Surf City XIX

Huntington Beach High School

IAEA

Topic A: *Addressing Fuel and Waste Management for Nuclear Energy*

Topic B: *Nuclear Medicine within Developing Nations*

Welcome Letter

Dear Delegates,

On behalf of the Huntington Beach High School Model United Nations Program, we would like to welcome you to our Surf City XIX advanced conference!

Our annual Surf City conference upholds the principles and intended purpose of the United Nations. Delegates can expect to partake in a professional, well-run debate that simulates the very issues that those at the United Nations discuss every day. Both novel and traditional ideas will be shared, challenged, and improved.

It is our hope that all delegates will receive the opportunity to enhance their research, public speaking, and communication skills as they explore the intricacies of global concerns through various perspectives, some of which may be very different from their own. We hope their experiences here give them new insight and values that they can apply outside of the realm of Model UN for the betterment of the world community.

Please do not hesitate to approach our Secretariat or Staff Members with any questions or concerns that you may have throughout the day. We wish the best to all our participants and hope that they may share a fulfilling experience with us!

Enjoy the conference!

Sincerely,

Zach Bernstein
Secretary General

Vivian Bui
Secretary General

Lauren Le
Secretary General

Alison Miu-Martinez
Secretary General

Meet The Dais

Mary Sharkoff

Hey guys! My name is Mary and I am a senior at HBHS this year. MUN has been a major part of high school for me and has helped me get over my fear of public speaking and also learn about many concerning world events. The first topic I ever had for MUN was what helped me decide that I want to become a pediatrician or biomedical engineer after college. In school I am also a part of clubs such as the Doctors of Tomorrow Club. Outside of school I mostly spend my time dancing at my studio or tutoring. I love to read, bake, and watch sappy rom coms with my best friends when I'm not crammed with homework. I have been in a multitude of IAEA committees throughout my time in MUN which is why I am so excited to chair for you guys and cannot wait to see everyone in committee!

Ryley Barry

Hello delegates, my name is Ryley Barry and I am ecstatic to be chairing for you all! As a senior at HBHS, my passions lie within international relations and language learning, primarily in Russian, Spanish, and American Sign Language. Speaking with delegates from around the world through MUN sparked my interest in studying abroad at university as well as working for the Foreign Service as a political diplomat in the future. On the HBHS campus, I am the NHS President of External Affairs, a Track and Field Captain, and a student representative for UCI's Diversity, Inclusion, and Racial Healing Program. In my free time, you'll mainly find me binging Netflix, taking my dogs on a walk, volunteering with the Teen Climate Council at the Aquarium of the Pacific, or catching a few extra hours of sleep. I'm excited to hear all of your discussions during committee!

Lucas Pham

Hello! My name is Lucas Pham and I will be serving as one of your chairs for IAEA this year at Surf City. I am currently a Junior at Huntington, where I am involved in the National Honors Society, Green Team, and most importantly, Model United Nations! I absolutely love to learn about important topics and discuss them with others, which is why I have been a part of the HBHSMUN program for three years thus far and formerly Mock Trial for three years. Outside of school, I take interest in any form of art like drawing, painting, decoration, graphic design, and music. My favorite part about MUN is being able to meet new people from new places, so I hope that you all are able to enjoy Surf City as one of these experiences. I am so honored and excited to have the opportunity to chair IAEA and witness thrilling and thoughtful conversation. See you in committee delegates!

All Papers are due on **JANUARY 30, 2022** by 11:59pm to

surfcity.iaea@gmail.com

Topic A: Addressing Fuel and Waste Management for Nuclear Energy

Background

Nuclear waste is a term that is used to describe the product remaining after fuel has been used in a nuclear reactor.[1] Although it tends to maintain the same appearance before and after use, the processes involved in nuclear reactions causes the compounds within it to change and become extremely dangerous to the health of all organisms.[2] This waste can be produced from fuel processing plants, hospitals, research facilities, and the deconstruction of nuclear appliances. Also referred to as radioactive waste, this byproduct can be classified by either high or low levels of radioactivity.

Waste with high levels (HLW) is typically uranium fuel that has been spent, meaning completely drained of use, in a nuclear power reactor, producing radiation doses that are extremely harmful upon exposure. The fission, or the splitting of the nucleus, of uranium atoms in the fuel used in nuclear plants creates fission products, which are the isotopes of elements that are lighter than uranium and largely responsible for the heat and radiation in high-level waste. Additionally, elements that are heavier than uranium can form and create transuranic waste (TRU) that generates much less heat and radiation, but takes much longer to decay. After 1,000 years, much HLW is still hazardous due to TRU that has not yet decayed, and some transuranic isotopes can take nearly 50,000 years to disintegrate. However, once radioactive isotopes do decay, they become matter that is completely safe to the health of living beings.

Waste with low levels (LLW) is typically the result of commercial uses of radioactive materials, including medical, academic, and industrial applications. Articles such as clothing, tools, or equipment that have been exposed to radiation or radioactive materials make up this category and are generally defined as being any nuclear waste that is not high-level. Because it contains levels of radiation that decays in short periods of time, LLW is often stored within nuclear facilities until it can be discarded as regular trash or transported to a disposal site. Within the scope of LLW, there also exists very low-level waste (VLLW) that contains a level of radiation that is not harmful to humans or the environment. VLLW is typically created from naturally-occurring radioactive materials that are used in industrial manufacturing, or from the demolition of nuclear sites in the form of concrete, pipes, and other demolished materials.[3] While it can be disposed of as household waste, VLLW - as with all radioactive entities - can still disperse its radioactivity onto other entities. Thus, repositories with a focus on VLLW, such as the Centre Industriel de Regroupement, d'Entreposage et de Stockage in France, have been established with the primary objective of preventing dispersion.[4]

In some cases, nuclear waste is further classified into a third category known as intermediate-level waste (ILW). While they do not reach the high temperatures of HLW, these materials exceed the radioactivity of LLW. Materials that are categorized as ILW are typically resin, sludge, and metal, as well highly radioactive contaminated items, such as the parts of a decommissioned nuclear reactor.

Overall, LLW composes 90% of the volume of all waste, ILW composes 7%, and HLW composes 3%. But in terms of radioactivity, LLW composes only 1% of waste, while ILW composes 4% and HLW composes a staggering 95%. Consequently, one of the most important distinctions between the different products of nuclear processes is the caution that must be taken into account when handling them: LLW does not need to be shielded when handled, ILW does need to be shielded, and HLW must be both shielded and cooled. Therefore, there are two widely accepted disposal methods to accommodate these requirements: near-surface disposal and deep geological disposal. LLW and short-lived ILW are able to undergo near-surface disposal, which usually occurs immediately and at or slightly below ground level. HLW and long-lived ILW undergo deep geological disposal, where the waste is stored in a pond or dry cask to decrease the radioactivity and heat, then taken for deep geological disposal.[5]

In most cases, deep geological repositories are used to store and isolate HLW in networks of underground tunnels and rooms. However, these sites are meant for the direct disposal of radioactive waste with no intention of further use.[6] Consequently, some nations - such as the United Kingdom - have explored a technique called reprocessing in order to recycle spent fuel to create usable fuel. Reprocessing works by separating uranium and plutonium (a transuranic element) from the fission products, which can be used as fuel. While this can maximize the effectiveness of nuclear materials, it also generates liquid HLW that requires further dedication to return to a solid state.[7] Geological disposal has historically been the most effective and popular method, but it is certainly not the only method with the development of new technologies.[8]

Conventionally, the waste substances themselves are contained in steel that is surrounded by a concrete cylinder in order to contain the nuclear materials and prevent dispersal so that the surroundings are not exposed to radiation. While this is commonly used as an effective and efficient method of containment that does not require special treatment, it still is vulnerable to various conditions. Due to the long half life of radioactive isotopes that prevent them from breaking down quickly, the contents of the cylinders will remain dangerous for thousands of years. This poses a threat if people with malicious intentions gain access to radioactive matter, which is often stored in unspecialized locations. With this, the location for which to store nuclear waste is also under debate as it is necessary to find a secure area that will be able to store incoming waste for years to come. Researchers have suggested disposal in outer space, the ocean, and ice sheets, but none of these have proven to be successful or viable for the international community.[9] Additionally, while containers and other nuclear plant structures are generally sturdy, they are not invincible to forces that may damage them and expose the surroundings to radioactivity. In the past, earthquakes and tsunamis have destroyed facilities, with one effect being illness and genetic complications for plants and animals.[10] For example, the Fukushima Daiichi Accident occured in Japan after an earthquake and tsunami cut the power supply of 3 reactors. As the nuclear cores of these reactors melted, over 100,000 people had to be evacuated from the surrounding areas with 2,313 related deaths occurring among these evacuees.

The improper disposal of nuclear materials and accidents can also result in hazardous consequences. Waste can be deposited into bodies of water directly or indirectly, which can harm humans by seeping into and polluting underground reservoirs. In northern Europe, nuclear fuel reprocessing plants are the greatest source of the man-made nuclear waste that has been discovered in the ocean, reaching as far as Greenland.[11] Some humans also put themselves at risk of radiation exposure intentionally by scavenging in abandoned radioactive waste to meet the market that some countries have for such goods. One city where this is an issue is Ibadan, Nigeria, where 66% of hazardous materials are improperly disposed of.[12] Practices similar to this are extremely dangerous because those who have been exposed to radioactivity can further expose others, with the most extreme consequence being death. In addition, there is a high cost associated with nuclear accidents due to the cleaning and inspections that must be done to ensure the area is safe for life again. It can take tens of years for an area to be safe for human visitation, not to mention the natural organisms that must be able to grow and live normally.[13] The 1968 Chernobyl nuclear power plant accident that occured in Ukraine and contaminated 150,000 square kilometers of land with radioactive waste is projected to leave the area uninhabited for the next 3,000 years.[14] The proper handling of nuclear waste is of the utmost importance, due to the risk it holds over the wellbeing of humans and the environment.

United Nations Involvement

The International Atomic Energy Association (IAEA) was created in 1957 as the “Atoms for Peace” organization to oversee the responsible use of atomic energy.[15] Presently, the IAEA hosts a number of conventions related to nuclear waste, with the most recent being the IAEA International Conference on Radioactive Waste Management: Solutions for a Sustainable Future.[16] This conference was focused on advancements and current applications of effective waste management. In particular, the opening of the first deep geological repository for HLW in the world was held in the spotlight as evidence of progress towards a sustainable future in radioactive waste.[17]

Before the IAEA, in A/RES/913 of December 3, 1955, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established to assess the impacts of radiation exposure.[18] With nuclear waste being a cause of a large number of negative effects on the environment, the UNSCEAR has been detrimental to identifying such effects and finding solutions to them.[19] Every year, the UNSCEAR Report is released to detail important findings of radiation damage, with one of the areas of focus in 2019 being illnesses and genetic abnormalities caused by the nuclear waste from atomic bombings.[20]

The IAEA created the International Nuclear Fuel Cycle Evaluation (INFCE) waste management and disposal report in 1980 in regards to the disposal of radioactive fuel and waste management.[21] It called for the establishment of national, multinational, and international repositories for nuclear waste with the understanding that all nations are responsible for handling the radioactive materials within their own jurisdiction. The INFCE report also advocated for the creation of centralized disposal centers to reduce the risk that the improper handling of waste poses to the world. With this in mind, two guidelines for security in disposal facilities were brought into effect: the removal of nuclear substances from the human domain and the prevention of activities that intentionally pose a threat to human life. Furthermore, three concepts were fashioned by the IAEA in 2004, with the belief that multinational nuclear disposal facilities should be added to large national programs, under international advisory, and a collaborative effort between nations.[22]

The IAEA has also established numerous other projects aimed to deal with nuclear waste. The E-learning on Spent Fuel and Radioactive Waste Management, Decommissioning and Environmental Remediation initiative is a free public resource created by the IAEA that covers the policies, strategies and prerequisites of nuclear waste and the various methods of disposal. This has been an important resource in recent times because it offers education on nuclear topics and is globally accessible during the coronavirus pandemic.[23] The IAEA International Low Level Waste Disposal Network (DISPONET) was also created to address LLW through the use of shared knowledge, technical guidance, and training experiences. With the involvement of developed nations like France and Hungary, this network has guidelines for funding and approaching LLW management in developing nations.[24] The IAEA International Network of Laboratories for Nuclear Waste Characterization (LABONET) is a worldwide initiative meant to strengthen less developed disposal facilities. Some of the largest initiatives of this organization were the International Conference on Radioactive Waste Management: Solutions for a Sustainable Future, which allowed nations to search for sustainable alternatives to current waste management practices, and the technical reports on waste packages, which brought a more effective approach to the handling of waste.[25] Lastly, the IAEA International Network on Spent Fuel Management (SFM Net) addresses the use of fuel and the handling of spent fuel. Nations have been able to collaborate under the SFM Net to fully realize the use of clean energy in nuclear facilities, with China expected to host the International Conference on Fast Reactors and Other Fuel Cycles in 2022.[26] The United Nations and IAEA has been successful in uniting the global community to seek safe and efficient methods of managing radioactive waste, but these methods vary from country to country, with some being more effective than others.

Case Study: Sweden

A vital example of successful foundations established for nuclear energy usage and waste disposal can be seen in Sweden as nuclear energy accounts for 40% of the nation's electricity.[27] While Sweden has reduced its nuclear capacity with time, as seen with the shutdown of two Swedish reactors in 1999 and 2005, its current capacity is one of sustainability and precaution. Sweden currently has a repository for short-lived low to intermediate level waste and is in the process of developing a repository for both spent fuel and for long-lived intermediate-level waste. Every three years inventories are reported in accordance with the IAEA Joint convention and the EU Radioactive Waste Directive to promote transparency in the quantities of waste Sweden produces. On the whole, nuclear energy usage has largely been agreed upon by the public as seen with The Novus Sweden Panel concluding in the summer of 2021 that 31% of the nation supports the continuation of nuclear power plants and 46% of the nation supporting constructing new nuclear power plants.

The notion of the nuclear industry was first introduced in 1947 through the establishment of AB Atomenergi, an organization committed to atomic energy consumption research. An experimental nuclear reactor was instituted in 1954 and led to the development of nuclear usage becoming a political issue in the 1970s. In 1977, the first legislation regarding waste management of nuclear waste was proposed and further reaffirmed with the Nuclear Activities Act of 1984. This act, building on Sweden's Atomic Energy Act of 1956 which established twelve commercial reactors across the nation, stated that whoever produced the given waste was ultimately responsible for its overarching management and future disposal.[28] However, Sweden has yet to specify procedural focuses regarding nuclear waste at the level produced from sources such as scientific laboratories or hospitals. The process of such legislation is currently being reviewed in tandem with the Radiation Protection Act which focuses on the preservation of worker safety from given hazards.[29] Currently, organizations such as Studsvik Energiteknik AB will dispose of hazards from such sources for a given fee although this is primarily viewed as a corporational responsibility rather than as a government responsibility at this time.[30]

However, Sweden has not always remained in such continuous unanimous support regarding nuclear energy usage and waste management. In 1979, the United State's Three Mile Island Unit 2 Reactor experienced a partial melt down, an event that could have proved to be disastrous regarding radiation exposure and the preservation of human safety.[31] In turn, this led the international community to be increasingly wary regarding nuclear energy usage, leading to a 1980 Swedish referendum on nuclear energy usage. Consequently, Sweden decided to slowly eliminate nuclear power usage within the country until its complete elimination by 2010. Due to this decision, the Swedish Nuclear Fuel and Waste Management Company (SKB), a corporation that manages the fuel cycle of nuclear energy and profitability margins, began to change. The SKB began to increasingly sign contracts for nuclear waste disposal and fuel reprocessing with other foreign companies, such as France's Cogema. As a result, 10% of projected fuel discharges in Sweden were from reprocessing contracts alone. However, after reprocessing 140 tons of spent fuel in the UK, Sweden has now decided to directly dispose of its nuclear fuel for the future.

With a Low to Intermediate Level radioactive waste level (LILW) of 13,800 m^3 in interim storage and a LILW disposed of 39,000 m^3, Sweden has a total of 52,800 total generated LILW as of 2016. Currently, Sweden stores all spent nuclear fuel in its interim storage facility located in Oskarshamn. However, Nordic countries such as Sweden lack the abundance of montmorillonites and salt rocks necessary to store nuclear waste in the Earth's continental crust. As a result, the two Nordic countries utilizing nuclear power, Finland and Sweden, have had to utilize crystalline rocks as a supplement. However, an issue faced by crystalline rock usage is its permeability which results in negative groundwater fluxes.[32] To counter this issue, Sweden is close to approving the implementation of the nation's first encapsulation plant and nuclear fuel repository in conjunction with the Radiation Safety Authority, which has been in development since 2011.

The disposal process of nuclear waste in Sweden first begins at the nuclear power plants themselves with spent nuclear fuel needing to cool in a multi-year long process. The fuel is then moved to a wet storage facility found in a centralized intermediate storage facility. After movement into a repository, which in Sweden is located 500 meters deep in bedrock, the fuel is placed in the floor of underground tunnels filled with holes. The SKB typically disposes of such highly-radioactive waste through its KBS-3 method which utilizes copper canisters, Bentonite clay and bedrock. Surrounding the nuclear waste, the copper canisters are roughly 5 centimeters thick with inserts of nodular cast iron to prevent the erosion of the external layer, exposing the spent fuel. Such 5 meter long canisters are placed into the aforementioned holes to stabilize the material. Bentonite clay is then placed around the copper canisters as a functioning buffer to prevent further erosion and any harm that may source from surrounding rock movement. Lastly, after the tunnels are also packed with clay, the surrounding bedrock - which in Sweden is typically a granite material - further protects the given material. Not only does this prevent radioactive material from seeping out but additionally prevents other materials from entering the canister. Typically, such a storage facility will last for at least 100,00 years although this may vary given environmental changes.[33]

Compared to other nuclear energy using nations, Sweden stands out for its early financing of nuclear waste and fuel disposal. Sweden's 1981 Financing Act established that given services must pay a sum of money to the government equivalent to the electricity produced from nuclear energy. Such a charge would be utilized by the National Board for Spent Fuel for nuclear utilities the following year and would also supply loans to the given utilities. In the 1990s, Sweden implemented a tax on nuclear capacity which nearly doubled by 2006. However, after the nuclear tax posed a threat to the development of nuclear power plants, Sweden's political parties agreed to eliminate the tax slowly until 2017. This notion was reaffirmed under Sweden's 2006 Act on Financing of Management of Residual Products from Nuclear Activities as it discussed the potential future costs of nuclear waste mangement and the role of future research in reducing such a price.

Regarding international legislation, Sweden has played a key role in the development of nuclear fuel and waste management within the global community. Sweden's Nuclear Liability Act, or SFS 1968:45, discusses the commitments of Sweden to implementing the 1963 Brussels Convention Supplementary to the Paris Convention and the 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy.[34] The Brussels Convention establishes that in the event of a nuclear incident to which Sweden may be found responsible, victims will be entitled to no more than 6 million Swedish Krona *kr) or $657,113 USD.[35] This convention additionally built upon the Paris Convention which established that the nuclear installation operator is held responsible for any and all accidents and that the aforementioned compensation must be provided to the given individual within 10 years of the incident.[36]

Recently, in August of 2010, Sweden has been struggling to manage the waste produced by its nuclear reactors, leading to projected electrical blackouts due to its dependency on the resource.[37] While a difficult situation, this case brings attention to the lacking development of long-term solutions for spent fuel storage as nations work towards carbon neutrality to combat climate change. For example, Finland has approved the implementation of a repository, as previously proposed by Sweden's SKB, while Russia has approved the recycling of nuclear waste. On the whole, it remains vital to consider the progress made by Sweden in order to allow for significant progression in the longevity of nuclear fuel and waste disposal management.

Questions to Consider

1. Should nuclear fuel reprocessing play a role in nuclear fuel and waste disposal?
2. What policies can be enacted in order to incentivize nations to implement nuclear waste disposal programs?
3. How has fuel and waste management of nuclear energy been managed in your country? Are there any solutions that can cater to the discrepancy between developing and developed nations?
4. In what way(s) can improper waste disposal best be regulated within your nation and globally?
5. Should the responsibilities of corporations compared to the government differ regarding nuclear fuel and waste disposal? If so, in what ways?
6. Can countries safeguard against nuclear incidents occurring at the final disposal phase? How will this protection differ given varying levels of radioactivity?

Endnotes

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Topic B: Nuclear Medicine within Developing Nations

Background

Nuclear medicine consists of using small amounts of radioactive materials and radiopharmaceuticals in order to monitor the functioning of the body and detect diseases. [38]Nuclear medicine imaging typically utilizes what are known as radiotracers in order to determine the level of function of whatever organ or tissue is under examination.[39] Radiotracers, which are radioactive substances that include different forms of elements such as technetium and gallium, are typically injected into the body, and emit radiation in the form of gamma rays.[40]

Gamma rays are typically detected by devices such as Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT) scans.[41] PET scans work by identifying radiotracers analogous to glucose, known as fluorodeoxyglucose (FDGs).[42] FDGs are known to accumulate in malignant cells due to their high rate of glucose metabolism, thus providing an efficient way for physicians to detect malignant lesions that may have been overlooked. While PET scans are efficient for the detection of cancer formation, SPECT scans help to mainly diagnose disorders of the heart, brain, and bones. The most common radiotracers used for SPECT scans include iodine-123, xenon-133, and fluorine-18, with the type of tracer used dependent upon the organ or tissue of study. While PET scans use radiotracers that accumulate within tissues, the radiotracers utilized for SPECT scans are meant to remain in the bloodstream to demonstrate how organs such as the brain and heart are functioning. However, both PET and SPECT scans use gamma ray emission in order to create 3-D images of an organ or body to be examined.

While nuclear medicine can be used for the detection and diagnosis of medical conditions, as radiotracers accumulate often in areas of inflammation, infection, or cancerous tumors, it can also be used in treatment as well. After diagnosis, one main form of treatment that can be used is radioimmunotherapy. Radioimmunotherapy consists of using a radioactive element, such as iodine-133, that is tagged to a monoclonal antibody in order to kill off any cancerous cells.[43] These radioactive monoclonal antibodies are injected into a patient's bloodstream and meant to bind to cancer cells and deliver harmful doses of radiation. Radioimmunotherapy is typically used when chemotherapy is proven to be ineffective, and has been seen to treat cancers such as Non-Hodgkin Lymphoma, which begins in the lymphatic system due to the abnormal growth of white blood cells. [44]

Beyond radioimmunotherapy, radiation therapy is also a common use of treatment. Radiation therapy includes both external and internal forms of treatment meant to slow the growth of and kill cancerous cells. External beam radiation therapy entails targeting high energy x-rays or electron beams generated by a linear accelerator at regions of cancer within a patient.[45] Internal radiation therapy involves a patient injesting some sort of radiation source in either liquid or solid form. Radiation therapy in the liquid form is known as systemic therapy and involves either swallowing the treatment or receiving an injection for it to travel through the bloodstream and reach the target tissues. Radiation therapy in the solid form is known as brachytherapy and includes using seeds, ribbons, or capsules, placed near or within a tumor, resembling the local treatment administered within external radiation therapy. While treatment through nuclear medicine has been slowly adopted and increased within hospital systems, there still remains concern among patients and nations on the use of radiology and its effectiveness and validity. [46]

One of the main concerns with nuclear medicine is the harmful effects of radiation which could possibly cause the formation of cancer or damage tissues, and therefore has created a reluctance among many citizens within nations to turn to nuclear medicine.[47] The two main concerns surrounding nuclear medicine for citizens include the harmful exposure a patient may fear they can receive and the risk of exposure when interacting with an individual undergoing radiation therapy.[48] While the side effects of radiation therapy are mild and include symptoms such as fatigue, low thyroid, weight loss, and nausea, the effects that normal radiation exposure has seen to have had in cases of nuclear power plant issues has created a sense of fear within patients.[49] Truly, ever since the consequences of the Chernobyl nuclear power accident of 1986 that is connected to over 20,000 documented cases of thyroid cancer, a term coined as radiation phobia syndrome has developed within many nations and citizens.[50] Radiophobia is what ultimately creates a fear and stigma of nuclear medicine diagnosing and treatment, and results in the paradigmal view that radiation, in any quantity, is a carcinogen.[51] Yet, despite these fears and misconceptions of radiation treatment and technology, it is found that health care workers that interact with radiation therapy patients remain healthy and unaffected. Despite evidence of nuclear medicine's success and helpful capabilities, wariness of nuclear medicine has become widespread, mainly due to prevailing stigma and lack of understanding. For instance, a study conducted by the National Institute of Health in the United States found that typical citizens were 1.5 times more likely to fear nuclear technology and medicine than experts on nuclear applications. While the stigma of nuclear medicine is a challenge for its establishment worldwide, there are a multitude of other barriers concerning its implementation in developing nations alone.[52]

The main issues that prevent the flourishing of nuclear medicine within developing nations include a lack of access to nuclear reactors that provide the necessary elements for radiotracers, therefore leading to an increased cost for importing supplies.[53] For instance, to treat one patient with nuclear medicine would cost at least 400 USD without considering extra burdens of transportation or needs of equipment, while tumor imaging for a patient on average costs 1204 USD.[54] Furthermore, a lack of stable electricity and new equipment also leads to the deterioration of machines and incapacity to perform procedures to the best ability. For instance, in 2015, over 30% of hospitals and clinics in sub-Saharan Africa lacked electricity, which resulted in their inability to use nuclear medicine or related technology.[55] Furthermore, the issue of poorly trained practitioners, or lack of enough health care workers at all not only prevents the establishment of nuclear medicine but also leads to unstable health care systems within developing nations. An example of a lack of physicians can be seen with Mozambique, in which for their population of over 22 million, there are only 548 properly trained doctors. Therefore, with issues ranging from cost to training to supplies, nuclear medicine, despite its novel applications in diagnosing and treating patients, is extremely difficult to implement within the developing nations that could actually benefit from them the most.[56]

United Nations Involvement

The main way that the UN has focused on nuclear medicine and implementing it throughout countries is by the IAEA's programs. One section of the IAEA, known as the Nuclear Medicine and Diagnostic Imaging Sections, primarily focuses on fostering the implementation of nuclear medicine to further advance diagnostics and treatment plans. This is done through providing access to education and aid on nuclear medicine with seminars and other public meetings.

Furthermore, the IAEA also centers on promoting RPOP, or Radiation Protection of Patients to ensure that both physicians and patients are educated on nuclear medicine and that individuals are kept safe and provided with the proper care and treatment. Through monitoring of the amount of radiation used for procedures within hospitals, the IAEA works to keep everyone safe and healthy and successfully ensure the integration of nuclear medicine into hospital systems.

Furthering onto the promotion of RPOP, the IAEA has also worked to establish a multiple of seminars and conferences to educate on the topic and application of nuclear medicine within hospitals and healthcare systems. This can be seen through the IAEA's constant presence in the third through tenth Asia and Oceania Congresses on Nuclear Medicine, where, from 1984 to 2012, participants from over 23 countries gathered to attend symposiums and scientific discussions on the current breakthroughs and uses of nuclear medicine that can be implemented within healthcare systems. Another example of the IAEA's involvement can be seen with the International Conference on Nuclear Cardiology, which occurs every two years and is organized with the IAEA and organizations focused on promoting nuclear medicine. This conference focuses on encouraging European countries, especially on adopting and promoting nuclear medicine, especially in the field of cardiology within their major hospitals.[57] With their involvement in international conferences, the IAEA usually aids in providing guidelines and frameworks on how to implement this growing technology, and encouraging its establishment alone. The main example of this can be seen by the IAEA's release of their own guidelines for nations and hospitals on the use of nuclear medicine and applicable resources. With the last guideline book released in 2020, these procedural rules and instructions cover the safe and correct use of medical imaging technology and nuclear medicine treatment options that can be used by healthcare workers to aid in the public health sector.[58]

The IAEA has also established the Human Health Program, which allows for support and aid given to nations applying nuclear techniques, such as nuclear medicine. Mainly, the Human Health Program works to support nations with establishing new and improving existing nuclear imaging machines in order to increase the efficacy of diagnostic and treatment rates for citizens worldwide. A last example of an IAEA related program is the Program of Action for Cancer Therapy. Through this program, the IAEA works to mobilize the distribution of resources that help to detect and treat cancer, while also ensuring the integration of radiotherapy in partnership with the World Health Organization and IAEA Member States. Ultimately, through the IAEA's, and thus indirectly the UN's, support of nuclear medicine through conferences, programs, and guidelines, it becomes clear that radiation diagnostic use and treatment is increasingly supported in its establishment worldwide.[59]

Case Study: Egypt

Recognized as a lower middle-income nation by the United Nations Economic and Social Council, Egypt is a developing economy that has taken great strides towards improving upon its nuclear medicinal research.[60] As of 2013, Egypt possessed a life expectancy of 71 years, indicative of its status as a lower intermediate country on the epidemiological transition.[61] As a nation, Egypt is at the unique point in which it currently faces challenges from both non-communicable disease (NCD) and communicable disease (CD).[62] Regarding CDs, Egypt is primarily focused on combating the pressing threats of Avian Influenza and Viral Hepatitis C.[63]

Nonetheless, Egypt has been successful in nearly eradicating CDs like Measles and Leishmaniasis. On the other hand, Egypt has a 25% probability of dying prematurely due to NCDs, necessitating the further development of nuclear medicine to combat such threats. According to the World Health Organization, 17% of Egyptian adults were found to have rapidly increasing glucose levels in the blood, responsible for the 1% mortality rate of diabetes-related complications.

Historically, a focus on using nuclear energy for medicinal capabilities first began in Egypt in the early 1960s through the utilization of a Norwegian production plant and a Russian 2Mw reactor to produce diagnostic isotopes.[64] As Egypt's capacities began to develop, the Norwegian dry distillation method to obtain radioiodine was later supplemented by Hungary's molten tellurium dioxide methodology in 1995.[65] A secondary research reactor was established in 1998 with the ability to utilize boron neutron capture therapy.[66] This method injects boron into the brain to detect large brain tumors such as meningiomas and destroy them through the use of alpha particle emission. In order to detect the presence of specific drugs, hormones, or enzymes in the body, Egypt has primarily relied upon the usage of radioimmunoassay (RIA) kits. Such kits utilize radioisotopes to combat antigens found in small quantities within the body. [67]Implemented within 38 Egyptian laboratories, this successful system has also led to the small-scale usage of enzyme linked immunosorbent assay (ELISA) kits, which uses enzymes to combat antigens found in the human body.[68] However, the RIA kit usage has yet to reach a tremendously large scale due to issues facing the importation of the product, a challenge shared among many developing nations. Ever increasing costs, issues in reliability and timeliness of transport, along with fluctuating exchange rates have all played a key role in the severity of such an issue.[69]

The nuclear medicine sector within Egypt heavily relies upon the production and usage of radioisotopes. These neutron deficient entities source from a MGC-20 cyclotron machine particle accelerator established in Insha's Nuclear Research Centre created by the Egyptian Atomic Energy Authority. The MGC-20 cyclotron machine, established in 2001, utilizes a 18-MeV external proton energy beam to accelerate charged particles and obtain radioisotopes.[70] Such production is vital in the field of nuclear medicine as radioisotopes work in conjunction with imaging devices and emitted gamma rays to diagnose issues within a person's body. [71]Technetium-99m, the most commonly used radioisotope in nuclear medicine, has been the basis of many kits used for medical diagnosis throughout Egypt.[72] Moreover, such technology has allowed Egypt to locally produce Indium-Ill (used for tumor detection), Gallium-67 (which can detect cancer variations) and Iodine-123 (contributes to the study and treatment of thyroid disease).[73] Iodine-131 based radiopharmaceuticals, which function to destroy overactive thyroid tissue, have also been successfully utilized in Egypt.[74] Radioisotopic techniques have additionally been implemented in various hospitals throughout Egypt, making up a portion of the total 10,000 international hospitals that utilize radioisotopes for medicinal purposes.[75]

However, given its role as a still developing nation, Egypt has had to source support for such technological development through external sources.[76] For example, the Egyptian government has obtained economic support from the IAEA for their Nuclear Research Centre through the establishment of a radiofrequency system for isotopic production.[77] In addition, the IAEA has provided Egypt with nuclear medicine training equipment, aided in the refurbishment of the Insha cyclotron in 2007 and funded the creation of the ETRR-2 research reactor in 2018. Through international cooperation, 854 individuals have been trained in nuclear medicine in Egypt along with 211 aided global professionals. In turn, this has enabled Egypt to further develop their own training capacities with 174 lecturer and professional presentations created by

Egypt on nuclear medicine training for other developing nations seeking international engagement in the field of nuclear science.[78]

It has been recognized that there is significant regional variation in nuclear medicine training, specifically within developing countries. This notion can be exemplified in Egypt where obtaining a degree often coincides with a vocational training program in a typically clinical environment.[79] Depending on the region of focus, training can last anywhere from two to five years and concludes with one of the following degrees: Master in Philosophy, Master of Medicine, Master of Science, or Doctor of Medicine.[80] As discussed by the Egypt Cancer Network USA, which brings together Egyptian and American researchers to combat cancer, nuclear-medicine training sources from the IAEA whenever possible to understand how to safely handle radioactive materials.[81] Moreover, intergovernmental efforts have furthered Egyptian training systems as seen with the Regional Center for Isotopes training for the Arab countries. Cooperating with institutions such as Cairo University, The Cairo Center was created on the basis of the Middle Eastern Regional Radioisotopes Centre for the Arab Countries.[82] This center focuses on training individuals on specific radioisotopic applications to fields such as medicine and agriculture along with sharing research technologies on hydrology. [83]

Based on such international support, Egypt has enacted several national projects to further medicinal development. Working with the IAEA, Egypt has established the National Training Center and Developing Information and Communication Technology Materials to Build Technical Skills in the Field of Nuclear Science and Technology.[84] This project focuses on utilizing nuclear energy science and capabilities in a peaceful manner that promotes sustainability and the vocational training of individuals for future development.[85] Egypt has obtained funding for such projects and technological development through its collaboration with multinational institutions to designate $500 million USD towards the sector of medicine. In light of COVID-19, Egypt has established a $50 million USD agreement with the World Bank to create a domestic plan to specifically tackle disease prevention with the creation of hospitals, further developing the capacities for nuclear medicine. Currently, Egypt is working to obtain a $9.3 million USD grant from Japan to obtain more advanced medical equipment.[86]

When compared to neighboring Middle Eastern nations, Egypt has made significant progress regarding research and technological potential. Egypt remains one of a mere five nations in the Middle East that has the capability to create a 99Mo - 99mTc generator; the other four developed nations are Iran, Saudi Arabia, Turkey, and Israel.[87] A 99Mo - 99mTc generator remains extremely difficult for developing nations to implement due to their high costs and production of large amounts of radioactive waste which many developing countries lack the infrastructure to manage.[88] The aforementioned nations and Egypt additionally have the capabilities to produce the isotope Re 188, used to detect rheumatoid arthritis and bone metastasis.[89] Technologists training in nuclear medicine for a Bachelor's Degree, however, is available in Iran, Jordan, Turkey, Kuwait, and Egypt. However, remaining Middle Eastern nations have yet to develop such a high educational level of training and therefore heavily depend upon field-level instruction. Although it has remained a common pattern for those obtaining such a degree to explore other fields such as radiology. In turn, this results in technologists becoming specialized not in nuclear medicine but rather as laboratory technicians, deviating from the initial intent of the training.[90] Despite its status as a continuously developing nation, Egypt has been able to maintain strides equivalent to those of developed nations due to management of funding and cooperation with the IAEA.

Questions to Consider

1. Are there any viable ways to lower the cost of nuclear medicine advancements in developing nations?
2. What role should developed nations play in aiding developing nations and their aims to utilize nuclear medicine?
3. How will your nation work to combat the stigma associated with nuclear energy and nuclear medicine usage?
4. In what way can the local availability of radioisotopes and related kits be ensured?
5. What type of infrastructural development does your nation believe is most vital towards improving upon nuclear medicine in developing regions?
6. How do you plan on promoting clinical vocational training and education within developing nations lacking the resources to do so?

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