize was due to a confluence of technical, political, and public hurdles; this underscored the difficulties and roadblocks associated with setting up nuclear waste sites, particularly when confronted with substantial local and political resistance.

POSSIBLE SOLUTIONS

Stable Storage Options

Stable storage solutions are essential to addressing the problem of managing radioactive waste safely. The creation of secure, affordable and attentively watched geological depots is one strategy. These repositories entail building deep underground, multi-barrier buildings intended to keep radioactive waste away from the environment for a lengthy amount of time. This method depends on the chosen site's geological stability and reduces the chance of radioactive material polluting the surrounding area. Dry cask storage above ground is an additional feasible alternative that guarantees tight confinement and lowers the risk of leakage. With this technique, spent nuclear fuel is kept in sturdy, air-cooled containers, making maintenance and monitoring simpler. These two reliable storage choices provide vital long-term answers for the secure handling of radioactive waste.

Conduct Risk Assessments

To protect against possible risks related to radioactive waste, comprehensive risk evaluations are necessary. This entails meticulous site selection research for disposal locations for waste, with an emphasis on geological stability, isolation, and little human intervention. These factors lessen the possibility of mishaps and environmental pollution. Reevaluating safety procedures in light of new scientific findings and conducting ongoing reviews of possible dangers are equally vital. To guarantee the efficient containment and isolation of these materials, safety procedures and processes must be improved and adapted as our understanding of radioactive waste management advances.

Advanced Waste Treatment

It is essential to investigate sophisticated waste treatment solutions in order to address the problem of radioactive waste. Encouraging research into state-of-the-art reprocessing techniques that can lower the amount and radioactivity of radioactive waste is one way to do this. Reprocessing lowers the amount of waste that needs long-term storage while enabling the separation and possible reuse of valuable nuclear elements. Furthermore, research into recycling and transmutation methods can help

reduce the environmental effect of radioactive waste even further. These cutting-edge techniques might greatly improve nuclear energy production's safety and sustainability. Cross-national research collaboration is critical to fostering innovation and efficiency in waste management because it facilitates the sharing of knowledge and resources to create waste treatment systems that are more efficient.

Improved Transportation Safety

Tight transportation laws should be put into place, defining safe routes, containers, and thorough emergency response plans, among other things. It is essential to utilize specific containers made to withstand mishaps and stop radioactive material leakage. Moreover, creating safe transit routes that stay away from crowded areas and environmentally delicate places can help reduce the likelihood of mishaps while in transit. The use of cutting-edge tracking and observing technologies can improve the safety of transportation. Real-time tracking of radioactive waste shipments is made possible by technologies like GPS and remote surveillance systems, which offer an extra degree of protection and guarantee the safe transportation of waste from the place of origin to the destination. By taking these precautions, the risks connected with transporting radioactive waste are reduced, and both human and environment.

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"Handling and Processing of Radioactive Waste from Nuclear Applications." www-pub.iaea.org/MTCD/Publications/PDF/TRS402_scr.pdf.

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