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Radioactive Future

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Abstract

Prior to being decommissioned in 1987, the Hanford Site— a nuclear production complex located in Benton County, Washington— was the local for reprocessing a large portion of the nation's supply of plutonium and uranium. Now, over 30 years later, 430 million curies of radioactive waste are kept on-site in surface facilities or underground tanks which are beginning to deteriorate, and nearly two thousand capsules of highly radioactive cesium and strontium sit in an aging facility. This waste includes cesium-135, a by-product of plutonium production which has a half life of nearly two million years. While the proposed disposal method of burial in a deep geological repository provides a means of isolating the waste from the human populace, in two million years, human culture will be fundamentally different, if not gone entirely. Contextualized by decisions made at other nuclear waste disposal sites globally, this paper discusses ways in which policymakers have grappled with both managing and warning future generations about nuclear radiation, an object massively distributed throughout space and time that challenges normative conceptions of what an "object" is to begin with. While there is a wide array of proposals to deter future interference with waste stored deep underground, the inevitable design flaws suggest that perhaps nuclear waste should not be buried out of public sight at all. The present remediation at the Hanford Site provides a unique opportunity to reflect upon mankind's direct role in the creation of nuclear waste and consider strategies to inform future generations of its presence in ways which surpass written word.

Keywords: hyperobject, risk society, the Hanford Site, nuclear waste, remediation, disposal

Introduction

In Southeastern Washington State, 35% of the nation's human-made radioactive waste resides within the Hanford Site following decades of plutonium development amidst World War II and the Cold War (Gephart, 2010). Scientists and policymakers alike are now tasked with the country's largest and most complex clean-up and remediation project in history, as well as determining a long-term solution to protect citizens and the surrounding environment from the colossal amount of radioactive material left on-site, material that will not be considered stable for thousands of years. Doctor Timothy Morton, Rita Shea Guffey Chair in English at Rice University, designates such sizable events like nuclear radiation as 'Hyperobjects', entities of such vast temporal and spatial dimensions that they undermine normative ideas about what an object is in the first place (Morton, 2013). Applying Morton's definition to the present remediation actions at the Hanford Site brings about two significant questions: how can reliable decisions be made regarding phenomena massively distributed throughout both space and time and how do decision-makers inform future generations about substances that will still persist many centuries after our culture has either fundamentally changed or dissipated entirely?

Utilizing Timothy Morton's theory of hyperobjects and Ulrich Beck's sociological theory of 'Risk Society', the way in which modern society organizes around and responds to risk, this paper investigates attempts to answer these questions and analyze policy-making regarding long-term site remediation, including storage in deep underground repositories. Contextualized by decisions made at other nuclear waste disposal sites globally, this paper additionally explores policy decisions that aim to control for and protect future generations against potentially enormous risks, which are not certain to occur at any given time but may pose a threat over a long period of time.

Washington State's Development of Nuclear Weapons

On October 11th, 1939, president of the United States Franklin D. Roosevelt was hand-delivered an urgent letter written by Hungarian-American physicist Leó Szilárd, along with fellow scientists Edward Teller and Eugene Wigner, and co-signed by Albert Einstein. This letter warned that German scientists had not only discovered nuclear fission, they could also be developing an atomic bomb (Atomic Heritage Foundation, n.d.). The "Einstein-Szilárd Letter" encouraged Roosevelt to bolster funding of the nation's own nuclear weapons and development program to compete with foreign development and protect national security. The Advisory Committee on Uranium (later known as the S-1 Advisory Committee) was established the same year with the daunting mission of achieving a greater understanding of uranium and its potential uses within wartime technologies.

As the Advisory Committee on Uranium transitioned from research to development, it initiated The Manhattan Project: a classified American-led effort to produce a functional atomic weapon. To meet the expansive development needs as well as to maintain project secrecy, three sites across the country were designated as "Atomic Cities." Among these sites was Hanford Engineer Works in Richland, Washington, a 1740 square kilometer parcel of sparsely-populated, old-growth, shrub-steppe habitat alongside the Columbia River. This area was selected for the nation's first plutonium facility known as the Hanford Site, designed for the construction and operation of "... several nuclear reactors, fuel management facilities, and chemical separation facilities, which would produce sufficient amounts of the fissionable element plutonium for the nation's nuclear weapons" (Harvey, 2000). Operations at Hanford contributed to several infamous developments in nuclear technology and testing; most notably, the first batch of weapons-grade plutonium from the Hanford Site was utilized in the plutonium implosion device detonated in the New Mexico desert as a part of the Trinity Nuclear Test (Atomic Heritage Foundation, 2014). The true nature of both the Trinity Test and the Manhattan Project was unveiled to the public when the "Fat Man" bomb, powered by plutonium-239 transported from Hanford, was dropped on Nagasaki killing an estimated 80,000 citizens (Atomic Heritage Foundation, 2014).

Development at the site expanded rapidly following World War II due to the decades-long nuclear arms race between the US and the USSR. Alongside the reprocessing of 96,900 metric tons of uranium and the production of "...54.5 metric tons of weapons-grade plutonium and 12.9 metric tons of fuel-grade plutonium..." During operation, Hanford released an abundance of radioactive and chemical waste into the surrounding environment; one expert estimates that "nearly 2,000 fuel elements ruptured during the 43 years Hanford reactors ran" (Gephart, 2010). Despite best efforts of operators, there are several recorded occurrences of accidentally released fission byproducts into the Columbia River, and the Washington State Department of Health has detected long-lived radionuclides in the river sediment. These radionuclides directly impact the river's water quality in multiple areas across the site; consequently, utilizing the river's water for fishing, irrigation, and drinking can lead to varied levels of radionuclide exposure. The United States Nuclear Regulatory Commission (2017) details that while low dose radiation exposure over a period of time is unlikely to cause an immediate health problem, this type of exposure can influence the development of cancer and genetic effects later in life.

Hanford's decommissioning in 1987 did not end the macrocosm of nuclear and environmental management posed by Hanford's nuclear development; the attention of policymakers and site operators was soon redirected to the critical environmental and public health crisis birthed from multiple instances of faulty management of vast amounts of hazardous material impacted by limited time and resources. Out of the 177 massive steel-shelled tanks holding 56 million gallons of highly radioactive liquid waste that are held in underground tank farms, 67 are suspected of gradually leaking their contents into the surrounding soil and potentially into the groundwater (Gephart, 2010). Uncontained leakage of chemical and radioactive waste has the potential to contaminate the Columbia River and the various life forms within it. Furthermore, 1,936 stainless-steel capsules of highly radioactive cesium and strontium sit underneath 13 feet of cooling water at the Waste Encapsulation and Storage Facility (WESF), a facility that is still in operation nearly twenty years after its designed life-span (United States Department of Energy, 2014). Cesium in particular, known to emit a powerful form of gamma radiation during decay, threatens the structural integrity of the concrete basin over time— this could lead to complete structural failure of the facility if remediation action continues to be stalled.

The DOE's Office of the Inspector General (2014) asserts that, beyond possible structural failure of the WESF, the facility is threatened by seismic activity and natural disasters. If an earthquake were to reach the facility and damage the building's vulnerable concrete foundation, allowing enough cooling water to escape the facility, the radiation levels in the building from exposed cesium and strontium will be so high that human entry is rendered impossible (Columbia Riverkeeper, 2020). If this loss of water were to continue, eventually humans will be unable to safely approach within 50 yards of the building due to massive, heat-generating radiation fields. With a complete loss of cooling water the capsules will promptly overheat, rupture, and spill all contents into the surrounding environment. If this occurs, the heat generated from the Cs-137 and Sr-90 will cause the facility temperature to soar to immensely high temperatures (several hundred degrees centigrade), collapsing the building. Following this domino-effect of events, no emergency response or cleanup will be feasible at the Hanford site for an indefinite period of time.

The Department of Energy and associated entities face immense pressure to promptly dispose of a massive amount of highly radioactive waste in various forms which poses a significant threat to public health and the environment, a threat which will be perpetuated for thousands of years. Several methods of disposal have been considered across the recent decades: storage in an underground geological repository, disposal in deep boreholes drilled into crystalline basement rocks, even launching waste into space. While limited in time, funding, and political support, the greatest challenge faced by the DOE is a lack of certainty. Radioactive waste management forces decisionmakers into an uncanny situation where both inaction and action can lead to grave consequences spanning so far into the future that it transcends normative concepts of time and space.

Hyperobjects

In his theoretical conjecture of human's withstanding relationship with the environment, *Hyperobjects: Philosophy and Ecology After the End of the World*, Doctor Timothy Morton (2013) investigates objects which he calls "uncanny," vast events such as global warming and plutonium radiation which transcend spatiotemporal specificity which Morton labels "hyperobjects." Morton presents the term hyperobject as a starting point for conceptualizing events that cannot be seen directly, those which outlast and out-scale human existence and society thus far, and challenge original perceptions of what an object even is. A styrofoam cup, Morton suggests, can be tossed into a trash bin and perceived to be thrown away. Ecology presents a different world; a world where waste is not transported into some unperceivable "ontologically alien realm," a world where there is no "*away"* (Intellectual Deep Web, 2019). Styrofoam, a non-degradable pollutant, can take an estimated 500 years to decompose. All of the styrofoam ever produced on this Earth presents an even more complicated, massive, and long-lasting environmental conundrum. The fate of styrofoam is not just expansive, it is an event that will outlive the current living human population and many generations after that. 500 years into the future there will be nobody meaningfully related to any individual alive today, a personal connection to and ability to fully grasp an issue this expansive becomes complicated and blurred.

Nuclear radiation and its legacy are even more immeasurable and potentially dangerous. Approximately 35% of the nation's human-made radioactivity alone resides at the Hanford Site, and among the most concerning and long-lasting radioactive elements at the site are the plutonium production by-products strontium-90, cesium-135, and cesium-137. At Hanford, these elements can be found nearly anywhere: soil, spent fuel rods, nuclear reactors, and within liquid and solid waste across the site. Strontium-90, an element with a half-life of 28.8 years, is a highly carcinogenic radioactive material known to build up in the bones of animals and humans alike due to its similarities to calcium (United States Nuclear Waste Technical Review Board, 2017). Because of the sheer volume of this material across the site, Strontium-90 will take over 800 years to decay to the radioactivity level currently allowed for classification as low-level waste (National Research Council, 2003). Similarly, carcinogenic and highly radioactive cesium-137 has a half life of around 30.2 years. Cs-135, existing alongside the stored Cs-137, "...has a half-life of about *2 million years*, and it will become the dominant source of radioactivity in the cesium capsules in about 600 years" (National Research Council, 2003).

The lifespan of cesium-135 is nearly unimaginable. There is no way of knowing how humanity will present itself in two million years, nor if it will exist at all. However, mere decades of human activity such as plutonium development and detonation of atomic bombs produced the massive amount of atomic waste seen today. Because humans produced this waste, humans are now tasked with the responsibility of its management and disposal, decisions which will impact the population thousands of years into the future.

Risk Society

Beyond the distortion of timescales and spatial scales, hyperobjects challenge commonly accepted notions of what an object is to begin with. Hyperobjects are stuck to us just as we are stuck to them, they are viscous. The presence of global warming, for instance, can impact the human body through heat on bare skin which leaves painful rashes and burns. Though the UV radiation from the sun's rays isn't visible, the impacts on human health and the environment are very real. Even when radioactive material is stored underground in a geological repository, it has not lost its radioactive force. Unlike sunlight, we cannot see radiation. Yet, the effects of radiation impact the human body far more intensely than surface-level rashes and burns we can see.

Furthermore, hyperobjects are nonlocal. Despite the fact humans feel their presence, they are not present in one measurable location. An immeasurable amount of radiation has been released and continues to be released into the air, soil, and groundwater at the Hanford site, its total reach across the Washington landscape unknown. Traditional scientific measurements are intrinsically local, and as such they are not advanced enough to provide definitive causality between accidental waste release and exposure in surrounding areas (Morton, 2013). Knowledge of these potentially life-threatening risks of radiation; however, has forced government policy to address the distribution of risk across several generations. Simultaneously, inescapable awareness of the long-term effects of hyperobjects diminishes the ability of policymakers to make firm decisions in the present (Intellectual Deep Web, 2019).

Sociologists Ulrich Beck's and Anthony Giddons' social theory of 'Risk Society' grapples with the question of how humanity can approach anticipated problems as well as problems we may fail to anticipate in the future. Beck's book *Risk Society* followed the 1986 Chernobyl nuclear disaster, a nuclear power meltdown that led to Beck's assertion that environmental risks are not an unpleasant but manageable side-effect of industrial society, but the predominant product of industrialization itself. "Risk Society" refers to the ways modern society formulates in response to risk, a unique development where society begins to accept the fact that new risks are produced by humans themselves, not just uncontrollable forces. People in the present are suffering the "latent side-effects" of the "victories of modernity" (Beck, 1992). This scenario is clearly illustrated throughout Hanford's history, where industrialization which called for the massive production of uranium, the development of nuclear bombs, and subsequent testing and usage of nuclear weapons left behind an immeasurable amount of hazardous waste threatening food, air, soil, and water and will continue to pose harm for thousands of years.

In the 20th century the United States participated in the "first modernity" where taking risks, such as plutonium production, advances humanity and in the case of the Cold War and WWII protects national security. The second, 'reflexive modernity' is where we exist now as humanity is more cautious of the risks brought about by industrialization and progress. Individuals, Beck posits, begin to lose faith in the "institutions of modernity" such as science, and acknowledge modernity and progress as a part of the overall problem. At the Hanford Site, policymakers tasked with determining long-term storage for all levels of hazardous waste are frequently challenged by justifiable criticism from the public and politicians, as well as unresolved scientific issues on the siting and procedure for waste containment. In 2010, the construction of a nuclear waste repository at Yucca Mountain was suddenly halted by the Obama administration, following decades of scientific studies and analysis of previous geological waste repositories disputing if the site would safely contain the designated hazardous waste. Along with the site's inadequate size and vulnerability to seismic and volcanic events, Nevada residents and politicians alike fervently opposed the site due to the potential for water pollution and decreased tourism (Li, 2016). Mass fear and distrust regarding the management of long-lasting waste which impacts the physical environment and human health is to be expected. In the face of massively distributed events with immeasurable risk, policymakers are often caught between attempts to find quick solutions which delay management of the entire problem in the face of public criticism, as well as prolonged testing of solutions which risks avoidance of problems which pose imminent risk.

Abandoning self-interest

Cost-benefit analyses (CBA), centered on achieving benefits while limiting spendings, are often used by decision-makers when weighing policy options. The reliability of CBAs, however, falters when applied to events with significant uncertainties, especially regarding the future. CBAs are unable to fully account for intangible benefits of public policies due to a reliance on quantitative values which are necessary for comparison and analysis. A hyperobject such as nuclear radiation requires a significant investment in uncertain technology to mitigate damages to the environment and human health which materialize over an indefinite measure of time. Furthermore, hyperobjects are phased: it is impossible to see these objects in their entirety as they occupy a high-dimensional space (Morton, 2013). Applying a CBA to the management and remediation of hazardous waste is extremely difficult due to the inability to quantify the cost or benefit in monetary terms.

How can decisions be made about a risk such as cesium-135 radiation— which lasts so long that utilitarian concepts often used for policy making such as cost-benefit analyses cannot be ethically nor meaningfully applied? Morton suggests decision-makers must transcend normative self-interest theories and adapt and explore theories of ethics that are based on much larger scales and scopes (Intellectual Deep Web, 2019). This is not to say intimacy with one's surroundings must be rejected— in fact, dropping self-interest allows for a deeper contact with other lifeforms as well as future selves. To abandon self interest is to bring "the other" into consideration when making decisions. This ideology spans to account for one's own "future self," a self that may have values astronomically different from one's present self but will be subject to the same consequences posed by hyperobjects. Self-interest theories, especially when applied to events vastly distributed across space and time, obscure the ability of decision-makers to account for the risks which may impact future generations. Abandoning these theories and pursuing collectivism reframes one's perception of risk, cost, and benefit, and allows for a more sustainable solution to complex problems which span into future generations.

Admittedly, due to the profit-oriented sphere of self-interest that is capitalism, abandonment of self-interest theories appears to be an ambitious pipe dream. Yet, Beck and Morton assert that massively distributed events, such as nuclear radiation, transcend structures such as income inequality and impacts will be experienced more evenly across the population over time. While the elite may have more resources to delay the impacts, they cannot achieve immunity. This is not to disregard disproportionate impacts on individuals who vary across class and race, but to suggest that even with access to advanced technology such as biospheres, there is no escape from harm if the entire world faces ecological disaster. Therefore, a politician may be more inclined to make this transition away from self-interest and pursue collectivism in the face of a worldly event which threatens the well-being of every living being. Nuclear radiation, if unaddressed or improperly handled, could be this catalyst.

Long-term Storage of Nuclear Waste

Hyperobjects are *temporally undulated*, existing across such a vast expanse of time it is difficult for human cognition to fully comprehend and process. While humans can comprehend the number “2 million,” the half-life of cesium-135, it is difficult to understand or measure its significance and impact. The effects of cs-135 radiation across this massive timescale cannot be accurately predicted nor comprehended through existing scientific tools of measurement. To cope with this lack of understanding, the typical policy response is to “...withdraw from or displace hyperobjects” (Morton, 2013). Vastly supported and utilized global methods for high-level nuclear waste disposal, including storage in deep underground geological repositories or deep borehole disposal in crystalline basement rock, rely upon keeping nuclear waste out of sight.

The world’s first and only permanent nuclear-waste repository for high-level spent fuel is located on Olkiluoto Island, situated in western Finland. The vast pit leading underground named Onkalo, meaning “cavity” in Finnish, is designed to permanently house 3,250 canisters containing 6,500 tonnes of highly radioactive uranium (Gordon, 2017). The canisters will be sealed 420 meters underground and backfilled and sealed with rubble and concrete. Onkalo must reliably contain the canisters of radioactive waste for at least 100,000 years. Yet throughout the next 100,000 years, as the contained nuclear waste continues to threaten human and environmental well-being, the population of Finland will change exponentially. Knowledge of the massive timescale nuclear waste encompasses as well as the immeasurable risk it may pose centuries into the future, scientists involved with Onkalo are additionally tasked with determining how and if future generations should be warned of the buried nuclear waste. Director of the nuclear waste and material regulation department at STUK (the Finnish Radiation and Nuclear Safety Authority) Jussi Heinonen firmly believes the nature and design of Onkalo alone prevent against the risk of future generations intruding upon high-level waste stored underground. The site will lack any warning to future generations indicating the significant danger posed by the buried contents of the repository, but just because the waste is stored below ground does not mean it is absent from risk.

Although radioactive waste disposal is a recent conundrum, experience with deep geological disposal has already demonstrated that design alone may not protect future generations from risk. In Lower Saxony, Germany, 120,000 drums of waste stored within a former salt mine (the Asse II mine) were buried following pressure from surrounding rocks initiating the collapse of the mine walls (Gordon, 2017). The German government had believed, prior to this collapse, that the salt mine would be a permanent underground storage site for the drums of radioactive waste. Unpredicted structural failure from geological activity site developers failed to predict led to the present-day efforts to recover the waste before its contents permanently contaminate surrounding groundwater systems. Despite such risks, Onkalo fails to provide a system which will communicate the presence of waste to future generations prone to significant impacts on public health and the environment if the structural integrity of the repository or the capsules within fail over time, endangering the environment like the failure of the Asse II mine, or if the waste is unintentionally or intentionally uncovered by civilizations unaware of the dangers of the contained material.

The latter scenario is just as imaginable as structural failure. While leaving geological repository sites unmarked and isolated may prevent direct interference initially, once this secrecy is breached, deterrence efforts at the site fail completely. For instance; in 2011, newfound satellite imagery of Egypt unveiled 17 lost pyramids and thousands of hidden tombs (Pringle, 2011). Since discovery, these sites once tucked away have become sites of excavation and archaeological monitoring. Without any system in place to warn future generations of the concealed radioactive contents in Onkalo and other geological repositories, it is likely future generations will interfere with the sites following inevitable discovery.

Methods of casting waste “away” falsely assume that the danger of radioactive waste ceases when the waste is buried. Consequently, future generations will bear the environmental costs and long-term effects of nuclear waste stored underground. Current belief systems about ‘tangible’ phenomena reliant upon causality and scientific certainty are ultimately flawed, as they prioritize impacts which change the present while failing to account for future impacts which bypass the current generation.

Communicating the Presence of Waste to Future Generations

In 2013, the Department of Energy proposed that, for the permanent remediation and storage of the capsules of radioactive cesium and strontium held in Hanford’s WESF facility, a geological repository will be sited by 2026 and operations will begin by 2048 (United States Nuclear Waste Technical Review Board, 2017). The safety and integrity of underground containment of hazardous waste cannot be guaranteed, especially when accounting for a lack of knowledge regarding future events and risks. Therefore, if the effectiveness of the method of containment itself cannot be assured, and if the hazardous nature of the radioactive waste cannot be nullified with storage and disposal, decision makers are responsible for warning future generations of the life-threatening risks posed by contained waste. The entities in charge of the construction and facilitation of this soon-to-be constructed geological repository are faced with the decision to communicate the existence and nature of the repository's contents as well as the presence of risk and danger to generations thousands of years into the future, after culture and language have fundamentally changed.

In the late 20th-century, Sandia National Laboratories (SNL) (1993) challenged a diverse panel of experts with designing a system to mark the Waste Isolation Pilot Plant (WIPP) in New Mexico non-linguistically in a way that can deter human interference for 10,000 years, one that can convey this message of danger:

> This place is a message... and part of a system of messages... pay attention to it! … We considered ourselves to be a powerful culture. This place is not a place of honor... no highly esteemed deed is commemorated here... nothing valued is here. What is here was dangerous and repulsive to us. This message is a warning about danger. The danger is in a particular location... it increases towards a center... the center of danger is here... of a particular size and shape, and below us. The danger is still present, in your time, as it was in ours. The danger is to the body, and it can kill. The form of the danger is an emanation of energy. The danger is unleashed only if you substantially disturb this place physically. This place is best shunned and left uninhabited. (Trauth, Hora, & Guzowski, 1993).

As a final storage site for transuranic radioactive waste, the SNL researchers insisted the WIPP must be marked in a manner where its purpose cannot be misinterpreted, not just for this generation but for generations in the future that have undergone significant shifts in culture and communication. While the concept of leaving the site unlabeled, as in Onkalo, was discussed; mining and petroleum activities in the area further convinced the panel that the site must be labeled. The end goal for this project was to make an effective warning system that can then be referenced and utilized across all nuclear waste disposal sites around the country.

The panel relied upon the core assumption that, if future generations are able to interpret the message and understand the nature of the contents stored at the geological repository, they would not interfere with the site. How can messages appeal to humans and their instincts in a way that transcends diverse cultures and languages, existing and not yet in existence? To effectively communicate a message of danger to the unknowable future, the panel concluded that the method of communication must surpass pure words and pictures. The panel decided to use methods of communication which evoke emotion, specifically those of horror and sickness, something which the SNL report (1993) asserts is shared and unchanging across all humans.

The vehicles conveying the messages, such as the material for the site markers, the arrangement of the markers, and the appearance of the site itself, should convey that this place is unsuitable for individuals to spend a lot of time (Trauth, Hora, & Guzowski, 1993). Everything on the site must be intentional, "...from the very size of the whole site-marking down to the design of protected inscribed reading walls and the shapes of materials and their joints" (Trauth, Hora, & Guzowski, 1993). If the marking of the site is to account for a transformation of multiple cultures over an extensive period of time, panelists further asserted that the communication mode used in the marking of the entire site should not be rooted in any existing culture, so it remains unaffected by predicted cultural transformation. The physical form of the site itself must exist as "natural language," capable of notifying onlookers of the dangers within non-linguistically. Proposed site designs intentionally dissuade inhabitation and utilization in its very architecture; for instance, forms such as sky-reaching vertical structures which typically symbolize 'perfection' were barred. Furthermore the site must be vast, yet this vastness must also be visible from an accessible point so that the site can be seen and understood in its entirety.

These design guidelines, as well as numerous others, inspired multiple proposed architectural designs which intend to communicate meaning. Among these are:

a. Landscape of Thorns

Figure 1. Landscape of Thorns (concept by Michael Brill and art by Safdar Abidi).

The Landscape of Thorns site design utilizes shapes which communicate danger, shapes which hurt the body, “wounding forms” (Trauth, Hora, & Guzowski, 1993). The concrete spikes are irregular and their shape is non-repetitive, evoking a sense of chaos. However, in terms of durability, this architectural design is predicted to eventually develop minute cracks which will expedite decay due to tension in the upper surfaces of the protruding concrete spikes.

b. Menacing Earthworks

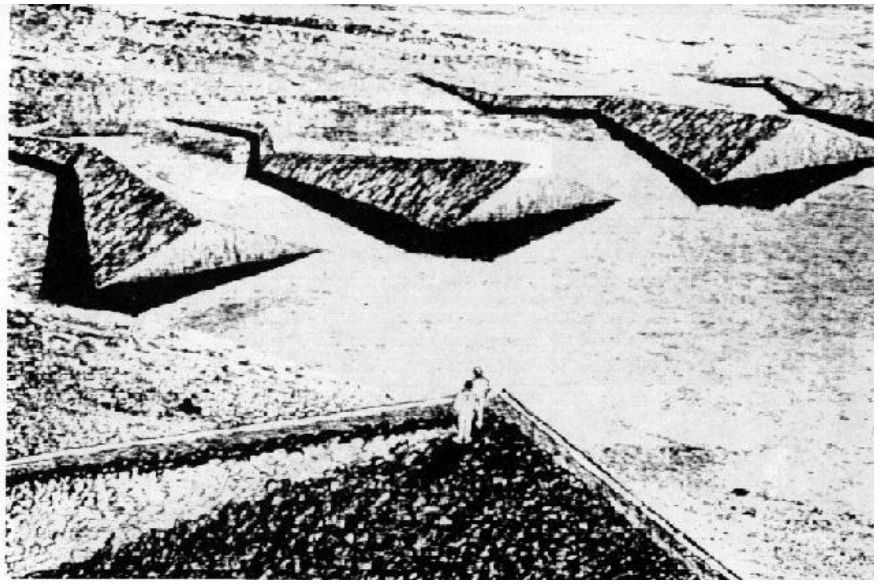

Figure 2. Menacing Earthworks, view 2 (concept by Michael Brill and art by Safdar Abidi)

The Menacing Earthworks design features immense, zig-zag earthworks which surround and radiate out of a central 'keep'— the predicted local for the final internment area. Like the spike field, the lightning-shaped earthworks are intended to suggest harm to the body. As one enters the maze of earthworks, the massive structures are designed to cluster around the visitor and eventually cut off their sight of the horizon. This design is intentional as it disorients those who enter the site, blurring one's sense of place altogether. Reading walls with cautionary information and symbols will exist on the surface of some of the earthworks. The earthworks are not the only deterrent at this proposed site; if a person were to enter the central keep, they would be met with a walk-on, domed world map depicting the locations of all radioactive waste repositories worldwide as well as a 50-foot wide map of New Mexico and the WIPP. This site is predicted to be structurally sound for at least 10,000 years.

c. Spike Field

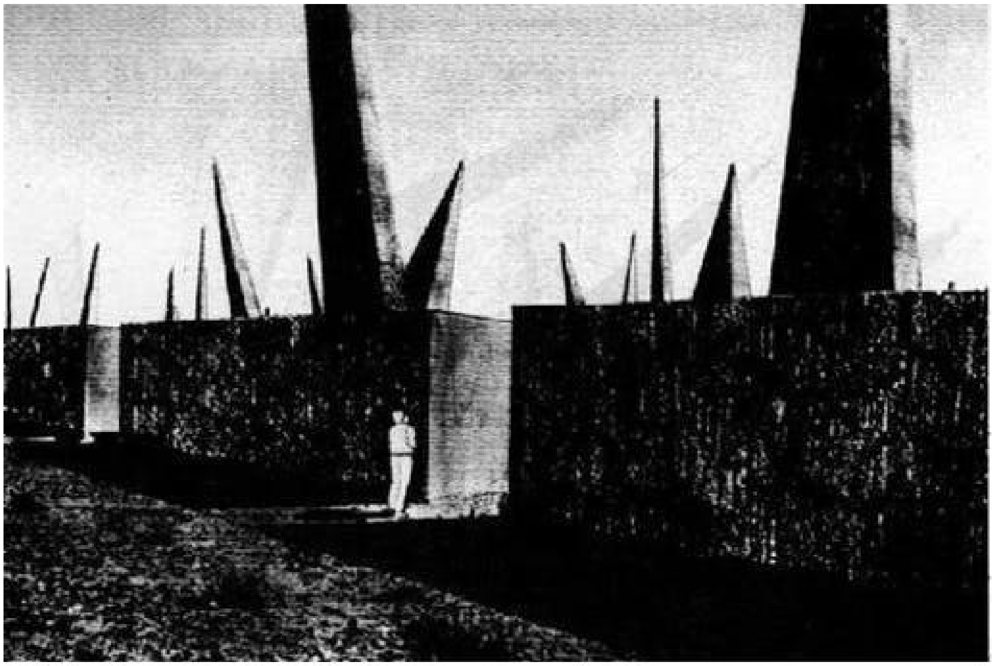

Figure 4. Spike Field, view 2 (concept by Michael Brill and art by Safdar Abidi)

Similar to the Landscape of Thorns, the Spike Field design features towering stone spikes which protrude out or and around the central Keep. Along with provoking a sense of unsafety and danger, these stone spikes discourage drilling in the area. This site, like the Menacing Earthworks, is estimated to last for at least 10,000 years.

d. Forbidding Blocks

Figure 5. Forbidding Blocks, view 2 (concept by Michael Brill and art by Safdar Abidi).

The Forbidding Blocks design utilizes a grid of enormous concrete/stone blocks, each an estimated 25 feet tall, manually dynamited, and dyed black. The black dye on the cubes is meant to generate heat throughout the area, so hot especially during the summer that even being at the site is uncomfortable. Rather than being smooth, neat cubes, the blocks are intentionally misshapen and distorted to create an environment which is intolerable and, like the namesake, forbidding. Pictorial messages and reading walls along some of the stone cube faces would contain cautionary information as well as basic information of the site and its contents. Between the stones, there are several cramped 'streets' which appear to lead into the structure. In actuality, the streets lead nowhere, nor do they provide any utility. Instead, the streets and blocks are presented in a way which deters use of the area, makes farming and even meeting others unfeasible, and disorients those who venture close.

The ambitious marking systems proposed by the teams of scientists in the SNL thought project attempt to predict and subsequently mitigate potential intrusion upon the hazardous waste contained at the WIPP. Yet, the proposed systems are not without flaw. For instance, pictorial messages incorporated into the facility design are ambiguous, and although planners of today may design a marker of a face distorted in pain to portray the harmful nature of contained waste, generations down the line may interpret the symbols in a different manner. Even with the development of symbols which successfully portray the presence of danger, there is a potential for the dangerous architecture and symbology to be interpreted as a method to deter tomb raiders and looters from buried wealth and riches as opposed to the dangerous waste contained within.

Additionally, written messages must be translated, a process that can take decades if future civilizations choose to invest the effort at all. Warnings left for future generations have repeatedly gone unheeded. For instance, in the Japanese village of Aneyoshi, a 10-foot tall stone tablet, dated around 1896, engraved with a warning meant to deter future generations from settling in the area due to susceptibility to devastating earthquakes and tsunamis (Lewis, 2015). This tablet, as well as several others in the surrounding area, were likely constructed in the aftermath of two deadly tsunamis in the 1890's which killed nearly 22,000 individuals. Despite the dire warning on the "tsunami stone," many coastal towns in the area continued to grow while government-built seawalls were entrusted as viable protection against potential natural disasters. As foretold by the stone tablets, in 2011, another devastating earthquake and tsunami hit the area and killed nearly 29,000 people. Even if a system is decided upon to prevent inadvertent interaction with the WIPP and other geological repositories, individuals existing today will never know if we have successfully communicated with our descendants.

Nuclear Guardianship/Atomic Priesthood

There are a multitude of known as well as unknown factors which influence the plausibility of underground waste repositories successfully containing waste which has been hidden away in a manner that protects future generations from harm. Yet, the concept of "Atomic Priesthood" derived from semiotician Thomas Sebok during his work with SNL takes deterrence a step further. Sebok's ambitious and somewhat unsettling proposal suggests that a new religion ought to be founded, whose singular role is to ensure that relevant information pertaining to nuclear waste repositories is transmitted throughout generations. Knowledge of nuclear waste would be passed down through artificial legends, myths, and scripture which would then be translated as new languages arise over the next several thousand years. Sebok offers a disturbing method of surpassing the incomprehensibility that will render written messages of risk as it pertains to hazardous waste unusable, a safety net that— while deceitful— attempts to connect moral right versus wrong to a complex and long-living public risk. A less extreme model of incorporating the existence of nuclear waste into culture and practice, such as incorporation of annual waste repository monitoring and management into the duties of the United State's military or a related department, may be an effective method for nuclear risk mitigation.

Is the fundamental flaw of radioactive risk prevention the underground storage of waste as a whole? To rationalize meaningful action and risk management of the unknown unknowns of hyperobjects, Morton insists, "humans must learn to care for substances— fatal substances— that will outlast them and their descendants beyond any meaningful limit of self interest" (Intellectual Deep Web, 2019, 35:40). This approach stems from Dr. Timothy Morton's concept of object-oriented ontology, a rejection of anthropocentric and biocentric viewpoints and embrace of the idea that objects exist independently of human perception (Morton, 2013). Rather than burying nuclear waste underground, Morton suggests it be kept out in the open in view of the public. The Nuclear Guardianship project poses a similar stance; "When the material is stored *where present and future generations can see it*, the maintenance required for its continual isolation from the environment is more readily facilitated" (Hibakusha Stories, n.d.). Not only would waste be visible, mankind's decision to have created the waste in the first place would be in full view rather than tucked away 420 meters underground.

Nuclear Guardianships preserve the ideal of closeness and intimacy with profound objects; instead of shielding the truth from humanity through a deceitful religion revolving around nuclear radiation, individuals should be custodians of nuclear waste. Morton suggests that if this method of waste monitoring were to be embraced, the relationship between humans and nonhumans would change in a profound manner. "Hyperobjects force us into an intimacy with our own death because they are toxic, with others because everyone is affected by them, and with the future because they are massively distributed in time" (Intellectual Deep Web, 2019, 28:20).

We cannot fully see radioactivity, nor the extent of its impact; however, we know it exists and humans play an explicit role in its creation, therefore we should care about it.

Conclusion

Developing and implementing strategies for safe disposal of nuclear waste comprises only a portion of the efforts necessary to solve the country's largest and most complex clean-up and remediation project in history. Even after disposal, radioactive material such as cesium-135 threaten human life and the surrounding environment millions of years into the future. As technology to contain and dispose of hazardous waste cannot be considered infallible, policymakers must develop strategies to control for and communicate to future generations about the potentially enormous and uncertain risks of nuclear radiation. A failure to warn future generations about the presence of nuclear waste repositories, such as the massive unlabeled facility located on Olkiluoto Island, could leave inhabitants prone to significant damages to public health and the environment if the structural integrity of the repository or the capsules within were to fail over time. Yet, proposed methods of deterring human intervention from waste repository sites present numerous other disaster scenarios if the intention of the site's architecture, symbology, and reading walls are misconstrued. Though the future risk of nuclear waste cannot be fully predicted, nor will current generations know if we have successfully communicated risks with our descendants, present society created the massive amount of hazardous waste seen today; therefore, it is the responsibility of this society to dispose of the waste in a safe and environmentally acceptable manner.

The Hanford Site offers a unique opportunity for humans to acknowledge the direct impact industrialization and modernity has on our surrounding environment as well as our future selves and those lives thousands of years after ours. As the effectiveness of methods for warning future generations of the dangerous contents of geological repositories appear increasingly unreliable, perhaps methods of incorporating the nuclear waste into culture and politics such as proposed by the Nuclear Guardianship movement can be pursued. Rather than hiding nuclear waste from the future and hoping risks will never surface, keeping waste in the public eye could be a feasible method of ensuring future generations are aware of both the hazard’s existence and mankind's explicit role in its creation.

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