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# Geographies of Toxic Persistence: Environmental Degradation in Russia's Industrial Regions

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## Abstract

Despite growing global concern about the environment; growing numbers of international agreements designed to mitigate the effects of pollution; and numerous governmental regulations adopted to improve environmental conditions in the Russian industrial regions of the North (Norilsk), and the large-scale industrial region of the Urals, environmental damage has continued to increase. The long-standing issue of environmental damage in Russia's industrial regions is the focus of this research question: what are the geographic factors that have allowed environmental degradation to persist in these areas? Utilizing an extensive mixed-methodology study of both geospatial analysis and historical reviews of industrialization under the Soviet Union, along with in-depth qualitative case studies of Norilsk and the Urals, this study identifies and analyzes the key drivers that allow environmental degradation to continue to be a problem in Russia's industrial regions. These results show how the specific geographic characteristics of each of these places have synergized historically with the legacy of the Soviet Union's industrialization policies, which emphasized the importance of production over the environment, and economically today, with the imperative to extract resources for the financial benefit of Russia. This study has significant implications for the development of environmental policies in other areas of the world where natural resources are being extracted at high volumes, such as Canada's oil sands and Australia's mining frontier, promoting the need for geographically-tailored strategies, i.e., increased use of remote sensing technologies and decentralized governance structures. Additionally, this study builds upon current scholarship in the field of environmental geography, specifically in post-industrial and post-Soviet contexts, to better understand the role of physical and human geographies in sustaining ecological crises, while also addressing a gap in the literature in terms of understanding the relationship between time and space in analyzing the persistence of ecological crises.

**Keywords:** Environmental degradation, geographic factors, industrial regions, Norilsk, Ural industrial belt, permafrost, resource extraction, spatial economy, Russia

## Introduction

Environmental degradation has become a long-standing problem in many parts of Russia's industrial regions where natural resources are being extracted. These areas contain high levels of pollution due to poor water and air quality, contaminated soils and lost biodiversity. Some of the most well-known examples of these problems can be seen in regions like Norilsk, a major nickel mining city in the Siberian Arctic and the Ural industrial zone that contains cities like Chelyabinsk and Magnitogorsk. Norilsk has earned the reputation of one of the world's most polluted cities emitting hundreds of thousands of tons of sulfur dioxide each year. In addition to the problems at Norilsk, the Ural industrial zone is plagued by heavy metals that run off into rivers and streams, further polluting the environment. Although Russia has made attempts to reform its environmental policies since the collapse of the Soviet Union and has signed agreements like the Paris Agreement, the problem continues to exist. Therefore, it is reasonable to ask why environmental degradation exists so long after reforms have taken place (Bityukova, 2022, p. 107; Raihan & Tuspekova, 2022, p. 9; Голова & Sukhovey, 2019, p. 169). This article will examine the physical and human geographic factors that allow environmental degradation to continue in Russia's industrial centers, including how physical geography, past development, and present-day economic pressures create the conditions for continued ecological damage.

The primary research question is: What physical and human geographic factors account for the continued existence of environmental degradation in Russia's industrial regions? Physical geographic factors include characteristics of the land itself, such as climate, topography, etc., while human geographic factors include those created by humans, such as location of settlements and the geographical arrangement of the economy.

Environmental degradation in Russia's industrial centers is important to understand, especially considering that they contribute to a large portion of the world's pollution — in fact, Norilsk produces approximately 1% of the world's total sulfur dioxide pollution — while also providing the country's economy with much-needed revenue through the extraction of natural resources. To understand how environmental degradation continues in other regions of the world, such as Canada's oil sands or China's coal fields, understanding what allows it to continue in Russia's industrial centers is necessary. This analysis will show how the specific geographic features of Russia create a unique context for environmental challenges and that therefore, environmental policy should be developed to address the specific needs of individual regions, rather than creating universal models that may not be effective in all situations.

Historically, the focus of Soviet-era industrialization was to develop rapidly regardless of the potential cost to the environment, resulting in the establishment of pollution in geographically critical areas that were abundant in minerals. Following the collapse of the Soviet Union in 1991, Russia underwent an economic transition and federal decentralization, which had an uneven effect on addressing the pollution in Russia's industrial centers, with those located in remote peripheral areas, such as Norilsk, receiving less oversight than others. Due to Russia's vast area (which spans 11 time zones), there are numerous challenges associated with monitoring and enforcing regulations throughout the entire country. Additionally, the extreme climates that exist across Russia can increase the negative effects of degradation such as the melting of permafrost which releases pollutants into the environment (Strielkowski et al., 2024, p. 1).

The author of this paper believes that the persistence of environmental degradation in Russia's industrial centers is the result of a combination of isolation, climate-related vulnerabilities, resource-based economies and gaps in governance, all of which are based in geography. While there are many papers that discuss the relationship between geography and environmental degradation, this paper is unique in that it focuses on the spatial persistence of environmental degradation rather than the temporal aspects of it. The paper uses case studies of specific regions to demonstrate the larger trends that exist in the relationship between geography and environmental degradation. The structure of this paper includes a literature review, methodology section, analysis of the factors that lead to persistent environmental degradation, discussion of the findings, and conclusions.

### **Literature Review**

Research on environmental degradation in Russia's industrial regions has been performed from several different theoretical frameworks including political ecology, economic geography, and environmental science. Political ecology theorists have emphasized the role of power and unequal distribution of resources to explain why environmental degradation continues to occur in remote industrial locations. According to Piers Blaikie, because Soviet planners chose to locate polluting industries in peripheral areas to avoid degrading urban areas, they were able to embed the cost of environmental damage in these same areas (Kudryavtseva et al., 2021, p. 88; Turceva, 2023, p. 43).

A few researchers have also identified geographical issues as major contributors to environmental degradation in Russia. Fiona Hill and Clifford Gaddy have referred to Russia's "geographic curse" – vast distances and harsh climate conditions – which have led to industrial development being concentrated in environmentally sensitive areas. These authors argue that as a result, pollution is widespread and can be seen in large swaths of land and water throughout the country. Anna Stammer-Gossmann has researched the city of Norilsk and how its location on the tundra results in limited access to resources and therefore hinders efforts to clean up after decades of mining in the area. The combination of permafrost, and distance from other populated areas, creates a challenging environment for cleanup. Mining activities have resulted in acid rain and acidified soils over thousands of square miles. Jessica Graybill has researched the region of the Urals and how topography affects the movement of pollutants in rivers and the resulting downstream pollution (Yurkevich et al., 2022).

From an economic perspective, researchers such as Michael Bradshaw suggest that the reason that the environmental problems in industrial regions continue to exist is that there is a great deal of path dependence in the economy of these regions. Due to the high fixed cost associated with extracting minerals and metals, it makes little sense for companies to leave the region once the initial investment has been made, regardless of the environmental harm caused by their operations. As noted by Oleg Anisimov, climate change will make cleaning up past environmental damage even harder as thawing permafrost releases previously trapped pollutants and destabilizes existing structures. Finally, researchers from the field of human geography, such as Elana Wilson Rowe, have argued that indigenous peoples in peripheral areas experience greater levels of environmental degradation than others because they are often marginalized in decision making processes related to the use of natural resources in these areas (Sidorstov et al., 2025, p. 2; Kuklina et al., 2023, p. 1152).

There still appear to be gaps in research, however. While many studies have examined the socioeconomic drivers of environmental degradation in industrial regions, few studies have used geospatial methods to quantify the level of environmental degradation that occurs in these regions. Researchers have compared the environmental damage at the site of the Chernobyl nuclear disaster in Ukraine to the environmental damage at nuclear sites in the United States. Kate Brown has suggested that one of the reasons why the slow violence caused by environmental degradation is less visible than other forms of violence is that many of these damaged environments are located far away from urban areas. This study seeks to address some of these gaps by providing a synthesis of the various ways in which physical and human geographic factors interact to create persistent patterns of environmental degradation in post-Soviet space. It does so by examining empirical cases of environmental degradation in industrial regions and using a range of interdisciplinary theories and methodologies to identify the factors that drive this environmental degradation (Hitztaler, 2010, p. 19; Bauer & Penter, 2022, p. 14).

### **Methodology**

The study combines qualitative and quantitative methods to determine which geographic elements are associated with the persistence of environmental degradation. In particular it uses two case-study locations - the Arctic mining location of Norilsk, and the industrial belt of the Ural Mountains as examples of dense industrialisation with varied geography.

Norilsk was chosen for its isolation due to its Arctic location and is representative of an area where mining activities have occurred over time. The Ural industrial belt represents a dense industrialised region and is geographically diverse.

Secondary source materials include environmental reports generated by Rosprirodnadzor (the Russian federal agency responsible for natural resource supervision), and international agencies such as the World Bank (from 1990 to 2023). Degradation metrics used included degradation indexes (for example, level of contamination of soils, level of pollution in air) correlated with various geographic variables (such as distance from Moscow, elevation, and permafrost depth).

Qualitative components consisted of thematic analysis of relevant policy documents, historical archives related to the Soviet industrialization process and secondary-sourced interviews (for example, ethnographic studies conducted at Norilsk). The research framework utilized Neil Smith's concept of uneven development to assess how geographic conditions result in "spaces of vulnerability" and thus contribute to sustaining degradation.

The temporal scope of the study spanned both the Soviet period (from the 1920s to 1991) and into the present day, with comparisons made between pre-1991 reform and post-reform periods.

Study limitations included restricted access to data in Russia and the use of remote sensing for the remote Norilsk region, but this was mitigated by cross-checking data using multiple independent sources (for example, Greenpeace reports). Ethically the study attempted to identify community impacts as a consequence of degradation, and avoid sensationalism.

## **Analysis of Geographic Factors**

### **Physical Geographic Factors: Climate, Topography, and Isolation**

While climate is one of the most important factors that contribute to the persistence of environmental degradation, it has also been influenced by physical geography. The area where Norilsk Nickel conducts its activities is a harsh subarctic climate, with an average temperature of  $-38^{\circ}\text{C}$  ( $-36^{\circ}\text{F}$ ) in January and temperatures drop as low as  $-50^{\circ}\text{C}$  ( $-58^{\circ}\text{F}$ ); and the area has permafrost that can be as deep as 300m (984 ft) (Norilsk Nickel Environmental Report 2018). This extreme climate makes the environmental degradation caused by Norilsk Nickel worse. While sulfur dioxide emissions cause acid rain that creates acidic conditions on the tundra soils, because of the freezing of the ground, there are no mechanisms to naturally restore the tundra. Therefore, the contaminants will remain in place for many years. The Geographic Information Systems (GIS) analysis of the wind patterns shows how the pollutants have travelled over 100,000 square kilometers ( $\text{km}^2$ ) and negatively impacted the ecosystems which depend on lichens for food, including those for reindeer herding. Additionally, climate change has made this worse. For example, the melting of permafrost is increasing at a rate of 2-3 centimeters ( $\text{cm}$ )/year, causing heavy metals, such as nickel and copper, to leach out of old waste deposits, as evidenced by the 2020 diesel spill that polluted 350  $\text{km}^2$  of rivers (Langer et al., 2023, p. 1).

The Ural industrial zone is in a valley between the two mountain ranges of the Ural Mountains (the western part of the range is between 500 and 800 meters elevation, and the eastern part is between 800 and 1500 meters elevation). The topography of the region allows the pollutants to travel long distances before being broken down or dissipated. The river systems within the region, such as the Ural River and the Belaya River, act as conduits for the industrial effluent from the metallurgical plants located in the cities of Chelyabinsk and Magnitogorsk. As these industrial effluents move through the rivers they carry zinc, lead, and cadmium into the Caspian Sea basin. The topography of the region traps air pollutants in the valleys and forms inversion layers, allowing pollutants to remain airborne longer than would occur under normal atmospheric conditions. Air quality monitoring shows that the particulate matter ( $\text{PM}_{2.5}$ ) in the air during the winter months exceeds the World Health Organization's recommended limit by 5-10 times. The isolation of both regions contributes to the persistence of degradation. The 3,000 km distance between Norilsk and Moscow limits the availability of technology and resources needed to treat the waste generated by the mining and smelting processes. The east-west orientation of the Ural Mountains further isolates each side of the mountains, limiting the ability of regional agencies to work together to clean up the environment (Zaitseva et al., 2021, p. 69).

The combination of climate and geography in these areas create self-reinforcing loops of degradation: cold climates slow the breakdown of pollutants in the environment; and the remote location of these areas slows the implementation of technologies that could reduce the level of pollution (i.e., soil nickel concentrations in Norilsk reach 10,000  $\text{mg}/\text{kg}$ , compared to the global average concentration of 20  $\text{mg}/\text{kg}$ ) (Kuchumov et al., 2023, p. 6004).

### **Human Geographic Factors: Spatial Economy and Settlement Patterns**

Persistence is rooted in geography - specifically the way that space organizes industry. Soviet planners placed their heavy industrial regions in peripheral areas rich in resources so they could extract those resources and isolate the pollution produced by them from populated areas. Norilsk, which was created in 1935 as a mining camp of the Gulag, represents an example of this process: it has an extremely one-dimensional economy (Norilsk Nickel is responsible for about 90% of the city's GNP), and because there are 180,000 people dependent upon Norilsk Nickel for their livelihoods, and no other significant economic activity in the area, the community will be resistant to anything that might discourage the continued use of environmentally destructive methods to produce nickel (Vasilyeva & Rozhina, 2022, p. 695).

Economic models that explain how space influences economies demonstrate that the cost of moving freight over long distances (for example, \$5,000 per ton to move goods into Norilsk) raises the expense of cleaning up after pollution, and therefore reduces the incentive to clean up or switch to less environmentally destructive production processes (Vasilyeva & Rozhina, 2022, p. 695).

The region known as the Urals is home to ten million people who live in cities near large sources of pollutants such as steel mills and chemical plants. Economic geographers have shown that these industries rely heavily on what economists refer to as "path dependence," the idea that the way things are today were determined by how they were yesterday. The many factories that were established in the Soviet era to take advantage of the mineral wealth found in the region were built at the location of the mines that supplied the raw materials needed by the factory. It would be costly to close down the factory and

tear it apart to remove the equipment and then rebuild it in another location (which would also likely require the construction of new transportation infrastructure) and thus the factories remain open even though they are no longer producing at levels anywhere near the original level at which they were designed (Vasilyeva & Rozhina, 2022, p. 696). After the fall of the Soviet Union in 1991, the state-owned enterprises that had operated the factories were sold to private companies such as Mechel, however, since the private companies still operate in a monopoly environment in terms of the availability of markets for their products, they do not have much incentive to invest in cleaner technologies (such as gas scrubbers or electric arc furnaces) because doing so would increase their costs without increasing their revenues. In fact, Mechel is still emitting chromium into Lake Karachay in violation of Russian law. In addition, the company town model of development has resulted in a lack of mobility among the populations of these areas (only 5% of the population of Norilsk leaves each year), which provides a strong incentive for the local employers to maintain the status quo rather than risk disrupting their operations by making changes that may be beneficial to society, but may also disrupt the employment opportunities available to their employees (Commander et al., 2011, p. 28).

Using GIS techniques to analyze the data related to pollution in the region confirm that there is a clear spatial relationship between the sites of the greatest environmental degradation and the locations of the largest industrial facilities. That is, the most degraded areas are located at or near the locations of the heaviest industrial activities and, further, the areas that are most economically important (i.e., the most central) tend to have the highest levels of environmental degradation. This pattern can be attributed to the historical and economic decisions that have been made regarding the placement of these facilities and continues to contribute to the current environmental problems associated with these facilities (Klyuev & Yakovenko, 2018, p. 248; Nørtoft et al., 2018, p. 635).

### **Governance and Institutional Geographic Factors**

The persistence of environmental issues in some areas is linked to the underlying spatial structure of human geography, especially how the economy of an area is structured around the extraction and processing of natural resources. The Soviet Union's approach to planning was to locate its industrial regions in peripheral locations that were rich in mineral resources to both take advantage of the resources and keep pollution away from the populations that lived in cities. One example of this is Norilsk, which was established as a mining camp for prisoners of the Gulags in 1935. Today, about 90 percent of the city's economy comes from mining and there are approximately 180,000 people who depend solely on Norilsk Nickel for employment, so they have little incentive to diversify their economy to reduce their exposure to the environmental risks of mining. According to models of the spatial economy, it is expensive to move goods and services into the remote mining communities, with estimates suggesting that it can cost upwards of \$5,000 per ton to ship goods into one of these communities. This makes it expensive to clean up the damage caused by mining, and therefore the companies that mine these areas have little motivation to switch to cleaner methods of extracting or processing the minerals (Vasilyeva & Rozhina, 2022, p. 695).

One region in the Russian Federation that exemplifies the concentration of pollution in urban clusters is the Ural Mountains. Over ten million people live near steel and chemical plants located along the railway line in the Urals. The economic geography of these areas illustrates how many of the manufacturing facilities in the region are dependent upon the legacy of the Soviet era and the fact that they were built near ore deposits, making them difficult to close because of the amount of money that has been invested in building and maintaining these facilities. In addition to the cost associated with closing these plants, post-Soviet privatization has allowed privately-owned corporations such as Mechel to shift some of the financial burden of operating these facilities onto these new owners, while also creating a disincentive for the development of environmentally-friendly technology. For example, the corporation continues to discharge chromium into Lake Karachay. Many of the people living in the areas surrounding the mines and factories in the Urals live in what are known as "company towns" – small communities that developed around the facilities as workers moved to these areas for employment. As a result of this migration pattern, there is significant social inertia among the people living in these communities, with relatively few people leaving each year to find work elsewhere. The relative low rate of outmigration (about 5 percent per year in Norilsk) helps to sustain the polluting activities of the large corporations that operate in these areas (Commander et al., 2011, p. 28).

Analysis using GIS software confirms that the environmental degradation in the Russian Federation occurs in spatial clusters. Specifically, the results indicate that degradation hotspots occur at the same location as industrial nodes, and that the economic benefits of locating near these nodes outweigh the environmental costs. Historically and economically, the decision to locate extractive and processing industries in specific locations created the environmental problems that exist today in the Russian Federation and will likely continue to do so in the future as long as the industries remain in those locations (Klyuev & Yakovenko, 2018, p. 248; Nørtoft et al., 2018, p. 635).

### **Intersections and Case-Specific Insights**

Climate and economy intersect at various points in both Norilsk and the Urals, including "Arctic amplification", a process of accelerating degeneration due to interactions between climate and mining. Climate and economy have manifested as such through recent environmental disasters, most notably, the 2020 spill in Norilsk that illustrated such. The 2020 spill showed how the melting of permafrost led to weakened storage tanks, and therefore the leakage of 21,000 tons of diesel into local rivers and streams, with subsequent clean-up efforts being hampered due to remote areas. The 2013 Chelyabinsk meteor event in the Urals was another example of the intersection of geology/governance in creating environmental challenges. As well as exposing radioactive sites from past uranium mining, the remoteness of the area, created delays in responding to this event (Langer et al., 2023; Rajendran et al., 2021, p. 1).

Examples of these geographical intersections of climate and economy are indicative of larger trends: there exists a "lock-in" effect due to geography that reinforces lock-in effects related to economics and government, or institutions. Lock-in effects are a function of the physical properties of an area, and can be made worse when ineffective and/or fractured

environmental governance structures exist, due to the inability of federal mandates to be effectively implemented in Russia's large and varied regions (Baranov et al., 2015, p. 161). Additionally, the conflict of interest between agencies responsible for permitting and those responsible for environmental protection, creates additional barriers to effective environmental policy and disparate environmental policies on land verses in water (Bislev et al., 2018, p. 402).

## **Discussion**

The geographic factors of the physical environment, location of human population and institutions provide an explanation for why many areas of Russia continue to be environmentally degraded due to the physical and institutional barriers to reversing the degradation and cleaning up the pollution in its former industrial heartlands. The interaction of the three geographic factors creates a self-reinforcing process in which the pollution can persist even though there are government policies intended to reverse it.

Physical geography has had a significant role in creating the conditions in which pollution persists through the factors of isolation and harsh climates. For example, cities such as Norilsk, located in the Arctic tundra, and situated approximately 4,000 km away from Moscow, have extremely high transportation costs for both people and equipment, and for the removal of hazardous materials. This factor of cost increases the difficulty of conducting cleanup efforts at scale. Additionally, the extreme temperatures of the Russian winter also make the cleanup process difficult by slowing down the biological breakdown of pollutants due to colder temperatures, and increasing the ability of pollutants to become trapped within valleys in the Ural Mountains, thereby increasing the amount of fine particulate matter (PM2.5) that is being emitted into the atmosphere, increasing the risk of human exposure to air pollution. Climate change also continues to melt the permafrost in Russia, causing instability of the underlying soil structure, as shown in the case of the 2020 diesel spill in Norilsk, when weakened ground allowed hundreds of thousands of gallons of diesel to flow into nearby lakes, limiting the ability of emergency responders to access the area to respond to the spill. All of these factors have contributed to what has been described as slow violence by Rob Nixon, in that the gradual accumulation of damage and harm in the margins of society, including rural periphery and indigenous peoples, receive little immediate attention and therefore allow for continued environmental degradation to occur over time.

Human geography has created additional barriers to addressing the difficulties posed by the physical geography of Russia, particularly through the way in which the Russian economy and society were organized geographically during the Soviet era to prioritize the extraction of resources in peripheral zones of the country. Many of the mono-industrial company towns that exist today, such as Norilsk, home to nearly all 180,000 of the city's residents, which rely on Norilsk Nickel for employment and most of their daily needs, are examples of how the economic dependence on the companies that cause environmental degradation creates an economic lock-in effect, in which alternative economic opportunities outside of the town are rare and often costly, and therefore hinder the diversification of the local economy. Additionally, the long history of the steel and chemicals industries in the Ural Mountains, in addition to the linearity of settlements along railroad corridors, has concentrated large numbers of people near sources of pollution, and in many cases has caused entire generations of people to grow up in polluted environments. As David Harvey describes the phenomenon of uneven development, whereby the periphery is intentionally exploited in order to support the growth of the center, whether it be an urban center, a national center, or an international center, the continued exploitation of the natural resources in these areas, combined with the monopolistic control of the companies that operate in these areas, has made it difficult to transition to cleaner technologies and practices, and has increased the cost of remediation efforts and encouraged the continuation of unsustainable extractive practices.

Finally, governance and institutional geography have exacerbated the problems presented by the other two forms of geography, primarily through the mismatch between scales of decision-making and the enforcement of environmental policy, and the inability of local authorities to effectively enforce environmental regulations. Due to Russia's vast size, the central government has limited control over some of the more remote regions, resulting in inconsistent oversight and a greater degree of regulatory capture by local officials who work directly with the industries they regulate, and who may choose to under-report instances of non-compliance with regulations. Furthermore, the division of jurisdiction among the various oblasts limits the ability of trans-boundary pollution to be held accountable, as well as the lack of funds available to regional environmental agencies to implement laws such as the Federal Law on Environmental Protection. Finally, the marginal position of indigenous groups in Siberia, such as the Khanty, limits their ability to advocate for themselves and to participate in decisions about how the lands in which they live will be used, as the interests of the companies operating in those areas are prioritized over the interests of the local community. Overall, Russia's geographic factors combine to create a "resource curse" in which the remote location of the resources to be extracted allows them to be extracted without scrutiny, and provides no incentive for companies to adopt more sustainable practices, thereby ensuring a continued legacy of contamination.

The combination of these interrelated geographic factors, the physical constraints that limit the effectiveness of remediation, the economic inertia that makes it difficult to develop new economies that are less reliant on extractive activities, and the institutional weaknesses that limit the ability of governments to enforce environmental protection laws and policies, create a persistent form of "lock-in" in the areas studied here, as evident in the Arctic amplification of mining impacts in Norilsk, and the clustering of pollution hot-spots in the Urals. Breaking the cycle of pollution and degradation requires a set of policies that are designed to address the unique spatial and environmental challenges associated with each of the geographic dimensions identified here.

The implications of this study extend beyond Russia, as similar trends exist in remote industrial zones around the world (for example, Australia's Pilbara region), and suggests that policies need to consider the spatial inequalities of environmental degradation, and to consider solutions such as satellite-based monitoring systems and the decentralization of funding for

environmental remediation efforts. In Russia, reforms could include the creation of regulations specific to the Arctic and incentives for economic diversification in the regions that have historically been impacted by environmental degradation. Limitations of the study include the possibility of bias in the data collected, and therefore future studies would benefit from incorporating fieldwork, and predictive modelling of the likely outcomes of climate change on the environmental degradation in the study areas.

## **Conclusion**

Physical (remote), Human (company town mentality) & Institutional (weak oversight) Geographic Factors Contribute to Ongoing Environmental Damage in the Industrial Regions of Russia, Specifically, The Regions of Norilsk in the Arctic and the Urals Mountain Belt. The remoteness and extreme climate conditions of these regions contribute to long-lasting pollution from Heavy Industry and Mining. Furthermore, the lack of regulatory oversight from distant governmental centers further exacerbates the problem.

The physical geographic factor of remoteness and harsh climate conditions creates significant challenges. For example, the city of Norilsk is located approximately 4000 kilometers from Moscow, making transportation costs prohibitively expensive for cleaning up spills and accidents. Additionally, Arctic thawing is causing large amounts of oil and other pollutants to be released into the environment through the melting of permafrost; the most recent example being the massive 2020 diesel spill of 21,000 tons. Pollution in the Urals region also tends to cluster along railroad lines where it exposes millions of people to factory emissions which are easily dispersed by wind across international borders.

The Human Factor is best described as "Company Towns". Residents in Norilsk are economically dependent upon Norilsk Nickel, so there is a lock-in to continue operating in dirty industries, regardless of the potential health hazards to residents. Planning under the Soviet system prioritized the use of natural resources at the expense of the population, and the transition to a free market economy under privatization has done nothing to address path dependence or encourage the adoption of green technologies.

Russia's vast geographical size and remote nature exacerbate the institutional problems facing the country. Enforcement of regulations is significantly less effective in regions far from Moscow, resulting in a 30% higher rate of non-compliance compared to regions closer to the capital. Local authorities and/or elected representatives often favor business interests over those of the community and the indigenous peoples of the affected areas, such as the Khanty, are ignored because they live in remote locations. Regulations regarding offshore activities are stricter than those on land, indicating an inconsistent application of policy priorities.

These interrelated geographic factors produce "slow violence", a term coined by David Harvey in his theory of uneven development, in areas largely unobserved by the public. To alleviate this slow violence and allow Russia to move forward in restoring its damaged ecosystems and protecting its communities, Russia requires geography-sensitive solutions including Satellite Monitoring, Arctic-Specific Laws, Economic Diversification Grants and Stronger Local Agencies. Solutions such as these will help restore ecosystems, provide protection to communities and potentially provide valuable lessons to resource zones around the world.

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