September 2021

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HONORS 3100-004

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April 18, 2021

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Issues of justice and ethical dilemmas transcend time and will affect humanity's future beyond the generation they currently influence. This is the case of radioactive waste management; how will our decisions affect life beyond our time? Since its beginnings in the 1950s, the atomic energy industry has had the arduous task of developing effective disposal methods for toxic materials (Cotton). However, this issue has proven to be complicated, and its ethical ramifications have proven a challenge for past and present radioactive waste management officials. Because nuclear waste remains radiotoxic for up to 100,000 years, public officials must make sound and effective management choices when disposing of the waste. The ethical dilemma can then be seen as nuclear waste's intergenerational implications and the search for sustainable development options under the United Nations Development Agenda (Tondel 338).

Intergenerational equity refers to the notion that current generations have duties or rights that they owe to, or project upon, future generations (Marshall). Consequently, sustainable development can be defined as the intersection between intergenerational ethics and development, meaning that it meets current generations' needs without compromising future generations' ability to meet their own needs (Tondel 338). It is then, with a focus on the concepts of intergenerational justice and sustainable development, that officials must develop radioactive waste management strategies. In St. Louis, MO, we are currently facing a nuclear waste dilemma due to poorly disposed uranium ore materials in the West Lake and Bridgeton landfill areas. To best address the ethical dilemma of radioactive waste in St Louis, we must develop an intergenerationally equitable and sustainable solution that combines the fair distribution of risks, the equitable availability of resources, and the best safety outcomes for both the current and future generations.

Background

The West Lake Landfill is located at St. Charles Rock Road in Bridgeton, MO. This landfill is located adjacent to the Bridgeton Sanitary Landfill (West). In 1973, uranium ore, a highly radioactive material, was mixed with the soil in the west lake landfill area, creating a toxic hazard to the surrounding regions (DeGarmo). This radiotoxic material was used in the development of nuclear bombs and was left behind from Mallinckrodt Chemical Co.'s Cold War-era uranium processing operations (DeGarmo). The West Lake landfill was not designed for nuclear waste hold and resides in a flood plain near a heavily populated area. The positioning of uranium material in such proximity to urban areas is highly dangerous; nonetheless, the poor management experienced at this site has raised concerns from the community about the toxic material (Criss).

The adjacent Bridgeton Landfill is experiencing a seemingly natural, subsurface heat reaction deep within the landfill, producing faster waste decomposition and an excess of gas and liquid (Bridgeton). West Lake's ethical dilemma becomes the possibility of harming future generations depending on the Bridgeton reaction's growth rate; what will happen to the poorly stored nuclear waste if reached by a heating agent? According to Bridgeton Landfill LLC, the company in charge of monitoring the heat reaction, this subsurface fire is not likely to reach the uranium in at least 1000 years (Bridgeton). However, many radiotoxicity experts claim that nuclear materials remain toxic for at least 100,000 (Taebi 180), meaning that our future generations will bear the burden of our nuclear waste and might experience even more significant risks if the heat reaction reaches the uranium. Why should future generations deal with the consequences of our actions when they are not the ones who benefited from nuclear materials? This essay will examine solutions that can create intergenerational justice and allow all future generations to thrive accordingly.

Methodology

Before examining the waste disposal methods necessary for the improvement of the St. Louis dilemma, it is essential to define the terminology used when referring to nuclear waste's long-term effects. The term' future generation' is commonly used when discussing nuclear waste, particularly nuclear waste management and disposal. When discussing toxic materials, referring to future generations has been an ethical dilemma adopted by nuclear management authorities since the first mention of sustainable development in 1980 by the United Nations (Tondel 338). However, according to Celine Kermish, future generation is a term so broad that it does not fully grasp the meaning of intergenerational justice in the nuclear waste management industry ("Can"). Therefore, the following concepts of "close" future generations (those who still have memory and knowledge of radioactive waste and its location) and "remote" future generations (those who have lost all memory of the waste) will be applied to the research concerning nuclear waste disposal. The separation of this term will help us better evaluate the effects different radiological waste management strategies will have in society.

Management Strategies for Radioactive Waste:

Open Fuel Cycle (OFC)

The open fuel cycle process provides the most short-term safety and stability. However, it transfers all risks to close and remote future generations, with a higher impact rate on remote generations. In an OFC, the nuclear material is irradiated once, and the spent fuel is disposed of right away. This resulting waste remains radiotoxic for almost 200,000 years (Taebi 178). For an OFC, the most crucial aspect is to isolate the material from the environment right away, ignoring the future concerns to alleviate the present circumstances; therefore, this method is called a "once-through" strategy because it does not undergo further treatment (Taebi 181). This isolation creates short-term relief, which constitutes increased toxicity for remote future generations.

This process does not represent fairness or justice toward society's future because it negates their needs by allocating most nuclear risks to them. The consequences of OFC can then become reducible to a trade-off between generations. However, one could argue that, when talking about future generations, we should consider the possibilities of improved technology and resources that could help them better manage the waste. Society has a history of technological advancement, which should be considered when determining the benefits of OFC. If future generations are better equipped for radioactive waste management, it would be fairer to transfer the nuclear waste burden. Despite that possibility, future generations are unable to consent (Marshall 27), which then begs the question: is it unethical based on intergenerational justice to make decisions based on assumptions?

Closed Fuel Cycle (CFC)

Close fuel cycle refers to a process that compromises short-term public health and safety but improves sustainability and involves less long-term radiological risks by implementing reprocessing (Marshall 27). In a CFC, irradiated material is reused, diminishing its volume and toxicity by converting long-lived radiotoxic matter into shorter-lived matter (Taebi 180). This short-lived material enhances sustainability by creating less long-term radiological risks to the environment because it reaches neutral toxicity levels 5,000 years after disposal. However, the CFC process involves more immediate short-term concerns since the recycling of spent fuel can implicate more safety hazards for contemporary people (Taebi 181).

Close fuel cycle is a process in which the primary outcome is the fair and just allocation of risks based on future generations' well-being and development. CFC follows the principles of intergenerational justice and sustainable development by allocating the risks more evenly. Generational trade-offs occur between us and future generations and will continue to occur between close and remote generations. Consequently, ensuring equitable opportunity for all should be a top priority in order to secure equity.

"Retrievable" Geological Disposal

Geological disposal refers to a process in which radioactive waste material is stored in high-tech vaults buried in stable underground repositories that provide a natural toxicity barrier (Kermish, "Specifying" 1801). Retrievable disposal is a method that allows for the retrieval of the materials and might provide future generations with the ability to monitor and use the waste (Tondel 340). However, Celine Kermisch argues that this method is only useful for close future generations due to the challenges of preservation and upkeep of information that we might face in the next thousands of years ("Specifying" 1802). Retrievable waste depositories would allow future generations to access the resources and close the sites when considered appropriate. Nevertheless, if the waste is forgotten before the disposal site is permanently closed, the radiotoxic risks would increase.

Retrievable waste management guarantees justice for close and remote future generations because it considers their consent and opinions on the matter (Kermisch, "Can"). The nuclear material remains available, and future generations decide what to do with the matter based on their unique needs. However, retrievable waste can also open a door towards the misuse of nuclear materials and, if poorly managed, could lead to the environment's contamination. The preservation of information has not been a prominent characteristic of past civilizations. Our possible inability to pass on information on safety measures would lead to future generations not understanding nuclear waste's implications and could lead to radiological disaster because of miscommunication between generations (Marshall 29).

"Non-Retrievable" Geological Disposal

Non-retrievable geological disposal sites are a solution designed to be definitive and withstand the pass of time. This method does not allow for retrieving materials. It relies on the assumption that waste toxicity will naturally decay and has the advantage of not depending on future generations for management or monitoring (Kermisch, "Specifying" 1801). The non-retrievable repository is a method that guarantees long-term sustainability (Tondel 340); however, it does not allow for close or remote future generations to evaluate and take advantage of those nuclear resources.

Ethical Decision Making: Proposed Solution

While OFC and CFC methods both provide pros and cons to current and future generations, CFC seems like the most intergenerationally equitable. It allows for fair distribution of risks and assures a sustainable future; however, it does not assure the present population's safety. The ethical dilemma presented by this makes sustainable decision making a transfer of risks and puts the current generation in a position where their safety will be compromised for the benefit of societies not yet developed. We must then determine if future generations deserve the same consideration as the current generation.

Non-retrievable and retrievable methods are opposites of each other. On one side, it would be fair to allow close future generations to gain from resources left by the current generation and make their own decisions. Nevertheless, would it be fair and just for future remote generations to be in danger of radiotoxic materials they have never benefited from? When critically evaluating these two methods one can argue that fairness comes from allowing future generations to make their own choices. Nonetheless, one can also argue that intergenerational justice comes from taking away the burden of radioactivity and definitively dealing with the issue we have caused rather than pawning it onto others.

While analyzing the four disposal methods, it is clear that no one method can solve the radiological waste management dilemma in its entirety. The ethical components that must be analyzed to make an intergenerational and sustainable decision make it difficult to finalize an answer. Based on intergenerational ethics we can weight the consequences of the disposal methods; the decision is then summarized as a trade-off between generations. However, this trade-off must consider techno-scientific aspects as well. In his article, Alan Marshall states that nuclear waste management's scientific components should come second to the social, ethical components due to the issue's intrinsic nature (26). Meaning, regardless of how technical nuclear management is, the decision must be based on what is better for the people. The concepts of close and remote future generations can help us better determine each method's impact on our future societies.

Through the above considerations, the CFC method will guarantee the safety of current generations and few close generations; however, is that safety worth potentially destroying remote future generations' ability to thrive? In contrast, is retrievable depositories the best solution, or will we be exposing remote future generations to unsupervised highly toxic matter for the benefit of a few close generations? If radioactive waste management is based on public safety and fairness, none of these methods constitute viable options for all current, close, and remote civilizations. It is, however, the combination of methods that will allow for an equitable and fair solution. Therefore, a combination of CFC and retrievable disposal could present itself as the ideal solution by combining the fair distribution of risks, fair availability of resources for close future generations, and safety outcomes for remote future generations.

The St. Louis Dilemma

When we talk about radioactive waste management, the issue of intergenerational equity and sustainable development becomes apparent. Like that of the West Lake landfill, poorly managed nuclear waste threatens the concept of intergenerational equity by not considering future generations as a factor when deciding disposal methods of the waste. The CFC method proposes a solution in which short-term public health and safety are compromised, but that improves the disposal site's future sustainability and lessens the material's long-term radiological risks (Marshall 27). CFC implements reprocessing, a method in which nuclear materials go through a sequence of processes that help diminish the waste's volume and toxicity (Taebi 180). This reduction in volume and toxicity help increase sustainability because the waste then reaches neutral toxicity after 5,000 years rather than 100,000 (Taebi 181). This process increases the risk of short-term safety because of the waste's reprocessing; however, it allows for a fairer distribution of burdens. The CFC method would aid in the West Lake dilemma because it allows for ethical intergenerational justice. The current society should have a moral duty to lay an even playing field for future generations to thrive without carrying the burden of our choices. However, intergenerational equity also means that we should grant future generations the same availability to resources the current generation possesses.

Intergenerational equity is a phrase used to describe the obligations and rights that, morally, the current generation owes, or project upon, future generations (Marshall 27), which means that we must value future generations' rights to prosper and should, implement sustainable development (Tondel 339). However, this also means that we must secure future generations the same rights and privileges the current generation possesses. Concerning radioactive waste management, this implies that we must allow for future generations to have the ability to access the nuclear materials our generations have benefitted from. Therefore, retrievable geological repositories would be the method necessary to ensure intergenerational equity (Kermisch 1802). Geological disposal refers to a process in which radioactive waste material is stored in high-tech vaults buried in stable underground repositories that provide a natural toxicity barrier (Kermish 1801). Retrievable disposal is then a method that allows for the retrieval of the materials and might provide future generations with the ability to monitor and use the waste (Tondel 340). This method allows for the most ethical approach to intergenerational justice because it considers future generations' needs and wants.

The West Lake landfill is contaminated with highly toxic uranium ore; however, this same material can develop nuclear energy and could benefit future generations in their technological advances (West). Therefore, implementing a retrievable repository would allow for the fair availability of resources while simultaneously increasing the current generation's safety by implementing a disposal method that takes away the radiotoxic material from our environment. Retrievable waste depositories would allow future generations to access the resources and close the sites when considered appropriate. This disposal method could aid the St Louis community by turning the poorly managed waste site into a safe and ethical intergenerationally equitable facility.

Because nuclear waste remains toxic for 100,000 years, the retrievable repositories method has been criticized for adding unnecessary risks to future generations if the waste's memory is forgotten by society (Kermish 1802). If the disposal site, and the materials inside of it, are forgotten before the repository is permanently closed, the unmanaged toxic waste can lead to environmental contamination. This is why a combination of both CFC and retrievable repositories is necessary for intergenerational equity. If the nuclear waste were to be reprocessed before being disposed of in a retrievable repository, it would only remain toxic for up to 5,000 years (Taebi 181). Therefore, increasing the safety outcomes for future and current generations without ignoring the ethical implications of intergenerational justice and sustainable development.

A combination of these approaches, however, can also raise many questions regarding fairness between generations. The CFC method poses a threat to current generations by manipulating the waste and decreasing the safety of those around it. However, especially in the West Lake landfill dilemma, it can be argued that the safety of those currently around the waste is already compromised, and our inability to manage the waste will only lead to more safety hazards (Stelzer). Nonetheless, retrievable waste can also open a door towards the misuse of nuclear materials and, if poorly managed, could lead to the environment's contamination. The preservation of information has not been a prominent characteristic of past civilizations. Our possible inability to pass on information on safety measures could lead to future generations, not understanding nuclear waste's implications (Marshall 29). However, when combined with CFC, this argument becomes virtually irreverent. Societies ability to pass on information will not increase the dangers of retrievable waste because the waste will lose its toxicity and become neutral before it can pose a threat of contamination (Taebi 190). Although there is no perfect solution for the radioactive waste dilemma, the CFC process and retrievable disposals make for a sound and ethical method to aid towards an intergenerationally equitable and sustainable future.

Conclusion

Radioactive waste has been an issue in our society for the past 70 years. Our inability to fix it by now only alludes to the hardships we have had with toxic material. These hardships should serve as examples of why we must develop sustainable policies and protocols to prevent future generations from suffering from poor management skills. Issues of justice are transcendent and will continue to develop and affect society as it grows. We know the issue of radioactive waste will continue to impact society for years to come because of the nature of toxicity. One hundred thousand years is a long time, and we are unable to scientifically predict its future implications and the level of damage it can cause to humankind's future. Because we cannot determine future generations' abilities, resources, and social hierarchies, it is unethical not to do what we can to protect them with the information we currently have. Therefore, current radioactive waste management decision-makers must adopt sustainable and intergenerationally conscious practices to secure the well-being of generations to come.

A combination of CFC and retrievable disposal presents itself as the ideal solution to radioactive waste management by combining the fair distribution of risks, fair availability of resources for close future generations, and safety outcomes for remote future generations. In the West Lake dilemma, a combination of CFC and retrievable waste management would decrease public safety and health concerns by implementing real change that current and future generations could see and experience. The West Lake landfill has been in the process of clean-up since 2017; however, not much has been done, and residents are not ensured of their safety (Stelzer). Waste management officials state that they are closely monitoring the waste and its reactions; however, they fail to declare a final solution (Criss). The CFC and retrievable method would expedite the clean-up process by providing a sound and ethical solution instead of continuous waste monitoring. Although issues of justice and ethical dilemmas are inevitable in our society, focusing on intergenerational equity and sustainable development can aid in providing solutions that will lessen the burden of these issues for generations to come.

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