Ensuring global regulations for nuclear waste management

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Issue: Ensuring global regulations for nuclear waste management

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Introduction

The use of sustainable energy is nowadays becoming a more and more pressing problem, with the hole in the ozone layer widening, and global temperatures steadily rising. It is clear that the human abuse of fossil fuels cannot continue much longer if we wish to continue life as we know it on this unique planet. In the past years, multiple solutions have presented themselves. Think of Photovoltaic Solar energy, Wind energy or Hydroelectric energy. While these may be the most well-known types of sustainable energy, there is another type, that has grown in popularity in the last decade: **nuclear energy/power**. Nuclear power is the use of nuclear reactions to produce electricity. Nuclear power can be obtained from three different types of reactions: nuclear fusion, nuclear decay, or nuclear fission. Right now, the **nuclear fission** of uranium and plutonium, which happens in nuclear power plants, is how the majority of nuclear electricity from nuclear power is produced globally. The advantage of nuclear power, compared to other types of energy, is the very large amount of energy produced from a very small amount of fuel, and the fact that the amount of waste produced is relatively small. There's just one, not so slight, problem. Much of the trash that is produced is **radioactive** and thus damaging to humans and the environment. Therefore, it must be managed, as it is a **hazardous material**, in order to keep it from interacting with the **biosphere**. The products in nuclear waste that are of most concern are Tc-99(Technetium-99), I-129(Iodine-129), Np 237(Neptunium-237), Pu-239(Plutonium-239). The last one is particularly problematic, due to it being the isotope of plutonium that is used for the production of nuclear weapons. This hazardous material must be treated, and then a long-term strategy must be devised for the management of the material, involving storage, disposal, or transformation into a nontoxic form. In the following research report, I will inform you about the different existing types of nuclear waste management, their pros and cons, and the need for global regulations concerning nuclear waste management.

Definition of Key Terms

Nuclear Energy/Power

Nuclear power is the use of nuclear energy to produce electricity.

Nuclear fission

Nuclear fission is a reaction in which the nucleus of an atom splits into two or more, smaller nuclei. This process releases a very large amount of energy.

Radioactive

Emitting ionizing radiation or particles.

Hazardous material

Substances or chemicals that pose a health hazard, a physical hazard, or harm to the environment.

Biosphere

The worldwide sum of all ecosystems.

Subduction zone

A place where two tectonic plates meet, and one is thrust beneath the other. Subduction zones provide the opportunity to dispose of waste in such a way that it is carried into the earth's mantle.

General Overview

There are 3 different types of nuclear waste: Low-level waste (**LLW**), referring to objects containing a small amount of short lived-nuclear waste, Intermediate-level waste (**ILW**), which contains a higher level of radioactivity and therefore requires some shielding, and High-level waste (**HLW**), which is highly radioactive, and extremely hot, due to decay heat, and therefore requires not only shielding, but also cooling.
All of the existing techniques for disposing of nuclear waste can be categorized into two different groups: short-term management (STM) or initial treatment, and long-term management (LTM).

Initial Treatment

Vitrification

This is the practice of converting nuclear waste into a type of glass, which is stored in a cylinder. After this, the waste products are expected to be immobilized for thousands of years. This method cools the waste and shields the outside world from it. The only problem is the fact that if it were to be implemented on a wide scale, the number of cylinders could become a problem. Where do these cylinders then have to be stored? And what happens when the waste remobilizes? Phosphate Ceramics

Essentially the same as vitrification, but the waste is incorporated into crystalline ceramic. It has the same advantages and the same disadvantages.

Ion Exchange

The practice of concentrating the radioactivity into a small volume. The decreased amount of radioactive bulk now must be stored.

Synroc

Similar to vitrification, nuclear waste is solidified and immobilized. Solidifying the waste, instead of giving it in liquid form, has the advantage that it cannot leak into the environment or waterways.

Long Term Management

When dealing with the LTM of radioactive waste, you can be dealing with a time frame of anywhere between 10.000 and 1.000.000 years. This is the main problem with radioactive waste. It is quite difficult to find a solution for the management of something so far into the future. Much research must be done into this. Nevertheless, there are many already existing methods for the long-term management of nuclear waste.

Remediation

Remediation is the practice of using algae to degrade nuclear waste. This practice unfortunately only works with nuclear waste containing the element strontium, as thus far, no type of algae has been proven to have the ability to absorb or degrade any other nuclear product.

Above-ground disposal

This is the practice of storing already cooled HLW by sealing it into a steel cylinder, which is placed within a concrete cylinder, which shields the outside world from its radioactivity and is kept above ground. This practice has two advantages. First of all, it is relatively inexpensive. Secondly, the waste is easily accessible and can be retrieved for reprocessing. However, it does take up a large amount of space.

Geologic disposal

Geologic disposal is the practice of isolating radioactive waste deep underground, inside a rock volume that ensures that no harmful quantities of radioactivity can ever reach the surface again. This can be done by locating geological formations and using mining equipment to excavate rooms or vaults where HLW can be disposed of, and consequently sealed from human access forever. Many people dislike this method due to the fact that the waste in question is inaccessible after it is disposed of. They would prefer the waste to be perpetually managed and monitored. Another type of geologic disposal is ocean floor disposal, where the HLW is buried under abyssal plains, up to 10 000 meters under the surface of the planet, or burial in a subduction zone, where the waste would slowly be carried into the earth's mantle. Any type of ocean floor disposal is valid and would make it easier to come to an international solution to the issue of radioactive waste. However, any type of ocean floor disposal would require a change in the Law of the Sea, which protects all bodies of water, and the subsoil pertaining to them, from any type of waste disposal. A solution to this is the proposed land-based subductive waste disposal method that disposes of waste in a **subduction zone** that can be accessed by land. This would thus not be prohibited by international agreements. This method of land-based subductive disposal is often regarded as the most viable. Yet another type of geologic disposal is deep borehole disposal (DPD), which consists of disposing of HLW in extremely deep vertical boreholes, as much as 5 kilometres from the surface, or in horizontal boreholes, 1km under the surface, which is then filled in and sealed. In 2013, the UK government's proposal of beginning work on an underground storage dump for nuclear waste was rejected by a local council.

Transmutation

This is the practice of using reactors that consumes and transmutes nuclear waste into other, less harmful, nuclear waste. In 1977, President Carter banned transmutation in the US, but Reagan rescinded the ban in 1981. Both the US and the EU are currently working on this method.

Re-use

A way to reduce the amount of nuclear waste that must be dealt with, it is possible to find applications for certain components of nuclear waste. These components would then be extracted from the waste and used for whatever purpose. (Mainly industrial applications).

Space Disposal

This is the practice of the complete removal of nuclear waste from the planet earth. It does unfortunately have several disadvantages, such as the possible failure of a launch vehicle, which could spread radioactive material around the world through the atmosphere. Another problem is the fact that a very high number of rockets would be required, due to the tremendous amount of existing nuclear waste. This is very economically draining and increases the chance of a launch failure. Space disposal would further require international agreements on the regulation of such a program.

Timeline of Key Events

Date Event

1977 President Carter bans transmutation in the US 1981 President Reagan rescinds Carter's ban 1982 US establishes procedure for permanent HLW repository 1983 Sweden begins research for a permanent repository 1985 China begins research into geologic disposal of HLW 1991 The EPA in Russia bans the import of spent fuel for reprocessing.

1993 Belgium suspends reprocessing of spent fuel in France 1999 US begins entombing military-generated waste in New Mexico site

2001 Putin rescinds the ban on import of spent fuel in Russia 2009 Obama puts end to project of building HLW repository under Yucca Mountain

2010 Obama establishes Blue-Ribbon Commission on America's Nuclear Future

2011 Swedish SKB hands in application for construction of permanent nuclear waste repository

2022 Swedish government approves application for construction of permanent repository

2025 Swedish permanent waste repository is operational, storing waste for the coming 100,000 years

Major Parties Involved

China

There are currently 51 operational nuclear units in China, accounting for 5% of their electricity. They have been studying geological disposal since 1985 and have begun constructing an underground research laboratory in the Gobi Desert, with the goal of determining the area's suitability for future geologic disposal of HLW. The IAEA is currently supporting these efforts. China has also recently made a breakthrough in HLW disposal technology, by officially putting into use a method of melting nuclear waste into a glass (a type of vitrification) in Guangyuan. This makes China one of the few countries in the world to acquire such a technique.

India

There are currently 22 operational nuclear reactors in India. Concerning HLW, India has adopted the closed fuel cycle process. In this process, the spent fuel is reprocessed and recycled. The reprocessing results in only 2-3% of the spent fuel becoming waste. The rest is recycled and reused. The waste fuel, which is HLW, is vitrified. It is cooled during about 30 years, and then it is placed within geological disposal facilities.

Belgium

There are 7 nuclear power plants in Belgium at the moment, providing 52% of their electricity. Originally, Belgian spent fuel was sent to France for reprocessing, but this was suspended in 1993 by the Belgian parliament. Instead, spent fuel is currently being stored at the nuclear sites. Since the reprocessing was suspended, Belgium has been doing research into deep geologic disposal of HLW. The method of disposal that is currently being considered is the construction of an underground network, between 23 and 60 km under the surface.

France

There are 56 nuclear reactors in France (the most in Europe) providing them with about 75% of their electricity. Since the introduction of nuclear power, France has been reprocessing their spent fuel, even reprocessing spent fuel for other countries, with the waste being returned to the country of origin. France has been researching what to do with the generated waste since 1991, resulting in them opting for deep geological disposal in 2006. The Industrial Centre for Geological Disposal, otherwise known as Cigeo, is a deep geological disposal facility for radioactive waste that will be built. This center will consist of an underground area for HLW disposal, as well as surface storage and research facilities.

Russia

There are currently 38 nuclear reactors in Russia, accounting for about 20% of their electricity in 2018. Russia has a very long history of reprocessing spent nuclear fuel, even importing spent fuel from other countries in order to reprocess it. This was banned by the Environmental Protection Act in 1991, but legislation allowing it was controversially passed and signed by Putin in 2001. Russia has built the Mining and Chemical Complex (MCC) for an integrated approach to spent fuel management, where all the steps in the process of reprocessing spent fuel are done in the same place, providing efficiency and simplicity. The MCC will also handle the reprocessing of a new type of fuel, that can be recycled by up to seven types, which can cover the entire lifespan of some types of reactors. In the long term, the current Russian plan is deep geologic disposal.

Sweden

Sweden currently has 6 operational nuclear reactors, representing approximately 30% of their national power supply. The SKB, the Swedish Nuclear Fuel and Waste Management Company is responsible for the disposal of nuclear fuel in all of Sweden. The SKB operates an interim storage facility for spent fuel and is responsible for the construction of a permanent repository. Research into a permanent repository has been ongoing for 40 years, since 1983. The application for the construction of this permanent repository was handed in in 2011 and was recently approved by the Swedish government in 2022. The facility will be operational by 2025. The waste that is deposited there will be safe for 100,000 years.

United Kingdom

There are 9 operational nuclear reactors in the UK at the moment. Most of its spent fuel is processed through vitrification, followed by it being sealed into canisters for dry storage above ground for about 50 years, which precedes the eventual deep geological disposal. The company responsible for nuclear waste in the UK, NIREX, has developed a concept for a deep geological repository, based on the Swedish model, but a site has not yet been selected. The selection of a site, and the construction of a geological disposal facility is something the UK government is actively working on.

The United States of America

The USA currently ppossesses92 operational nuclear reactors, powering tens of millions of homes and communities, and accounting for 20% of the country's electrical energy generation. In 1982, the USA decided to establish a procedure and timetable for constructing a permanent HLW geological repository by the 1990s. The chosen site was Yucca Mountain in Nevada, where the final permanent repository was expected to open in 2017. This project received a lot of opposition, due to the necessity of long-distance transportation of nuclear waste, which increased the possibility of damaging accidents. The Obama administration rejected use of the site in 2009. The US has however been entombing military-generated nuclear waste in a site in New Mexico since 1999. In 2010, President Barack Obama established the BBlue Ribbon Commission on America's Nuclear Future. This commission conducted a study on nuclear waste disposal. Two years later, it provided a report containing recommendations not for a specific site, but for disposal strategies, the most important/notable being:

1. The US should undertake an integrated waste management program that leads to the

development of several permanent deep geological facilities for the disposal of spent fuel and other HLW

2. A new organization is needed to develop and implement an integrated program for transportation, storage, and disposal of nuclear waste.
3. The processes for the development of nuclear waste facilities must be
   - A) Adaptive – the process is flexible and makes decisions based on new information and any developments
   - B) Staged – key decisions are revisited and modified if necessary
   - C) Consent based – affected communities have an opportunity to decide whether to accept facility siting decisions
   - D) Transparent – all stakeholders have the opportunity to understand key decisions and engage in the process meaningfully
   - E) Standards- and science-based – the public can have confidence that the facilities meet the objective, and frequently applied standards of safety and environmental protection.

Possible Solutions

As made clear in the Major Parties Involved section of this report, there is a very large variation in how advanced different countries are in their techniques and projects for the management and disposal of nuclear waste. The IAEA plays a major role in this, as they have the power to financially and otherwise support different projects in different countries. But the IAEA also provides its member states with the opportunity to band together in efforts to create international projects and legislation for nuclear waste management. Achieving some sort of international cooperation on this level would be ideal, if possible, as it combines the knowledge and technologies of different member states. Delegates could attempt to create international scientific committees for research and development of waste management technologies, concerning long/short term management of mainly HLW, including processing, disposal, etc.

Another thing delegates could consider is the possibility of an international disposal point, a project that would be worked on by several different countries. Much would have to be decided for this. What type of disposal would it be? Where? Delegates must keep in mind not only the disposal and management but also the safe transportation of radioactive waste, as that is also a key element in this issue. If an international effort would be made, it would also have to be followed by the creation of international legislation for the regulation of such a project, the creation of which would require a sub-committee. The delegates could take the recommendations of the Blue Ribbon Commission on America's Nuclear Future as an example if they are to create international solutions.

In conclusion, there are 4 points that lie at the core of this issue, which the delegates must attempt to make progress on:

1. Initial Management – Is the waste reprocessed and recycled, vitrified, or must something else be done with it?
2. Transportation – Once the waste has been managed initially, it must be stored somewhere before disposal. Is the temporary storage on-site? Probably not. Most power plants don't have room for the temporary storage of so much waste. It must then be safely transported somewhere where it can be stored before eventual disposal.

3. Storage – Before the waste is permanently disposed of, it must be stored somewhere, perhaps even awaiting completion of the construction of the final disposal location 4. Disposal – Where, and according to what permanent disposal technique, is the waste finally managed in the long term?

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