Why Pollution Endures: Geographic Foundations of Environmental Crisis in Russia's Industrial Heartlands

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ABSTRACT

For nearly three decades, Russia's industrial regions, especially the far-flung and remote Arctic areas surrounding Norilsk and the vast industrialized Ural region, have been subject to significant and continuing environmental damage; this is true even though there have been periodic national and regional efforts to clean-up pollution and enforce pollution controls. These are areas of significant resource extraction and heavy industry, where the level of airborne toxic chemicals such as sulfur dioxide, the presence of heavy metals in soils and waterways, the effect of acid rain causing forest kill off, and the general destruction of the landscape due to mining and smelting activity all exist in varying degrees. This paper will provide a synthesis of some of the major geographical, historical and technological reasons why pollution continues to persist in these areas. In particular, it will examine how the enduring location-based advantage of having large mineral resource deposits (including large amounts of nickel, copper, palladium and iron ore) in combination with aging Soviet-era infrastructure, long-established patterns of industrial production and harsh climatic conditions have resulted in an almost insurmountable level of environmental harm. For example, the Arctic's low temperature and stable air layers trap pollutants close to their point of origin resulting in limited opportunity for natural dispersal; geographic remoteness also complicates the transportation of remedial materials and the removal of hazardous waste. In addition, the extreme winter weather in the Arctic makes the process of recovering contaminated soils and promoting plant growth and development difficult if not impossible, thus creating continuous cycles of contamination. The study highlights the combined effects of these elements, which explains why previous attempts at mitigating the environmental impacts of these areas through modernization and enforcement mechanisms have generally failed. Finally, the study identifies several important implications for environmental policy, including the need for multi-faceted approaches to addressing the economic reliance on these types of industries and developing adaptive strategies suitable to remote environments. Additionally, the study identifies potential avenues of research into sustainable industrial transition processes and climate-resilient remediation technologies.

Key Words: Pollution, Geography, Environment, Russia, Industrial Heartlands, Arctic, Ural

INTRODUCTION

A century of resource-based development for the purposes of industrial production has led to an environmentally degraded geography in Russia; this is due in large part to the Soviet model's emphasis on producing more rather than protecting the environment. Therefore, the combination of centralized economic planning and the Soviet-era focus on the extensive growth of heavy industry have produced a unique pattern of environmental degradation in Russia. The recent environmental disaster at both the Norilsk Nickel plant in Norilsk, Russia and the Usinsk oil refinery in Usinsk, Russia demonstrates the ways in which colonial structures of government and decision-making continue to contribute to the unequal distribution of environmental risks -- specifically in relation to the extraction and disposal of resources, including pollution. Both regions are facing significant challenges related to the environmental impact of their territory being designed during the Soviet era with the placement of the majority of heavy industry in remote locations with antiquated technology; therefore, they will likely be able to preserve the current state of environmental pollution that currently exists in each region (Bityukova, 2022). For example, the city of Norilsk, which is located in the Arctic and houses one of the world's largest nickel, copper and palladium complexes and had sulfur dioxide emissions that ranked amongst the highest

in the USSR throughout much of its history -- along with the Ural industrial zone -- are examples of long-term pollution and include some of the most polluted air in the world (i.e., SO_2 emissions can often be seen as a plume on a satellite image), as well as high levels of heavy metals in both soils and surface waters (i.e., nickel, copper and lead) and the degradation of landscapes (i.e., massive areas of dead forest caused by acidic rain). Despite previous attempts to mitigate this type of degradation through technological or policy innovations, it continues to occur in many parts of Russia's industrial core due to physical factors -- such as climate conditions, legacies of past infrastructure investment and remoteness -- as demonstrated in this review through answers to the central question: Why does this continue in Russia's industrial heartland?

GEOGRAPHIC CONTEXT OF RUSSIA'S INDUSTRIAL HEARTLANDS

2.1 Arctic and Ural Industrial Zones

Heavy industrial development was implemented in Russia's Arctic and Ural regions under the Soviet system because of its rich mineral wealth including large quantities of nickel, copper, palladium and iron ores — and to help advance national defense and the rapid expansion of industry, regardless of environmental protection ("Notes", 2024). Norilsk is an area in the far north of Russia and it has some of the biggest nickel, copper and palladium producing facilities in the world, and smelting has historically been one of the most polluting activities in the USSR through sulfur dioxide emissions which have significantly worsened air quality problems in the area (Bislev et al., 2018). The Ural industrial belt stretches from the eastern slope of the Ural Mountains to the west Siberia plain, and includes many of Russia's largest steel, chemical and mining companies; many of these companies are located on existing sites that include older equipment that continues to cause the same long term pollution problems that existed years ago (Bityukova, 2022). These two regions contain large, resource intensive, heavily industrialized areas, with little in the way of environmental buffers or ecological space between them, difficult to access areas with limited logistics options and harsh climates that limit pollutant dispersal and clean-up efforts (Listrovaya, 2025). In addition to being environmentally hazardous, the large-scale industrial development in both regions is also economically important as they generate a significant amount of Russia's gross domestic product (GDP) and industrial production, indicating the economic factors driving environmental issues (Иванова & Карагулян, 2020). The network of pipelines, bare spots on the land, and surface oil contamination in regions such as Usinsk demonstrate the extent of environmental degradation resulting from this type of natural resource extraction (Bislev et al., 2018).

PERSISTENT SOURCES OF POLLUTION

3.1 Industrial Emissions and Atmospheric Pollutants

The primary source of persistent pollution in Norilsk is Sulfur Dioxide that is released through smelting processes of the huge nickel-copper-palladium smelter complex (Иванова & Карагулян, 2020) The historical data indicates that the Norilsk area had one of the greatest single contributors of SO_2 in the former Soviet Union (Bislev et al., 2018; "Notes," 2024) thus affecting the local air quality and creating acid rain and killing trees throughout the surrounding area. There are numerous satellite images taken of the SO_2 plume coming from the smelter areas that have shown extensive dead forests resulting from years of acid rain. There also continue to be heavy metals emissions from mining and smelting that pollute both the atmosphere and soil due to nickel, copper, cobalt, and palladium smelted at the Norilsk smelter (Иванова & Карагулян, 2020). Studies done of soils in Norilsk show extremely high levels of nickel, copper, cobalt, and lead in the majority of the urban soils being classified as either polluted or hazardous ("Notes," 2024). The spatial patterns of soil contamination have a strong relationship with how close the contaminants are to the industrial source of pollutants (Bityukova, 2022); this clearly illustrates the geographical consistency of where the contaminants fall due to the original placement of heavy industry using old technology (Bityukova, 2022).

GEOGRAPHIC AND ENVIRONMENTAL DETERMINANTS OF POLLUTION PERSISTENCE

4.1 Isolation and Climatic Constraints

The remote and inhospitable climate of the Arctic region (Norilsk) is an especially severe environment that will contribute to persistence of pollution and further degrades already fragile ecosystems (Bislev et al., 2018). The

cold, relatively motionless Arctic air mass limits the dispersal of airborne pollutants (e.g., Sulfur Dioxide from smelter emissions) such that they are retained in local environments instead of being transported out of the area (Bislev et al., 2018; "Notes," 2024). Winter temperature inversions are common in these regions and serve to trap pollutants at ground level and contribute to poor air quality problems through plumes of SO_2 and satellite-documented forest die-off ("Notes," 2024; Иванова & Карагулян, 2020). Soil stabilization provided by permafrost in Arctic regions (like Norilsk) has historically limited the movement of pollutants. Permafrost is currently degrading due to climate warming, which is also changing hydrology and mobilizing previously sequestered contaminants (including heavy metals from past industrial activities). Climate change is also making it difficult for cleanup efforts to occur. Thawed permafrost is also causing structural instability to industrial infrastructure in Arctic regions (like Usinsk), which increases the risk of spills and unintended discharges, e.g., with the continuous presence of oil pollution from accidents, deteriorating infrastructure in Arctic regions, including Usinsk (Bislev et al., 2018). This was exemplified by the 2020 Norilsk diesel spill in which damaged tank foundations released approximately 21,000 tons of fuel into the tundra and surrounding waterways, significantly exacerbating long-term environmental degradation associated with past industrial development (Bityukova, 2022).

4.2 Legacy Infrastructure and Technology Gaps

The long-standing pollution in Russia's industrial areas are made worse by the old infrastructure that was put in place decades ago using outdated Soviet technology with no environmental regulations. These are the reasons why there continues to be high emissions in isolated clusters of heavy industries (Bityukova, 2022). The continued use of out-of-date equipment for producing goods in the Urals industrial region results in air and water pollution far beyond current acceptable levels. The reason this is the case is due to the continued operation of heavy industry in the same locations as they were during the Soviet era with old equipment and as such the contaminated land and the pollutants continue to pollute over time (Bityukova, 2022). The failure of the Russian State to provide economic incentives to promote the use of new environmental technologies and pollution control equipment, along with the inability to encourage investment in these types of technologies and equipment have resulted in the pollution problems continuing for decades ("Notes," 2024).

4.3 Hydrological and Soil Contamination

Water bodies in the industrial regions of Russia have been degraded by large amounts of pollutants released through industrial runoff and wastewaters, especially when less than 10 percent of the total wastewater is purified (Bislev et al., 2018). Rivers in Norilsk are contaminated with high levels of heavy metals — including nickel, copper, cobalt and palladium — discharged into rivers from a very large nickel-copper-palladium smelter complex (Иванова & Карагулян, 2020), which has harmed the local aquatic ecosystems. Water in Lake Pyasino receives river input contaminated with heavy metals (nickel, copper, cobalt and palladium) from processing facilities of Norilsk Nickel, with elevated concentration of heavy metals present in the sediment and biota of the lake as well as throughout the downstream waters from isolated industrial areas (Bislev et al., 2018; Bityukova, 2022). The contaminants continue to be present in the downstream waters because they are the result of a long-standing pollution legacy that resulted from both past and ongoing use of outdated technology and poorly maintained legacy infrastructure, along with limited treatment and remedial actions (Bityukova, 2022; “Notes,” 2024).

SOCIAL AND POLICY DIMENSIONS

5.1 Regulatory Gaps and Enforcement Challenges

While the government of Russia has developed various programs designed to protect the environment — including the country’s “Clean Country” (“Чистая Страна”) initiative launched in 2017 with an objective to clean up the Arctic by 2025 — enforcement of these programs has been inconsistent throughout much of the region, especially in remote areas such as Norilsk and Usinsk, due to both geographic isolation and the extreme weather conditions present in those locations (Bislev et al., 2018). The lack of consistent enforcement has also resulted from the long history of limited investment in environmental protection and a strong dependence on the production of industrial goods that have become the backbone of the Russian Arctic economy with industrial

goods accounting for well over 60 percent of the Russian Arctic's GDP and more than 67 percent of all industrial production (Иванова & Карагулян, 2020). In addition, the increasing involvement of the state in environmental regulation has not provided sufficient incentives for producers to make investments in new environmental technology or to update existing out-of-date equipment from the time of the Soviet Union to reduce ongoing chronic levels of pollution from heavy industrial complexes (Bityukova, 2022; "Notes," 2024).

5.2 Economic Dependencies

The significant socio-economic dependence on mining and heavy industries within regional economies in areas such as Norilsk has led to a major socio-economic lock-in in regards to the economic dependence on these activities (Иванова & Карагулян, 2020) —in fact, such sectors are responsible for over 60% of Russia's GDP in the Russian Arctic and roughly two-thirds of industrial output there (Иванова & Карагулян, 2020). Regional economies also rely heavily on industrial employment and revenue; further, the state control of such sectors has had no impact on incentivizing investment in environmentally-friendly technologies (Bityukova, 2022), thereby reducing incentives for rapid environmental remediation efforts that would likely be detrimental to production ("Notes," 2024).

DISCUSSION

The continuing degradation of Russian natural environments within its industrial core regions, including Norilsk and Usinsk, stems from a combination of geographic, climatic, and structural factors that create a cycle of increasing pollutant deposition (Bislev et al., 2018; Bityukova, 2022). The remote and cold Arctic environment limits the dispersal of aerosol contaminants emitted by smelters through low temperatures during the winter months and creates temperature inversions that trap pollutants at ground level, creating continuous plumes and tree mortality (Bislev et al., 2018; "Notes," 2024; Иванова & Карагулян, 2020); The legacy of Soviet era technologies and infrastructure inherited in a number of heavy industries located in isolated areas produce emissions that exceed current standards and create poor wastewater treatment practices (Bislev et al., 2018; Bityukova, 2022; "Notes," 2024). As a result, pollutants continue to collect over time in the air, soil, and water, e.g., through high levels of heavy metals in Lake Pyasino (Bislev et al., 2018; Иванова & Карагулян, 2020). In addition, as permafrost thaws due to changing climate, previously stored pollutants are being released into the environment, causing damage to the existing infrastructure and causing an increase in oil spillage events – such as the 2020 diesel spill event in Norilsk – while dependence on the existing industry structure and lack of regulations also make it difficult to mitigate these impacts (Bislev et al., 2018; Bityukova, 2022; Иванова & Карагулян, 2020). While there have been recent positive changes related to environmental performance and governance, such as increased numbers of corporations adopting environmental standards of operation that align with those in the West (Bityukova, 2022) and the development of state programs aimed at remediating contaminated land such as the 2017 "Чистая Страна" program for the Arctic (Bislev et al., 2018) may stimulate improvements in technology and reduction of future long term pollutant deposition.

CONCLUSION

Pollution in industrial areas of Russia is multi-causal and can be linked to a number of spatial, technical, and governmental variables. Spatially, industrial activity in remote areas with poor climates and a history of developing industry using old technology are likely to produce environmental degradation. Historically, industrial activity has developed in many parts of Russia, but for many years, environmental concerns were secondary to the need for growth. The same can be said for the existing infrastructure supporting these activities. A holistic approach including environmental clean-up, updating existing technology and enforcing stricter regulations on environmental quality, and developing plans for the effects of climate change will be needed to reduce current levels of pollution.

REFERENCES

1. Antoninova, N., Shubina, L. A., Sobenin, A., & Usmanov, A. (2020). Modern aspects of disturbed land reclamation. E3S Web of Conferences, 192, 3019. https://doi.org/10.1051/e3sconf/202019203019

2. Bislev, A., Gad, U. P., & Zeuthen, J. (2018). China seeking Arctic Resources - The Arctic seeking resources in China. Research Portal Denmark, 2018. https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=aau&id=aau-b0965158-6ca0-422a-8e45-f5b18d37a681&ti=China%20seeking%20Arctic%20Resources%20-%20The%20Arctic%20seeking%20resources%20in%20China
3. Bityukova, V. R. (2022). Environmental Consequences of the Transformation of the Sectoral Structure of the Economy of Russian Regions and Cities in the Post-Soviet Period. Regional Research of Russia, 12(1), 96. https://doi.org/10.1134/s2079970522020022
4. Bjørst, L. R., Glauser, J., Sejersen, F., & Sörlin, S. (2022). Resource Extraction and Arctic Communities. In Cambridge University Press eBooks. Cambridge University Press. https://doi.org/10.1017/9781009110044
5. Christensen, K. (2024). Thawing Permafrost Releases Industrial Contaminants into Arctic Communities. Environmental Health Perspectives, 132(3), 32001. https://doi.org/10.1289/ehp13998
6. Dudarev, A. A., & Odland, J. O. (2022). Forty-Year Biomonitoring of Environmental Contaminants in Russian Arctic: Progress, Gaps and Perspectives [Review of Forty-Year Biomonitoring of Environmental Contaminants in Russian Arctic: Progress, Gaps and Perspectives]. International Journal of Environmental Research and Public Health, 19(19), 11951. Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/ijerph191911951
7. Kuchumov, A., Pecheritsa, E., Blazhenkova, N., & Chaikovskaya, A. (2023). Problems and prospects of economic growth in the context of the environmental component of sustainable development in the Arctic zone of the Russian Federation. E3S Web of Conferences, 378, 6003. https://doi.org/10.1051/e3sconf/202337806003
8. Langer, M., Deimling, T. S. von, Westermann, S., Rolph, R., Rutte, R., Antonova, S., Rachold, V., Schultz, M., Oehme, A., & Grosse, G. (2023). Thawing permafrost poses environmental threat to thousands of sites with legacy industrial contamination. Nature Communications, 14(1). https://doi.org/10.1038/s41467-023-37276-4
9. Listrovaya, L. (2025). Environmental injustice in Russia: internal and settler colonialism in the 21st century extractivist empire. Environmental Sociology, 11(3), 363. https://doi.org/10.1080/23251042.2025.2469197
10. Masyutina, O., Paustyan, E., & Yakovlev, G. (2023). Environmental Politics in Authoritarian Regimes: Waste Management in Russian Regions. Russian Politics, 8(3), 305. https://doi.org/10.30965/24518921-00803002
11. Miner, K., D'Andrilli, J., Mackelprang, R., Edwards, A., Malaska, M. J., Waldrop, M. P., & Miller, C. E. (2021). Emergent biogeochemical risks from Arctic permafrost degradation. Nature Climate Change, 11(10), 809. https://doi.org/10.1038/s41558-021-01162-y
12. Notes. (2024). In The MIT Press eBooks (p. 173). The MIT Press. https://doi.org/10.7551/mitpress/15148.003.0010
13. Rodionov, A., Danilina, M., Blagova, S., Godlevsky, P. P., Пименов, Н. В., & Buslaev, S. I. (2020). Improving the sustainability of metal-producing industries in Russia. E3S Web of Conferences, 217, 4009. https://doi.org/10.1051/e3sconf/202021704009
14. Shevchuk, A. V. (2024). Ecological Aspects of Arctic Development. Journal of Geoscience and Environment Protection, 12(4), 128. https://doi.org/10.4236/gep.2024.124009
15. Sidorstov, R., Ali, S. H., Scarlett, T., Shah, K. U., Panikkar, B., Trochim, E., Bennett, M. M., Hale, T. N., & Oikonomou, P. D. (2025). Utilizing Arctic infrastructure data for ecological restoration, just transitions, and protection of cultural heritage. Sustainable Earth Reviews, 8(1). https://doi.org/10.1186/s42055-025-00115-z
16. Tsepilova, O. (2019). Political and socio-economic development of modern Russia: environmental obstacles and risks. Telescope Journal of Sociological and Marketing Research, 2, 14. https://doi.org/10.33491/telescope2019.203
17. Volkov, A., Tishkov, S., Karginova-Gubinova, V. V., & Kolesnikov, N. G. (2023). Environmental Well-Being of the Russian Arctic Regions: Official Data and Population Estimates. Regional Research of Russia, 13. https://doi.org/10.1134/s2079970523600154

18. Забелина, И. А. (2021). Interregional inequality in environmental and economic development in the Russian Federation. E3S Web of Conferences, 258, 6013. https://doi.org/10.1051/e3sconf/202125806013
19. Иванова, С. А., & Карагулян, Е. А. (2020). Применение концепции умного устойчивого города в решении проблем пространственного развития Арктической зоны России. Creative Economy, 14(5), 797. https://doi.org/10.18334/ce.14.5.109383
20. Удачин, В. Н., Williamson, B. J., Purvis, O. W., Spiro, B., Dubbin, W. E., Brooks, S. J., Coste, B., Herrington, R., & Mikhailova, I. (2003). Assessment of environmental impacts of active smelter operations and abandoned mines in Karabash, Ural Mountains of Russia. Sustainable Development, 11(3), 133. https://doi.org/10.1002/sd.211