Committee: Environmental Commission

Issue: Limiting the environmental consequences from the disposal of radioactive weapons

Student Officer: Panagiotis Sachinis

Position: President

PERSONAL INTRODUCTION

Dear Delegates,

My name is Panagiotis Sachinis, and I am an IB2 student, attending St. Catherine's British School in Athens. I have been involved with MUN since 2017 in my early high school days, and have amassed significant experience in every part of the conferences. I am absolutely honored to be the President of the Environmental Commission for the upcoming ACGMUN 2021 Conference.

As a society, we have all faced some serious adversity in the past year. I believe that these MUN conferences, despite being online, are a great way to break away for a weekend and meet others with similar interests, like-minded people who all share a common desire to address and solve critical world issues. MUN also allows us to see the world from a different angle, to reflect on the actions and decisions that we all take that shape our global community. The environmental consequences from the disposal of radioactive weapons have always been a significant threat, which has only escalated in recent years to due increased disarmament and nonproliferation, making it a vital issue in securing our environmental sustainability.

Although this study guide will provide and serve as a strong foundation towards your understanding and research of this topic, I do strongly advise that you conduct further research and extend your own knowledge of it. Furthermore, it is recommended to look particularly into your delegation's policy and other related issues.

If you have any questions, please feel free to contact me at any time through my email, which will be attached below. I wish you all best of luck in your future endeavours, stay safe and healthy, and I look forward to meeting and working with you all soon!

Sincerely,

Panagiotis Sachinis

Email: pansachinis@gmail.com

TOPIC INTRODUCTION

The disposal of nuclear and radioactive weapons has been of key concern ever since the height of the cold war in the 20th century, and is one of the biggest threats to global environmental security. Beginning with the Manhattan Project prior to and during World War II, the eventual disposal of nuclear weapons was initially largely disregarded, as the focus was placed on quick development and mass production. The adverse effects of nuclear radiation on the environment were first seen during the bombings of Hiroshima and Nagasaki at the end of the Second World War, and the long-term effects intently studied in the following years.

The Cold War between the United States of America and the Soviet Union facilitated another arms race, which incentivized both states to mass produce and stockpile nuclear weapons. While, rather fortunately, none of these weapons were ever used as acts of war, the majority of the nuclear weapon stockpiles remain. With the increased decommissioning facilitated by Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and other such treaties, questions have been raised regarding the disposal of these aging nuclear materials. Knowing the potentially adverse effects the incorrect treatment and handling of these weapons can have on the environment, organizations such as the International Atomic Energy Agency (IAEA) have placed significant focus on this issue.

It is estimated that currently there are roughly 70000 warheads which are yet to be decommissioned and disposed of properly. The proper disposal of these weapons must consider both the short-term potential environmental challenges, such as avoiding radioactive leakage and explosions, and the long-term effects, such as the duration of radioactivity in these materials and the potential future effects. Radiation leakage has the capability to severely contaminate the environment, particularly through soil and air particle contamination, leading to adverse effects and disruptions in entire ecosystems. The contamination of ground water and other water sources is also of significant concern, and must be addressed.

Figure 1: A US Nuclear Warhead [1]

Most current plans to dispose of nuclear weapons rely on mass underground bunkers to 'bury' the materials deep underground. While effective, these methods are expensive and not as viable due to the high effort and cost required to sustain them. The effects of improper storing and containment of nuclear waste has already been witnessed, with events such as the Hanford Containment Facility Leaks and the Chelyabinsk Facility explosion in 1957, where almost all vegetation and life was destroyed within a 200 km^2 area around the facility. The proper disposal and containment of nuclear weapon materials post-decommission is an issue of global environmental security, and is of vital importance to ensuring the sustainability and future of nuclear non-proliferation.

DEFINITION OF KEY TERMS

Radioactive Weapons

"Weapons that disperse radioactive agents to inflict injury or cause contamination or damage."[1]

Nuclear Material

"Plutonium except that with isotopic concentration exceeding 80% in 238Pu; 233U; uranium enriched in the isotope 235 or 233; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore residue."[2]

It is effectively any radioactive materials enriched with isotopes enough to make them viable for use in nuclear weapons.

Non-Proliferation

"The controlling of the spread and/or amount of something, especially nuclear or chemical weapons."[3]

Radioactivity

"The property possessed by some elements (such as uranium) or isotopes (such as carbon 14) of spontaneously emitting energetic particles (such as electrons or alpha particles) by the disintegration of their atomic nuclei."[4]

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[1] International Risk Management Institute, Inc. "Radiological Weapon | Insurance Glossary Definition | IRMI.Com." *IRMI*, https://www.irmi.com/term/insurance-definitions/radiological-weapon.

[2] International Atomic Energy Agency. *IAEA Safety Glossary: 2018 Edition*. Glossary, 2018 Edition, International Atomic Energy Agency, 2019, p. 278, https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1830_web.pdf.

[3] "Non-Proliferation." *Cambridge Dictionary*, https://dictionary.cambridge.org/dictionary/english/non-proliferation.

[4] "Definition of RADIOACTIVITY." *Merriam-Webster*, https://www.merriam-webster.com/dictionary/radioactivity.

Radioactive Half-Life (Decay Time)

“A ‘half-life’ is defined as the amount of time taken for the number of nuclei present in a sample at a given time to exactly halve.”[5]

A halving of the nuclei present in a sample also results in a halving of the overall radiation emitted, and thus is key to calculating the time required to store radioactive and nuclear materials.

Radionuclide

“An unstable form of a chemical element that releases radiation as it breaks down and becomes more stable.”[6]

Radioactive Contamination

“Undesirable radioactive material (with a potentially harmful effect) that is either airborne or deposited in (or on the surface of) structures, objects, soil, water, or living organisms (people, animals, or plants) in a concentration that may harm people, equipment, or the environment.”[7]

Nuclear Fallout

“Fallout is the radioactive particles that fall to earth as a result of a nuclear explosion. It consists of weapon debris, fission products, and, in the case of a ground burst, radiated soil.”[8]

Nuclear-Weapon States (NWS)

“The nuclear-weapon states (NWS) are the five states—China, France, Russia, United Kingdom, and the United States—officially recognized as possessing nuclear weapons by the NPT.”[9]

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[5] “Radioactivity : Radioactive Half-Life.” Radioactivity.Eu.Com, https://www.radioactivity.eu.com/site/pages/Radioactive_Half_life.htm.

[6] National Cancer Institute. “Definition of Radionuclide.” *NIH - National Cancer Institute*, 2 Feb. 2011, https://www.cancer.gov/publications/dictionaries/cancer-terms/def/radionuclide.

[7] United States Nuclear Regulatory Commission. “Radioactive Contamination.” *NRC Web*, 24 Aug. 2020, https://nrc.gov/reading-rm/basic-ref/glossary/radioactive-contamination.html.

[8] Atomicarchive.com. “Radioactive Fallout.” *Atomicarchive.Com*, https://www.atomicarchive.com/science/effects/radioactive-fallout.html.

[9] Kristensen, Hans M., and Matt Korda. “United States Nuclear Forces, 2019.” *Bulletin of the Atomic Scientists*, vol. 75, no. 3, May 2019, pp. 122–34. *DOI.org (Crossref)*, doi:10.1080/00963402.2019.1606503.

BACKGROUND INFORMATION

Ensuring environmental security is one of the hardest adversities which global society faces in modern times. From the threat of climate changing and climbing global temperatures, preserving ecosystems, and ensuring the sustainability of the climate has been tirelessly challenging scientists for the past decades. However, the environmental consequences of nuclear war and nuclear power can never be overlooked. The proper handling and decommissioning of nuclear weapons is of utmost importance in ensuring that global environmental security, and has highlighted many issues and difficulties in this topic.

Historical Information

The development of nuclear weapons first began in the late 1930s due to the need for an innovative, stronger weapon to allow the United States to maintain military dominance. The atomic bombs dropped on Hiroshima and Nagasaki, Japan by the United States towards the end of World War II, resulting in 130,000 casualties, have been the only active demonstration of nuclear power and its subsequent destruction in war. Besides the horrifying death toll and direct effect these bombs had on human life, they brought about devastating nuclear destruction to the environment. Primarily, nuclear fallout plagued the cities and the surrounding areas for days after the initial explosions. The thick 'black rain' of radioactive fallout led to significant contamination of soil and nearby water resources, along with vital food resources. Air contamination led to much of the radiation being transported over a widespread area and causing radioactive contamination in areas besides the two cities. The contamination of water resources eventually led to a considerable number of radioactive isotopes reaching the ocean, which were then carried far away from Japan to neighboring states.

Figure 2: The Fat Man Nuclear Bomb Dropped by the US on the Japanese city of Nagasaki [2]

The end of the Second World War sparked another arms race between the United States and the former Soviet Union, appropriately called the Cold War. Lasting between 1947 and 1991, the Cold War saw rising tensions between the US and the USSR, and arms race to develop and stockpile mass nuclear weapons. Since the end of World War II, there have been 2121 nuclear tests with 2476 nuclear devices.[10] However, the testing of nuclear weapons has rather seized since the signing of the

[10] Yang, Xiaoping, et al. *Worldwide Nuclear Explosions*. Science Applications International Corporation, Center for Monitoring Research, p. 92, https://www.ldeo.columbia.edu/~richards/my_papers/WW_nuclear_tests_IASPEI_HB.pdf.

Comprehensive Nuclear-Test-Ban Treaty (CTBT). Despite the seizure of nuclear testing, the adverse environmental effects of such nuclear testing cannot be disregarded.

With the signing of the Treaty on the Non-Proliferation of Nuclear Weapons in 1968 and the signing of the CTBT in 1996, the production and testing of nuclear weapons has largely seized. Through the global bid for nuclear non-proliferation, and by some states even complete abolition of nuclear weapons, nuclear weapon decommissioning has been adopted by all the five Nuclear Weapon States (NWS). This has increased the amount of disposal and protection needed for unused nuclear materials. Thus, large nuclear stockpiles bring a potential for severe environmental consequences. While the direct risk of a nuclear war is, thankfully, not on the near horizon, the handling of such nuclear materials is still a risk-heavy process, which must be addressed and handled correctly.

Nuclear Disarmament after the Cold War

Since the signing of the NPT in 1970 and the height of the cold war, the declared NWS have taken measurable steps and quantitative reductions to their nuclear arsenals. It is estimated that at the height of the Cold War roughly 70,000 nuclear warheads were held by the five states, with approximately 14,200 left in 2018[11]. This has taken place unilaterally by at least four of the NWS, through various agreements, including the bilateral binding agreement between the United States and the Russian Federation. The only NWS which is increasing their nuclear stockpile is China. This leaves roughly 56,000 nuclear warheads which have been decommissioned and disposed of by the *NWS alone*, disregarding other nuclear states such as India and Pakistan, which are not officially recognized as NWS, but are known to have nuclear weapons. This excess of nuclear materials has mostly remained in temporary storage facilities, as the methods to fully dispose of or permanently store them has not yet been fully implemented or developed.

Process of Radiation and Disposal Sources

Decommissioning nuclear weapons as a process does not bring about significant environmental consequences. The potential dangers of nuclear weapon disposal lie in the incorrect processing and treatment of the nuclear materials that are used in nuclear weapons, such as unstable Uranium and Plutonium isotopes. Any potential for disaster or fault in the disposal and long-term storage process for nuclear materials should be considered as a threat to global environmental security, and should be directly addressed.

[11] NTI. *Nuclear Weapon Reduction | Disarmament of Nuclear Weapons | NTI*. 15 Dec. 2020, https://www.nti.org/analysis/reports/nuclear-disarmament/.

The most prevalent type of radiation which is emitted from the unstable isotopes used in nuclear weapons is alpha (α) and beta (β) radiation. This type of radiation can disrupt atoms, which creates positive and negative ions, and thus can cause significant biological harm, from the molecular to the cellular level[12]. This applies not only to human life, but to every constituent part of the environment: plant life, other animal life, single-celled organisms, and other non-living components of the environment such as water and soil. A certain amount of radiation is constantly present in the environment, whether that is from natural causes such as Radon gases, solar rays, or cosmic background radiation. Albeit this, the environment is not adapted to handle the presence of many radionuclides presented after a nuclear disaster. Radiation decay occurs when certain unstable elements (such as U-235 and Pu-239) spontaneously breakdown and release energy and matter from the nucleus of the atoms, creating so called 'daughter nuclei'[13]. These are stable atoms of lower mass and energy. The released energy and matter are what can interact with matter and lead to radioactive contamination. The process of radioactive decay in materials used in nuclear weapons takes a long time, and thus can take thousands of years to become safe. The time it takes for a material to halve the number of radioactive isotopes within it is called the radioactive half-life, and is an important value in determining the longevity of nuclear materials.

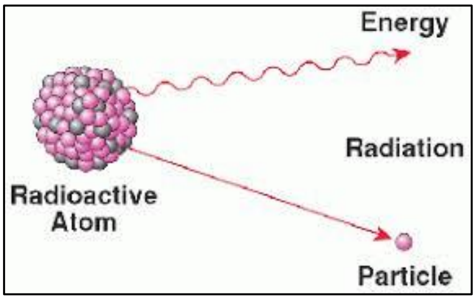

Figure 3: Process of Radioactive Decay [3]

Environmental risks are present in every step of the decommissioning process. The transportation of such volumes of nuclear materials in itself proves to be quite a challenge, ensuring the protection of not only the environment, but also of surrounding areas, civilians, and the protection of such materials against nuclear attacks. Accidents or restrictions to travel can hamper this process, and could create unwarranted environmental risks. Water and airborne discharges from reprocessing plants further play a significant role, as they directly influence the local environment, and often can travel further and contaminate entire regions. Furthermore, a key issue which is relevant to the current situation, as most nuclear weapon waste is stored in large facilities, potential leaks and faults in these facilities could bring about catastrophic damage to the environment, largely depending on the scale of the disaster. By recent accounts of the IAEA and the WHO, the global capacity for nations

[12] Guide to the Nuclear Wallchart. "Radiation in the Environment." *Guide to the Nuclear Wallchart*, 9 Aug. 2000, https://www2.lbl.gov/abc/wallchart/chapters/15/0.html#toc.

[13] NDT Resource Center. "Radioactive Decay." *NDT Resource Cente* https://www.nde-ed.org/EducationResources/HighSchool/Radiography/radioactivedecay.htm.

to undergo these types of processes is insufficient, and thus a major threat to environmental security[14].

Environmental Consequences of Improper Radioactive Material Disposal

The direct environmental consequences of nuclear material disposal are a multifaceted issue, which involves all aspects of the environment. Due to the catastrophic nature of radionuclides and nuclear radiation, it is important to consider all three primary levels of environmental damage: risks to the general environment, risks to local and global ecosystems, and risks to life.

General Environmental Risks

The most crucial environmental risks that could be caused by the potential mishandling of nuclear weapon materials is the contamination of primary resources, correlating to the contamination of soil, water resources, and the atmosphere. In minor leaks and local events, the first resource that will be contaminated is the soil. Due to the properties of radiation, it is almost impossible to process and clean large amounts of contaminated soil. Thus, it would remain contaminated for years to come. This soil would become unusable, and would present a considerable risk to nearby agriculture and infrastructure.

Figure 4: Dead Trees as a Result of Soil and Ground Water Contamination in Chernobyl, Ukraine [4]

The contamination of water resources is an imminent risk, either through ground water contamination, water sources such as rivers, or direct ocean contamination. Since water is perhaps the most key component of the environment, contamination of this resource could have devastating consequences to ecosystems and species populations.

Lastly, particularly from any explosive or gas-related events, the atmosphere will also become heavily contaminated. As seen in events such as Chernobyl, Fukushima, and even the nuclear bombings in Japan, radiation emitted in the local region was heavily spread throughout entire continents. This works to contaminate

[14] WHO Director-General. *HEALTH AND ENVIRONMENTAL EFFECTS OF NUCLEAR WEAPONS*. World Health Organization, 26 Apr. 1993, p. 8, https://apps.who.int/iris/bitstream/handle/10665/175987/WHA46_30_eng.pdf?sequence=1&isAllowed=y.

further water and soil resources far away from the local region, and thus expands the environmental risk of misuse and improper radioactive material disposal[15].

Effects on Ecosystems and Life

Due to the contamination of major resources, entire ecosystems will be heavily damaged. Radiation will largely enter the ecosystems from two primary sources: the contamination of habitats, and the contamination of resources. Habitats and systems located near the site of the implication will most likely be destroyed due to the high amounts of radioactive exposure. There will be a distinct reduction in biodiversity, changes in species dominance, and perhaps even changes to the food web of the ecosystem. Irradiation of animals and plants will lead to a disruption in the ecological relationships of different parts of the ecosystem, and could lead to local species extinctions. For the species of plants and animals that do survive, there will be distinct genetic changes depending on the levels of radioactive exposure[16]. Contamination may lead to an enhanced resistance in the populations of the ecosystem, and will most likely lead to species mutations.

Figure 5: Dead Fish in the Pacific Ocean after the Fukushima Disaster [5]

Radioactive contamination of such scales on ecosystems has the potential to cause significant harm further up the food chain. Contaminated soil can lead to agricultural resources becoming contaminated, and thus carrying the radionuclides to the human population. This also applies for livestock and other animals, and thus can have significant effects on human life. This is besides the direct effects of nuclear radiation on human health, which will not be discussed in this committee.

MAJOR COUNTRIES AND ORGANISATIONS INVOLVED

United States of America

The USA is one of the recognized Nuclear-Weapon States, known to currently have 6,200 active warheads, and is the only state to have deployed a nuclear attack in

[15] "Environmental Impacts of the Manhattan Project." UKEssays.Com, 28 Sept. 2017, https://www.ukessays.com/essays/environmental-studies/long-term-environmental-impacts-of-the-manhattan-project.php.

[16] Geras'kin, Stanislav A., et al. "Effects of Ionizing Radiation on Populations and Ecosystems." *Genetics, Evolution and Radiation: Crossing Borders, The Interdisciplinary Legacy of Nikolay W. Timofeeff-Ressovsky*, edited by Victoria L. Korogodina et al., Springer International Publishing, 2016, pp. 237–50. *Springer Link*, doi:10.1007/978-3-319-48838-7_20.

war. It has faced one of the largest decommissioning processes in history, and as of 2013 has roughly 37.5 tons of excess weapons-grade plutonium as a result of the arms race during the Cold War. Nuclear weapon disposal strategies are being developed, such as creating a large underground bunker in Nevada, or the current method to convert the excess uranium and plutonium to MOX fuel used in nuclear power plants.

Russian Federation

The Russian Federation is another NWS, also involved directly in the Cold War with an estimated current stockpile of 6,500 nuclear warheads. It has also dramatically reduced its nuclear stockpiles since the Cold War through the NPT and a bilateral agreement with the USA to move towards disarmament. Currently, Russia faces issues such as lost nuclear submarines in Murmansk and the Arctic Ocean, which present a severe environmental threat as the radiation slowly leaks into the sea[17].

India

India is not a recognized NWS, however, it is known to both possess nuclear weapons and extensive nuclear energy capabilities. It has advocated for non-proliferation and a ban on nuclear testing since its independence, despite its relatively large nuclear arsenal. When developing tactics and methods to limit the environmental consequences of nuclear weapon disposal, it is important to recognize the capabilities of non-NWS, which may not have the infrastructure to cooperate as other NWS.

International Atomic Energy Agency (IAEA)

The IAEA's involvement in disarmament and the environmental consequences is vital, as the UN organization oversees such processes and provides constant reports and guidelines on managing these issues. The IAEA has placed significant focus on ensuring the environment is not significantly affected from disarmament processes, and such could be used a framework.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

The UNSCEAR is an organization set up by the General Assembly in 1955, with the purpose to hold annual meetings to determine and develop reports on the effects of nuclear radiation. This includes effects of every type of radiation, from peaceful and military purposes, transport, etc. There are 21 states designated to provide scientists for this purpose, and it is a significant international effort.

[17] Luhn, Alec. "Russia's 'Slow-Motion Chernobyl' at Sea." *BBC Future Planet*, 2 Sept. 2020, https://www.bbc.com/future/article/20200901-the-radioactive-risk-of-sunken-nuclear-soviet-submarines.

European Repository Development Organization (ERDO)

The ERDO Working Group has the primary aim to safely control and manage "long-lived radioactive wastes"[18], which include nuclear weapon and energy waste. It is stated that every state must have the ability to handle its own radioactive waste correctly and safely. The ERDO WG works towards developing such methods, and perhaps to allow for the construction of one or more joint European geological repositories.

TIMELINE OF EVENTS

Date	Description of event
1942	The first controlled nuclear chain reaction takes place in the United States – result of the Manhattan Project.
1945	The United States drop two atomic bombs in Japan.
1945-1970	Hanford Reservation in the USA discharging radioactive waste into the Columbia River.
1947	The Cold War begins.
1955	The UNSCEAR is created by the United Nations General Assembly.
1957	The Chelyabinsk plutonium production plant explodes, spreading nuclear radiation over a large area. Considered the second worst nuclear disaster, following Chernobyl.
1961	The Tsar Bomba is detonated by the USSR, the largest nuclear weapon in history.
1968	The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is signed.
1970	The NPT goes into effect.
1975	The London Convention enters into force.
1986	The Chernobyl disaster takes place near Pripyat, Ukraine. A radioactive cloud is released that causes environmental harm to most of Europe and parts of Asia.

[18] *ERDO - Working Group*. http://www.erdo-wg.com/.

1991	The Cold War ends with the dissolution of the USSR.
1994	The Convention on Nuclear Safety is adopted.
1995	UNGA 50/70 M resolution adopted.
1997-2001	The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management is adopted.
2002	The MOX program is established in the United States.
2009	The ERDO forum convenes for the first time.

RELEVANT RESOLUTIONS, TREATIES AND EVENTS

Treaty on the Non-Proliferation of Nuclear Weapons (NPT) - 1970

The NPT was a major step in beginning nuclear non-proliferation and the safe usage of nuclear materials. Its objective is to "prevent the spread of nuclear weapons and weapons technology, to promote cooperation in the peaceful uses of nuclear energy and to further the goal of achieving nuclear disarmament and general and complete disarmament."[19]

50/70 M – UN General Assembly – 1995 - "Observance of environmental norms in the drafting and implementation of agreements on disarmament and arms control" -

This resolution, adopted in 1995 by the General Assembly, was created with the primary aim to ensure that any resolutions drafted by the GA and the UN regarding disarmament and nuclear arms limitations are created in accordance to portrayed environmental norms, with the bid to increase environmental security[20].

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management – IAEA – 1997-2001

Entering force in 2001, the Joint Convention is the "first legal instrument to address the issue of spent fuel and radioactive waste management safety on a global

[19] United Nations General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (NPT) – UNODA*. https://www.un.org/disarmament/wmd/nuclear/npt/.

[20] United Nations General Assembly. *Observance of Environmental Norms in the Drafting and Implementation of Agreements on Disarmament and Arms Control – UNODA*. https://www.un.org/disarmament/topics/environmentalnorms/.

scale."[21] While the primary focus of the convention is on nuclear energy waste, many of the methods adopted apply to nuclear weapon waste and disposal as well.

London Convention - 1975

The "Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter" was one of the first global conventions to protect the marine environment from waste and general human activities[22]. Its primary focus is to prevent pollution of the sea through waste dumping. While not directly related to nuclear waste, it is important to consider while developing methods to deter environmental threats.

PREVIOUS ATTEMPTS TO SOLVE THE ISSUE

Due to the intricacy of the situation, there have not been any significant attempts to solve this issue. Several methods have been identified and pursued to store and dispose of decommissioned nuclear materials, however none of these have been proven to be feasible and viable. Burying the material in deep underground geological facilities has been considered to be the best solution[23], however has shown to be a costly and perhaps environmentally dangerous solution. Burying the material also requires large infrastructure projects in isolated areas of the Earth, which in themselves could bring about significant environmental and geologic damage. New radioactive material waste streams are being created due to the advancing decommissioning of nuclear weapons, and thus there is significant pressure on governments and international agencies to respond to this.

Figure 6: Underground Radioactive Waste Disposal [6]

Other methods have also been devised in recent years to combat this issue, although these are usually also quite costly and difficult to implement. For example,

[21] International Atomic Energy Agency. *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. IAEA, 25 July 2014, https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste.

[22] International Maritime Organization. "Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter." *International Maritime Organization (IMO)*, https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx.

[23] World Nuclear Association. "Storage and Disposal Options for Radioactive Waste - World Nuclear Association." *World Nuclear Association*, Mar. 2020, https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx.

the United States has created the Mixed Oxide Fuel Fabrication Facility at the Savannah River plant, where surplus plutonium from nuclear weapons is mixed with uranium oxide to make mixed oxide (MOX), and then used as fuel in some nuclear reactors[24]. While this process does still have certain environmental risks, it adopts basic ideologies such as the recycling of material, and could open a new economic sector. However, it is extremely expensive and rather inviable for large amounts of nuclear material.

POSSIBLE SOLUTIONS

There are two fundamental issues which must be addressed to minimize the environmental risks of nuclear weapon disposal. Firstly, the weapons and materials must be correctly decommissioned and transported to facilities. Secondly, there is the vital issue of storing or processing the materials following decommissioning.

Decommissioning and Disposal Process

Ensuring the safety of the decommissioning process is vital to ensure environmental security. To achieve this, there must be increased international and agency regulation, by organizations such as the IAEA and the United Nations Office for Disarmament Affairs (UNODA) to create specific guidelines and methods for incorrect decommission. Furthermore, an increase in intergovernmental cooperation between states of the NPT and other such agreement could be imperative to improving such methods. It should be stated however, that each state has the responsibility to adhere correctly to such guidelines independently, and holds the responsibility for any environmental consequences caused. It is imperative that environmental implications of such processes are constantly monitored to ensure through the procedure, and that they all adhere to international treaties and conventions. Depending on the infrastructure and capabilities of each state, special decommissioning and disposal plants could be created for nuclear weapon materials to increase the environmental safety of the state. Lastly, the transportation process must also be closely monitored and safeguarded.

[24] Pincus, Walter. "The Explosive Cost of Disposing of Nuclear Weapons." *Washington Post*, 3 July 2013. *www.washingtonpost.com*, https://www.washingtonpost.com/world/national-security/the-explosive-cost-of-disposing-of-nuclear-weapons/2013/07/03/64f896e0-e287-11e2-80eb-3145e2994a55_story.html.

Storage and Processing Methods

Since there are no viable methods currently available to either store excess nuclear weapon materials or to process them, it is imperative that such methods are developed.

In regards to storing materials, temporary and permanent storage site locations must consider potential environmental implications, and thus must be located far from endangered and delicate ecosystems and areas of the environment. This must also consider the potential impacts to inhabited locations and the implications to human life. The state must also have the capabilities to ensure the safety of the facilities, being able to prove their safekeeping for generations into the future. Redundancies could be established to ensure that radiation cannot be leaked to the environment. Such sites must also consider the possibility of terrorist attacks, and as such must have high levels of both environmental, civil, and military security.

With regards to new methods of processing materials, preexisting methods such as the MOX conversion method currently adopted by the United States could be considered. However, these methods must be optimized to increase not only processing efficiency, but to decrease costs and increase their viability. The future environmental implications of these processes must also be considered. Converting weapon materials into usable nuclear fuel does not entirely remove the eventual environmental consequences, as the nuclear waste from power plants can also cause significant environmental harm. Thus, methods could be developed which fully neutralize the materials although these will most likely be costly and ineffective in the short-term.

Responding to Environmental Disasters

Lastly, there is the issue of responding to environmental nuclear disasters. While it is always better to prevent rather than respond to such disasters, it is imperative to be prepared to respond in the case that one does break out. Through guides from the IAEA, the UNODA, the UNSCEAR, and other organizations, there must be enhanced international cooperation regarding this topic, and there must be a global preparedness to respond to and assist with the environmental consequences of nuclear disasters. This includes developing more effective methods to remove nuclear radiation from the environment, as well as limiting the damage radiation has on ecosystems. To achieve this, there must also be multilateral cooperation between local and national governments, and international organizations and NGOs.

The case of unregulated nuclear weapons must also be considered since there is a significant amount of illicit nuclear material trafficking. These issues could be approached through nuclear forensics, in a bit to limit the illicit trafficking and presence of unregulated nuclear materials. Such materials present perhaps one of the largest risks to the environment, as they are often not located in safe locations away from sensitive environments, and are quite mobile.

Finally, the possibility to contain nuclear radiation must be considered, with the aim of reducing the international and global spread of radiation and minimizing the damage done to the environment.

BIBLIOGRAPHIES

Main Bibliography

Abel J. Gonzalez. "THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT - ACHIEVING INTERNATIONALLY ACCEPTABLE SOLUTIONS." *IAEA Bulletin*, Mar. 2000, p. 14.

Atomicarchive.com. "Radioactive Fallout." *Atomicarchive.Com*, https://www.atomicarchive.com/science/effects/radioactive-fallout.html.

"Definition of RADIOACTIVITY." *Merriam-Webster*, https://www.merriam-webster.com/dictionary/radioactivity.

"Environmental Impacts of the Manhattan Project." *UKEssays.Com*, 28 Sept. 2017, https://www.ukessays.com/essays/environmental-studies/long-term-environmental-impacts-of-the-manhattan-project.php.

ERDO - Working Group. http://www.erdo-wg.com/.

Geras'kin, Stanislav A., et al. "Effects of Ionizing Radiation on Populations and Ecosystems." *Genetics, Evolution and Radiation: Crossing Borders, The Interdisciplinary Legacy of Nikolay W. Timofeeff-Ressovsky*, edited by Victoria L. Korogodina et al., Springer International Publishing, 2016, pp. 237–50. *Springer Link*, doi:10.1007/978-3-319-48838-7_20.

Guide to the Nuclear Wallchart. "Radiation in the Environment." *Guide to the Nuclear Wallchart*, 9 Aug. 2000, https://www2.lbl.gov/abc/wallchart/chapters/15/0.html#toc.

International Atomic Energy Agency. *IAEA Safety Glossary: 2018 Edition*. Glossary, 2018 Edition, International Atomic Energy Agency, 2019, p. 278, https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1830_web.pdf.

---. *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. IAEA, 25 July 2014, https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste.

International Maritime Organization. "Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter." *International Maritime Organization (IMO)*, https://www.imo.org/en/OurWork/Environment/Pages/London-Convention-Protocol.aspx.

International Risk Management Institute, Inc. "Radiological Weapon | Insurance Glossary Definition | IRMI.Com." *IRMI*, https://www.irmi.com/term/insurance-definitions/radiological-weapon.

Kristensen, Hans M., and Matt Korda. "United States Nuclear Forces, 2019." *Bulletin of the Atomic Scientists*, vol. 75, no. 3, May 2019, pp. 122–34. *DOI.org (Crossref)*, doi:10.1080/00963402.2019.1606503.

Lakshman D. Guruswamy and Jason B. Aamodt. *Nuclear Arms Control: The Environmental Dimension*. Stanford University, 1999, p. 52, http://large.stanford.edu/courses/2017/ph241/stevens2/docs/guruswamy.pdf.

Luhn, Alec. "Russia's 'Slow-Motion Chernobyl' at Sea." *BBC Future Planet*, 2 Sept. 2020, https://www.bbc.com/future/article/20200901-the-radioactive-risk-of-sunken-nuclear-soviet-submarines.

National Cancer Institute. "Definition of Radionuclide." *NIH - National Cancer Institute*, 2 Feb. 2011, https://www.cancer.gov/publications/dictionaries/cancer-terms/def/radionuclide. nciglobal,ncienterprise.

NDT Resource Center. "Radioactive Decay." *NDT Resource Center*, https://www.nde-ed.org/EducationResources/HighSchool/Radiography/radioactivedecay.htm.

"Non-Proliferation." *Cambridge Dictionary*, https://dictionary.cambridge.org/dictionary/english/non-proliferation.

NTI. *Nuclear Weapon Reduction | Disarmament of Nuclear Weapons | NTI*. 15 Dec. 2020, https://www.nti.org/analysis/reports/nuclear-disarmament/.

Pincus, Walter. "The Explosive Cost of Disposing of Nuclear Weapons." *Washington Post*, 3 July 2013. *www.washingtonpost.com*, https://www.washingtonpost.com/world/national-security/the-explosive-cost-of-disposing-of-nuclear-weapons/2013/07/03/64f896e0-e287-11e2-80eb-3145e2994a55_story.html.

"Radioactivity : Radioactive Half-Life." *Radioactivity.Eu.Com*, https://www.radioactivity.eu.com/site/pages/Radioactive_Half_life.htm.

United Nations General Assembly. *Observance of Environmental Norms in the Drafting and Implementation of Agreements on Disarmament and Arms Control – UNODA*. https://www.un.org/disarmament/topics/environmentalnorms/.

---. *Treaty on the Non-Proliferation of Nuclear Weapons (NPT) – UNODA*. https://www.un.org/disarmament/wmd/nuclear/npt/.

United States Nuclear Regulatory Commission. "Radioactive Contamination." *NRC Web*, 24 Aug. 2020, https://nrc.gov/reading-rm/basic-ref/glossary/radioactive-contamination.html.

WHO Director-General. *HEALTH AND ENVIRONMENTAL EFFECTS OF NUCLEAR WEAPONS*. World Health Organization, 26 Apr. 1993, p. 8, https://apps.who.int/iris/bitstream/handle/10665/175987/WHA46_30_eng.pdf?sequence=1&isAllowed=y.

World Nuclear Association. "Storage and Disposal Options for Radioactive Waste - World Nuclear Association." *World Nuclear Association*, Mar. 2020, https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx.

Yang, Xiaoping, et al. *Worldwide Nuclear Explosions*. Science Applications International Corporation, Center for Monitoring Research, p. 92, https://www.ldeo.columbia.edu/~richards/my_papers/WW_nuclear_tests_IASPEI_HB.pdf.

Figure Bibliography

[1] Perry, William J., and James E. Cartwright. "Opinion | Spending Less on Nuclear Weapons Could Actually Make Us Safer." *Washington Post*, 16 Nov. 2017. *www.washingtonpost.com*, https://www.washingtonpost.com/opinions/spending-less-on-nuclear-weapons-could-actually-make-us-safer/2017/11/16/396ef0c6-ca56-11e7-aa96-54417592cf72_story.html.

[2] Wikipedia. "Fat Man." *Wikipedia*, 1 Feb. 2021. *Wikipedia*, https://en.wikipedia.org/w/index.php?title=Fat_Man&oldid=1004213903.

[3] "Radioactive Decay - New World Encyclopedia." *New World Encyclopedia*, https://www.newworldencyclopedia.org/entry/Radioactive_decay. Accessed 1 Feb. 2021.

[4] Marc Lallanilla. “Chernobyl Trees Barely Decomposed, Study Finds.” *Livescience.Com*, 24 Mar. 2014, https://www.livescience.com/44318-chernobyl-trees-barely-decomposed.html.

[5] “Pacific Ocean Life Devastated by Fukushima Radiation: Fisheries Populations Have Crashed 91 Percent – The Daily Rapid | Dead Fish, Ocean Life, Fish.” *Pinterest*, https://www.pinterest.com/pin/415034921887300067/.

[6] DMT. “Radioactive Waste Disposal.” *DMT*, https://www.dmt-group.com/radioactive-waste-disposal.html. Accessed 1 Feb. 2021.