The International Atomic Energy Agency (IAEA)

Chair Report

[Agenda A: Addressing Challenges In Nuclear Waste Disposal And Its Environmental Impact]

Yonsei Model United Nations 2025

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About the United Nations

The United Nations is the largest intergovernmental organisation that was founded in 1945 after World War II. Consisting of 193 member states, the United Nations endeavours to sustain international peace, security and cooperation, guided by the United Nations Charter.

A replacement for the League of Nations, the United Nations has been the centre of discussion and euphony for multilateral issues such as general disarmament, international security, multilateral cooperation, international economy, human rights affairs and sustainable development. The United Nations is operated under six major organs - The Secretariat, General Assembly, Security Council, Economic and Social Council, Trusteeship Council and the International Court of Justice. The United Nations has also assigned other specialised agencies and rapporteurs in reach for international peace and security.

Sessions of committees pertaining to the United Nations carry arduous responsibilities of perpetuating peace and humanitarian rights. Delegates of member states thrive to represent their designated nation and to form an international consensus on a myriad of agendas.

Committee Introduction

The International Atomic Energy Agency (IAEA) is a specialised UN agency dedicated to promoting the safe, secure, and peaceful use of nuclear energy. Established in 1957 as an intergovernmental organisation, the IAEA was created in response to the critical need for international governance following the Second World War, aiming to prevent any potential devastation from the misuse or overuse of nuclear technology. The IAEA's mission extends beyond nuclear weapons to encompass the practical and beneficial applications of nuclear technology, promoting safety, security, and non-proliferation while fostering development in sectors such as healthcare, agriculture, and energy. For example, the agency has expanded the use of nuclear technology for cancer treatment worldwide, including in developing nations.

The IAEA plays a critical role in encouraging states to follow and implement the provisions of the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment—the only international legally binding agreements for the physical protection of nuclear material and nuclear facilities used for peaceful purposes—by offering legislative and technical support to countries upon request. Additionally, the agency administers the *Nuclear Security Series* to provide internationally accepted guidelines for nuclear security, helping states fulfil their commitments under treaties. To achieve its objectives, the IAEA collaborates with its 164 Member States and various international partners through regulations, technical cooperation, and financial assistance. This includes directly aiding countries to help enhance their nuclear safety infrastructure by offering training, sharing technology, and conducting on-site inspections. In terms of systematic efforts, the agency maintains global nuclear safeguards through a comprehensive system of reporting and verification.

Agenda Introduction

Agenda A: Addressing Challenges In Nuclear Waste Disposal And Its Environmental Impact

Nuclear energy is used in various industries, including nuclear power plants and weapons production for national defence. These processes generate nuclear waste, which requires careful and precise handling to ensure safe and effective disposal due to the serious risks involved. In light of these concerns, this agenda addresses the challenges associated with nuclear waste disposal and its impact on the environment.

Nuclear waste, or radioactive waste, is generated primarily from spent fuel in nuclear reactors fueled by uranium-235 and from minor uses such as medical, academic, and industrial activities, as well as during the decommissioning and dismantling of nuclear facilities. Such wastes are classified into several categories including high-level and low-level waste. High-level waste refers to the spent fuel removed from reactors after producing electric power, while low-level waste comes from relatively minor uses of radioactive materials. Each type of waste requires specific disposal methods based on its potential impact on human health and the environment, and all nuclear waste remains radioactive for many years, necessitating strict disposal measures to ensure safety.

Regardless of its source, nuclear waste contains radioactive and hazardous substances that remain dangerous for many years, posing significant risks to both human health and the environment if not properly managed. Once the materials are leaked, it is evident that it would pose an irrecoverable threat to agricultural land, marine life, freshwater sources, life on land, and eventually, to the human race. There are rising concerns over the long-term safety of geological disposal with uncertainties about how well these sites will safely contain radioactive materials over time, while many nations still lack the necessary facilities for nuclear waste disposal. Additionally, inter-nation disputes, especially between countries sharing nearby coastal waters, further complicate nuclear waste disposal, as the environmental risks and potential for contamination transcend national borders.

Therefore, delegates must explore comprehensive, sustainable, and secure waste management solutions including advancements in technology, stricter regulatory frameworks, and international cooperation. It is encouraged that delegates keep close attention to the future as well as contemporary problems with a thorough understanding of both the sciences and social sectors.

Key Terms

Nuclear energy

Massive energy generated from inside an atom's core through either nuclear fission or fusion. The two differ according to the mechanism of the physical process that produces the massive amount of energy from atoms, and the former is what is commonly used in the contemporary field, while the latter is still in the developing process. The nuclear energy discussed in this agenda encompasses all applications across various fields, including medical devices, electricity generation, and weapons production.

Nuclear fission

A reaction in which an atom splits into two or more pieces, releasing energy. Of the two physical processes that generate nuclear energy, nuclear fission is the one currently in use, as nuclear fusion remains unfeasible due to technical limitations. Nuclear fission generates energy for the nuclear reactors inside nuclear power plants.

Nuclear fusion

A reaction in which two or more atomic nuclei combine to form one or more different atomic nuclei and subatomic particles. It is the reaction that powers stars, like our Sun. Its high efficiency and immense power output make it a promising candidate for future energy production. However, despite extensive efforts to artificially replicate the process, extreme technical demands, such as sustaining extraordinarily high temperatures and pressures, make it impossible to implement for practical use with current technology. Ongoing research in this field continues to draw significant attention.

Uranium-235

A rare radioactive isotope of uranium making up about 0.72% of natural uranium that can sustain nuclear chain reactions, unlike other isotopes. It is used as fuel for facilities such as nuclear reactors after being enriched, a process that increases the percentage of uranium-235 from 0.7 percent to approximately 3-5 percent, making natural uranium usable as an energy source.

Nuclear waste

Nuclear waste, or radioactive waste, is a type of hazardous waste that contains radioactive materials, generated from various activities such as nuclear medicine, nuclear research, nuclear power generation, decommissioning of nuclear facilities, rare-earth mining, and the reprocessing of atomic weapons. To safeguard human health and the environment, the storage and disposal of radioactive waste are regulated by government agencies. Radioactive waste is categorised into different levels based on its radioactivity, with each level requiring specific precautions and disposal methods. The nuclear waste discussed in this agenda encompasses all types that fit this definition.

MWe

MWe, which stands for "Megawatts electrical," is a unit of measurement indicating the electrical power output of a power plant, specifically the amount of usable electricity it generates for the grid.

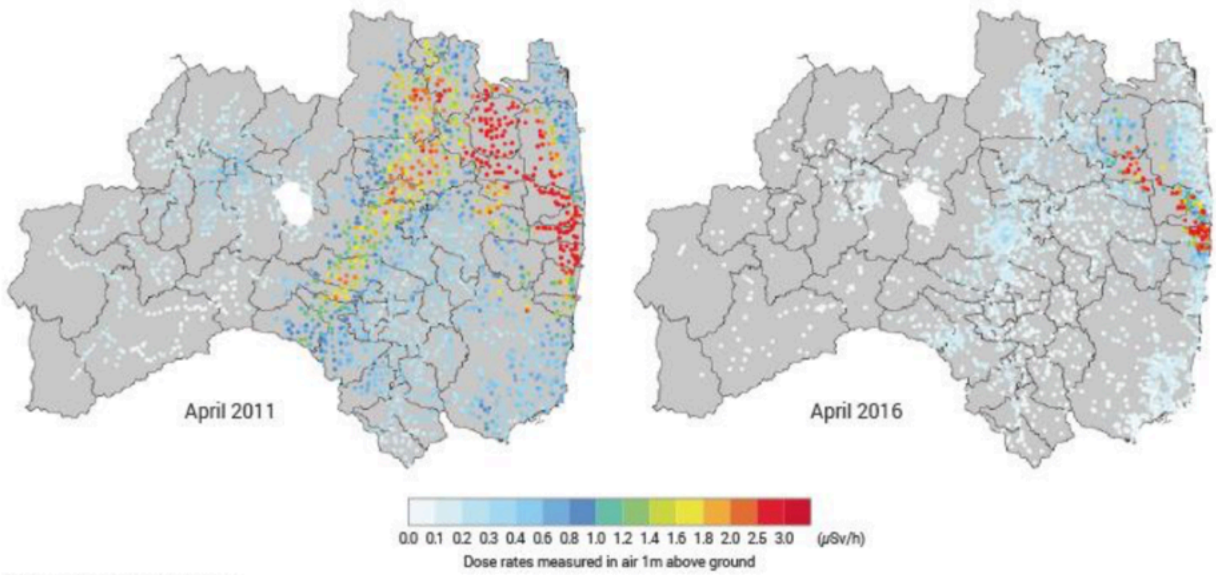
Historical Background

The Fukushima Daiichi accident was a major nuclear accident that occurred due to a major earthquake and tsunami in Fukushima, Japan, on March 11, 2011. Due to insufficient preparedness for such natural disasters, backup energy sources and the cooling system of the nuclear reactors were damaged. This caused a leak of radioactive materials in three of the six nuclear reactors. In response, authorities promptly ordered evacuations of over 150,000 people from the surrounding area, which was effective in means of minimising immediate radiation exposure to both air and ocean waters.

However, the incident also highlighted critical flaws in communication and evacuation logistics, adding towards immediate and long-term risks to public safety. When the natural disasters struck, authorities, including Japan's Nuclear and Industrial Safety Agency (NISA) and the Prime Minister's office, initially struggled to provide clear, consistent information on radiation levels in affected areas and evacuation protocols. To make matters worse, the Tokyo Electric Power Company (TEPCO) and governmental authorities had provided conflicting updates on contamination levels in agricultural products and water sources, eroding public trust and creating widespread anxiety. Due to this lag, many residents within a 20-kilometre radius of the damaged nuclear power plant were unaware of the severity of the radiation that they were being exposed to. This led the health of nearly 154,000 of those people to be placed in peril.

Additional risks arose from logistical challenges. Evacuation routes and transportation resources were severely compromised by the tsunami, which led many of the residents to be stranded in high-radiation areas for extended periods of time. Resources state that it is uncertain how much amounts of what toxic materials were dispersed airborne, but gradual reductions in the level of radiation have been examined as shown in the geographic material below.

Reduction of Radiation Levels in Fukushima Prefecture, April 2011 - April 2016



Source: Fukushima Prefecture

In specifics to water pollution, there have been disputes across the management of contaminated water from the Fukushima incident. The Japanese government has been working on accumulating contaminated water to remove radioactive elements, and debates are over the release of treated water back into the ocean. It was confirmed in April 2021 by the Japanese government that treated water will be released gradually, starting from August 2023 under IAEA's supervision. At this period, the action has commenced without alteration, but concerns remain about the safety and potential risks to neighbouring countries in that the materials involved are highly hazardous to marine environments and that it may also contaminate seafood through radioactive exposure. What escalates the tension even more is that the IAEA lacks legally binding authority over the Japanese government's actions, meaning that the Japanese may threateningly disseminate their potentially still radioactively polluted water to adjacent seas anytime, according to their own will.

One example of an international conflict that occurred due to such circumstances is the case between the Japanese and South Korean governments regarding the release of treated contaminated water from the Fukushima incident into the seas between the two countries. Since the release in August 2023, South Korean sceptics have been raising their voices of concern regarding the contamination of South Korea's ocean considering the two waters' geographical adjacency. The Japanese government has been working on accumulating contaminated water to remove radioactive elements, and debates are over the release of treated water back into the ocean. It was confirmed in April 2021 by the Japanese government that treated water will be released gradually, starting from August 2023 under IAEA's supervision. At this period, the action has commenced without alteration, but concerns remain about the safety and potential risks to neighbouring countries in that the materials involved are of highly hazardous nature and that the IAEA lacks legally binding authority over the Japanese government's actions.

These circumstances heightened concerns about nuclear waste storage and disposal, prompting governments to explore safer alternatives to nuclear energy. The case of Fukushima is a primal example that shows the consequences of radioactive contamination and the failure of communication regarding nuclear waste disposal. Although the IAEA has assembled a Task Force to conduct independent source and environmental monitoring, including thorough technical reviews of the cleanup and disposal process, concerns remain about the safety and potential risks to neighbouring countries, which stem from the hazardous nature of the materials involved as well as the fact that the IAEA lacks legally binding authority over the Japanese government's actions.

Status Quo

The disposal of radioactive waste, effectively speaking, is the process of ensuring its safe storage using various methods to prevent harm, including radiation exposure and environmental pollution, through meticulous long-term management. Methods differ in their mechanisms and geological disposal areas, and new approaches are continually developed.

Research into suitable options that ensure safe, environmentally sound, and publicly acceptable disposal has led to two primary disposal methods: near-surface disposal and deep geological disposal. The suitability of each method depends on the waste form, volume, and radioactivity of the material, meaning each option is not universally applicable to all types of waste.

Near-surface disposal, which involves storing waste at or just below ground level or in caverns below ground level, is commonly used to manage low-level waste (LLW) and short-lived intermediate-level waste (ILW). This approach is actively utilised in many countries, including the Czech Republic, Finland, France, Japan, the Netherlands, Spain, Sweden, the UK, and the USA for LLW, and in Finland and Sweden for ILW.

The IAEA defines near-surface disposal as the disposal of waste with or without engineered barriers in facilities at or just below ground level. Ground-level near-surface disposal facilities are engineered sites where radioactive waste is placed on or just beneath the earth's surface with a protective covering a few metres thick. These facilities are mainly intended for low- and intermediate-level radioactive waste, allowing for easier monitoring and management compared to deep geological repositories. Near-surface disposal in underground caverns, located several tens of metres below the surface, involves specialised facilities for low- and intermediate-level radioactive waste. These caverns provide additional natural barriers, with the surrounding geology further containing waste and minimising the risk of radioactive migration into the environment. Ground-level near-surface disposal facilities currently operate in the UK, France, Japan, the USA, and Spain, while cavern-based facilities are in operation in Sweden and Finland.

In contrast, deep geological disposal is employed for long-lived ILW and high-level waste (HLW), including spent nuclear fuel, and involves storing waste at depths of 250 to 1,000 metres in mined repositories or 2,000 to 5,000 metres in boreholes. As each country has different capabilities and preferences for ILW and HLW disposal, they are at various stages of technological development. Finland, for example, has made significant progress, with its Onkalo repository expected to commence operations in 2024. This will be the first geological repository aimed specifically at disposing of used nuclear fuel for civil purposes.

Deep geological disposal was developed to address materials that remain radioactive over extended periods. In this method, waste is stored deep underground in geologically stable regions, where isolation is ensured by a combination of engineered and natural barriers such as rocks, salt, and clay. The method aims to minimise environmental harm by isolating radioactive waste, allowing it to decay without reaching the biosphere, and ensuring that any potential leakage is dispersed over long periods, posing no significant radiological risk to people or the environment. This approach facilitates intergenerational management, as active oversight of these facilities is less frequently required.

Wastewater at the Fukushima Daiichi Nuclear Power Station is treated using the Advanced Liquid Processing System (ALPS), a filtration and pumping system that removes 62 radionuclides from contaminated water through chemical reactions. After treatment, the water is stored in specialised tanks, but one of the challenges is reducing the rate at which wastewater is produced, as available tank space is rapidly diminishing. Another significant issue is the ongoing geological disputes among neighbouring nations concerning the reliability and safety of the treated water. There is ongoing debate over the issue due to the ambiguity surrounding environmental responsibility, as it remains unclear whose ocean is being affected, who is accountable for the matter, and whether the issue should be considered a shared liability, highlighting the need for further international agreements.

Past Actions by Nations and Organisations

Efforts to address the challenges of nuclear waste disposal have progressed in a combination of national policies, international cooperation, and organisational initiatives. Several countries have implemented national programs to manage the accumulation and disposal of radioactive waste, often focusing on interim storage solutions. For example, the United States launched the Nuclear Waste Policy Act in 1982, establishing a framework for the disposal of high-level radioactive waste and spent nuclear fuel, aiming for developing a deep geological repository at Yucca Mountain in Nevada.

Throughout recent years, global proposals for regional and international nuclear waste repositories have gained significant traction. In 2003, the IAEA endorsed multinational repositories for high-level waste, emphasising collaboration to address limited technical capabilities and geological constraints in many countries. In Europe, the European Commission funded studies to explore regional waste management, leading to the creation of the European Repository Development Organization (ERDO), which promotes cooperation in nuclear waste disposal across 14 EU countries. Similarly, the International Framework for Nuclear Energy Cooperation (IFNEC) advocated in 2009 for multinational repositories, citing safety, security, and environmental benefits. IFNEC later recommended prioritising national repository projects before expanding to multinational levels.

The call for a multinational approach to nuclear waste disposal was reiterated by former IAEA Director-General Mohamed ElBaradei in November 2003. ElBaradei emphasised the necessity of such a strategy, pointing out that not all countries have the technology or geology for secure waste disposal. He suggested that such global cooperation would balance the disparities between nations, offering safety, security, and cost benefits, viewing the issue as a global challenge that requires a shared responsibility to address both technological gaps and the need for collective development.

There have been cases where regional cooperation has been pursued in practice as a way to share resources and expertise. For example, the Nordic countries have collaborated on nuclear safety and waste management through the Nordic Nuclear Safety Research (NKS) program, which facilitates knowledge-sharing among experts in Denmark, Finland, Iceland, Norway, and Sweden. Such regional partnerships have allowed countries with limited nuclear infrastructure to benefit from shared research and technical insights.

While these actions have led to some progress in managing nuclear waste, they underscore the need for continued innovation, transparency, and international collaboration to address the lingering challenges in ensuring the safe disposal of radioactive materials.

Stances of Major Countries and NGOs

In the current global landscape, over 400 nuclear reactors are in operation, with leading contributors including the United States, Germany, France, the United Kingdom, and China. These five nations play a significant role in shaping nuclear waste management strategies; it is highly worth examining the nuclear waste management strategies of these five influential nations.

The United States of America

The United States has 93 operating nuclear reactors and has successfully developed a robust status in the nuclear industry mainly during the second half of the twentieth century, leading the world in reactor numbers and exporting technology. Going forward, the United States is extending the lifespan of its nuclear power plants from the initial 40 years to 80 years, based on updated technical studies. In addition, it focuses on pioneering Small Modular Reactors (SMRs) with capacities under 300 MWe. These reactors, designed with modular construction, are cheaper and faster to develop than larger designs, offering promising, flexible solutions for future energy needs.

Germany

Germany, however, made a significant shift in its nuclear policy after the 2011 Fukushima accident. Once a nuclear leader with over 30 reactors, Germany is now dismantling its nuclear infrastructure as part of its energy transition to renewables. It has transitioned to an approach that includes a deep geological repository for managing spent fuel from its decommissioned reactors, alongside interim dry storage solutions. This transition underscores the importance of ongoing research and reflection for all nations to evaluate their strategies, ensuring that they are continually adapting and improving their approaches to address evolving challenges effectively.

France

France, which operates 56 reactors and generates 70% of its electricity through nuclear power, exemplifies a closed fuel cycle. It reprocesses used fuel, converting it into Metal Oxide fuel, a blend of plutonium and uranium oxides. This reprocessing method allows it to recover valuable plutonium from spent fuel, which would otherwise be treated as waste, and to incorporate it back into its fuel supply, providing approximately 5%. Although France is exploring options for deep geological storage, it currently relies on both wet and dry storage and is conducting research into advanced waste partitioning and transmutation techniques for sustainable disposal.

The United Kingdom

The United Kingdom also has a historical foundation in nuclear technology, having developed unique reactor types like the Gas Cooled Reactor (GCR). Unlike water-cooled reactors, GCRs generally use graphite as a moderator to slow down neutrons, making them efficient in certain fuel cycles and allowing them to use natural or low-enriched uranium; they were considered reliable for electricity generation due to their inherent safety features and fuel flexibility. Although it now only operates nine reactors, the United Kingdom plans to build new reactors, including SMRs, with projects underway at Hinkley Point C utilising European Pressurised Reactors (EPR), an advanced type of nuclear reactor designed to operate with a high level of redundancy and multiple safety systems, making it capable of withstanding extreme events, with 1,630 MWe capacity. For spent fuel, the United Kingdom continues to use reprocessing and centralised wet storage while exploring long-term geological disposal options.

China

China has firmly committed to nuclear energy, currently operating 55 reactors and building 21 more to soon surpass the United States and France. It adopts reprocessing technology, aiming to develop deep geological storage for high-level waste (HLW) by 2050. China's reactors primarily use the Pressurised Water Reactor (PWR) design and exports it worldwide, as the particular design is known for high stability and are widely used due to its reliable design and inherent safety features.

These nations employ either the open or closed fuel cycle. The open cycle, as used in the United States and Germany, involves direct disposal of SF, stored temporarily in dry casks until a geological repository is available. The closed cycle, employed by France, the United Kingdom, and China, reprocesses SF to extract reusable elements, lowering waste volume and enabling reuse of materials.

Some NGOs have taken a strong stance on the safety and security of nuclear waste storage, highlighting significant issues in current practices. For example, the anti-nuclear organisation Ausgestrahlt and the Munich Environmental Institute have raised concerns about Germany's interim storage facilities, reporting that many sites are not up to standard, with issues like rusting containers and unpermitted storage sites. They urge the German government to adopt a more rigorous and secure nuclear waste policy, calling for increased oversight and better interim storage conditions to prevent risks like sabotage and transportation hazards. Additionally, NGOs like BUND and Robin Wood support these demands, and the European Economic and Social Committee (EESC) has advocated for funding civil society groups to monitor radioactive waste management across the EU.

Possible Solutions

Nuclear waste disposal remains one of the most pressing challenges in global energy and environmental policy. With over 400 nuclear reactors currently operating worldwide, nations must address the safe, secure, and sustainable management of radioactive materials. This issue demands innovative solutions, international cooperation, and rigorous adherence to safety standards.

Nations must prioritise the development of advanced technologies to enhance the safety and efficiency of nuclear waste management. While methods such as deep geological repositories are currently employed, further research and innovation are essential to explore potential improvements and address existing limitations. Additionally, from an environmental perspective, it is necessary to mitigate risks of contamination to ecosystems and groundwater, as these can have long-lasting repercussions. Therefore, governments and institutions must invest in research to explore alternative disposal techniques and long-term storage solutions.

On an international level, strengthening global frameworks for nuclear waste disposal is a key step forward. Establishing clear protocols for resolving disputes related to nuclear waste management could foster greater accountability and cooperation. Furthermore, promoting international collaboration would enable nations to support each other more effectively, particularly in cases where one country faces significant challenges. In alignment with this goal, the development of multinational disposal sites could serve as a shared solution, pooling resources and expertise for mutual benefit.

Questions To Consider

- Which technologies are best suited for safely containing nuclear waste over the long term? Should the focus be on deep geological repositories or temporary storage facilities?
- What strategies can be implemented to reduce the risk of contaminating ecosystems and groundwater?
- How can the costs of nuclear waste management be fairly allocated, particularly to support nations with limited financial resources?
- Are current international agreements, like those led by the IAEA, adequate to ensure safety and accountability in managing nuclear waste?
- How might shared repositories address inequalities in geological conditions and technological capabilities among different nations?
- What are the differences in nuclear waste disposal strategies between nations, and what strengths or weaknesses do their systems demonstrate?
- Should emerging technologies, including advanced reprocessing techniques and Small Modular Reactors (SMRs), be integrated into nuclear waste management strategies?
- What can nations do to promote research into waste reduction and the development of alternative disposal methods?
- How can governments build public trust and ensure transparency in their nuclear waste management policies?
- What responsibilities do the current generation hold towards future generations in managing radioactive waste, considering its long-term hazardous nature?

The International Atomic Energy Agency (IAEA)

Chair Report

[Agenda B: Improving Emergency Response Frameworks For Nuclear Accidents And Radiological Incidents]

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Agenda Introduction

Agenda B: Improving Emergency Response Frameworks For Nuclear Accidents And Radiological Incidents

Nuclear technology plays a critical role in modern society, contributing to various sectors such as medicine, scientific research, and the production of energy. However, these benefits are accompanied with the ever-present risk of accidents and radiological incidents. Accidents involving radioactive materials, whether through mishandling, equipment failure, or malicious acts such as the use of dirty bombs, can expose communities to radiation. These events, though rare, can lead to devastating consequences, including widespread environmental contamination, long-term health risks, and severe socioeconomic disruptions. The Fukushima Daiichi disaster in 2011 and the Chernobyl meltdown of 1986 serve as stark reminders of the catastrophic consequences of nuclear accidents; thus, it is evident that robust and adaptable globally coordinated emergency response systems are necessary for managing these incidents.

This agenda seeks to build upon existing protocols, enhancing emergency response frameworks to better address the evolving nature of nuclear and radiological risks. With advancements in technology, emerging geopolitical tensions, and the increasing possibility of accidents or intentional incidents, it is crucial to continually update and strengthen our response mechanisms. By focusing on fostering international cooperation, improving regulatory frameworks, and seeking technological solutions, it is expected that delegates will contribute to our long-term coexistence with the numerous benefits that nuclear technology brings to humanity.

Key Terms

Nuclear accident

A nuclear accident involves the malfunction, failure, or destruction of a nuclear facility or device, leading to the release of radiation or other harmful consequences. Major nuclear incidents such as a reactor core meltdown or the significant release of radioactive isotopes into the environment cause severe damage to people, the environment, and infrastructure, with long-lasting health and ecological impacts.

Radiological incident

Radiological incidents refer to any event where radioactive material is released without a nuclear explosion. These incidents come with contamination or exposure to radiation through either accidents or intentional acts such as the use of radiological dispersal devices (dirty bombs).

Emergency response framework for nuclear and radiological incidents

Emergency response frameworks for nuclear and radiological incidents refer to the set of guidelines, protocols, and procedures including strategies for evacuation, medical treatment, containment, communication, and recovery that could ensure an organised and effective response during related crises. These frameworks are essential for minimising human lethal impacts and environmental damage from radiation, as they could protect public health and safety while mitigating the long-term consequences of such emergencies.

Geopolitical tension

Geopolitical tensions refer to conflicts, rivalries, or strategic power struggles between nations or regions that can impact global stability. These tensions often arise from disputes over territorial claims, resource competition, military confrontations, ideological differences, or nuclear capabilities. In the context of this agenda, emerging geopolitical tensions can escalate the likelihood of accidents, conflicts involving nuclear materials, or intentional misuse of nuclear technology.

Historical Background

The history of nuclear accidents and radiological incidents dates back to the early stages of nuclear technology development. The risks of nuclear accidents have been a concern since the construction of the first nuclear reactors. However, despite efforts to prevent major disasters, humanity has endured multiple tragic events. One of the major nuclear accidents in history is the Chernobyl disaster and the Fukushima incident. These are the only events that are rated at 'maximum severity' on the International Nuclear Event Scale (INES), which is the international standard scale for rating the severity of nuclear incidents introduced by the IAEA for better communication and response to each event.

The Chernobyl disaster of 1986 began with the explosion of the Chernobyl 4 reactor at the Chernobyl Nuclear Power Plant located in a city in northern Ukraine. The explosion was due to a dramatic power surge in the reactor as operators carried out a simulation test despite a problem with the power level of the reactor. As a result, the reactor ruptured, leading to a meltdown and a massive fire that spread radioactive materials across many parts of the USSR and Europe, posing significant short and long-term threats to humans and the environment.

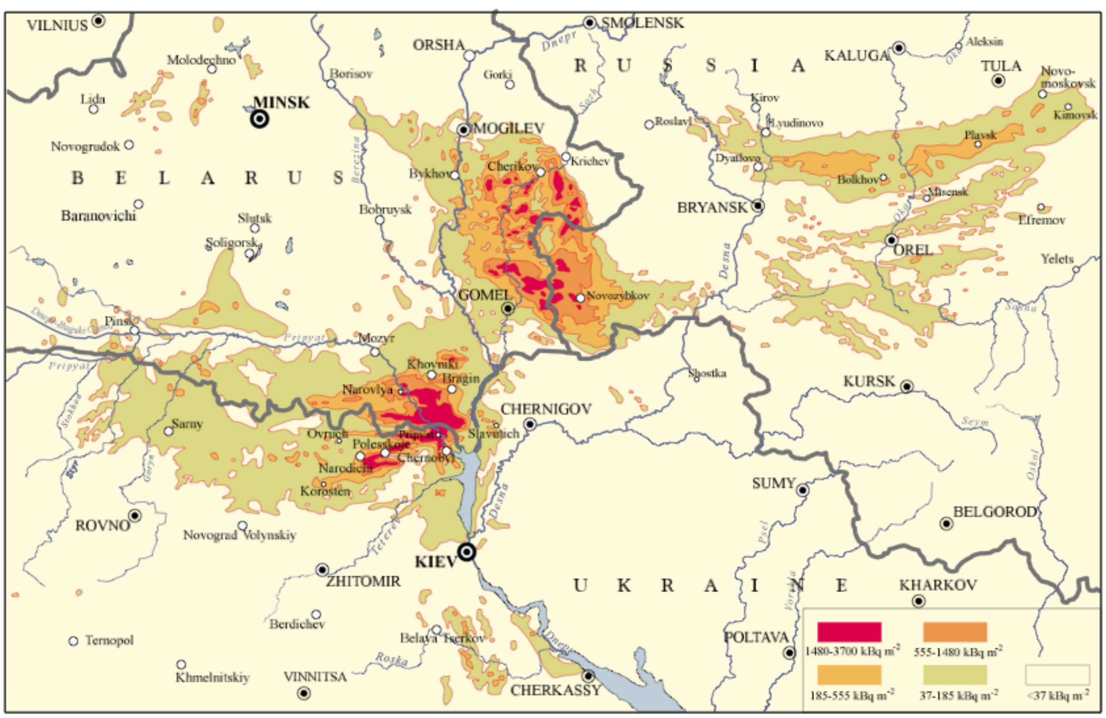

Figure VI. Surface ground deposition of caesium-137 released in the Chernobyl accident [I1, I3].

Within three months, 30 operators and firemen lost their lives, with additional fatalities reported later. More than 600 personnel on-site were directly exposed to radiation, with the most significant exposures resulting from external irradiation. Acute radiation syndrome (ARS)—or radiation poisoning—was diagnosed in 237 people who were involved in on-site operations and was later confirmed in 134 cases, 28 of whom died within a few weeks. Due to the scale of casualties and contamination, Chernobyl remains one of the most devastating nuclear accidents in history.

The environmental consequences were severe, as large quantities of radionuclides were released, affecting both plants and animals. Radioactive contamination was later detected in milk, meat, forest food products, freshwater fish, and wood. According to the UN Chernobyl Forum, increased mortality rates among living organisms and genetic anomalies, such as reproductive dysfunctions, have been reported over time. Radiation exposure also slowed the decomposition of organic matter, raising the risk of forest fires.

The widespread dispersion of radioactive materials is further evidenced by elevated radiation levels in certain lakes across Europe, which are comparable to those in lakes much closer to the incident site, such as in Ukraine and Belarus. This demonstrates the far-reaching impact of the radioactive release on ecosystems well beyond the immediate vicinity of the accident.

The way how the Chernobyl disaster was handled, in regards to preventive measures and execution of emergency measures contain significant deficiencies, which offers critical lessons for future nuclear safety protocols. The emergency response measures to the explosion of Reactor 4 on April 26, 1986 was marred by delays and inadequate measures, including a 36 hour delay in evacuating the residents of a radiation-exposed nearby city, Pripyat. The delay was partly due to the Soviet government's reluctance to acknowledge the severity of the harm of the radiation level, leading to a lack of timely action. Furthermore, insufficient communication with the public and the international community hindered the widespread use of crucial information and delayed external assistance, which exacerbated human and environmental damage.

Since the 1950s, when the first commercial nuclear power plants began operations, over 250,000 tons of highly hazardous nuclear waste have been generated and are now spread across

14 countries globally. Typically, this radioactive material is stored in decommissioned nuclear facilities. In the case of Chernobyl, several reactors still hold large quantities of waste that will remain hazardous for tens of thousands of years, which makes it a mandate for the global society to heed careful attention in establishing efficient preemptive measures for such potential accidents.

Status Quo

Although there has been significant advances in the global preparedness for nuclear accidents and radiological incidents, substantial gaps remain. Despite the progress made in fostering nuclear safety through initiatives like the Nuclear Security Series and the establishment of Incident and Emergency Centre (IEC), disparities remain in the continued implementation status of such initiatives across member states due to resource availability. Developing nations often lack the technological resources, trained personnel, and financial capacity to establish robust safety frameworks, which leads to a more difficult situation for them to secure durable facilities. Moreover, geopolitical tensions and emerging cyber threats further complicate the issue by raising the risk of sabotage or coordinated attacks on nuclear facilities.

The reliance of many nations on outdated emergency response frameworks, which fail to address evolving risks such as cyberattacks arising from the increasing complexities of modern nuclear infrastructure and its interconnected systems, is another critical gap that must be addressed; therefore, response frameworks must evolve to keep pace with these developments. While the burden of having to spend large amounts of money has been the cause for these inefficiencies, a request for a cooperative monetary policy on the international level through institutions such as the World Bank could be a working solution.

Additionally, low public awareness on the radiological risks have led to a lack of efficient safety measures in numerous regions, further hindering effective crisis management. Despite existing international conventions like the Convention on Early Notification of a Nuclear Accident, the variability in response readiness among states leaves significant vulnerabilities, particularly in regions with high seismic activity or political instability. Given the importance of minimising cross-border threats and addressing potential risks posed by inconsistencies in response methods, the pressing need for a robust and unified international framework to bridge gaps in preparedness is significant, aiming to ensure an effective response to nuclear emergencies for all nations, regardless of unique challenges or limitations.

The international Emergency Preparedness and Response (EPR) framework, maintained under the governance of the International Atomic Energy Agency (IAEA), serves as a global response mechanism for nuclear-related emergencies. Built on international legal instruments, IAEA safety standards, and various agreements and arrangements, the framework encourages nations to exchange information and provide assistance during emergencies. Its significance lies in fostering a coordinated international response, improving preparedness and effectiveness, and mitigating the adverse effects of nuclear emergencies on public health and the environment. However, its adequacy is often criticised due to disparities in technological capabilities among nations and varying levels of integration of the framework into national systems. Additionally, emerging risks such as cyberattacks targeting nuclear infrastructure remain a critical challenge to address.

Past Actions by Nations and Organisations

Notable efforts have been made in the global community to address the risks of nuclear and radiological emergencies, but the extent of success has been quite uneven. The IAEA has been at the forefront of this mission, creating guidelines and hosting emergency response training programs for member states to strengthen nuclear safety. The Incident and Emergency Centre (IEC) has provided support to this initiative, playing their role in assisting with technology and coordinating international responses during situations of crises. However, the problem with this approach is that real effects may be limited by the political and logistical constraints of member states.

There have been global efforts to address these measures, with countries reinforcing their regulatory frameworks in the aftermath of disasters. For example, Japan established the Nuclear Regulation Authority (NRA) following the Fukushima crisis to improve oversight and safety protocols. Similarly, the United States developed the Radiological Emergency Preparedness (REP) program, which includes community-based drills and public education campaigns to prepare for nuclear emergencies. In Europe, the European Nuclear Safety Regulators Group (ENSREG) initiated cross-border nuclear level tests to evaluate reactor safety. International conventions, such as the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, have also provided support by facilitating resource sharing during emergencies.

Yet, many of these frameworks lack enforcement mechanisms, leaving their effectiveness reliant on voluntary compliance. NGOs have been making initiatives to contribute in closing these gaps, with Greenpeace and the Union of Concerned Scientists conducting actions on public advocacy, with their emphasis on transparency in disclosing the environmental consequences of nuclear energy. These efforts have been instrumental in pushing governments to adopt stricter safety measures. The problem with these approaches, however, is that they often face resistance from powerful nuclear lobbies.

Stances of Major Countries and NGOs

United States

The United States has been strong advocates for robust emergency response systems and international collaboration to mitigate nuclear risks. Domestically, the Nuclear Regulatory Commission (NRC) enforces rigorous safety protocols and extends technical assistance to other nations. The U.S. actively participates in International Atomic Energy Agency (IAEA) initiatives and is a key supporter of conventions such as the Convention on Early Notification of a Nuclear Accident. Additionally, their investments on advanced technologies, including real-time monitoring systems and AI-based risk assessment tools, have enhanced both their preventive measures and emergency response capabilities.

Russia

Russia emphasises state-controlled safety measures and consistently underscores the importance of national sovereignty in nuclear governance. It advocates for flexible international safety standards that can be tailored to individual nations' capabilities, often opposing rigid frameworks. Russia frequently engages in bilateral agreements for nuclear safety cooperation, particularly with countries within its sphere of influence. However, it remains cautious about participating in transparency-focused international initiatives, citing concerns about national security.

Japan

Japan, learning from the Fukushima disaster, has become a staunch proponent of stricter global safety regulations. Domestically, it established the Nuclear Regulation Authority (NRA) to overhaul and strengthen safety protocols. Internationally, Japan actively supports IAEA training programs and encourages the sharing of knowledge and best practices among nations. Japan also conducts high investments in enhancing the resilience of its nuclear infrastructure, particularly against seismic risks.

France

As a leading producer of nuclear energy, France advocates for multilateral agreements to improve global nuclear safety. It plays a prominent role in the European Nuclear Safety Regulators Group (ENSREG), working to coordinate safety measures across Europe. France also shares its technical expertise with nations developing nuclear energy infrastructure, demonstrating its commitment to fostering global safety. Moreover, they have a close collaboration with the IAEA for measures to refine international guidelines for responding to radiological incidents.

Greenpeace

Greenpeace actively opposes nuclear energy, highlighting its environmental risks and the potential for catastrophic accidents. They conduct high-profile campaigns to raise awareness about the dangers associated with nuclear power and radiological incidents. With their advocacy for transitioning to renewable energy sources, Greenpeaces emphasises safety in using nuclear energy and seeking for energy sustainability. They also publish reports detailing safety lapses in nuclear operations and pressure governments to increase transparency and accountability in nuclear governance.

Union of Concerned Scientists (UCS)

The Union of Concerned Scientists (UCS) emphasises accountability and scientific rigour in nuclear safety. It conducts comprehensive analysis of existing safety standards and emergency preparedness frameworks, offering recommendations for improvement. The UCS advocates for stronger regulatory oversight, particularly in nations with weaker governance systems, and campaigns for reducing dependence on nuclear energy in favour of safer and more sustainable alternatives.

Possible Solutions

Improving the emergency response framework for nuclear accidents and radiological incidents requires a strategy that integrates prevention, preparedness, response, and recovery. Strengthening international frameworks, such as expanding the scope of the Convention on Early Notification of a Nuclear-Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, is vital to addressing modern threats like cyberattack and climate-related risks. These agreements must include enforceable compliance mechanisms and standardised emergency protocols to ensure global coordination.

Additionally, building the capacity of developing nations through technical assistance, training programs, and regional safety hubs equipped with emergency tools and medical facilities can help bridge existing disparities. A global nuclear safety fund, financed by nuclear energy-producing nations or loaned from international monetary facilities, can further support equitable resource allocation and readiness in vulnerable regions.

Advancing technology also presents opportunities to revolutionise emergency preparedness. AI-driven early warning systems can monitor reactor conditions in real-time, while blockchain technology can ensure efficiency in resource distribution during crises. The deployment of drones and robotics for radiation measurement, and containment in high-risk zones can enhance the safety and efficiency of initial responses. Simultaneously, enhancing public awareness through education campaigns and community drills is critical for empowering local populations, particularly those living near nuclear facilities, to respond effectively during emergencies.

Finally, addressing geopolitical challenges is essential to prevent risks associated with conflicts involving nuclear materials. Establishing neutral emergency response teams under the International Atomic Energy Agency (IAEA) and fostering cross-border cooperation can mitigate the impact of political tensions during crises. Coupled with investments in research and development for innovative containment technologies, health studies, and ecological restoration, these measures may contribute towards establishing a safer and more resilient global framework for managing nuclear and radiological emergencies.

Questions To Consider

- How can international agreements be restructured to ensure enforceable compliance with nuclear safety protocols, especially in regions prone to geopolitical tensions?
- What specific measures should be adopted to enhance the technological capabilities of developing countries in managing nuclear and radiological emergencies?
- How can the IAEA address emerging risks such as cyberattacks on nuclear facilities and integrate them into global safety frameworks?
- What lessons from past disasters like Chernobyl and Fukushima can be institutionalised to prevent future incidents, particularly in high-risk areas?
- How can the global community improve public awareness and trust in nuclear safety measures to ensure effective emergency responses?
- What role should NGOs and civil society organisations play in bridging gaps between government initiatives and public engagement in nuclear safety?
- How can international collaboration in nuclear safety be insulated from the effects of geopolitical conflicts, ensuring that safety protocols remain effective even during periods of political instability?

- What innovative technologies, such as artificial intelligence or blockchain, could revolutionise emergency response frameworks and improve global preparedness for nuclear incidents?

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