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Nuclear Clay: Prerequisites for Geological Disposal of Radioactive Waste in Soviet Lithuania and Russia

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ABSTRACT

Amidst a period marked by growing volumes of nuclear waste and ongoing discussions regarding its management, technologies that utilise natural materials for containment are gaining prominence. This article takes a historical view of Russian nuclear waste management practices with a focus on the role of clay as a natural material for containing nuclear waste. In particular, it explores the use of clay in multi-barrier technology, highlighting its dual role as a protective layer and a resource for managing nuclear safety risks. The siting of the liquid nuclear waste disposal at the Ignalina NPP site in Lithuania (1976–1980) and of solid nuclear waste disposal at Leningrad NPP in Sosnovy Bor, Russia (2013–2018) are the main foci of this article. These cases contribute to understanding nuclear waste disposal siting in the USSR and modern Russia and enable analysis of nuclear waste discourses describing the sites' geology as a static or dynamic environment within active or passive safety systems.

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INTRODUCTION

Seventy years since the establishment of the first nuclear power plant (NPP) in Obninsk in 1954, the decommissioning of nuclear facilities and the management of nuclear waste have become increasingly critical concerns in Russia. The Russian nuclear corporation Rosatom has set a goal to phase out the remaining Chernobyl-type reactors by 2030 and to establish a national system for nuclear waste management, including geological disposal sites for radioactive waste. However, the implementation of this ambitious plan has been delayed due to lengthy technological research processes, innovation endeavours and negotiations with local communities. As a result, only one nuclear waste disposal site has been commissioned so far, in Novouralsk, with bureaucratic decision-making and public discontent hindering progress at other sites. Additionally, nuclear waste management concerns may have decreased in importance within Russia's nuclear governance agenda, particularly following the invasion of Ukraine in February 2022 and the full seizure of the Zaporizhzhia Nuclear Power Plant. The ongoing transition to a military economy has led to a shortage of budgetary and financial resources for addressing nuclear waste concerns.

This article examines the issue of nuclear waste disposal as a socio-technical challenge within the Soviet and Russian nuclear industry, exploring the discourses generated among techno-scientific actors and nuclear governance institutions. The collapse of the USSR led to a prolonged period without adequate legal, institutional and technological frameworks for nuclear waste management in Russia (Kasperski and Stsiapanau 2022). Established only in 2011, the nuclear waste management programme focuses on the transition from storage to the final disposal of low and intermediate-level radioactive waste and on technological solutions for high-level waste disposal. Technical solutions for nuclear waste management include near-surface or landfill disposal sites for low-level and short-lived intermediate-level waste, while deep geological disposal is considered a preferred option for spent nuclear fuel and high-level waste. This article focuses on the historical analysis of the controversies around nuclear waste technologies for low and intermediate radioactive waste developed during the Soviet time and in modern Russia. In particular, it scrutinises how natural resources, such as clay, have been utilised in the techno-scientific and political discourses for nuclear safety purposes.

Geology matters in nuclear waste management, as modern multi-barrier technologies integrate both engineering layers and natural geological layers for waste containment. The geological prerequisites, structure, retarding and absorbing properties of the geological layer – referred to as the geomedium in geoscientific terminology – influence the selection of disposal sites. For instance, Miller et al. employ natural analogues as a method to demonstrate how geological disposal can ensure long-term nuclear safety (Miller et al. 2001). Examples include the Oklo uranium mine in Gabon, the Cigar Lake uranium mine in Canada and the Dunarobba fossil forest in Italy, among others. These analogues provide insights into natural long-term containment, illustrating the corrosion of materials used in engineered barrier systems, as well as the behaviour of radionuclides in the environment over extended timeframes (Turner et al. 2023).

Meanwhile, natural and social scientists are debating whether natural analogues can serve as a valuable method for nuclear waste disposal. While Groopman highlights that the rock in the Oklo uranium mine possesses a natural mechanism for retaining radioactive elements (Groopman 2018), Hecht insists that it has limitations and cannot provide a complete solution for nuclear waste repositories, as each disposal site has unique geological properties that must be taken into account (Hecht 2018).

Such natural materials as clay, salt or bedrock are employed in nuclear waste multi-barrier technology as a passive safety barrier, which, in principle, secures the performance of the technology and geology of the site without direct human intervention. According to extensive research on the role of the natural barrier in the nuclear waste disposal system, clay is considered a material with retardation properties for radionuclide migration (Norris et al. 2019). Consequently, clay serves to contain radioactivity and ensures the nuclear safety of waste disposal. This agency of clay is central to this article – specifically, how does its application within nuclear waste discourses moderate the radioactive materiality of nuclear waste? This inquiry introduces a dual perspective – socio-technical and socio-material – which we will explore as a theoretical and methodological framework.

Clay is a versatile natural resource and traditional material that has played a crucial role in driving scientific and industrial advancements (Bergaya and Lagaly 2006). It is not merely a passive component but possesses significant economic value, making it a popular choice for a wide range of industrial applications. Its history can be followed through technology and industry developments. Its abundance and relatively low cost have made it an attractive option for gas, oil, paper, and chemical production industries (Murray 1991). The role of clay in the nuclear industry is multifunctional and applicable through several stages of the nuclear fuel cycle, from research and mining to waste management. Its application depends on the results of detailed study and investigation of the material and what new properties have been discovered and articulated for nuclear industry purposes.

Therefore, clay can be viewed as an informed material, as its material structure accumulates more and more information. This information results from research into the material's microscopic structure and allows for the extraction and tailoring of the properties specific to industrial needs (Bensaude-Vincent and Stengers 1996). Geological and chemical studies of the clay rock in various sites in the United States, France, Belgium, Canada and Russia have revealed that clay has high absorption properties that can be instrumental in immobilising radioactive elements in the geomedium.[1]

For instance, in Russia, during the discussions about nuclear waste disposal in Novouralsk, Tomsk region, in October 2019, the nuclear waste authorities and scientists advocated the burial of radioactive waste in clay as a technologically sound solution that effectively prevents the filtration of groundwater and surface water and allows the radioactive waste to be put in a natural container, where it remains sealed away with its radioactivity fully contained:

> I know that the whole point is that they [the Russian national operator for nuclear waste] build their burial sites in a thick layer of clay, which prevents the filtration of groundwater and surface water; the rocks there are arid. The national operator began its work actively by creating several sites – in Novouralsk in Tomsk, and I do not see any problems here, especially of an environmental kind. The designed systems are multipurpose engineering facilities of the multi-barrier type; they make it possible to contain radioactive waste in a limited space – where one puts it, that is where it will lie.[2]

So declared a professor from Tomsk University, Leonid Rikhvanov, in October 2019, during the public discussions about nuclear waste disposal organised in Novouralsk, Russia.

This discourse sample about nuclear waste disposal illustrates how the relationship between the natural environment, technology and nuclear waste becomes 'constituted, contested and defined within institutional practices, environmental discourses and forms of expertise' (Irwin 2003, p.3). It displays the technopolitics of nuclear waste – to design the technology, an engineering system, and to find a site with an appropriate geological structure where the nuclear waste can be 'immobilised'. 'Immobilisation' discourse is twofold. On the one hand, it encompasses the multi-barrier approach that aims to minimise or prevent the release of radioactive elements into the environment. On the other hand, it underscores the role of natural resources, such as clay or crystalline rock, in mediating industry and state assurances regarding the safety and control of nuclear waste management. Through such technopolitical strategies of displacement of power onto technical things (Hecht 2011, p.3), techno-scientific actors use the environment to mitigate risks and uncertainties associated with nuclear waste technology.

In this paper, I suggest that, within Russian nuclear waste politics, the radioactive materiality of waste is discursively made manageable through the specific geology of the disposal site. I argue that the clay, crystalline rock or geology of the site serves in nuclear safety discourses as a tool for nuclear waste containment and as a tool for political reassurance regarding the transition from waste storage to its final disposal, while connecting the NPP site (waste production) with the waste disposal site. To probe this assumption, the geology of the nuclear waste disposal site in this article is considered a long-term safety actor, as noted by Schröder et al. 2016. Thus, clay, used as a geological or geotechnical barrier in nuclear waste disposal, becomes a natural material ensuring the safety of nuclear waste disposal in the long term. Including clay in nuclear waste management makes it possible to reconsider the agency of natural materials in nuclear waste technologies and discourses: How do radioactive waste technology and its generated discourses transform clay into a nuclear safety factor? How is the natural property of clay to retard the migration of the radionuclides used in nuclear waste siting discourses in Russia to mitigate nuclear safety risks associated with the transition towards underground disposal?

The article begins by outlining the theoretical framework, emphasising socio-technical and socio-material perspectives, along with the methodology employed. It then examines two case studies related to the siting of nuclear waste disposal. The first case involves the Ignalina Nuclear Power Plant (NPP) in Lithuania during its construction in the late 1970s and early 1980s and illustrates how clay has been materialised as the argument within techno-scientific controversy. The second case focuses on the public hearings concerning the siting of a waste repository in Sosnovy Bor, located near the Leningrad NPP site, and illustrates how political and scientific actors leveraged the clay deposit as a justification for the disposal site. Together, these cases yield critical insights into the radioactive materiality of waste, highlighting how clay, as a natural material, embodies a nuclear safety function in nuclear waste discourses.

1 See the book of abstracts of the 7th International Conference on Clay in Natural and Engineered Barriers for Radioactive Waste Confinement, Davos, Switzerland, 2017: https://www.sciencedirect.com/journal/applied-geochemistry/special-issue/10K7LR0ZVTN

2 Prof. Rikhvanov during a visit to the disposal site in Novouralsk: https://obzor.city/article/614968---seversk-novouralsk-ozjorsk-kak-v-rossii-strojat-punkty-finalnoj-izoljacii-radioaktivnyh-othodov (accessed 25 Aug. 2023).

THEORETICAL FRAMEWORK: A SOCIO-TECHNICAL AND SOCIO-MATERIAL PERSPECTIVE ON THE MULTI-BARRIER CONCEPT

The global nuclear industry is entering a phase of decommissioning nuclear facilities, leading to a significant increase in volumes of radioactive waste, including spent nuclear fuel. During a period of early technological optimism about nuclear expansion and the development of civilian nuclear programmes, the problem of nuclear waste remained in the background of the national nuclear policies. Some nuclear energy countries, including the Soviet Union, the United States and Great Britain, used natural environments for dumping radioactive waste. From the late 1940s, the ocean was used as a solution for nuclear waste disposal before the partial international prohibition within the 'London Convention' came into force in 1975. This dumping of nuclear waste into nature caused a technological delay in searching for an appropriate solution for waste management (Hamblin 2008). Nuclear waste disposal remains a controversial issue in countries that host such waste.

Focusing on public participation and governance, scholarly works in STS, environmental history and the history of technology have questioned the methods of nuclear waste management and analysed it through the lens of socio-technical controversies. Landström and Bergmans are investigating how nuclear waste governance is changing with the transition from siting to hosting nuclear waste in terms of complexity, residual risks and perpetual uncertainty (Landström and Bergmans 2015). Schroder considers geological disposal a socio-technical experiment that 'involves relations between surface and subsurface, between humans and non-humans, between the social, material and natural realm' (Schröder 2015). Barthe, Elam and Sundqvist investigate histories of conflict over geological disposal in Sweden and France, suggesting a reevaluation of the technological controversies through the lens of divisible and non-divisible conflicts (Barthe et al. 2020). Concerning public engagement, scholars explore how the issue of reversibility/retrievability of nuclear waste (Lehtonen 2010) and various forms of participation have impacted the site selection process for nuclear waste repositories (Krütli et al. 2010).

In the Russian context, the issue of nuclear waste management is not discussed as a socio-technical controversy but as a technological solution to the problem of the accumulated volumes of nuclear waste. Extensive research published in the Russian language in natural and engineering sciences focuses on the nuclear waste inventory, its management, the role of natural and engineered barriers in nuclear waste containment, and its environmental and health impacts (Linge et al.2015). The Russian Nuclear Safety Institute (IBRAE) describes the nuclear waste issue as a 'nuclear legacy' issue, focusing on the accumulated radioactive waste from Soviet military and civilian nuclear programmes (Evstratov et al. 2012; Bol'shov et al. 2015). A limited number of scholars have studied the legal and political aspects of nuclear waste management in Russia in the 1990s (Maloney-Dunn 1993; Ziegler and Lyon 2002), the spent nuclear fuel issue in the 2000s (Stulberg 2004) and the formation of a new nuclear waste management system in the 2010s (Jaitner 2018). Historical studies of nuclear waste in Russia emphasised the dynamics of spent nuclear fuel management in the Soviet Union (Högselius 2010) and the changing status of military waste within nuclear politics in Russia (Kasperski 2019). This article aims to fill the gap in socio-technical discussions about nuclear waste programmes in Russia and contribute to a broader study of nuclear waste disposal technology based on the multi-barrier principle.

In social studies related to nuclear waste management, there is a strong focus on the socio-political aspects of site selection for disposal facilities. This often highlights the tendency of nuclear waste discourses to displace power onto technical things or 'delegate complicated social and political problems to technological solutions' (Barthe et al. 2020, p. 215). Within multi-barrier technology, the displacement or delegation serves as a rhetorical device illustrating the interplay of technical, geotechnical and geological barriers, with one representing a more reliable protection layer than the others. For instance, the British Nuclear Industry Radioactive Executive (Nirex) started the geological investigation of possible hosting sites at the end of the 1980s, prioritising the design of a waste disposal system based on 'the natural safety barrier of geological formation, complemented and augmented by an engineered system designed to provide physical and chemical containment of the wastes' (Cotton 2017, p 95). In contrast, the Swedish nuclear waste company (SKB) promoted nuclear waste technology relating geological and technological safety barriers to each other, 'sometimes emphasising the ability of the bedrock, but most often the quality of the engineered barrier' (Lidskog and Sundqvist 2004, p. 252). In the United States, during the investigation of Yucca Mountain as a nuclear waste disposal site, the focus shifted from geological barriers with volcanic tuff as a repository material to engineered features (MacFarlane 2003).

These shifts are not merely rhetorical; they are ontological as they are integral to the broader phenomenon of nuclearity (Hecht 2006). They demonstrate how various actors have approached the multi-barrier concept in a distinct way, adapting either an engineering or natural barrier as the primary or secondary layer, contingent on siting strategies and prevailing techno-scientific and political narratives. Thus, the multi-barrier technology embeds not only technological and natural layers but also socio-political dimensions of siting nuclear waste disposal; this is a technopolitical assemblage. This allows us to reconsider the multi-barrier concept within socio-technical and socio-material perspectives.

From a technical point of view, the multi-barrier concept of nuclear waste disposal represents a mix of engineering and natural barriers and its operation in combination for waste containment. From the socio-technical perspective, the multi-barrier concept involves various actors and agencies, both nuclear and non-nuclear, human and nonhuman, participating in the siting, design, assessment and commissioning of the depository. It also incorporates a mixture of natural and artificial materials, engineering ideas, visions and concepts. Social practices such as communication, negotiation with host communities and testing and evaluation are also integral to the concept.

From a socio-material perspective, multi-barrier technology exemplifies a collaboration of human practices, technical systems and the associated material processes, along with the natural dynamics inherent in geological formations. This approach highlights the interplay among human agency, engineered solutions and the geological context, fostering a comprehensive understanding of barrier systems within their operational environment (Schürkmann 2022). Thus, we can argue that the multi-barrier concept involves the multi-layer approach towards the nuclear waste disposal process, where the form of intervention of each actor depends on the understanding and interpretation of how engineering and natural barriers interact and how combined materials ensure nuclear safety.

Nevertheless, approaching using natural materials such as clay in nuclear waste technology can be challenging, as it raises questions regarding the definition of its material and non-human agency. However, as Barry shows with the example of metal in the pipeline infrastructure, materials can be central to knowledge controversies and studied not only from the perspective of their agency but also from the relationships created by their usage (Barry 2013). Such an approach allows us to elaborate on the material's role in public discourses.

Based on the socio-technical and socio-material considerations of nuclear waste containment technology, this article suggests focusing on the materiality of nuclear waste by investigating how clay, as a natural material, emerges as an actor in nuclear safety discourse across various political and historical contexts, ensuring that nuclear waste technology functions effectively and that radioactivity remains contained for a hundred years. This framing positions clay at the core of nuclear waste technology, prompting the reexamination of nuclear waste management through the lens of natural resources. It invites consideration of their significance in containment technology, the siting process, public communication and the transition toward final disposal.

To summarise, the following theoretical framework could be elaborated. Firstly, the multi-barrier principle includes technical, engineered and natural layers and connects the underground and aboveground processes. For instance, it showcases how technological solutions for underground disposal can be used as a means to address risks and uncertainties in public discourse. Second, the multi-barrier principle as a nuclear safety discourse is not fragmented; it operates in connection with nuclear waste and industry histories – in our case, the history of the Soviet atomic programme – and should be considered in relation to previous nuclear waste management solutions. Third, the use of the multi-barrier approach in nuclear waste technology across different nations opens an opportunity to compare how various techno-scientific and political actors are delegating nuclear safety issues to nonhuman actors.

METHODOLOGICAL FRAMEWORK

This article draws upon case studies of nuclear waste disposal at Ignalina NPP and Leningrad NPP, encompassing divergent historical periods, political and social systems, and different types of nuclear waste. To compile the case studies, I used historical analysis as a method to work through archival documents from the Central and Special Archives in Lithuania, many of which pertain to the Soviet nuclear industry and have been declassified, making access straightforward. Most documents are written in Russian, with some in Lithuanian, languages familiar to the researcher. In addition to analysing these archival materials, I conducted field trips to Sosnovy Bor in Russia, where I carried out several interviews. During one of these interviews, I received documents related to the public hearings on the siting of the nuclear waste repository, including links to the video recordings and the transcripts. The collected materials and data informed the selection of cases that examine the continuity of nuclear waste politics within both Soviet and Russian nuclear programmes and highlight the role of clay in techno-scientific controversies and public discussions. Together, these cases contribute to the broader concept of nuclearity by elaborating on how geological material is becoming nuclear through a set of technopolitical practices of siting waste disposal.

The first case examines the knowledge-based disputes between Lithuanian national scientific institutions and the central Soviet scientific and nuclear governance bodies during late 1970s. It demonstrates how clay transitions from niche expertise to a significant political argument against the establishment of the nuclear waste facility at the

NPP site. In this context, the agency of clay becomes apparent through institutional and expert practices, gaining political relevance through its interactions with both human and non-human actors. This dynamic generates tensions between political and techno-scientific actors in the context of colonial relations.

The second illustrates how clay is presented in public hearings as a key argument for the siting of nuclear waste facilities at the Leningrad NPP site at the beginning of 2010s. This phenomenon can be likened to the public life of clay, where its agency extends beyond experts and politicians to engage a broader audience. Its role as an informed material becomes multifaceted, providing information on nuclear safety, facilitating decision-making and persuading the public. In this framework, the materiality of nuclear waste is intricately linked to underground resources and the aboveground processes of participation and deliberation.

HISTORICAL OVERVIEW

The construction of the Leningrad NPP commenced in 1967, and the first RBMK reactor reached criticality in 1973. It was the first NPP in the USSR with this new type of reactor which was later built at the Ignalina NPP. Both NPPs were designed and engineered principally by Russian specialists at the Ministry for Medium Machine Building (Minsredmash) scientific institutes in Moscow and Leningrad: the Research and Development Institute for Energy Technology (VNIPIET, Leningrad), the Kurchatov Atomic Energy Institute (Moscow) and the Research and Development Institute of Power Engineering (NIKIET, Moscow). In the late 1970s, personnel and engineers working at the Leningrad NPP moved to the construction site of the Ignalina NPP. The planners and builders considered the geological conditions at both sites quite similar as both featured Cambrian clay. During the construction, the area at the Leningrad NPP was already tested for nuclear liquid waste disposal. However, this idea of a disposal facility was ultimately removed from the initial project design of the site.

The discussions among techno-scientific actors about the natural containment of nuclear waste in the USSR commenced at the end of the 1960s. Soviet scientists searched for an economically reasonable method to dispose of liquid radioactive waste generated in significant amounts by mining, enrichment and research facilities. They eventually suggested the direct geological injection of these wastes (Yudin et al. 1968). The special polygons for geological injection of the liquid radioactive waste into the deep underground were commissioned in Russia in Dimitrovgrad, near the Research Institute for Nuclear Reactors (NIIAR) in 1965 and at the Mining Chemical Combine (GKhK), in Krasnoyarsk region in 1967. During the 1970s, this technical solution was proposed for liquid waste management at nuclear power plants (NPP) and featured in the initial technical project of the Ignalina NPP in Soviet Lithuania. This method was portrayed by Soviet scientists as a 'technological fix' for low and intermediate-level liquid radioactive waste management, transforming the site of nuclear waste production into the site of nuclear waste disposal as well. From the technological point of view, this method represented a pump installation with steel tubes injecting the radioactive water directly into the geological medium – clay rock – situated at depth (500 metres). According to this technical principle, the radioactive substances settled as sediment on the clay rocks, and water was self-purified. This technical solution implied the direct injection of nuclear waters into the geomedium without any technical barriers. The Lithuanian scientists opposed this method, with the main argument being the inappropriate geology of the site, and tried to prevent the construction of such a disposal facility at Iganlina NPP.[3]

The second case involves efforts to locate a site to dispose of low and intermediate-level nuclear waste at the Leningrad NPP in post-Soviet Russia, spanning 2013 to 2018. This siting case is integral to Russia's national nuclear waste programme initiated in 2011, which seeks to transition accumulated radioactive waste from NPP sites to underground repositories. From a technological point of view, the project for nuclear waste disposal at Leningrad NPP represents a landfill disposal installation in a tunnel with packed and sealed barrels containing nuclear waste at a depth of seventy metres in the clay deposit. This case focuses on the institutional discourse of the National Operator for Nuclear Waste Management during the public hearings about nuclear waste disposal construction in Sosnovy Bor in 2013.[4]

Although occurring at different times and locations, these two cases are linked through the trajectory of Soviet programme advancements and Russia's ambitious objective to transition from aboveground nuclear waste storage to an underground disposal infrastructure. The geological formations of the Baltic region, where both nuclear sites are situated, share a common layer of clay deposits (Korkutis 1971). This geological similarity aligns

3 The analysis of this case is based on the official communication between the Lithuanian Communist Party and Minsredmash and scientific reports about nuclear waste disposal from the Lithuanian Academy of Sciences and the USSR Academy of Sciences found at the Central and Lithuanian Special Archives (LYA). In addition, the geological data used in this article originates from the research publications in special journals and documents of the Earth Sciences Institute in Saint-Petersburg.

4 This case analysis relies on the transcript and video recordings from the public hearings conducted in Sosnovy Bor in December 2013, along with several interviews held with participants and experts in Sosnovy Bor during the fieldwork in 2013, 2016 and 2019.

these cases in terms of history and geography, allowing for the examination of clay as a shared resource utilised in nuclear waste disposal discourses by diverse actors in various contexts. This cross-national and historical research approach contributes to comprehending the process of nuclear waste siting in both the USSR and contemporary Russia. It also sheds light on how technical and natural barriers have been interwoven in this process. This perspective permits an analysis of natural barriers in nuclear waste discourses, revealing how they function as socio-technical tools that shape the perception of a site's geology – whether as a static or dynamic environment – within the framework of active or passive safety systems.

INJECTING RADIOACTIVE WATERS UNDERGROUND: NUCLEAR WASTE DISPOSAL AT THE IGNALINA NPP (1976–1980)

Prior to the 1970s, the feasibility and significance of implementing a civilian nuclear energy programme in the USSR were hindered by a range of challenges stemming from conflicting political forces of decentralisation and centralisation, diverse technological options, intricate negotiations, disputes within the scientific community, and the Soviet political structure, and shifts in nuclear governance organisation (Schmid 2015). The implementation of the Soviet nuclear programme adhered to a centralised and vertically integrated decision-making structure. The Ministry for Medium Machine Building (Minsredmash) was the governmental entity accountable for nuclear innovation, research, construction and oversight. In contrast, the Ministry of Energy assumed responsibility for the large-scale production of reactors subsequent to Minsredmash's introduction of the initial reactor iteration. Consequently, intense competition arose between these two bodies concerning nuclear production and related aspects of post-production. Due to rivalry between ministries and bureaucratic impediments, waste disposal often required heightened attention and consideration.

Geology and mineralogy in the USSR were intricately connected to investigation and research initiatives centred on natural resources. They operated as instrumental tools for resource exploration, bolstering rapid industrial advancement driven by political objectives (Bolotova 2004). Geological investigations for the nuclear industry were conducted by the Second Geological Division of the Ministry of Geology of the USSR, directly reporting to the Ministry of the Medium Machine Building. The extraction of uranium, thorium and radium was prioritised for Soviet nuclear military programmes starting from the early 1940s. With the inception of the Soviet civilian nuclear programme in the 1950s, the Second Geological Division became responsible for geological investigations related to NPP siting. Geology was never integral to the nuclear industry, whether military or civilian, but operated within a separate system. This organisational separation likely contributed to a delay in fully considering natural barriers such as clay in safety discourses.

The lack of clear requirements, including geological prerequisites for the NPP construction, affected the site selection process for the Ignalina NPP construction in Soviet Lithuania in the late 1970s. In most cases, central government made determinations about where to build new stations and limited the role of republics in nuclear decision-making (Dodd 1994). Lithuanian scientists were involved in investigating the possible locations for the INPP but had yet to participate in the final decision on site selection. Correspondence between the Lithuanian political authorities and Minsredmash shows that the central conflict about site selection was related to the need for more geological research. The Lithuanian authorities insisted on additional investigations of the site chosen for the INPP construction with the participation of the Lithuanian Geological Council (Stsiapanau 2021).

The imbalanced relations were symptomatic of colonial dynamics under the Soviet Union. The nuclear industry played a significant role in these colonial entanglements, establishing an infrastructure for mining, scientific research and energy generation, all while exerting control over national resources and populations, as well as energy production, distribution and further developments (Hecht 2012). Rindzeviciute et al. elaborate on the concept of Soviet nuclear colonialism, highlighting the case of Iganlina NPP as entirely governed by Soviet central institutions and lacking support from both techno-scientific and political national elites (Rindzevičiūtė et al. 2025). Unlike other Soviet Republics, such as Ukraine and Belarus, Soviet Lithuania did not advocate for a nuclear facility, citing concerns that nuclear development could adversely affect the country's natural environment. The tensions surrounding the Ignalina Nuclear Power Plant arose from techno-scientific controversies and challenged colonial relations. Since geological science had not been fully integrated into Soviet nuclear knowledge production, this gap created opportunities for counter-expertise from the Lithuanian Geological Council, leading to techno-scientific disputes with their counterparts in Moscow.

The dispute concerned the proposal to use geological injection for liquid waste disposal planned at the Ignalina NPP site and included in the initial technical project. This method was advocated by the Soviet Academy of Sciences in Moscow as safe and necessary for building the appropriate nuclear energy infrastructure at the site. The suggested method of liquid nuclear waste management on the INPP site included two possibilities – solidification with bitumen or the injection of liquid radioactive waste without significant treatment into the aquifer at a depth of 500 metres. The latter had been previously tested for the Leningrad NPP site but had never been applied as a method for liquid radioactive management at the NPP site in the USSR. At that time, only one polygon for geological injection was commissioned in Dimitrovgrad next to the Nuclear Reactor Research Institute.

In February 1978, the Lithuanian Academy of Sciences scientists sent a critical report[5] about underground radioactive waste disposal to their counterparts in the Soviet Academy of Sciences, arguing that the underground disposal of liquid radioactive waste at the INPP site was not adequately elaborated from a technical point of view and relied on insufficient studies about the geological structure of the site. Lithuanian scientists used environmental and technological arguments against underground nuclear waste disposal. They wrote that 'safe disposal of radioactive waste has been relegated to a secondary place, which has led to a lag in the development of safe storage and future disposal of radioactive waste'.[6] The authors of this report introduced unusually critical rhetoric questioning the environmental impact of nuclear technology and generated waste:

> From an environmental point of view, the development of nuclear power will be accompanied by an increase in the amount of radioactive waste, which must be continuously monitored. It is necessary to ensure that the products of nuclear reactions introduced into the cycle of nature do not seriously impact the environment, including humans.[7]

Moreover, the Lithuanian scientists challenged the nuclear reactor technology itself, connecting the RBMK design with the generated volumes of waste: 'The single-loop NPP with channel reactors of the RBMK type produces a significantly larger (up to 10 times) amount of solid and liquid radioactive waste in comparison with any other type of reactors.'[8]

Lithuanian scientists argued that the complex water management system and volumes of generated liquid waste had caused problems during the RBMK reactor start-ups at the Leningrad and Kursk NPPs and resulted in leakages exceeding the levels determined by the project design. Thus, the report authors advocated nuclear safety principles in waste management that were uncommon in the Soviet nuclear industry: choosing a nuclear reactor with minimal waste production and minimum risk for future generations. They wrote, 'We must act in such a way as to minimise the extension of risk to future generations, especially when it can be done without overburdening the present.'[9] In a word, they were critical of the potential for techno-scientific errors resulting from an overestimation of the reliability of the site geology as a natural barrier for radionuclides migration as well as from the economic assessment of the nuclear waste management methods.

Combining environmental and technological criticism, Lithuanian scientists defined the geology of the site as a core argument in the techno-scientific debate about siting disposal. Geological prerequisites became, therefore, an object of claims about the geological dynamics and possible technological and social risks. Lithuanian geologists argued that the site's geology was unique due to a contact line between the lower and the upper water aquifer that supplies the aboveground waters of the whole region. The geological layer (Lomonosov aquifer of the Lower Cambrian) into which the injection of liquid radioactive waste was planned was not homogeneous in terms of the lithology of the site; tectonic fissures (one of the tectonic fissures went through the Ignalina NPP construction site) could increase this contact line in the future. They noted, 'All this creates a real possibility of the penetration of radioactive substances from the aquifer burying layer into other overlying aquifers and the gradual expansion of the source of pollution both in vertical and horizontal directions.'[10]

Finally, the Lithuanian scientists argued that such dynamic geology of the site might lead to radioactive contamination of surface groundwater systems with unpredictable social consequences due to the possible need to evacuate affected people and clean up contaminated areas. The scientists considered geological injection as an inappropriate solution for liquid nuclear waste because the geology of the site did not guarantee the performance of such disposal. They noted, 'the available data on the geology and hydrogeology of the Ignalina NPP construction area and adjacent territories do not guarantee a reliable spatial and temporal containment and a complete isolation of buried liquid radioactive waste in aquifers.'[11]

In its response in April 1978, the Minsredmash referred to a report prepared by scientists from the USSR Academy of Sciences in Moscow, insisting that geological injection was an appropriate liquid nuclear waste disposal method at Ignalina

5 'The note of the Academy of Sciences of the Lithuanian SSR on the underground method of disposal of liquid radioactive waste from Ignalina NPP' was prepared by scientists from the Lithuanian Institute of Physics, namely B. Styra, K., Z. Rudziskas, R. Jasiulionis.; from the Institute of Energetics – Y. Vilemas and L. Ašmantas; and from the Geography division of the Zoology Institute – V. Gudelis.

6 'The note of the Academy of Sciences of the Lithuanian SSR on the underground method of disposal of liquid radioactive waste from Ignalina NPP', Central Lithuanian Archives (LCVA), F. R-1034, ap.11, b.8, p. 5.

7 Ibid., p. 4.

8 Ibid., p. 15.

9 Ibid., p. 8.

10 Ibid., p.10.

11 Ibid., p.11.

NPP.[12] The authors of the report argued that the liquid radioactive waste generated at the NPP could be handled just as toxic industrial waste produced by other industries, which was usually disposed of underground. The USSR's Ministry of Geology developed a forecast map of the sites for the disposal of industrial liquid waste, including nuclear waste, on its territory. This comparison to industrial waste attempted to respond to environmental criticism and to show that the geological injection used for liquid waste – or industrial waters – could be used as a safe disposal method for radioactive waters. Here, the natural retardation properties related to the geology of the site became a core scientific argument in favour of the disposal:

> The main scientific prerequisite for the containment of liquid radioactive waste in deep aquifers is that in the bowels of the earth, dynamic natural processes are significantly slowed down in comparison with such processes occurring in the zone of active water exchange, on the earth's surface and in open water systems.[13]

Accordingly, this argument about static or dynamic geological structure explains the necessity of transition from the aboveground storage of the nuclear waste water to its underground disposal. The hydrogeological conditions and the adsorbing properties of the site selected for underground waste disposal in the area of the Ignalina NPP made such disposal preferable to the storage of radioactive waters in landfill water pools. The scientists from Moscow argued that the chosen area for geological injection was well isolated from the open water resource systems and protected by a waterproof and low permeable medium – clay. They pointed out that the area under the Ignalina NPP had three types of clay lying at different depths with a total capacity under waterproof ceilings of up to 300 metres. The age of this medium was more than 30,000 years, proving its excellent isolation from the active water supply zones and surface waters. In addition, according to Moscow specialists, hydrogeological estimations showed that the clay as a medium for nuclear waste confinement would retard the movements of radionuclides with a maximum spread contour of four to five metres during 25 years of the disposal exploitation period. After the end of the exploitation, the injected waste would be monitored through a network of wells. It was expected that it would move according to the natural movements of the geomedium – a maximum of up to five metres per year.[14]

As it was initially planned, the aboveground area of the nuclear waste disposal site would represent a sanitary zone with circulation restrictions and additional control to minimise any public health and social consequences in case of malfunctioning of the disposal facility. The protection provided by the passive geological layer would be completed with administrative control measures. In the report, nuclear safety and risk arguments were ultimately ignored, and the technical components of the disposal were not discussed. A natural 'container' without sufficient engineering protection was considered highly reliable and safe. Safety reassurances relied only on geological evidence related to the structure of the natural container and the clay's absorption and permeability properties. According to Moscow scientists, passive safety would be enough; the clay deposit would naturally contain radioactivity. This techno-scientific discourse on the natural mechanism of nuclear waste containment is similar to the arguments of the Soviet nuclear authorities and scientists about dumping nuclear waste into sea water and icecaps during the 1950s and 1960s. This discourse illustrated how Minsredmash and the Soviet Academy of Sciences defined the disposal of radioactive water at the Ignalina NPP as a 'technological fix' of the problem of liquid waste generated by the new RBMK reactor and made this technological solution 'indivisible' from the site of waste production.

The more the scientists from Moscow insisted on the geology of the site as the main argument for the nuclear waste disposal construction, the more their Lithuanian counterparts maintained that the geomedium under the Ignalina NPP was inappropriate for these purposes in terms of risks and safety for the environment and humans in a long-term perspective. The geological prerequisites were put at the centre of the techno-scientific debate about nuclear waste facility siting in Soviet Lithuania during the construction of the Ignalina NPP.

The clay deposit was a natural vessel for radioactive water, and the geological structure of the site appeared to have unique natural characteristics of permeability, stability and isolation that allowed argument in favour of or against the passive safety of the disposal. Lithuanian scientists insisted on the more dynamic conception of the geological structure of the site and tried to use it to highlight problems with nuclear safety. The scientists from Moscow, on the contrary, defined clay as a stable medium for nuclear wastewater confinement while also connecting the site of nuclear energy production with the waste disposal site. This rhetoric aimed to justify the need to build a more complete nuclear infrastructure on the Ignalina NPP site.

12 The report 'The evaluation of the method of disposal of liquid radioactive waste into deep aquifers and possibilities of using this method at Ignalina NPP' was prepared by A. Ilyin (biophysicist), K. Zaharova (chemist), D. Gusev (M.D.), M. Pimenov (engineer), A. Belitskij, B. Lebedev (hydrogeologists), B. Savin (geologist) and E. Teverovskij (geophysicist).

13 'The evaluation of the method of disposal of liquid radioactive waste into deep aquifers and possibilities of using this method at Ignalina NPP', Special Lithuanian Archives (LYA). F.1771, ap.255, b. 236, p. 14.

14 Ibid., pp. 17–18.

The scientists from Moscow, in their argumentation, put forward the physical properties of the clay deposit, while their Lithuanian counterparts focused more on the environmental implications of using the clay as a natural containment for radioactive waters, emphasising the relationships surrounding the material object. This difference is crucial, as it highlights contrasting perspectives on the role of the natural environment in nuclear discourses: one is more technology-oriented, concentrating on solutions for waste issues and delegating nuclear safety to the natural material, while the other is environment-oriented, emphasising the long-term consequences of natural containment.

It also reflects differing colonial visions of space and temporality concerning land use. For Soviet scientists in Moscow and its region, the Ignalina NPP site is perceived as a distant location in another Soviet republic. In contrast, for Lithuanians, it is part of their national territory, a land they are committed to protecting and conserving for future generations. This divergence became increasingly pronounced following the Chernobyl Disaster and was amplified by the late 1980s as social movements emerged, raising environmental concerns and damages resulting from Soviet occupation (Rinkevicius 2000).

Additionally, it demonstrates the capacity of Lithuanian scientific institutions to challenge the hierarchical relationships with Moscow using techno-scientific knowledge and arguments. As Barry noted, knowledge controversies can serve as elements in various political situations, and nuclear colonisation could be one such instance (Barry 2013). Lithuanian scientists leveraged political communication to advocate for their vision through the Communist Party in Lithuania, engaging national political elites in the debate against nuclear expansion in the country. Through this communication, accompanied by multiple exchanges of official letters and scientific reports, the clay materialised as a form of nuclear underground, acquiring significant political implications.

In August 1978, during a meeting of the Bureau of the Communist Party of Lithuania, a decision was taken about the need for additional geological investigation of the nuclear waste disposal site. In 1979, Lithuanian and Moscow scientists participated in this investigation and, finally, Vilnius and Moscow agreed by 1980 to abandon the initially planned construction of the liquid waste disposal facility. This techno-scientific debate affected the final decision; the site's geology was considered as an argument against the construction of the disposal site. Decades later, geological conditions as a critical argument in nuclear waste disposal siting resurfaced in another context – nuclear waste politics in contemporary Russia.

SITING NUCLEAR WASTE DISPOSAL AT THE LENINGRAD NPP (2013–2018)

In 1982, the IAEA adopted the requirements for geological disposal, focusing on the multi-barrier protection system (IAEA 1983). The same year, the Soviet Union delegation at the IAEA Conference presented its conception of nuclear waste management based on using crystalline rock, mineral salt and clay (Balukova et al. 2020). This conception prioritised the study of the crystalline rock in the Nizhnekamski massive (Krasnoyarsk region of Russia) and the clay deposits in the Leningrad region as possible geomedia for radioactive waste disposal. Clay deposits in the Leningrad region were used in subway construction works as waterproofing for tunnels (Proskuryakov et al. 1998), for disposal of industrial toxic waste at the Krasnyi Bor site (Eldina 2005) and for water supply to Saint Petersburg and its region (Mironova et al. 2006). The first geological tests of the clay formation during the metro tunnel construction in Saint Petersburg gave impetus to the development of clay formation research for radioactive waste disposal purposes in the Leningrad region. By the 1980s, the Geological Institute of Leningrad State University had undertaken comprehensive research on clay rock and its capacity for providing radioactive protection (Anderson et al. 2012). The clay formations in the Saint Petersburg region have been extensively studied and documented for various industrial applications. As an informed material, it exhibits enhanced nuclear safety properties.

In the 1990s, an investigation into the underground waters beneath the Leningrad NPP exposed instances of radioactive leaks stemming from the aboveground storage facility known as Radon, located in the neighbouring city of Sosnovy Bor. The assessment of clay formations and the collection of monitoring data at this site served a dual purpose: detecting the radioactive leaks that had entered the surrounding environment and evaluating the clay's potential for disposal applications (Rumynin et al. 2021). The leakage from the storage facility underscored the unique radioactivity-controlling attributes of the clay rock.

Throughout the 1990s and 2000s, multiple scholarly works in the fields of natural and engineering sciences affirmed that the clay deposit near the Leningrad NPP region held promise as a suitable geological formation for the disposal of radioactive waste (Rumynin et al. 2010; Maslennikov et al. 2010). Consequently, the clay deposit attracted considerable scientific attention, laying the groundwork from a techno-scientific perspective for waste disposal design and decision-making processes.

Meanwhile, in 1993, the Scientific Research and Design Institute of Energy Technology (Saint Petersburg), jointly with subway building organisations, elaborated the first project for radioactive waste disposal for low and intermediate-level waste in the Leningrad region. Later on, two projects were outlined in the framework of the TACIS programmes in 1997 and 2008 with international experts from France, Sweden, Finland, Germany, Netherlands and Great Britain.[15] In the framework of this research, the Leningrad region, home to numerous nuclear facilities (NPP, Research Institutions, storage facilities), was considered a site with a unique geological resource – clay formations lying close to the surface that could be used for the construction of the disposal facilities for solid low and intermediate level waste (Sorokin et al. 2010).

Remaining within academic publications and laboratory research, clay generated further insights for nuclear applications without sparking notable controversies before it entered the public sphere. By employing the geoscientific term geomedium to describe clay formations or deposits, we can contend that clay, in public discussions, serves not merely as a geomedium but as an intermediary among experts, politicians and the public. This dynamic aims to persuade the latter to consent to the siting of nuclear waste facilities.

In December 2013, during the public hearings about waste disposal for low and intermediate-level waste in the city of Sosnovy Bor, situated next to the Leningrad NPP, the director of the National Operator for Nuclear Waste, Yuri Polyakov, presented a technical project for a regional disposal site. As described in the project, the general performance of the disposal site relied on several elements: waste itself, the buffer, engineered construction and host rock. During the discussion that followed the technical presentation, Yuri Polyakov explained the choice of the site based on already accumulated waste at the Leningrad NPP site and the estimated amounts of waste resulting from NPP's decommissioning. In addition, he explained that the existing infrastructure of the NPP site would allow the construction of the disposal facility proximate to the place of waste accumulation with minimal transportation costs and associated risks:

> The suitability of geological characteristics is a fundamental principle, without which we cannot talk about the siting of the object [radioactive waste disposal facility]. Getting as close as possible to the places of waste accumulation is necessary. We need to face the truth; the amount of radioactive waste accumulated in the Leningrad region is a serious problem that needs to be solved.[16]

The site's geology appears as an argument that consolidates the choice of the site. It explains why the composition of the soil and rock is favourable for hosting a nuclear waste repository and connects such aboveground elements as the volume of waste and existing nuclear infrastructure with such underground elements as the geological qualities of the site. Geology thus becomes an undeniable part of the nuclear waste strategies of linking the place of waste production/accumulation to its final disposal. The clay rock empowered the political discourse about the necessity of disposal construction at a particular site. As Nikolay Lobanov, vice director of the National Operator, observes:

> To ensure the maximum environmental safety of this facility, we follow the principle of multi-barrier protection. That is the combination of the isolating properties of engineering and geological barriers. Nature created this site, where you and I are now and where we propose to locate our facility and place radioactive waste in the layer of the Upper Kotlin clay … because clay is one of the most promising substances for isolating medium- and low-level waste. Why? First, because this clay, especially your clay, has very low filtration coefficients, so the movement of radionuclides here is complicated, and second, because the absorption properties of clay are very high, and it also has a positive impact on the safety of this facility.[17]

Thus, the national operator portrays the clay deposit under the Sosnovy Bor site in the Leningrad region as unique with a very low coefficient of filtration and absorption properties and a monolithic and homogeneous composition. The ability to block the permeability of radionuclides appears, therefore, as an exceptional property of clay as a natural material that would stop a radioactive leak in case of an accident. This discourse transforms the clay into a universal material, a mix of physical qualities that help to contain the radioactivity and protect the environment. The radioactive nature of waste is mitigated by the properties of clay, effectively rendering clay a medium that becomes radioactive itself. This transformation is a part of the broader phenomenon of nuclearity, where non-nuclear materials are utilised to function with radioactivity without altering their fundamental characteristics or becoming classified as 'nuclear' materials. Furthermore, it reflects the process of delegating nuclear safety to a

15 TACIS. Protocol of the coordination meeting on the results of work on the TACIS project R4.05 / 04 'Concept and programme for creating a storage facility for short-lived waste of low and medium activity in the Leningrad Region'(LRP-1).

16 Greenworld, *Rasshifrovka slushanii po predvaritel'nomu OVOSu PZRO v Sosnovom Boru [Transcript of the hearings on EIA of nuclear waste disposal in Sosnovy Bor] on 27 December 2013]*. Available at: http://www.greenworld.org.ru/sites/default/greenfiles/slushania_PZRO_27122013.pdf (accessed 13 Dec. 2024), p .8.

17 Ibid., p. 9.

natural protection layer. Natural clay rock appears as a unique way to stop a radioactive leak, and even more secure than an engineered one from the perspective of time, able to serve 'the main isolation function for hundreds of years longer than engineered ones.'[18]

The clay formations surrounding the disposal would contain moisture that could affect the technical layer and provoke metal corrosion. If the acidity (pH) of the water destroys the technical barrier, it may also impact radionuclides' decay (Zinoviev and Chembura 2019). This situation can be considered as one of the possible scenarios of a radioactive leak into the natural environment and the migration of radionuclides into the clay deposit. In case of an accident, the clay formation ensures nuclear safety through a monitoring system after the closure and the conservation of the waste disposal site. At this stage, the monitoring concerns both engineered and natural barriers. A particular monitoring system will show the changes in underground isolation, such as the activation of seismotectonic processes and climate change.

Clay appears as a tool for monitoring as well. The data obtained from extracted clay samples would show possible leaks and indicate damage to the technical barrier. It thus connects the visible and invisible parts, as well as the underground and aboveground processes: the obtained data from underground monitoring (clay samples) can affect or even reverse nuclear waste decision-making in case of migration of radionuclides into the soil and water. The clay acts as a medium for nuclear safety discourse through the monitoring system. It illustrates changes in the geological structure, radionuclide migration and irradiation risks. These estimated irradiation risks were framed during public hearings as virtually inexistent. As Andrei Kuvaev, a hydrogeology expert, claimed in public hearings:

> Thus, calculations show that such a beyond-design accident – the extraordinary inflow of radionuclides into groundwater – would lead to a spread area that, in terms of strontium, would not exceed ninety metres. In theory. Well, vertically, the spread is limited to four to five meters. So, there is no radiation hazard to the public, zero probability.[19]

Such measurements and calculations go beyond geoscience as they illustrate how the risks associated with contamination and situations of emergency are minimised or even mitigated. Clay and the technical barrier transform the radioactive waste disposal site into a safe one so that even in 'possible emergencies, the doses would not exceed the limits. It means they would not impact human health', as Nikolay Lobanov claimed.[20] Within the discourse of nuclear safety, radioactive waste is contained, and its materiality is 'isolated' and 'retarded' by the clay rock, which absorbs it through natural decay processes. The radioactivity of the waste is rhetorically neutralised or immobilised, similar to the treatment of other types of toxic waste.

In nuclear waste discourses, the role of clay as a natural material has evolved to encompass significant 'nuclear' properties, along with a variety of associated practices such as investigation, drilling, monitoring, calculation, forecasting, etc. In public discussions, clay serves as a conduit that connects material with non-material through the articulation of its characteristics to contain radioactivity; the human with the non-human by functioning as a tool for monitoring; and the aboveground with underground by bridging the site of waste production and accumulation with its final disposal location. Furthermore, clay, as a natural barrier, plays a crucial role in closing the nuclear fuel cycle by ensuring the nuclear safety of the multibarrier nuclear waste technology. It is both a crucial material and a nuclear safety actor.

CONCLUSIONS

The multi-barrier concept of nuclear waste disposal, functioning both as a technology and a fundamental nuclear safety principle, is situated at the core of decision-making related to siting nuclear waste repositories and to the transition from aboveground storage to the final disposal of all kinds of waste in Russia. It is situated between technical and political considerations, appropriate technology, and the geology of the site. The discourse on multi-barrier safety allocates agency to an array of elements, encompassing nuclear and non-nuclear materials and human and nonhuman entities. Employing this discourse, diverse actors – including nuclear engineers, experts, governing institutions and politicians – promote reliance on nuclear waste technology and contribute to the materiality of nuclear safety.

Using natural materials in nuclear waste management generates particular stories about waste disposal. In the early years of Soviet nuclear industry development, the Ministry of Medium Machine Building and the scientists from the USSR Academy of Sciences promoted the construction of a liquid nuclear waste disposal facility at an NPP construction, settling on the Ignalina NPP in Soviet Lithuania as one site. During the late 1970s, a dispute between the Lithuanian Academy of Sciences and the USSR Academy of Sciences occurred via official communication over the site and its meaning. Both sides had different definitions of the geological prerequisites

18 Ibid.

19 Greenworld, *Rasshifrovka slushanii po predvaritel'nomu OVOSu PZRO v Sosnovom Boru [Transcript of the hearings on EIA of nuclear waste disposal in Sosnovy Bor] on 27 December 2013*. Available at: http://www.greenworld.org.ru/sites/default/greenfiles/slushania_PZRO_27122013.pdf (accessed 13 Dec. 2024), p. 23.

20 Ibid., p. 12.

for nuclear waste disposal. Lithuanian scientists argued in terms of nuclear safety and insisted that the site's dynamic geology made it inappropriate for waste disposal. Soviet scientists from Moscow, on the contrary, referred to the static character of the geological environment, with clay deposits capable of containing the radioactive waters. Here, the geology of the site and the clay deposit, in particular, featured as a passive safety layer without additional technical barriers and did not imply any human intervention, only an aboveground control. Two primary arguments lie behind this Soviet discourse about the reliability and sufficiency of natural barriers in nuclear waste containment. The first concerns the design of the RBMK reactor, which generated more radioactive liquid waste than other types of reactors. The suggested technological solution connected the NPP site with a liquid waste disposal facility and, thus, closed the nuclear water cycle at this one site. The second demonstrated the ability of the Soviet nuclear authorities to promote natural containment as a method of nuclear waste management in transitioning from temporary aboveground storage to eventual underground disposal. This technological fix, symptomatic of Soviet technological colonialism during the Cold War era, was translated into the choice of one particular strategy of moving the radioactive waste underground.

In contemporary Russia, where the national nuclear waste management programme started to be implemented only in 2011, the primary purpose of nuclear waste policy has remained the same – to ensure the process of transition from aboveground storage to geological or landfill disposal of nuclear waste. Within this programme, natural and engineered barriers are used as arguments to mitigate the risks and transform the radioactive waste into waste that would not affect the environment in the long term. The discourses about such natural resources as clay are articulated not only by nuclear experts, engineers and geology scientists but also by political actors and nuclear governance institutions implementing the disposal strategy in Russia. For instance, the National Operator for Nuclear Waste Management emphasises the presence of natural resources in determining the siting of nuclear waste disposal. The radioactive materiality of waste is understood to be manageable through the specific geology of the disposal site. The geological layer serves in multi-barrier protection discourses as a passive nuclear safety tool for nuclear waste confinement and as a connection tool between aboveground waste production and underground waste disposal infrastructures.

Both cases illustrated how clay as a material navigated through discourses on natural containment within various contexts. In particular, clay became a crucial point of contention in expert discussions between Lithuanian and Soviet scientists, revealing the political controversies of the period of Soviet nuclear colonisation. In another instance, clay featured in public hearings regarding nuclear waste disposal in Russia, where it was used to convince the public of the necessity of constructing disposal facilities in specific locations. This connection ties the clay deposits and underground sites to the aboveground community, endowing clay with what can be described as a 'public life'. The evolving role of clay generates a reciprocal effect while delegating to this geological material a nuclear safety function empowers it with a political capacity to influence the process of debating nuclear waste siting and disposal technology. In contrast, the discourses regarding the immobilisation of nuclear waste within geological formations place the waste not in isolation but in relation to other materials, revealing that the materiality of waste interacts through such natural elements as clay. This interaction remains dynamic and not fully contained.

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